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Physical activity and lifestyle sustainability: From childhood to old age

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Physical activity and lifestyle sustainability: From childhood to old age

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Editorial: Physical activity and lifestyle sustainability: From childhood to old age

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healthy lifestyle, exercise, children, adults, elderly, sedentary behavior

Editorial on the Research Topic
Physical activity and lifestyle sustainability: From childhood to old age

Introduction

The industrial revolution from the second half of the previous century and the communication revolution, which has been especially noticeable in the last 20 years, caused a change in lifestyle and forced man to adapt to his inventions (1). This led to a change in the behavior of children, adults, and the elderly, and more and more negatively contributes to their development, their working ability, and their health condition (2). The physical inactivity of children during the period of intensive physical and cognitive development will cause their genetic potentials are not fully developed and they more easily create bad behavioral habits which can be the generator of many health problems in old age (3).

Facing the negative trends of the modern way of life (given that previous research clearly indicates that physical inactivity and sedentary behavior can lead to impaired health, i.e., that an active lifestyle can ensure a healthy life and promote wellbeing for all) this Research Topic was created to develop knowledge and an understanding of physical activity and lifestyle sustainability (from childhood to old age); and thus to help identify possible solutions and strategies that provide (4) help the upbringing of strong children, a (2) healthy transition from childhood, *via* adulthood, to old age, in the long term, and also (5) to solving problems of adults and elderly.

The purpose of this Research Topic was to build a collection of new knowledge about the positive impact of physical activity on the health and wellbeing of community members of all age groups (From Childhood to Old Age). There are 24 articles included in this Research Topic.

Most of the studies from this Research Topic (six of them) studied the impact of physical activity on physical fitness and health status (two of them are systematic reviews and studied the period from 2004 to 2020; two of them are longitudinal studies and follow the changes after 5 weeks and after 8 years) among young and elderly. All of them agree in the conclusion that any kind of additional physical activity (even when it is only housework or active transport) if it is used continuously and not occasionally, has beneficial effects on physical fitness and health status (Bai et al.; Xiao et al.; Lomsdal et al.; Huang et al.; Baj-Korpak et al.), also that people who are more physically active achieve better physical fitness, overall health and wellbeing from less active ones (TeraŽ et al.).

Furthermore, five cross-sectional studies were interested in evaluating the impact of the COVID-19 pandemic on the amount of physical activity and the lifestyle of students and the elderly. Based on the results of four of these five studies, it is known that there have been certain changes in the amount of physical activity and lifestyle, i.e., that sedentary behavior and passive activities increase both in the student population and in the elderly population, but that students were able to maintain the recommended amount of physical activity, and their physical activity declined to a lesser extent than in the elderly (Sekulic et al.; Kim et al.; Pišot et al.; Obradovic et al.). The fifth study is differently conceived, but extremely interesting, it describes the diet of Lithuanian and Croatian students in this difficult period and shows that those students who are more physically active took better care of proper nutrition, which means that care for one type of healthy way of life encourages care for others (Mieziene et al.).

The following four studies presented new study protocols, scales for testing, and national surveillance systems which are designed and validated to assess and follow-up physical activity, physical fitness, and health status of their population (7–8 years aged children, pregnant females, adults and older adults) (Mutare et al.; Zhu et al.; Zhang et al.; Jurak et al.).

Another important stream of work is reflected in the next four studies that analyzed the influence of sociodemographic factors on health behaviors, physical activities, physical fitness, and physical competence of children, adults, and the elderly. In each of the studies, there is evidence that sociodemographic factors (gross national income, income, and education) are positively correlated with behaviors, with the extent of physical activity and with physical performance of children and elderly, also that football players from less economically developed countries in running performance are below the values achieved by those who compete in the countries of the European Union (Rodriguez-Rodriguez et al.; Liu Z. et al.; Santibañez-Gutierrez et al.; Goranovic et al.).

The last five studies are very different, but this diversity of studied topics raises the quality of this special edition. Each of these studies represents an important stream of work. The first examines the influence of lifestyle on depression and health and indicates that watching television is the least risky type of screen behavior (Kidokoro et al.). This means that social media, online games, and online videos are more associated with a higher prevalence of depression. The following studies indicate: that proteinuria can be a predictor of frailty (Chang et al.); that physically active male participants tend to discriminate against those they consider overweight (Xu et al.); that a campus football programs have a high injury risk and that injury prevention and management strategies should be improved (Liu H. et al.); and that messages that place an exceptional emphasis on the benefit or harm of a certain behavior are much more effective in influencing motivation than messages that are simply presented to the public without a special explanation (Wang et al.).

Conclusion

This Research Topic with its 24 studies very, very broadly covered the area of physical activity and lifestyle sustainability. The included studies indicate that the physical activity of subjects of all age categories is still constantly decreasing, even though the benefit of physical activity has long been proven (4, 5). However, published studies recommend various activities that have a positive effect on health and specify the minimum threshold of volume and intensity that is necessary to cause transformation in a positive direction, so they are extremely significant for practice. Furthermore, published studies confirm the damage that the COVID-19 pandemic has caused to humanity in the last few years, i.e., point to the fact that an adequate physical activity program that would prevent the decline of physical activity and fitness has not been found. Based on this, the question arises whether it was possible to design an adequate exercise program that could be carried out while respecting the rules on social distance, and thus strengthen immunity, and create the first line of defense of the organism so that it could more easily resist the virus? Also, the studies published in this Research Topic have designed several protocols for measuring, monitoring, and evaluating certain parameters, which will be used for improving the current situation in the field. Furthermore, this Research Topic reminded us of the strong influence of sociodemographic parameters on physical activities and physical fitness, but this is an area in which sports and health sciences are powerless to make changes. In the end, it drew attention to the risky behavior of those community members who need to change their behavior, and also to strategies that must be applied to improve the current situation in the field.

Author contributions

BM drafted the editorial. SP, JJ, and RM revised and approved the final version. All authors

contributed to the article and approved the submitted version.

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ORIGINAL RESEARCH
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Different Types of Screen Behavior and Depression in Children and Adolescents

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The purpose of this study was to examine the associations between different types of screen behavior and depression, taking into account exercise and sleep among children and adolescents. A total of 23,573 Japanese children and adolescents (aged 8–15 years) participated in this cross-sectional study. Different types of screen behavior, weekly exercise time, sleep duration, and prevalence of depression were assessed using a questionnaire. Independent associations between various types of screen behavior and prevalence of depression were examined using logistic regression analyses after adjusting for age, school, sleep duration, exercise time, and other screen behavior types. A two-way analysis of covariance was conducted to examine whether exercise and sleep can attenuate the negative effects of screen behavior. The associations between screen behavior and depression varied by screen behavior types and participant characteristics. More time spent engaging in newer types of screen behavior, including social media, online games, and online videos, was associated with a higher prevalence of depression. In contrast, more time spent on TV was associated with a lower prevalence of depression. Sufficient exercise can lower the prevalence of depression, regardless of the length of time and content of the screen, and its associations were particularly significant for junior high school girls. Sleep was not associated with the prevalence of depression among any participant group except elementary school boys. Our findings suggest that age- and sex-specific intervention strategies that also consider screen-based behavior can effectively lower the risk of depression in children and adolescents.

Keywords: screen time, 24-h movement guideline, mental health, youth, exercise

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INTRODUCTION

Depression and its increasing prevalence among children and adolescents (1, 2) is a serious concern. Depression can affect psychological (3), academic (4), and cognitive well-being (5). There is an ongoing debate as to whether the rapid, widespread use of screen devices such as smartphones and portable games is a potential cause for the increased trends of depression (6–9). To date, the evidence regarding screen-based behavior and depression is mixed with negative (10), positive (7, 11), no effect (12), or heterogeneous effects by contents and context of screen time (8, 13) and participants' characteristics (e.g., age and sex) (8, 14, 15).

Screen-based behavior is traditionally assessed in terms of time spent viewing TV, using computers, and playing video games. However, newer types of screen behavior such as watching movies (e.g., YouTube), using social media (e.g., Facebook, Twitter, and Instagram), and online games are emerging among children and adolescents (16). Importantly, evidence suggests that different types of screen behavior are associated differently with depression (8, 10, 17). For example, a recent systematic review of 70 studies showed that computer use and video game playing, but not TV viewing, were significantly associated with depression among youth (8). There are potential mechanisms underlying different effects according to screen behavior types, including displacement hypothesis (18, 19) and upward social comparison hypothesis (20–22). The displacement hypothesis posits that screen time is negatively associated with depression because healthier activities, including exercise and sleep, are displaced by screen behavior types (18, 19). In this scenario, the associations between screen behavior and depression should be equivalent across different screen behavior types because all of them displace time for participating in healthier activities within a 24 h framework (10, 23). In contrast, the upward social comparison hypothesis posits that the effects of screen behavior on depression can vary based on the content viewed on screens (20–22). In particular, upward social comparisons occur when people compare themselves to others who are in more favorable positions (20–22). Previous studies showed that upward social comparison also occurs while using social media because it creates feelings of inferiority (24–26). In this scenario, social media might have larger effects than video games, which do not contain depictions of actual real-life individuals to whom the youth can socially compare themselves (10). In either case, this evidence suggests that viewed contents should also be considered when the association between screen time and depression is examined.

Evidence suggests that sufficient physical activity, sleep duration, as well as low levels of sedentary behavior are all independently associated with better mental health (27–29). Importantly, these behaviors are interrelated and co-dependent (23). Considering these characteristics, Canada released 24 h movement guidelines that recommend children and youth achieve three recommendations (i.e., physical activity, recreational screen time, and sleep) simultaneously (23). A recent systematic review suggests that meeting all three recommendations is preferable to reduce the risk of depression compared to meeting none of the recommendations (30). Additionally, a cross-sectional study with more than 17,000 Canadian children (aged 10–17 years) indicated that those who achieved any given recommendation had better mental health, including life satisfaction, prosocial behavior, and fewer emotional problems than those who did not achieve any of the recommendations (31). While the previous study provided important implications, the authors only evaluated the time spent on TV, videos, DVD, and computer games (31), and they did not specifically evaluate the time spent on newer types of screen behavior including social media and online games that are becoming increasingly popular among children and adolescents (16). To the best of our knowledge, no study has examined the combined association between physical activity (or exercise), sleep, and various types of screen behavior, including traditional and newer screen behavior types, with depression among children and adolescents. Therefore, the purpose of the present study was to examine the associations between various types of screen behavior and depression, taking into account exercise and sleep among children and adolescents.

MATERIALS AND METHODS

Participants

This cross-sectional study was conducted as a census survey in Setagaya ward, Tokyo, Japan. The details have been described elsewhere (32). In brief, all children and adolescents (aged 8–15 years) from public elementary and junior high schools in the Setagaya ward were invited to participate in the present study. A questionnaire survey was conducted in March 2019 in these schools. The questionnaire for elementary school children was shared with parents who helped with completing it. Junior high school adolescents independently answered the questionnaire. Participants and their parents/guardians were provided with detailed information, including the purpose and contents of the present study. They were also informed about their right to withdraw from the study at any time and were provided with complete assurance regarding the confidentiality of their data. Among the total and eligible samples (n = 34,643), 251 were excluded as they did not submit written informed consent (0.7%). Among those who submitted written informed consent (n = 34,392; 99.3%), data from 10,819 students (31.2%) were excluded as there was at least one missing piece of demographic data (age and sex), exposure (screen behavior, exercise, and sleep duration) and/or outcome variables (depression). The final sample for the present study comprised 23,573 Japanese children and adolescents (aged 8–15 years) (elementary school students: n = 15,726, junior high school students: n = 7,847, valid data = 68.0%). **Figure 1** presents this sampling process. The present study was approved by the ethics committee of the Nippon Sport Science University (approval No. 015-H075).

Recreational Screen Behavior

The questionnaire, based on national surveillance (33), asked about recreational (i.e., screen behavior outside of school) screen time. Participants were asked the following four questions about their weekly activity. (1) How long do you watch TV, videos, DVD? (2) How long do you watch online videos? (3) How long do you use social media? (4) How long do you play online games? Participants were asked to report the time spent on each screen behavior in a week.

Exercise and Sleep Duration

For exercise time, participants were asked the following question: usually, how long do you play sports or exercise outside of school? Here, participants were asked to respond with their exercise time for each day of the week (from Monday to Sunday). Thereafter, the weekly exercise time was calculated by summing the exercise time for each day of the week. The questions were derived from an annual national

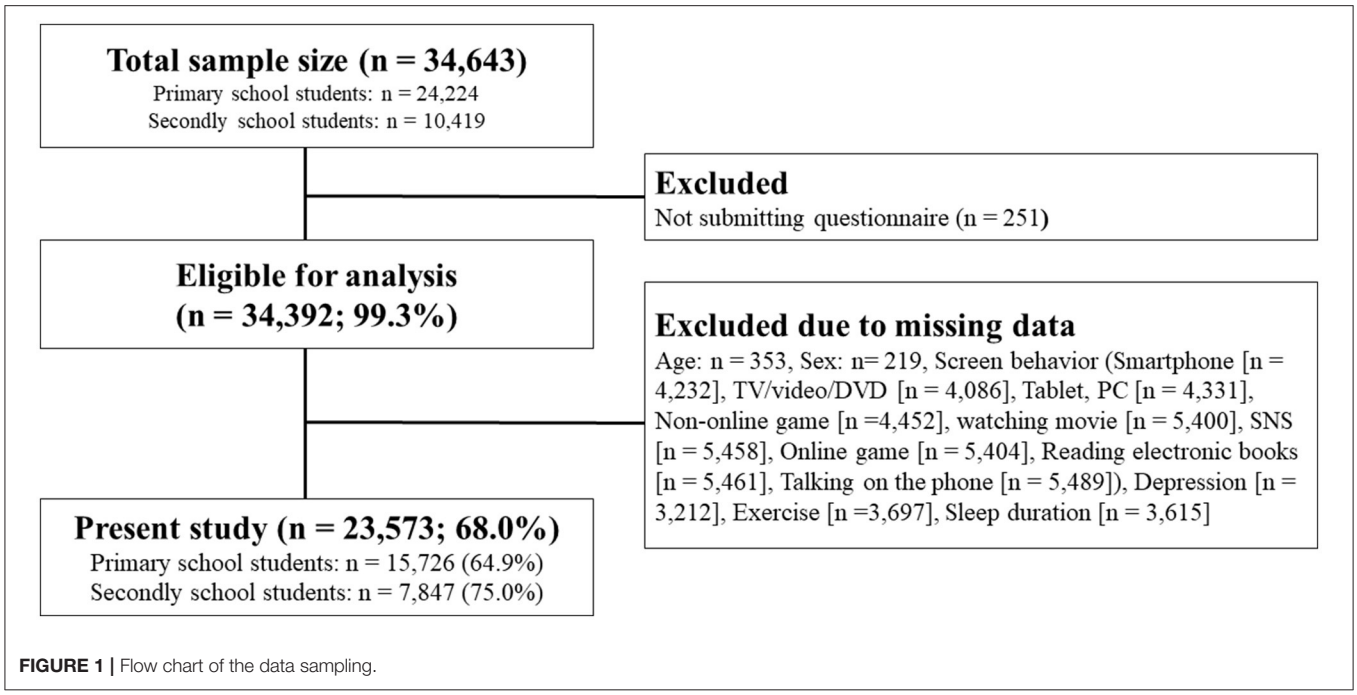

FIGURE 1 | Flow chart of the data sampling.

physical fitness survey among Japanese children and adolescents aged 10–11 and 13–14 years (called "National Survey of Physical Fitness, Athletic Performance and Exercise Habits") (34, 35). While the questionnaire has not been validated using objective physical activity measures (e.g., accelerometers and doubly labeled water), the time spent on exercise evaluated by the questionnaire has been shown to be significantly associated with health-related outcomes including objective physical fitness performance (34, 35). For sleep duration, participants were asked about their usual weekday wake-up time and bedtime. Thereafter, the sleep duration was calculated by subtracting the wake-up time from the bedtime. Participants were categorized into two groups (meeting sleep guidelines vs. not meeting sleep guidelines) based on the 24 h movement guideline that recommends 9–11 h/day of sleep for 5–13 years old children and 8–10 h/day of sleep for 14–17 adolescents (23).

Depression

Depression symptoms were measured using a modified version of the depression questionnaire developed by the American Psychiatric Association (36). The modified version of the questionnaire was developed by the Japanese Association of School Health for Japanese school-aged children, and the questionnaire has been tested for its validity and reliability among non-depressed Japanese children and adolescents (33). The questionnaire includes eight questions. Depression is defined using the criteria developed by the Japan Society of School Health (33).

Statistical Analysis

To examine if any difference existed in age, screen behavior, exercise, sleep, and the prevalence of depression by sex (boys vs. girls) and school type (elementary school vs. junior high school), *t*-tests were performed. Independent associations between various types of screen behavior and prevalence of depression were examined by logistic regression analyses. The presence of depression was considered as a main outcome variable after adjustments were made for age, school, sleep duration, exercise time, and other screen behavior types (e.g., when TV was modeled as the main exposure, the analysis was adjusted for the other three (i.e., online videos, online games, and social media) exposures). To understand the dose-response relationships between screen behavior and depression, we categorized the participants into four groups ("0–30 min," "30–60 min," "1–2 h," and ">2 h") based on time spent engaging in each screen behavior, with the least usage group (i.e., "0–30 min") henceforth mentioned as the reference group. Odds ratios (ORs) and 95% confidence intervals (95% CIs) were estimated. To examine whether exercise and sleep can attenuate the negative effects of screen behavior, a two-way analysis of covariance (ANCOVA) was conducted after adjusting for age, school, sleep duration (i.e., when the exercise was modeled as main exposure, the analysis was adjusted for sleep duration), exercise time (i.e., when sleep was modeled as the main exposure, the analysis was adjusted for exercise), and other screen behavior types (e.g., when TV was modeled as the main exposure, the analysis was adjusted for the other three exposures). For exercise, the participants were categorized into two groups ("High EX" vs. "Low EX") based on the median value of the time spent doing exercise. For sleep, the participants were

TABLE 1 | Descriptive characteristics of the participants.

	Elementary school (n = 15,726)		Junior high school (n = 7,847)		Comparisons, p-value			
					Boys vs. Girls		Elementary vs. junior high school	
	Boys (n = 8,010)	Girls (n = 7,716)	Boys (n = 4,189)	Girls (n = 3,658)	Elementary school	Junior high school	Boys	Girls
Basic characteristics								
Age (years)	9.7 ± 1.6	9.3 ± 1.7	14.0 ± 0.8	14.0 ± 0.8	**<0.001**	0.330	**<0.001**	**<0.001**
Screen behavior								
TV, video, DVD (min/day)	80.2 ± 57.0	84.5 ± 60.1	98.7 ± 88.7	112.1 ± 94.5	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Watching online video (min/day)	26.6 ± 40.8	25.4 ± 41.9	76.8 ± 80.2	75.7 ± 78.8	**0.019**	0.494	**<0.001**	**<0.001**
Social media (min/day)	1.6 ± 10.6	3.2 ± 13.8	28.5 ± 49.9	54.7 ± 67.3	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Online game (min/day)	18.7 ± 37.7	7.0 ± 20.9	74.1 ± 87.7	22.4 ± 50.6	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Depression								
Depressive symptom [% (n)]	3.3 (264)	2.7 (208)	9.5 (398)	8.8 (322)	**0.001**	0.245	**<0.001**	**<0.001**
Exercise and sleep								
Exercise time (min/day)	74.5 ± 58.9	47.1 ± 45.6	69.3 ± 62.0	52.3 ± 58.6	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Sleep duration (min/day)	545.1 ± 47.0	545.9 ± 49.0	449.4 ± 76.8	436.6 ± 73.5	0.189	**<0.001**	**<0.001**	**<0.001**

Data are expressed as mean (or percentage) and standard deviation. Bold values represent statistically significant p-values (< 0.05).

categorized into two groups ("Met sleep guideline" vs. "Not met sleep guideline") based on the 24-h movement guideline (23). All statistical analyses were performed using IBM SPSS Statistics for Windows, version 27.0 (IBM Corporation, Armonk, NY, USA).

RESULTS

Descriptive Characteristics of the Participants

There were significant differences in screen behavior types by sex (boys vs. girls) and school type (elementary school vs. junior high school) (**Table 1**). Boys spent more time watching online videos (elementary school students only) and online games than girls. In contrast, the girls spent more time watching TV, videos, DVD, and social media than boys. Junior high school students spent more time on all screen behavior types than elementary school students. Boys had a higher prevalence of depression than girls among elementary school students. Junior high school students had a higher prevalence of depression than elementary school students. Boys spent more time exercising than girls. Boys in junior high school spent less time exercising than boys in elementary school, but the opposite results were found for girls. Among junior high school students, boys spent more time sleeping than girls did. Junior high school students spent less time sleeping than elementary school students (**Table 1**).

Various Types of Screen Behavior and Depression

The associations between screen behavior and depression varied according to screen behavior type (**Figure 2**). Junior high school students (both boys and girls) who spent more than 2 h/day on social media had a higher prevalence of depression than the reference group. Girls in junior high school who spent more than 2 h/day playing online games had a higher prevalence of depression than the reference group. Additionally, boys in elementary school who spent more than 2 h/day of watching online videos had a higher prevalence of depression than the reference group. However, more time spent watching online videos was associated with a lower prevalence of depression among junior school boys. Furthermore, more time spent watching TV was associated with a lower prevalence of depression among boys and girls.

Combined Associations of Exercise and Screen Behavior Types With Depression

Figure 3 shows the results of the two-way ANCOVA analysis (exercise × screen behavior). Exercise significantly affects screen behavior of elementary school boys (online videos), junior high school boys (TV, online videos, and online games), and junior high school girls (all screen behavior types). There were no significant interactions between exercise and screen behavior in relation to the prevalence of depression.

Combined Associations of Sleep and Screen Behavior Types With Depression

Figure 4 shows the results of the two-way ANCOVA analyses (sleep × screen behavior). There were significant main effects for sleep among elementary school boys (TV and online videos). There were no significant main effects for sleep among girls and junior high school boys.

DISCUSSION

The present study examined the association between various screen behavior types and depression, while also taking into

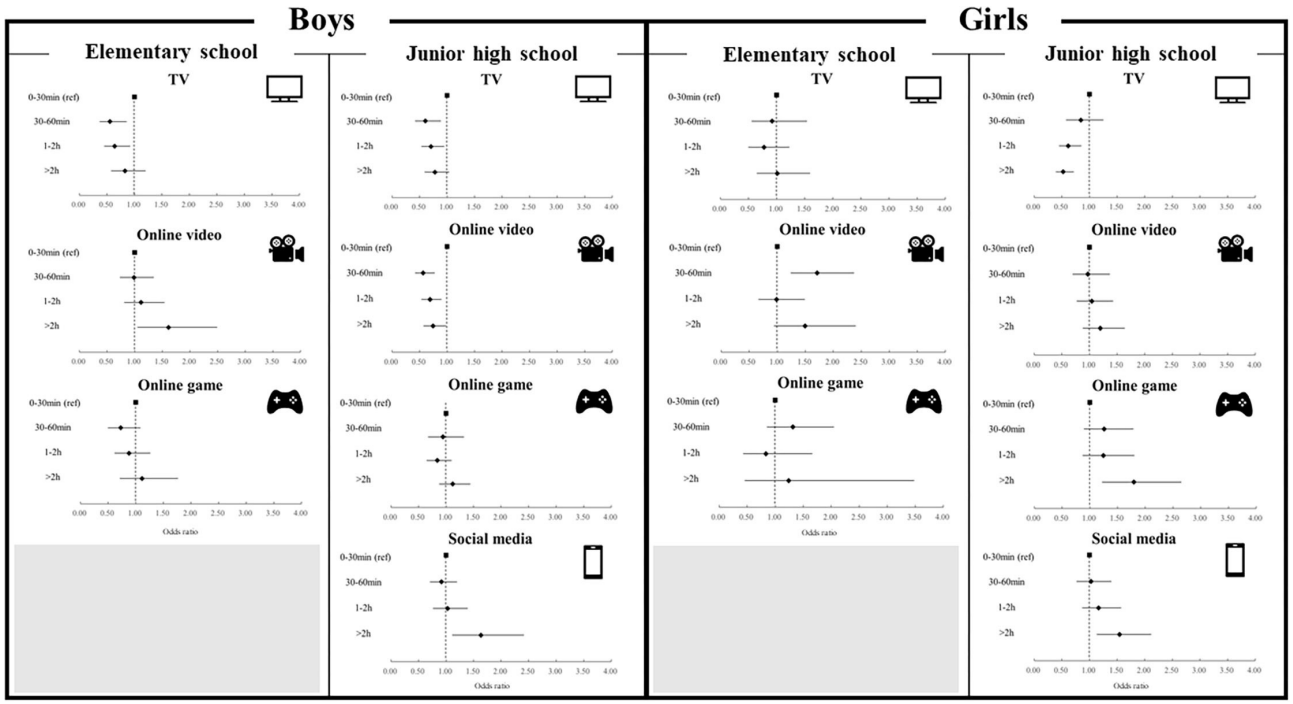

FIGURE 2 | Various types of screen behaviors and depression. Data are expressed as odds ratios and 95% confidence interval. Independent associations between various types of screen behaviors and prevalence of depression were examined by logistic regression analyses with the presence of depression as a main outcome variable after adjusting age, school, sleep duration, exercise time, and other screen behaviors [e.g., when TV was modeled as the main exposure, the analysis was adjusted for the other three exposures (i.e., online videos, online game and social media)].

consideration the influence of exercise and sleep, among a large sample of children and adolescents. The present study revealed that the associations between screen behavior and depression varied by screen behavior types and participant characteristics (sex and developmental stage). In general, more time spent on newer types of screen behavior, including social media, online games (among junior high school girls), and online videos (among elementary school students) was associated with a higher prevalence of depression. In contrast, more time spent on TV, which was traditionally assessed as screen behavior, was associated with a lower prevalence of depression. Sufficient exercise can lower the prevalence of depression, regardless of the length of time and content of screen behavior types, which was particularly significant for junior high school girls. Sleeping for recommended hours can lower the prevalence of depression, but only in elementary school boys. These results could provide important insights to promote psychological health among children and adolescents in the current digital society, where screen devices are ubiquitous (6).

Explanations of Main Findings

This is the first study to reveal that sufficient exercise (particularly for junior high school students) and sleep (at least for elementary school boys) can attenuate the negative effects of various types of screen behavior on depression in children and adolescents. There are several potential mechanisms that explain how sufficient exercise and sleep are associated with lower prevalence of depression. For example, exercise can reduce the risk of depression through biological (e.g., improving neuroplasticity, neuroendocrine response, inflammation, and oxidative stress) as well as psychological processes (e.g., enhancing self-esteem, social support, and self-efficacy) (37). The present study showed that exercise had greater effects on depression in adolescents, which can be explained by the higher prevalence of depression in adolescents (9.5% and 8.8% for boys and girls, respectively) than in children (3.3 and 2.7% for boys and girls, respectively). This is consistent with findings from previous studies suggesting that exercise is particularly beneficial for adolescents (38). Among junior high school students, exercise significantly attenuated the negative effects of TV, online videos, and online games on depression in both boys and girls. In contrast, exercise significantly attenuated the negative effects of social media on depression in girls but not boys. The sex differences can be explained by the shorter time spent on exercise and longer time spent on social media by girls compared to boys, which are consistent with previous studies (39, 40). Additionally, previous studies reported that there were larger protective effects of exercise on depression in girls than among boys (41, 42). These characteristics might have resulted in the larger protective effects of exercise from prolonged social media on depression among girls. Short sleep duration was negatively associated with brain function (43, 44), brain structure (44), executive function,

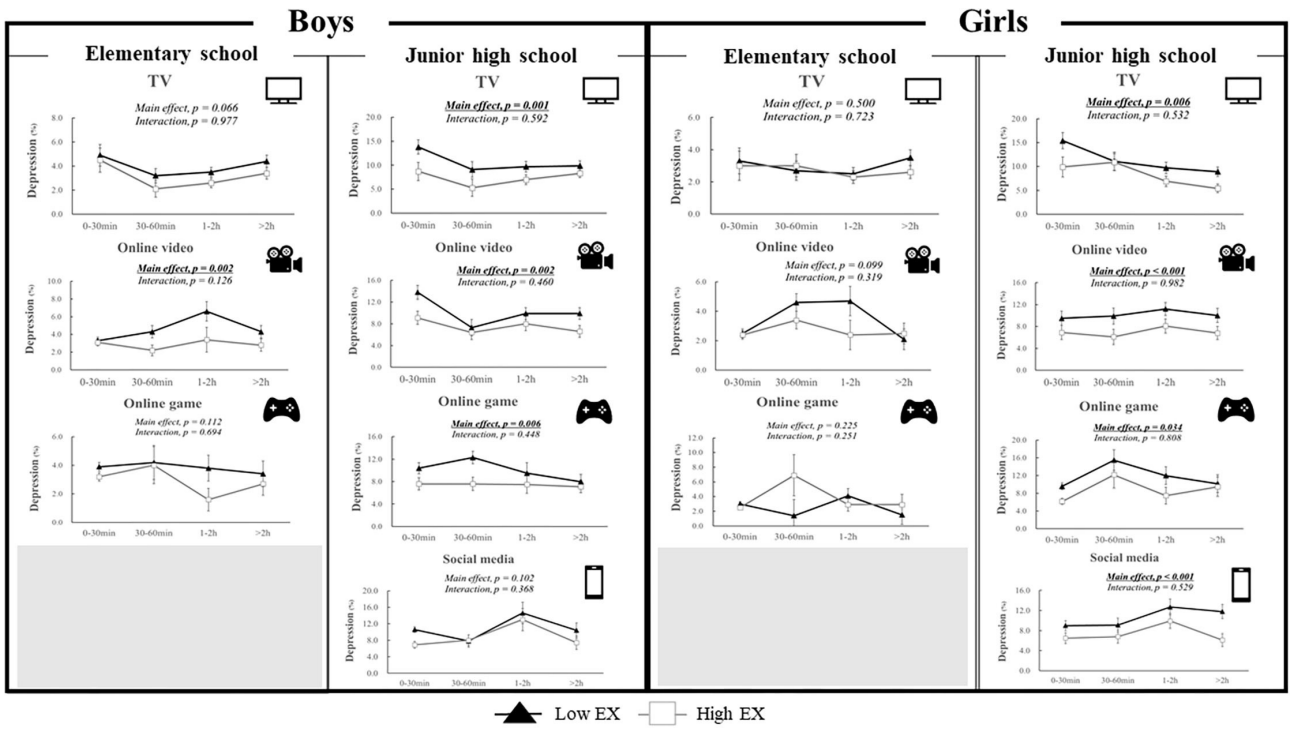

FIGURE 3 | Combined associations of exercise and screen behaviors with depression. Data are expressed as odds ratios and 95% confidence interval. Two-way analysis of covariance (ANCOVA) were conducted after adjusting for age, school, sleep duration and other screen behaviors (e.g., when TV was modeled as the main exposure, the analysis was adjusted for the other three exposures). The participants were categorized into two groups ("High EX" vs. "Low EX") based on the median value of the time spent in exercise.

including working memory and inhibitory control (45), and daytime active behavior due to sleepiness and fatigue (46). Since the Canadian 24 h movement guidelines were released in 2016 (23), numerous pieces of evidence for the combined associations of physical activity, sedentary behavior, and sleep with health outcomes have been published (30). However, most studies on this topic primarily focused on physical health outcomes, and little attention has been paid to mental health outcomes (30, 47). The present study adds to a small body of evidence by demonstrating the potential protective effects of exercise and sleep on depression, along with comprehensive assessments of various types of screen behavior. This is particularly important because types of screen behavior in children and adolescents have become more diverse than ever (16), and assessing only traditional screen time (such as TV viewing and computer gaming) may not be enough for a comprehensive understanding of screen behavior in this population.

Associations of Screen Behavior and Depression Differ by Screen Behavior Types

There are several potential mechanisms by which types of screen behavior are associated with depression, including the displacement hypothesis (18, 19) and upward social comparison hypothesis (20–22). The present study suggests that the associations between screen behavior and depression differ by screen behavior types. This suggests that there might be, at least in part, mechanisms other than the displacement hypothesis behind the associations. The upward social comparison hypothesis posits that the effects of screen behavior on depression can vary based on the content viewed on screens (20–22). In particular, upward social comparisons occur when people compare themselves to others who are in more favorable positions (20–22). Previous studies have shown that social media use might be particularly detrimental because it creates feelings of inferiority via upward social comparison (24–26), which is consistent with the findings of the present study. This is concerning because the majority of adolescents in today's world use social media and it has become an essential part of their social life (16, 48).

Strength and Limitations

The present study had several strengths. The large sample size of the present study enabled us to conduct stratified analyses (stratified by developmental stage and sex) taking into account exercise and sleep. Our results suggest that effective approaches to lower the risk of depression should vary according to sex and developmental stage, which have important implications for policy making, clinical practice, and future interventions. Second, we included both traditional types of screen behavior such as TV and newer types such as watching online videos, spending time on social media, and playing online games. This can provide important insights, given that types of screen behavior in today's

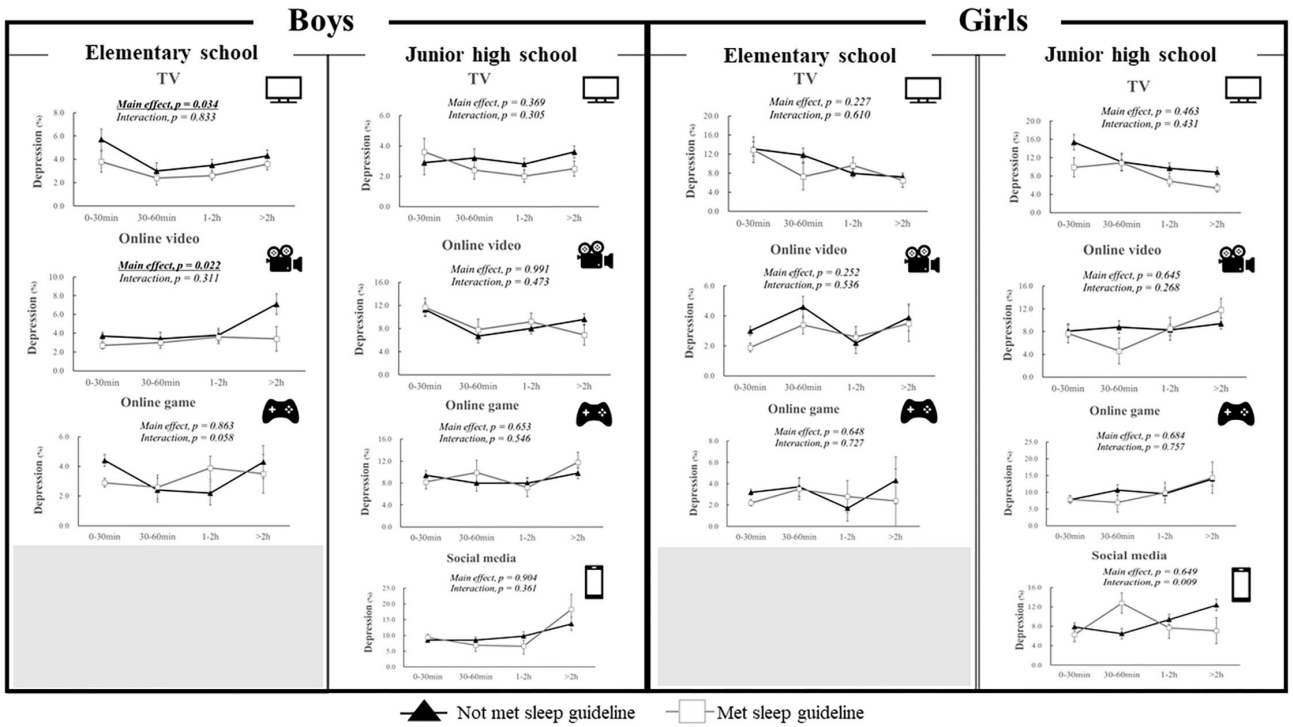

FIGURE 4 | Combined associations of sleep and screen behaviors with depression. Data are expressed as odds ratios and 95% confidence interval. Two-way analysis of covariance (ANCOVA) were conducted after adjusting for age, school, exercise time, and other screen behaviors (e.g., when TV was modeled as the main exposure, the analysis was adjusted for the other three exposures). The participants were categorized into two groups ("Met sleep guideline" vs. "Not met sleep guideline") based on the 24 h movement guideline (23).

children and adolescents have become more diverse than ever (16).

Despite the insights provided in our study, some limitations need to be addressed. First, we used a cross-sectional design; therefore, it was not possible to examine the causal relationships between screen behavior and depression. Indeed, it is possible that depressive children and adolescents are less likely to engage in favorable lifestyle behaviors, including exercise and sleep, as previously suggested (49, 50). Second, we used only self-report measures to assess the time spent on screen behavior types, exercise, and sleep, which may lack in precision. Third, the present study did not include any important co-founding variables, including in-person social interactions with friends and family, which should be considered in future studies (51). Fourth, we did not evaluate "how" participants engage in screen behavior. For example, children and adolescents can use social media while being mentally active (e.g., chatting with friends, posting comments, and pictures) or mentally passive (e.g., reading and scrolling through friends' comments and pictures). A recent review argued that there were differential associations between mentally passive and active sedentary behavior and depression (13). Therefore, the detail of "how" the screen is used should be examined in the future.

CONCLUSION

The present study revealed that the associations between screen behavior and depression varied according to screen behavior types and participant characteristics. We found that more time spent on newer types of screen behavior, including social media, online games (junior high school girls only), and online videos (elementary school students only) was associated with a higher prevalence of depression. In contrast, more time spent watching TV was associated with a lower prevalence of depression. Our results suggest that a sex- and developmental stage-specific approach should be used to effectively lower the risk of depression among children and adolescents. Additionally, sufficient exercise can lower the prevalence of depression, regardless of the length of time and content of screen behavior types. Furthermore, the protective effects of exercise may be particularly pronounced in junior high school girls. In contrast, sleep was not associated with the prevalence of depression among any participant group except elementary school boys. This study provides important insights into the current digital society, where screen devices have become a part of the social life of children and adolescents.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The present study was approved by the Ethics Committee of the Nippon Sport Science University (approval No. 015-H075). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

SN conceptualized the original idea and constructed the methodology. AS, RT, and KT participated in data collection. TK and NI performed statistical analyses. TK wrote the original manuscript. All authors have read and agreed to the published version of the manuscript.

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frontiers in Public Health

SYSTEMATIC REVIEW
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Effect of Brisk Walking on Health-Related Physical Fitness Balance and Life Satisfaction Among the Elderly: A Systematic Review

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Background: Although the elderly frequently engages in brisk walking as a form of exercise, little has been reported in the literature about the effect of brisk walking on health-related physical fitness, balance, and overall life satisfaction.

Objectives: The purpose of this systematic review is to determine the effect of brisk walking on the elderly's health-related physical fitness, balance, and life satisfaction.

Design: We conducted a comprehensive search from the PubMed, Web of Science, Scopus, and SPORTDiscus databases from January to September 2021. We selected studies through PICOS and conducted a systematic literature review according to the PRISMA guidelines.

Results: Thirteen studies met all criteria; 11 were classed as low risk of bias, while two were classified as high risk of bias. Generally, brisk walking has been shown to improve cardiorespiratory fitness, muscular strength, and body composition. Limited evidence was presented on flexibility, muscular endurance and development and life satisfaction, and there was conflicting evidence on balance. Moreover, evidence of restriction proves that high-intensity (80–85%) brisk walking is more effective than moderate-intensity (60–75%) brisk walking on the aerobic capacity of the elderly. Furthermore, there was less research conducted on males.

Conclusion: Brisk walking has been shown to improve cardiorespiratory fitness, muscular strength, and body composition. Other outcomes (balance, flexibility, muscular endurance, and life satisfaction) and the impact of the intensity of brisk walking on the elderly should be confirmed. Therefore, there remains insufficient research on brisk walking, while single brisk walking cannot meet requirements of elderly in terms of their health-related physical fitness, balance, and life satisfaction. Future research should aim to examine the effectiveness of combining several types of exercises to promote general health in the elderly, as the World Health Organization recommends. Unintelligible FITT (frequency, intensity, time, type) principles of brisk walking training should be trenched for the results of scientific and effective physical exercise.

Keywords: cardiorespiratory fitness, muscular endurance, muscular strength, body composition, flexibility, balance, life satisfaction

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INTRODUCTION

As a result of the global aging trend, many countries have increased their focus on the health of the elder population (1). Physical exercise has been shown to improve the overall health and quality of life (QoL) of the elderly by enhancing their physical and mental health (2–4). Walking is a low-cost, low-impact form of exercise. Not only does it improve general health and improve QoL, but it also plays a critical role in the prevention and treatment of numerous diseases (5).

Age is a significant risk factor for non-communicable chronic diseases (NCDs) such as chronic obstructive pulmonary disease, cardiovascular disease (CVD), type 2 diabetes, cognitive decline, dementia, and cancer (6), all of which have high associated diagnostic, treatment, and care costs. According to the WHO, more than 80% of the elderly suffer from at least one NCDs (7). Cardiovascular diseases account for most NCD deaths, or 17.9 million people annually (8). Moreover, falls are the second greatest cause of unintentional injury deaths. The risk of death or serious injury is greatest for older adults. Furthermore, some studies have shown that the worse the physical health, the lower the mental health score (9, 10). Mental health and physical health are equally for elderly, which influence greatly an overall feeling of well-being (8). Thus, the main issues of elderly include cardiovascular diseases, falls, and mental health. The World Health Organization (WHO) recommends ∼150 min of moderate-intensity physical activity or exercises per week to reduce the risk of death from any cause, cardiovascular disease, hypertension, site-specific cancers, type-2 diabetes, prevention of accidental falls, decreased mental health (anxiety and depression symptoms), cognitive health, and measures of adiposity (7). Thus, supporting healthy aging through physical activity, self-sufficiency, and leisure time becomes a critical public health problem for enhancing an individual's health (11). Walking is among the most popular physical exercises on a global scale (12). It features simple and natural movements, a moderate level of workout intensity, and a long lifespan. Meanwhile, it has the advantage of individuals being less prone to injury and posing little risk, making it an excellent choice for middle-aged and elderly individuals (13). Moreover, previous study have presented that walking can reduce falls times (14), prevent cardiovascular disease (15), ease up anxiety, and depression (16). Thus, walking may become one of the effective exercise methods to alleviate the current health-related problems faced by the elderly. Base on a book of ACSM's exercise for older adults, FITT (frequency, intensity, time, type) principle should be followed when elderly exercise, which improve physical fitness effectively (17). Generally, elderly people who participate in exercise are not sure how fast walking will have a greater impact on the health. Therefore, it is necessary to review the literature to sort out what exercise principles are most effective in promoting the health of the elderly.

Through combing the effects of brisk walking on the health of the elderly, discovered that most researchers only study its effects on part of the physical fitness such as lower body strength (18, 19), cardiorespiratory fitness (20–23), body composition (24), no studies mantled all components, and penurious researches on life satisfaction. Not only that some studies have unclear reports on exercise intensity (19, 25, 26). Moreover, only two papers contrast in brisk walking intensity (24, 27). Additionally, identifying workouts that have a greater influence on health-related physical fitness, balance, and life satisfaction to prevent and defend against the emergence of health problems warrants further research. The President Council on Physical Fitness has defined health-related physical fitness as "those specific components of physical fitness that have a relationship with good health" (28). Cardiorespiratory fitness, body composition, flexibility, muscular strength, and muscular endurance are all components of health-related fitness. Physical fitness has been demonstrated to be a strong independent predictor of death in previous research (29). Among them, improving cardiovascular fitness can reduce your risk of developing cardiovascular disease by increasing the efficiency of your heart, lungs, and blood vessels (30). Additionally, balance exercises are critical in avoiding elderly people from falling (31). Life satisfaction is more important to the mental health of the elderly (32). Hence, highly related to health-related physical fitness, balance and life satisfaction, and health-related issues of the elderly. According to the health-related fitness model (33), physical activity can promote health-related fitness eventually affect health which includes wellness, mortality, and morbidity. In this study, brisk walking as a physical activity to improve elderly health-related fitness and balance eventually affect health. Additionally, Life satisfaction is regarded as an indicator of the quality of life which, in turn, is associated with mortality (34–36) and morbidity in older adults (37, 38). Given that brisk walking is a necessary type of exercise for the elderly, what are the impacts on their physical health? Is it effective at preventing and protecting against a variety of chronic diseases that affect the elderly? As such, the purpose of this study is to determine the effect of brisk walking on the health-related physical fitness, balance, and life satisfaction of senior individuals.

MATERIALS AND METHODS

Eligibility Criteria

A systematic review was carried out according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement. **Table 1** summarizes the inclusion criteria for this review, which are Population, Intervention, Comparison, Outcome, and Study Design (PICOS). In addition to the above screening criteria, studies were included if they satisfied the following criteria: (1) full-length, peer-reviewed journal articles; (2) healthy study participants (excluding those who were obese or weak); and (3) consideration of objective measurements of health-related physical fitness, balance, and life satisfaction. Physical fitness for health is defined as a subset of fitness that encompasses cardiorespiratory fitness, muscular strength, muscular endurance, flexibility, and body composition. These components are related with daily activities and are critical for older individuals to preserve their independence (39). Balance and life satisfaction are related with falls and the mental health

TABLE 1 | Population, intervention, comparator, outcome, and study design (PICOS) detail screening criteria.

PICOS	Screening criteria
Participants	Healthy adults, age ≥ 60 yrs old (except obesity, frail, cancer, and other diseases)
Intervention	It must be a moderate and vigorous walking, excluding running and Nordic walking.
Comparison	No exercise group or exercise group in the control group
Outcomes	Strength, endurance, balance, flexibility, body composition, cardiorespiratory fitness, balance, life satisfaction
Study design	Randomized controlled trial

of the elderly. Additionally, they entail moderate and vigorous walking, but not running or Nordic walking. To eliminate duplication, the considered studies were loaded into Mendeley's reference management program. To begin, an experimental librarian led the search procedure. Second, the titles and abstracts were independently reviewed by two reviewers. Following that, pertinent full-text articles were selected for further investigation. In the event of any disagreement between two reviewers, a third reviewer served as a tiebreaker.

Data Sources and Search

A systematic search was undertaken on the existing literature on the impact of brisk walking on health-related physical fitness, balance, and life satisfaction in the elderly, published before December 2021. The study was designed and conducted in accordance with the PRISMA statement (40).

The literature search was conducted using four prominent scholarly databases: PubMed, Web of Science, Scopus, and SPORTDiscus. All keywords were searched by Mesh of PubMed and previous studies. Each database was searched by title using a predefined combination of keywords ("health-related physical fitness" OR "physical fitness" OR "muscular strength" OR "muscular endurance" OR "flexibility" OR "body composition" OR "cardiorespiratory" OR "balance" OR "satisfaction with life" OR "life satisfaction") AND ("brisk walk*" OR "moderate-intensity walk*" OR "high-intensity walk*") AND ("old people" OR "elders" OR "senior*" OR "old adult*" OR "aged" OR "older people" OR "older adults" OR "geriatric"). Terms were joined with the use of logical operators that can be utilized by the database search engines. Additionally, the authors consulted experts in the field.

Study Selection

An author conducted a search for articles and deleted duplicates. Two authors independently chose studies based on their titles and abstracts. If this was unsuccessful, the papers were screened by reading the complete text. The following information was extracted: (1) author/year; (2) design/sample/age/gender; (3) intervention time/frequency/duration; and (4) major findings.

Quality Assessment

The PEDro scale was used to assess the trials' methodological quality (41). The PEDro scale assesses four critical methodological features of a study: randomization, blinding, group comparison, and data analysis. It is based on a Delphi list developed by Verhagen et al. (42), which includes the following 11 items: specified eligibility criteria, randomization, concealed allocation, baseline comparability, blinded subjects, blinded therapists, blinded assessors, adequate follow-up, intention-to-treat analysis, between-group comparisons, and point estimates and variability. Two trained independent raters assessed the quality of trials in the PEDro database, and conflicts were settled by a third rater (43). The PEDro scale has a score range of 1 to 10; whereby a higher PEDro score indicates a higher-quality approach. To determine the method's quality, the following criteria were used: A PEDro score of <5 denotes poor quality, while a score of 5 or greater indicates excellent quality (**Table 2**) (47).

Data Syntheses and Analysis

This study is a Meta-aggregation of Qualitative Data Synthesis. The scientific evidence's strength was determined by utilizing the most effective evidence synthesis (BES). This evaluation system considers the quantity, methodological quality, and consistency of research across five levels of evidence: (1) strong evidence, provided by generally consistent findings in multiple (≥2) high-quality studies; (2) moderate evidence, provided by generally consistent findings in one high-quality study and one or more low-quality studies, or in multiple low-quality studies; (3) limited evidence, provided by only one study or inconsistent findings in multiple (≥2) studies; and (4) conflicting evidence, provided by conflicting findings in case–control studies (75% of the time) and (5) absence of evidence, in the absence of case–control research.

RESULTS

Study Selection

The database search returned 260 records: 141 from PubMed, 103 from Web of Science, 0 from Scopus, and 16 from SPORTDiscus. Duplicate references were removed, resulting in a total of 257 articles. One hundred and fifty-four articles were eliminated from consideration for inclusion based on the topic and abstract screening. Finally, 13 articles that were deemed to be extremely relevant were analyzed by reading the complete text. Consequently, 13 articles were selected for inclusion in this systematic review. The process carried out for the study is depicted in **Figure 1**.

Method Quality

The PEDro scale had a range of values between 4 and 7 (mean = 5.2; median = 5; mode = 5). Two studies received a score of <5, while the remaining 11 ($n = 11$) received a score of five or higher, indicating a mix of high- and low-quality studies. The publication year did not influence the quality of the studies, since the low-quality studies were published in 2016 and 2017, while the high-quality studies were published between 2004 and 2019 (see **Table 2**). The mostly met criteria were eligibility criteria ($n = 13$), group similar at baseline ($n = 11$), point measure and variability ($n = 9$), random allocation ($n = 10$), between-group comparisons ($n = 8$), and follow-up ($n = 13$). The criteria

TABLE 2 | Summary of methodological quality assessment scores.

References	Eligibility criteria	Random allocation	Allocation concealment	Group similar at baseline	Blind subject	Blind therapist	Blind assessor	Follow-up	Intention to Treat Analysis	Between group comparisons	Point measure and variability	PEDro score
Audette et al. (18)	1	1	0	1	0	0	0	1	0	1	1	6
Bernard et al. (20)	1	1	0	1	0	0	0	1	0	1	1	6
Blain et al. (21)	1	0	0	1	0	0	0	1	0	0	1	4
Fisher and Li (25)	1	1	0	1	0	0	0	1	0	1	0	5
Kubo et al. (19)	1	1	0	1	0	0	0	1	o	1	1	6
Morita et al. (22)	1	1	0	1	0	0	0	1	0	1	0	5
Nemoto et al. (27)	1	1	1	1	0	0	0	1	0	1	1	6
Okubo et al. (23)	1	1	0	1	0	0	0	1	0	1	0	5
Paillard et al. (26)	1	1	1	1	0	0	0	1	0	0	1	6
Song et al. (44)	1	1	0	1	0	0	0	1	0	1	0	5
Swoap et al. (24)	1	0	0	0	0	0	0	1	0	0	1	3
Wanderley et al. (45)	1	0	1	1	0	0	0	1	0	0	1	5
Yoo et al. (46)	1	1	1	0	0	0	0	1	0	0	1	5
Total	**13**	**10**	**4**	**11**	**0**	**0**	**0**	**13**	**0**	**8**	**9**	

The bold values means summary of the quality evaluation of all papers.

blind subject, blind therapist, blind assessor, and intention to treat analysis did not satisfy any analysis. In terms of concealed allocation, $n = 4$ (**Table 2**).

Study Characteristics

The study characteristics included in this review are shown in **Table 3**. All studies were published between 2004 and 2019. In terms of the study design of pre- and post-test ($n = 11$) (18–20, 22–24, 26, 27, 45, 46, 48), one study tested four times (44) and one study tested three times (25). Regarding the participants, the studies included males (26) and females (18, 20–22, 44–46), or both sexes (19, 23–25, 27), with the mean value of ages ranging from 61.83 to 71.9. The sample size ranged from 9 to 68 participants. Brisk walking comprised an experimental group or a control group. The total intervention time ranged from 12 to 52 weeks, while the frequency ranged from 3 to 7, and the duration ranged from 15 to 60 min. There are five ways to assess intensity which ranged from 40% to 85% of heart rate reverse, 40%-80% of maximum heart rate, $\geq$ 3 metabolic equivalents (METs) daily (22), ∼50% VO_2 peak (27), and "Light (11)" and "Somewhat hard (13)" according to the perceived exhaustion scale (23).

Effect of Brisk Walking on Health-Related Physical Fitness, Balance, and Life Satisfaction Among the Elderly

The research results of 13 papers were considered and showed the impact brisk walking on health-related physical fitness, balance, and life satisfaction among the elderly. **Table 3** summarizes the major studies included in this study.

Effect of Brisk Walking on Cardiorespiratory Fitness

Ten publications discussed cardiorespiratory fitness (21–24, 26, 27, 46, 48). Among them, walking endurance, VO_2 max, peak aerobic capacity, 6-min walk, and 6-min walking distance were used as measurement techniques. Among these, 3–7 times per week, 12–52 weeks of brisk walking (40–85% of heart rate reverse, 40–80% maximum heart rate, ≥3 metabolic equivalents (METs) daily (22), ∼50% VO_2 peak (27), "Light (11)," and "Somewhat hard (13)" (23) has a considerable effect on cardiorespiratory fitness. Six of them referred to females (18, 21, 22, 45, 46, 48), one referred to males (26), and three referred to both (23, 24, 27). Eight articles have concluded that there was a significant difference in the brisk walking group between the pre-test and post-test (21–24, 26, 27, 46, 48). Nevertheless, two articles showed no significant difference between the pre-test and post-test (18, 45).

Effect of Brisk Walking on Body Composition

Four of the 13 articles discussed the subject of body composition (24, 26, 45, 46). Two trials tested body composition by dual-energy X-ray absorptiometry (DXA) (45, 46). Fat mass (24) and body weight (26) were also considered measurements. One article was devoted to males (26), two to females (45, 46), and another a mixture of both (24). Three articles concluded that brisk walking (The training time ranged from 12 to 26 weeks, 3–5 times per week, 36–50 min, the intensity at 40–85% of heart rate reverse) has a significant influence on body composition between the pre-test and post-test (24, 26, 46). Conversely, one paper showed that there was no significant improvement (45).

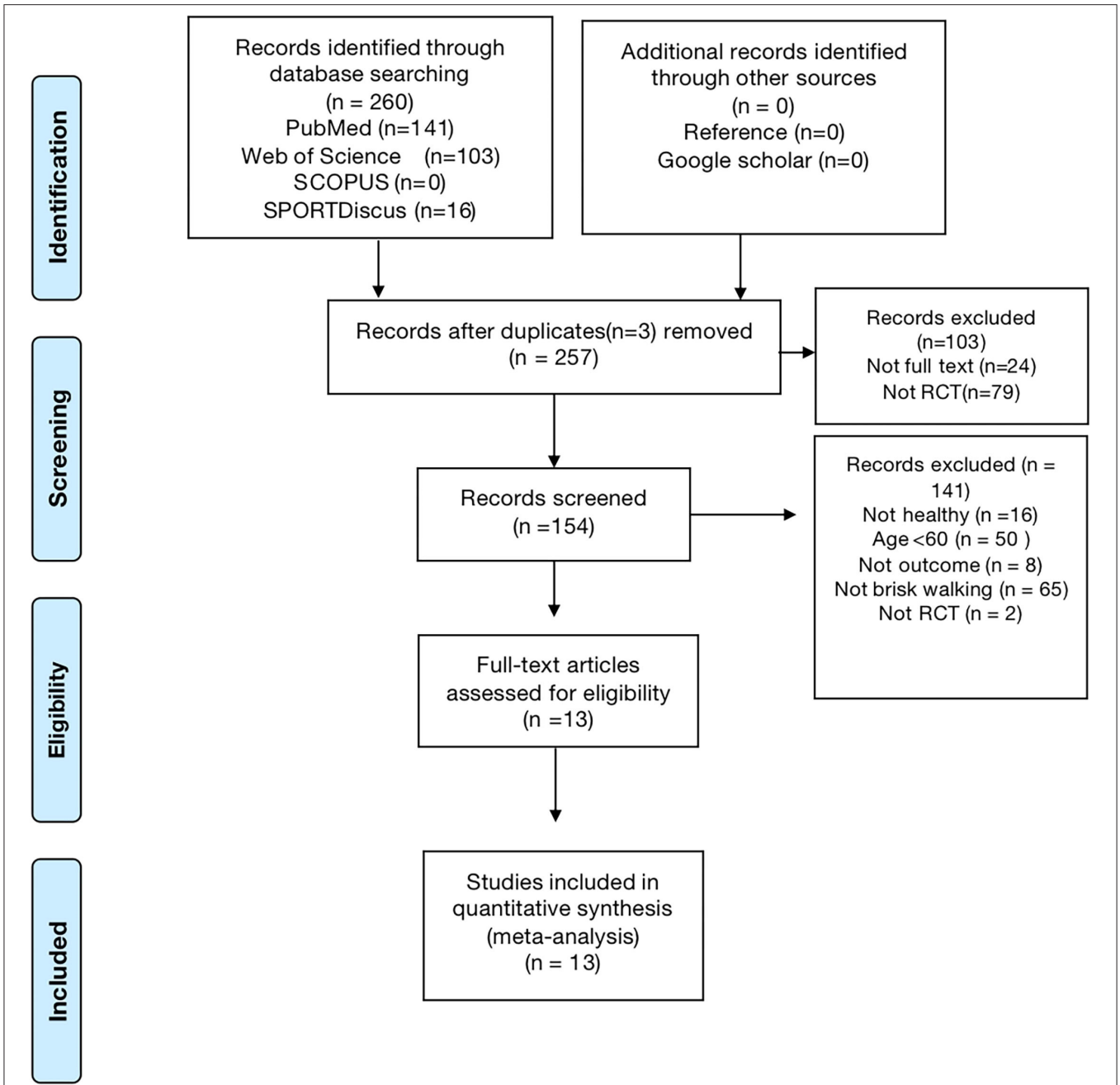

FIGURE 1 | PRISMA flow chart of the study selection process.

Effect of Brisk Walking on Flexibility

One of the 13 publications included a section on flexibility (45). There was no significant difference on chair sit-and-reach between baseline and 4 months among elderly women. Scilicet, no effect of brisk walking (50 min, 3 times per week, 16 weeks, at 50–70% of heart rate reverse) on flexibility.

Effect of Brisk Walking on Muscular Endurance

One of the 13 articles (45) established the concept of muscular endurance. Lower body muscular endurance (30 s chair stand) and upper body muscular endurance (30 s arm curl) were included in the test items (45). After 16 weeks of brisk walking (50 min, 3 times per week, at 50–70% of heart rate reverse), elderly women's lower limb muscular endurance improved, but there was no significant improvement in upper limb muscle endurance (45).

Effect of Brisk Walking on Muscular Strength

Five of the 13 articles discussed muscular strength (18, 19, 27, 44, 46). Measurements included right knee extension and

TABLE 3 | Characteristics of the studies examined in the present review.

References	Design	Participants	Age mean ± SD (yrs)	Main section content (CG/EG)	Intervention		Findings
					Intensity	(Wk/f/min)	
Audette et al. (18)	Pre-post-test	EG1 = 11 (F) EG2 = 9 (F) CG = 9 (F)	EG = 71.4 ± 4.5	EG1 = Tai Chi Chuan EG2 = Brisk walking CG = Sedentary comparison group	50–70% of their calculated target heart rate (220−age)	EG1 = 12/3/60 EG2 = 12/3/60	Significant improvement: non-dominant knee extensor strength ↑, single-leg stance time ↑ (Tai Chi Chuan vs. brisk walking, $P < 0.05$). No significant differences: on VO_2 max ↔.
Bernard et al. (20)	Pre-test, post-test1, post-test 2	EG = 61 (F) CG = 60 (F)	EG1 = 65.54 ± 4.04 CG = 65.46 ± 4.37	EG = Brisk walking group CG = Control group	60–80% of their maximal heart rate calculated by equation of Tanaka [FC_{max} = 208 – (0.7 × age)]	EG1 = 24/3/60 (brisk walking from 25 to 45 min) CG = 24/3/60	Significant improvement: 6MWT between pre-test and post-test 1 ↑, between post-test 1 and post-test 2 ↑.
Blain et al. (21)	Pre-posttest	EG1 = 61 (F) CG = 60 (F)	EG = 65.7 ± 4.3	EG = Brisk walking CG = Control group with physical activity allowed freely	40 to 60–80% of maximal heart rate and was calculated using Tanaka's equation [208 – (0.7 × age)].	EG = 24/3/50 CG = 24/3/50	Significant improvement: walking endurance (6MWD) ↑.
Fisher and Li (25)	Pre-test, post-test 1, post-test 2	EG = 28 (M\F) CG = 28 (M\F)	EG>65 CG>65	EG = leader led walking group CG = Information group	No presented	EG = 24/3/30-40 CG = 24/3/30-40	Significant improvements: in the primary outcomes of SWLS ($p < 0.05$) ↑ between primary and 6-month intervention.
Kubo et al. (19)	Pre-posttest	EG = 35 (M\F) CG = 10 (M\F)	EG = 68.4 ± 5.6 CG = 71.9 ± 2.7	EG = Walking training CG = No exercise	No presented	EG = 24/3/15-40	Significant changes: lower limbs strength (KF, DF, PF) ↑.
Morita et al. (22)	Pre-posttest	EG1 = 18 (F) EG2 = 14 (F)	EG>65	EG1 = Aerobic exercise (brisk walking) EG2 = Muscles training	≥ 3 metabolic equivalents (METs) daily	EG1 = 12/7/60 EG2 = 12/7/60	Significant improvement: cardiorespiratory fitness (6MWT) ↑.
Nemoto et al. (27)	Pre-posttest	EG1 = (M = 16, F = 59) EG2 = (M = 19, F = 68) CG = (M = 25, F = 59)	EG = 63 ± 6	EG1 = Moderate-intensity continuous walking training EG2 = High-intensity interval walking training CG = No walking training	EG1 = Walking more than 8,000 steps per day at ∼50% $VO_{2peak.}$ EG2 = low-intensity walking intervals (at ∼40% of the pre-training VO_{2peak}), followed by a 3-min interval of high-intensity walking (>70% but <85% VO_{2peak} for walking).	EG1 = 20/4/60 EG2 = 20/4/50	Significant changes: leg strength ↑, peak aerobic capacity ↑, and peak aerobic capacity ↑ were observed in the high-intensity interval walking training group. All these increases were significantly larger than those reported in the group receiving moderate-intensity continuous walking training.
Okubo et al. (23)	Pre-posttest	EG1 = 42 (F/M) EG2 = 33 (F/M)	EG1 = 70.3 ± 3.9 EG2 = 70.0 ± 3.7	EG1 = Balance group EG2 = Walking group	"Light (11)" and "Somewhat hard (13)" according to the perceived exhaustion scale	EG1 = EG2 = 52/3-5/30-50	Significant improvements: 6MWT ↑, one-leg stance with eyes closed ↔.
Paillard et al. (26)	Pre-posttest	EG = 11 (M) CG = 10 (M)	EG = 65.5 ± 2 CG = 66.8 ± 2	EG = Walking program CG = No exercise	No present	EG = 12/5/36	Significant improvements: lateral dynamic balance ↑, fat mass ↓, VO_2 max ↑.

(Continued)

TABLE 3 | Continued

References	Design	Participants	Age mean ± SD (yrs)	Main section content (CG/EG)	Intervention		Findings
					Intensity	(Wk/f/min)	
Song et al. (44)	Pre-test, post-test 1, post-test 2, post-test 3	EG = 35 (F) CG1 = 35 (F) CG2 = 35 (F)	EG = 61.83 ± 4.37 CG1 = 62.85 ± 5.29 CG2 = 62.14 ± 5.52	EG = Tai Chi Chuan CG1 = Dance Group CG2 = Moderate walking	The exercise intensity is con- trolled to be medium.	EG = 52/6/40 CG1 = CG2 = 52/6/40	Significant improvements: Post-test 1, eyes closed and stepping in place ↑, Hip extension strength ↑, knee extension strength ↑.
Swoap et al. (24)	Pre-posttest	EG1 = 10 (M) and 14 (F) EG2 = 14 (F) and 12 (M) CG = 9 (M) and 9 (F)	EG = 65.2 ± 4.2	EG1 = High intensity exercise EG2 = Moderate intensity exercise group CG = No exercise control group.	Moderate intensity at 40–50% to 65–70%of maximum heart rate reserve High intensity at 40–50% to 80–85%maximum heart rate reserve	EG1 = 26/3/45 EG2 = 26/3/40	Significant changes: VO_{2max} ↑, body weight ↓, and body composition ↓.
Wanderley et al. (45)	Pre-posttest	EG = 22 (F)	EG = 71.4 ± 5.9	EG = Moderate-intensity Walking	50–70% of heart rate reverse	EG = 16/3/50	Significant changes: systolic blood pressure ↓, and muscular endurance ↑, in the lower limbs' strength ↑, and upper limbs' strength ↑, body composition (DXA ↔, flexibility ↔, dynamic balance ↔, and aerobic endurance ↔.
Yoo et al. (46)	Pre-post-test	EG = 11 (F) CG = 10 (F)	EG = 70.9 ± 2.7 CG = 71.1 ± 2.7	EG = Exercise group CG = No exercise group	60% of heart rate reverse	EG = 12/3/60 CG = 12/3/60	Significant changes: upper body strength (handgrip strength) ↑, leg strength ↑, aerobic endurance ↑, and body composition (DXA) ↓, balance ↔.

EG, Experimental group; EG, Experimental group one; EG, Experimental group two; CG, Control Group; CG, Control Group one; CG, Control Group two; HRR, Heart rest rate; M, Male; F, Female; 6MWT, 6 min walk test; 6MWD, 6-min walking distance; KF, Muscle thickness for knee flexors; DF, Dorsi flexors; PF, Plantar flexors; DXA, Dual-energy X-ray Absorptiometry; ↑, significant improvement; ↓, significant decrease; ↔, no significant difference; SD, Standard deviation; Wk, week; f, frequency; min, minute.

left knee extension (18, 19), left handgrip, right handgrip, upper body strength, leg strength (46), muscle thickness, knee extensors, knee flexors, dorsi (19), hip extension strength, and knee extension strength (44). Five articles demonstrated that there was significant improvement in lower body strength, while one article showed that there was significant improvement in upper body strength (46). The total intervention time ranged from 15–40 to 60 min and 3 to 6 times, 12 to 52 weeks at different intensity [50–70% of heart rate (18), ∼50% VO_2 peak (27), 60% heart rate reverse (46)]. Three studies focused on females (18, 44, 46) and two considered a combination of both males and females (19, 27). No studies considered only males.

Effect of Brisk Walking on Balance

Six of the 13 papers discussed balance (18, 23, 26, 44–46). Balance is determined using a one legged balance with eyes closed and open (18, 23). Another study established that the best method for determining balance is to use a seesaw platform (26). There was no significant difference for balance in some of the studies (45, 46). There was significant difference in balance according to three studies (18, 26, 44). Nevertheless, there was no significant improvement in balance in three studies (23, 45, 46). The total time of intervention ranged from 30 to 60 min, 3 to 6 times per week, 12 to 52 weeks at intensity [50–70% of heart rate (18), 50–70% of heart rate reverse (45), Light (13), and Somewhat hard (15, 23)]. One study considered males (26), two considered females (18, 44), and three considered both males and females (23, 45, 46).

Effect of Brisk Walking on Life Satisfaction

Only one article discussed the effect of brisk walking (30–40 min, 3 times per week, 24 weeks) on life satisfaction. Life satisfaction was tested by satisfaction with a life scale. There was a significant difference in life satisfaction between the pre-test and 6 months on males and females (25).

DISCUSSION

Previous studies have shown that health related physical fitness is a strong independent predictor of mortality (49–51). Consequently, each of its components is very essential for the elderly to consider. This study aimed to explore whether brisk walking improves health related physical fitness, balance, and life satisfaction among the elderly. Overall, **Table 4** summarized the distribution of studies by component and the degree of scientific evidence according to risk of bias. The assessment of bias within brisk walking studies revealed that 11 were classified as low risk and two as high risk. Thus, based on the recognized criteria, there is compelling evidence that brisk walking improves cardiorespiratory fitness, body composition and muscular strength. There is limited evidence that brisk walking improves flexibility, muscular endurance, and life satisfaction, while one study reported conflicting results on balance.

Aging can cause changes in the heart and blood vessels that may increase a person's risk of developing cardiovascular disease, especially in the elderly (52). Cardiorespiratory fitness (CRF) reflects the functional capabilities of the heart, blood vessels, lungs, and skeletal muscles to perform work (53). A higher CRF is associated with improved survival and decreased incidence of CVD and other comorbidities, including hypertension, diabetes, heart failure, and atrial fibrillation (54). A previous study has shown that brisk walking can assist to improve cardiopulmonary fitness by increasing blood circulation, oxygen intake, and heart rate (55). Identically, this literature review revealed that moderate-intensity brisk walking had a positive and significant effect on cardiorespiratory fitness for elderly women and a mixture of males and females, but limited evidence presented on males (21, 22, 24, 26, 27, 46). High-intensity brisk walking for at least 60 min a week has a greater impact on cardiorespiratory fitness than those who walk at a leisurely-pace. However, with respect to moderate intensity activity, findings indicated that even when accumulated at high levels (i.e., ≥150 min/wk) did not result in significant improvements in cardiorespiratory fitness (56). Both brisk walking and resistance training (3 times a week at an intensity of 60–70% of their respective age-predicted maximum heart rate for 8 weeks) Can promote the cardiorespiratory fitness of the elderly has a more significant impact than brisk walking and resistance training (57). A number of studies have shown that brisk walking has a positive effect on cardiorespiratory fitness, among which high-intensity brisk walking has a more significant effect on cardiorespiratory fitness. Meantime, a study have shown that brisk walking combined with other exercises can promote cardiorespiratory fitness health greater than a single brisk walking, but this research still needs to be explored.

Aging causes changes in body composition, especially gradually increasing the obesity rate among the elderly (58). Studies have shown that the body composition anomalies are closely-related to lipid metabolic disorder, such as obesity, diabetes, and other diseases (59). Some research found that brisk walking has a beneficial and significant influence on body composition (24, 26, 46), whereas others found no effect on females (45). There is insufficient evidence regarding the effect of brisk walking on the body composition of elderly men (26), and mix of men and women (24), while there is a paradox on the effect of brisk walking on the body composition of women (45, 46). The heart rate should be between 75 and 80% of the maximum level. Brisk walking and similar activities should be no <30 min to elevate carbohydrates and fat utilization, and in turn alter the body's composition (60). Therefore, one study showed that walking at an intensity corresponding to 50–70% heart rate cannot influence body composition (45). As a result, the influence of brisk walking on body composition remains unknown and debated in the literature. Complementarily, the FITT of the brisk walking still need to be continuously proven the effects on body composition of the elderly.

Aging causes muscle mass and muscle strength to decrease (61). Improving muscular strength and endurance slows bone density and muscle loss and prevents osteoporosis and frailty in the elderly (61). Brisk walking stimulates leg muscle action, and when combined with the hip twist, it has a certain influence and promotion effect on the promotion of the lower limbs, waist, and abdomen strength (62). Therefore, brisk walking

TABLE 4 | The study of brisk walking and health-related physical fitness components was classified according to the risk of bias within the studies and the strength of the scientific evidence.

Health-related physical fitness component and balance	Studies that demonstrated association	Studies by risk of bias	Low risk of bias studies that showed significant association	Level of evidence
Muscular strength ($N = 5$)	YES: 5 (100%)	Low: 5 (100%) High: 0	Yes: 5 (positive association) No:	Strong evidence
Muscular endurance ($N = 1$)	YES: 1 (100%)	Low: 1 (100%) High: 0	Yes: 1 (positive association) No:0	Limited evidence
Cardiorespiratory fitness ($N = 10$)	YES: 10 (100%)	Low: 8 (83.3%) High: 2 (16.7%)	Yes: 8 (positive association) No:2	Strong evidence
Body composition ($N = 4$)	YES: 4 (100%)	Low: 3 (75%) High: 1 (25%)	Yes: 3 (positive association) No:1	Strong evidence
Flexibility ($N = 1$)	YES: 1 (100%)	Low: 1 (100%) High: 0	Yes: 1 (positive association) No: 0	Limited evidence
Balance ($N = 6$)	YES: 6 (100%)	Low: 6 (100%) High: 0	Yes: 3 (positive association) No: 3	Conflicting evidence
Life satisfaction ($N = 1$)	YES: 1 (100%)	Low: 1 (100%) High: 0	Yes: 1 (positive association) No: 0	Limited evidence

(above medium strength 50% of maximum heart rate) has a considerable effect on strength, specifically upper body strength (46), and lower limb strength (18, 19, 27, 44, 46), as well as on lower limb muscular endurance (45). Most studies indicated that brisk walking improves lower limb strength, but there remains insufficient evidence for upper body strength. Moreover, no study investigated the effect of brisk walking on elderly males. The effect in strength and muscular endurance of the upper limbs, and endurance of the lower limbs, remains unreported.

Falls account for 49.3% of all accidental injuries (7). It is a complicated issue that the elderly must address. Balance exercises are critical in avoiding elderly people from falling (63). A previous study identified that brisk walking benefits balance (64). Similarly, this study confirms that brisk walking improves balance (18, 26, 44). Nonetheless, there was no influence on balance by some studies (45, 46). Intervention on studies do not continuously lead to the outcome (23). Additionally, a small sample size also influences the results (45). Hence, there was inconsistency on the influence of balance in this study. Furthermore, further research is required to confirm the most effect of brisk walking on balance at which level of FITT.

Aging causes the loss of a small amount of flexibility because of the natural aging processes. This can occur for several reasons, including loss of water in the tissues and spine, increased stiffness in joints and a loss of elasticity throughout the muscle tendons and surrounding tissue (65). There is no stretching prior to and during brisk walking exercise, hence brisk walking is unlikely to result in changes in flexibility (66). As a result, it was concluded that 12 weeks of brisk walking did not improve flexibility in the elderly (45). Exploring the impact of brisk walking on the flexibility of the elderly is critical in future work.

Among older adults, life satisfaction correlates with health, mortality and successful aging especially with advancing years (67). Previous work reported that physical activity was significantly related to life satisfaction and happiness in older adults (68). Similarly, life satisfaction was improved in brisk walking intervention after 6 months (25). However, the evidence for a linkage of physical activity levels to life satisfaction or is not always positive (Evidence Category C) (69). Life satisfaction is a measure of well-being assessed in terms of mood, satisfaction with relationships, achieved goals, self-concepts, and self-perceived ability to cope with one's daily life (70). Additionally, satisfaction with the body, social or family relationships, and financial circumstances may all contribute to global life satisfaction. Satisfaction with physical function and appearance may also be important when judging levels of life satisfaction due to cultural prominence of certain body types (71). In aging, the health status of the elderly has the most important impact on life satisfaction (72). Consequently, life satisfaction is a relatively complicated item to evaluate. Considering whether the community-level physical activity intervention has an impact on the life satisfaction of the elderly is obviously insufficient and only one study showed this result. Thence, considering sundry factors to check the impact of brisk walking on life satisfaction is urgent in this field.

The results indicated that subjects in the high intensity (80–85% of maximum heart rate) exercise group have a significant improvement on aerobic capacity than moderate intensity (65–70% of maximum heart rate) of the maximal heart rate reserve exercise group (24). High-intensity (low-intensity walking intervals at ∼40% of the pre-training VO_{2peak}, followed by a 3-min interval of high-intensity walking >70% but <85% VO_2 peak for walking) 40-min intermittent brisk walking which undergo 3 times per week and 26 weeks activities performed daily had a greater effect on the elderly's aerobic capacity than moderate-intensity (Walking more than 8,000 steps per day at ∼50% VO_{2peak}) 50-min intermittent brisk walking exercises (27). WHO recommend that 150–300 min of moderate-intensity aerobic physical activity; or at least 75–150 min of vigorous-intensity aerobic physical activity or an equivalent combination of moderate- and vigorous-intensity activity throughout the week, as these provide additional health

benefits (8). Moreover, high-intensity cardiorespiratory exercise has a more significant impact on metabolic syndrome (MS) than low- and medium-intensity in sedentary, overweight, moderately hypertensive, post-menopausal women (73). However, moderate activity increased the probability of successful aging of the elderly by 0.76–0.78% ($P < 0.001$), while participation in vigorous and mild physical activity had no significant effect on successful aging ($P > 0.05$) (74). Therefore, according to most studies, high-intensity exercise has a better effect than low-medium-intensity exercise, but some health factors in the elderly require moderate exercise intensity, and research in this area is still to be studied.

Study Limitations

Overall, this review demonstrated the efficacy and favorable benefits of brisk walking on health-related physical fitness, balance, and life satisfaction in the elderly. This systematic review, however, has a few drawbacks. First, the sample size of the included studies is often small. Seven studies used a sample size of fewer than 30 participants in each category (18, 22, 24–26, 45, 46). Second, most of the studies focused on female health-related physical fitness balance and life satisfaction (18, 21, 22, 44–46, 48), only two studies focus on males (23, 26). Finally, the research had some significant flaws. Simultaneously, the measurement methods of exercise intensity are inconsistent, so that difficult to judge which intensity has the greatest impact on the elderly. There is no research on all indications of health-related physical fitness in the literature, although most studies focus on a single health-related component. There is only one paper on flexibility (45), muscular endurance (45), and life satisfaction (25), and it has a low level of credibility and persuasiveness. Although there are numerous publications devoted to muscular strength research, there is only one devoted to the same index of upper body strength (46).

CONCLUSION

This systematic review demonstrates that brisk walking improved cardiorespiratory fitness, muscular strength, and body composition among the elderly. There are less studies on the effects of flexibility, muscular endurance, life satisfaction, and additional research is necessary to demonstrate the effects of these three components. Additionally, conflicting evidence on balance should be confirmed by further research. Moreover, according to most studies, high-intensity exercise has a better effect than low-medium-intensity exercise but some study showed the most impact should be an apposite intensity. The measurement methods of exercise intensity are different, and it is impossible to accurately summarize which training principle of FITT has the safest and most comfortable effect on the elderly. Sum up, the research evidence of brisk walking is still insufficient and single brisk walking cannot satisfy the requirements of the elderly in terms of health-related physical fitness, balance, and life satisfaction. According to the ACSM, a combination of several exercise modalities can effectively boost the health of the elderly. Future research can discover multiple types of exercise methods to promote the health-related physical fitness, balance, and life satisfaction of the elderly. Additionally, the induction of brisk walking training principles of FITT is very vital for the health effects among the elderly. Hence, this is also a potential research that deserves to be unearth.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

The literature search, selection of studies, and study quality assessment was performed by XB and WX. Following an initial screen of titles and abstracts, full scrutiny of potentially eligible studies was independently screened by XB and WX using the specific inclusion criteria. KS and RO arbitrated any disagreements in study inclusion. OT and HC arbirated any disagreements in assessment study quality. All authors contributed to manuscript revision, read, and approved the submitted version.

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Effect of Exercise Training on Physical Fitness Among Young Tennis Players: A Systematic Review

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Background: Physical fitness comprises both health- and skill-related components that have been shown to correlate with the competitive ability of the athletes. Competitive ability of the athletes is strongly related to the positive or poor characteristics of physical fitness. Additionally, the adolescent stage is critical for the development of physical fitness. Physical fitness training for young tennis players should receive more attention. However, the current literature is deficient in in-depth reviews of the effects of exercise training on the physical fitness of young tennis players.

Objective: This review is aimed to investigate the effects of exercise training on physical fitness among young tennis players.

Methods: From October 2020, a comprehensive search was undertaken in four electronic databases (SCOPUS, PubMed, EBSCOhost (SPORTDiscus), and CINAHL Plus) and also on Google Scholar and other sources of gray literature references. The methodological quality of included studies was assessed using the Physiotherapy Evidence Database scale and the over scientific evidence was determined using the best evidence synthesis (BES). This review included only studies that employed an experimental design to assess the physical fitness components of young tennis players.

Results: Nine articles on exercise training met all inclusion criteria and were included in this systematic review. The studies were of a high standard of quality. The research findings are relatively credible. The results indicated that speed ($n = 8$) and agility ($n = 8$) were the most often investigated performance characteristics in exercise training interventions with young tennis players, followed by power ($n = 7$), strength ($n = 4$), and flexibility ($n = 1$). Exercise training significantly increased the physical fitness of young tennis players in terms of speed and agility. There is a lack of evidence about strength and flexibility. Meanwhile, there is conflicting evidence regarding the effect on power, and yet there is no evidence regarding the effect of exercise training on endurance.

Conclusions: This systematic review established a compelling case for the beneficial effects of exercise training interventions on physical fitness in youngtennis players. The review identifies current research gaps (i.e., athlete gender, with a particular emphasis on female athletes) that should be addressed in future experimental studies.

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INTRODUCTION

Tennis is the world's second most popular sport, trailing only soccer. It is played in 195 countries and has an estimated 87 million fans (who have played tennis at least once) and represents 1.17% of the world's population (1, 2). Tennis has evolved from a predominantly technical sport in which sport-specific technical skills (e.g., stroke skills) predominated to a more explosive sport characterized by increasing serve and stroke velocity and requiring significantly increased physical demands (3–5). Physical fitness levels of the tennis players are critical in determining who wins and who loses, especially those with extremely close competitive levels (6, 7). Tennis players must possess a combination of agility, speed, strength, aerobic capacity, and other physical fitness components in order to execute advanced shots and compete well against increasingly competent opponents (4, 5). This extraordinary performance cannot be boiled down to a single distinguishing physical attribute. Tennis demands a delicate interplay of several components of physical fitness. Tennis skill development and performance are the procedures that underpin these components of physical fitness (5). A healthy physical structure is critical for an athlete's performance to improve (8). Additionally, the International Tennis Federation recommended that tennis players undergo a physical fitness examination. It considers that speed, strength, flexibility, agility, and endurance are all comprehensive measures of a tennis player's physical fitness (9). As a result, these specific components of physical fitness were chosen for this study.

It is worth noting that adolescence is the most critical stage of human growth and development. Studies have established that adolescence is a critical period for tennis players' physical fitness development (10–12), as physical fitness is one of the most important factors affecting the competitive ability of the athletes (13, 14). As a result, it may be instructive to evaluate the effects of various training approaches on the physical fitness of young tennis players. Chen et al. (15) found that proper exercise training can significantly increase the general fitness of young tennis athletes. However, to our knowledge, no systematic examination of the specific benefits of exercise training on the physical fitness components of young tennis players has been conducted yet. Therefore, this systematic review's objective is to evaluate whether exercise training enhances the physical fitness component of young tennis players.

MATERIALS AND METHODS

Protocol and Registration

The protocol for this systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (16), and it was prospectively registered in the International Prospective Register of Systematic Reviews: https://www.crd.york.ac.uk/prospero, CRD 42020213145.

Search Strategy

SCOPUS, PubMed, EBSCOhost (SPORTDiscus), and CINAHL Plus were used to conduct a comprehensive search of the literature. The search lasted from the commencement date to October 2020. A search was performed using the following combination of keywords from each database: ("exercise training*" OR "fitness training*" OR "physical training*" OR "physical activity*" OR "physical exercise*" OR "physical therapy" OR "exercise*" OR "fitness" OR "rehabilitation" OR "aerobic exercise*" OR "functional performance" OR "exercise therapy" OR "physical intervention*" OR "physical rehabilitation*" OR "motor activity*" OR "motor skill intervention*" OR "active play" OR "active game*") AND ("physical fitness" OR "physical endurance" OR "cardiorespiratory fitness" OR "physical conditioning" OR "fitness, physical" OR "speed" OR "power" OR "strength" OR "endurance" OR "flexibility" OR "agility") AND ("adolescent tennis player*" OR "juvenile tennis player*" OR "teenager tennis player*" OR "youth tennis player*" OR "young tennis player*" OR "junior tennis player*"). Additionally, supplementary searches were conducted using Google Scholar. To ensure that the retrieval of publications was as extensive as possible, we selected eligible studies for inclusion from prior meta-analyses.

Eligibility Criteria

Population, intervention, comparison, outcome, and study design (PICOS) was used to identify the studies included in this study (**Table 1**). Studies were included if they met the following criteria: (1) the selected study must be a peer-reviewed publication written in English that discusses a randomized controlled trial (RCT) or a non-RCT (non-RCT) that assessed the effect of exercise training interventions on overall physical fitness; (2) participants of the study must be young tennis players (male and female); (3) this study

TABLE 1 | Inclusion criteria based on PICOS (population, intervention, comparison, outcome, and study design).

PICOS	Detail
Population	Young tennis players (male/female, age 12–18 years old)
Intervention	Exercise training
Comparison	Multiple and single-group trials
Outcome	Physical fitness components (speed, power, strength, endurance, flexibility, agility)
Study designs	RCT or Non-RCT

RCT, randomized controlled trial.

may include any exercise training method on physical fitness components. Studies that employ one or a combination of two or more types of exercise training methods as interventions are also included; (4) this study examined the effect of exercise training (i.e., physical exercise, physical therapy, exercise, fitness, rehabilitation, and aerobics) on young tennis players and evaluated at least one physical fitness component outcome, such as speed, strength, power, endurance, agility, and flexibility.

Studies were excluded if: (1) those that included young athletes from other sports; (2) those that combined exercise training interventions with other non-exercise training and included unsupervised training sessions; (3) observational studies and interventions focused exclusively on counseling for exercise training implementation were excluded; and (4) articles published and unpublished in languages other than English, conference abstracts, and letters to the editor, case reports, and brief communications were excluded.

Study Selection

After conducting a search in four international electronic databases, the information about the retrieved studies (i.e., title, author, and year) was uploaded into Mendeley reference management software to eliminate duplicates. To begin, this study benefited from the assistance of an experienced librarian during the retrieval process. Second, two independent reviewers screened the title and abstract for suitable full-text studies. Then they examined the entire text of the studies in accordance with the criteria for inclusion and exclusion and reached a decision based on the literature into the research standard. Throughout this process, the two independent reviewers (Xiao and Bai) worked independently. If a disagreement arose, a third reviewer (Soh) was consulted until consensus was obtained. The details of the selecting procedure are depicted in **Figure 1**.

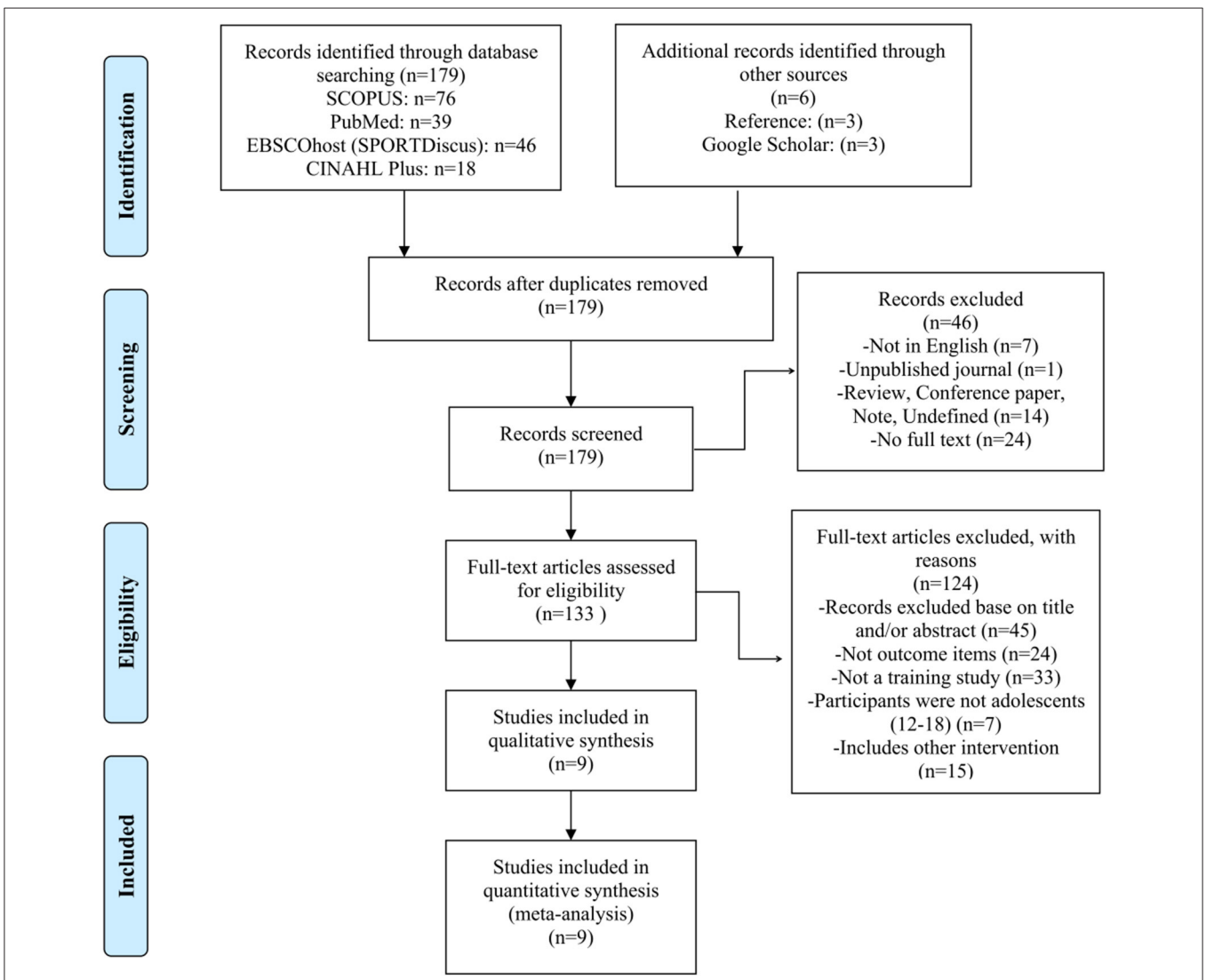

FIGURE 1 | The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of the literature selection process.

Data Extraction and Quality Assessment

After completing the research selection process, two independent reviewers (Xiao and Bai) gathered pertinent data from each included study, such as the study title, participant characteristics, study design, specifics of the exercise training program and index, and study outcomes.

The methodology of the included studies was evaluated separately by two reviewers using the Physiotherapy Evidence Database (PEDro) scale, a tool comprised of 11 items (**Table 3**) that evaluates four methodological domains: randomization, blinding, group comparison, and data analysis (26). The scoring system is based on a model of a Yes (1 point) or No (0 point) response rating scale (27). Each study's score was derived by adding the final scores obtained, as qualifying criteria were excluded from the total score due to their relevance to external validity. The PEDro scale measures methodological quality on a scale of 0–10, with a higher PEDro score indicating higher methodological quality: 8–10 indicates outstanding methodological quality; 5–7 indicates good methodological quality; 3–4 indicates medium methodological quality; and <3 indicates poor methodological quality (28). Additionally, this analysis made use of best evidence synthesis (BES) to assess the entire body of scientific data (29). The BES divides evidence into five categories depending on the methodological quality, the quantity of research, and the consistency of their findings (30). (1) Strong evidence: more than two high-quality studies concurred on the findings; (2) moderate evidence: one high-quality study and numerous low-quality studies concurred on the findings; (3) limited evidence from a single study or inconsistent conclusions from numerous studies; (4) conflicting evidence: there are conflicting study findings, while 75% of studies revealed consistent findings; and (5) there is no evidence: this finding was not made in any study.

RESULTS

Study Selection

Figure 1 illustrates the selection of records. We identified 179 papers in the initial search and six additional articles via manual searching. After reviewing the titles of 185 studies, 46 were excluded. We removed an additional 124 studies from the remaining 133 based on the exclusion criteria. Thus, nine RCTs and non-RCTs were included in this review of the literature to assess the effect of exercise training on the physical fitness of young tennis players (**Table 2**).

Study Quality Assessment

The Physiotherapy Evidence Database scores varied from 4 to 7 for the studies included in this review (**Table 3**). There were eight publications with a PEDro score of > 5, and only one with a PEDro score of 4, indicating that the included studies had a high degree of methodological quality and that the research findings were reasonably reliable. Additionally, all of these studies satisfied the criteria for randomization, group similarity at baseline, between-group comparison processes, point measurements, and variability; seven studies met the criteria for intention to treat analysis; and only one study met the blind assessor criterion. However, no study has been conducted to justify the use of concealed allocation concealment, blind participants, or blind therapists.

Population Characteristics

The population characteristics of the nine studies included in this review were evaluated on the following aspects: (1) sample size: there were 246 participants in the nine studies, ranging from 16 to 60, with a median of 26 and a mean of 27.3 sample size; (2) gender: all nine of these studies examined young tennis players. Six research studies focused exclusively on men, whereas the remaining three studies did not specify gender; (3) age: none were over the age of 18. The age varied from 12.2 to 17.1 years, with a median of 13.8 and a mean of 14.2 years; (4) training background: eight studies reported the training background of the participants; (5) dominant hand: five studies reported on the dominant hand of participants, while four articles did not report on the dominant hand of participants.

Interventions Characteristics

In total, 13 intervention programs were utilized in the included studies (**Table 2**). These interventions included resisted training (24), core training (21), a combination of high-intensity intermittent rounds and tennis-specific training, tennis-specific exercises (19), plyometric training (18), a combination of explosive strength and repeated sprint training (17), neuromuscular warm-up (NWU) training, dynamic warm-up (DWU) training (25), neuromuscular training (NMT) prior to tennis-specific training, NMT post-tennis-specific training (20), various stretching exercises (22), high-intensity interval training (HIIT), and on-court tennis training (OTT) (23). The duration of the trials covered in the nine studies ranged from 4 to 8 weeks (mean 6.6 weeks). Additionally, the majority of studies used one to three training sessions per week and varied the time of each session from 30 to 90 min.

All of the studies were RCTs with a pre-post design. Four studies had an experimental (EG) and a control group (CG) (17, 18, 21, 24), while only five studies included two experimental and no CGs (19, 22, 23, 25).

Outcome and Measures

Effect of Exercise Training on Speed

Among the included literature, eight studies examined speed. According to one study (22), when compared to static and static-dynamic stretching protocols, dynamic and static + dynamic stretching procedures resulted in a significant difference in 10 m acceleration and 20 m sprint time ($p < 0.05$). Additionally, when compared to static, static + dynamic, and dynamic + static stretching procedures, dynamic and non-stretching approaches resulted in a significant difference in performance between good and relatively mediocre performers ($p < 0.05$). Santos-Rosa et al. (25) found that when compared to DWU training, an NWU significantly improved sprint (5, 10, and 20 m) performance ($p < 0.05$). Fernandez-Fernandez et al. (18) reported that combining plyometric exercise with traditional tennis training has a significant ($p < 0.01$) effect on speed (20 m sprint test). Another study found that HIIT outperformed OTT in terms of

TABLE 2 | Characteristics of included studies.

References	Design	Population characteristics	Interventions	Type of exercise training	Measures index	Outcomes
Fernandez-Fernandez et al. (17)	Pre-post test	Sex: M, EG: $n = 8$, CG: $n = 8$, age: 16.9 ± 0.5 yr., WT: 74.7 ± 5.3 kg, ht.: 1.80 ± 3.6 m, TB: 8.0 ± 2.6 yr. DH: NP	Freq.: 2 times/week, time: 60 min, Length: 8 weeks	Combined explosive strength and repeated sprint-training (EG1), Control group (CG)	Speed (10, 20, 30m, RAS), Power (VJ)	10 m↑, RSA↑, 20 m→ , 30 m→ , VJ↑
Fernandez-Fernandez et al. (18)	Pre-post test	$n = 60$, Sex: male, TB: NP; age: 12.5 ± 0.3 yr., WT: 44.2 ± 7.0 kg, ht.: 156.6 ± 7.08 cm, DH: RH = 48, LH = 12	Freq.: 2 times/week, time: 30–60 min, Length: 8 weeks	Plyometric training (EG1), Control group (CG)	Speed (20 m sprint test), Agility (505 test), Power (CMJ), Strength (SLJ and OMBT)	20 m↑, 505 test↑, CMJ↑, SLJ↑, OMBT↑
Fernandez-Fernandez et al. (19)	Pre-post test	$n = 20$, Sex: NR, TB: 6 ± 1.2 yr., EG: age = 14.8 ± 0.1 yr., WT = 63.8 ± 7.1 kg, ht. = 174.7 ± 4.8 cm, DH: RH = 16; LH = 4	Freq.: 2 times/week, time: 40 min, Length: 8 weeks	Mixed high-intensity intermittent runs and Tennis- specific training (EG1), Tennis-specific drills only (CG)	Speed (20 m dash), Agility (505 test), Power (VJ)	20 m→ , 505 test↑, VJ→
Fernandez-Fernandez et al. (20)	Pre-post test	$n = 16$, age: 12.9 ± 0.4 yr., WT: 46.0 ± 5.7 kg, ht.: 157.0 ± 5.1 cm, TB: 3.0 ± 1.2 yr., Sex: M; DH: RH = 13, LH = 3	Freq.: 2 times/week, time: 32.4 ± 7.3 min, Length: 5 weeks	Neuromuscular training before tennis specific training (EX1), conducted Neuromuscular training after tennis specific training (EG2)	Speed (5, 10, 20m), Agility Test (505 test), Power (CMJ), Strength (OMBT)	EG1: 5 m↑, 10 m↑, 20 m↑, 505 test↑, CMJ↑, OMBT↑, EG2:10 m↑,20 m↓, 5 m↓, 505 test↓, CMJ↓, OMBT→
Fozia et al. (21)	Pre-post test	$n = 30$, Sex: NR; TB ≥ 1 yr., EG: age = 15.20 ± 0.41 yr., BMI = 20.23 ± 1.54, CG: age = 15.53 ± 1.06 yr., BMI = 20.71 ± 1.53, DH: NP	Freq.: 3 time/week, time: NR, Length: 5 weeks	Core training (EG1), Control group (CG)	Agility (*T*-test),	*T*-test↑
Kilit et al. (22)	Pre-post test	Sex: M, TB ≥ 2 yr., EG1: $n = 13$, age: 13.5 ± 0.2 yr., ht.: 151 ± 5 cm, WT: 45.5 ± 4.2 kg, EG2: $n = 13$, age: 13.3 ± 0.3 yr., ht.: 153 ± 3 cm, WT: 46.9 ± 4.8 kg, DH: NP	Freq.: 3–4 times/week, time: 80 min, Length: 4 weeks	Good performers group (EG1), Moderate performers group (EG2)	Speed (10, 20 m sprint), agility (T-drill test)	10 m↑, 20 m↑, T-drill test↑
Kilit and Arslan (23)	Pre-post test	$n = 29$, Sex: M, age: 13.8 ± 0.4 yr., ht.: 159.2 ± 7.5 cm, WT: 49.4 ± 6.1 kg, TB ≥ 2 yr., DH: RH = 29	Freq.: 3 times/week, time: 8–16min, Length: 6 weeks	High-intensity interval training (EG1), On court tennis training (EG2)	Speed (5, 10, 20, 400 m), Agility (T-drill test), Power (CMJ, SJ, DJ)	5 m↑, 10 m↑, 20 m↑, 400 m↑, T-drill test↑, CMJ↑, SJ↑, DJ↑
Moya-Ramon et al. (24)	Pre-post test	Sex: M, TB = 9.0 ± 2.6 yr., EG1, $n =$ 10; Age: 16.7 ± 0.1 yr., WT: 72.0 ± 5.2 kg, ht.: 181.6 ± 4.8 cm, CG, $n =$ 10; Age: 16.4 ± 0.3 yr., WT: 71.1 ± 7.2 kg, ht.: 179.9 ± 4.4 cm, DH: NP	Freq.: 2 times/week, time: NR, Length: 6 weeks	Resisted Sprint Training (EG1), Conventional Sprint Training (CG)	Speed (5, 10, 20 m sprint, and RSA), Agility (505 test), Power (VJ), Strength (SLJ)	5 m↑, 10 m→ , 20 m→ , RSA→ , 505 test→ , VJ↑, SLJ↑
Santos-Rosa et al. (25)	Pre-post test	TB: 5.0 ± 1.2 yr., Sex: NP, EG1: $n =$ 14, age: 14.96 ± 0.88 yr., WT: 60.34 ± 9.13 kg, ht.: 172.50 ± 7.08 cm, EG2: $n = 15$; age: 15.21 ± 1.40 yr., WT: 59.50 ± 10.90 kg, ht.: 172.57 ± 7.90 cm, DH: RH = 27, LH = 2	Freq.: 3 times/week, time: 75.5 ± 6.4 min, Length: 8 weeks	Neuromuscular Warm-up after tennis-specific training (EG1), Dynamic Warm-up before tennis-specific training (EG2)	Speed (5, 10, 20 m), Agility (505 test), Power (VJ), Strength (BMBT, FMBT, OMBT)	5 m↑, 10 m↑, 20 m↑, 505 test→ , VJ↑, FMBT↑, OMBT↑, BMBT↓

DH, dominant hand; WT, weight; ht., height; NR, not reported; yr., year; M, male; F, female; Freq., frequency; CG, control group; EG, experimental group; RH, right-handed; LH, left-handed; CMJ, vertical countermovement jump; SLJ, standing long jump; RSA, repeated sprint shuttle test; 505 test, modified 505 agility test; SJ, squat jumping; DJ, drop jumping; VJ, vertical jump; OMBT, overhead medicine ball throw; FMBT, forehand medicine ball throw; BMBT, backhand medicine ball throw.

TABLE 3 | Methodological quality assessment.

References	Fernandez-Fernandez et al. (17)	Fernandez-Fernandez et al. (18)	Fernandez-Fernandez et al. (19)	Fernandez-Fernandez et al. (20)	Fozia et al. (21)	Kilit et al. (22)	Kilit and Arslan (23)	Moya-Ramon et al. (24)	Santos-Rosa et al. (25)
Eligibility criteria	1	1	1	1	1	1	1	1	1
Random allocation	1	1	1	1	1	1	1	1	1
Allocation concealment	0	0	0	0	0	0	0	0	0
Group similar at baseline	1	1	1	1	1	1	1	1	1
Blind subject	0	0	0	0	0	0	0	0	0
Blind therapist	0	0	0	0	0	0	0	0	0
Blind assessor	0	0	1	0	0	0	0	0	0
Follow-up	1	1	1	1	1	0	1	0	1
Intention to treat analysis	1	1	1	1	1	0	1	1	0
Between group comparisons	1	1	1	1	1	1	1	1	1
Point measure and variability	1	1	1	1	1	1	1	1	1
PEDro total score	6	6	7	6	6	4	6	5	5

speed (5, 10, 20, 400 m sprint) (23). Within the group, significant changes in sprinting (5, 10, and 20 m sprints) and the 400 m running test time were observed between pre- and post-testing in the HIIT and OTT sessions ($p < 0.05$) (23).

Four studies concluded that certain speed indicators were statistically significant following exercise training. In the study conducted by Fernandez-Fernandez et al. (17), they observed a statistically significant ($p < 0.05$) improvement in speed (10 m sprint test) and a highly significant ($p < 0.01$) improvement in repeated sprint ability, but there were no significant changes in the sprint 20 and 30 m test (17). Moya-Ramon et al. (24) compared EG and CG using a resisted sprint training program. They concluded that while speed on the 5 m sprint time was considerably increasing (effect size 0.29), no significant difference was observed in the 10 m sprint time, 20 m sprint time, or repeated-sprint ability shuttle time (effect size −0.03).

Fernandez-Fernandez et al. (20) found that the NMT before tennis-specific training group had a positive effect on pre- to-post-test measures of speed (5 m—effect size 0.52; 10 m—effect size 0.32; and 20 m—effect size 1.08), whereas the NMT after tennis-specific training group had trivial effects on 10, 20 m, or negative effects on 5 m. Similarly, Fernandez-Fernandez et al. (19) reported that combining high-intensity training with sport-specific drill sessions vs. only sport-specific drill sessions resulted in no significant improvement in speed (20 m dash).

Effect of Exercise Training on Agility

In eight of the studies included, the agility test was examined. Fernandez-Fernandez et al. (18) found that combining plyometric training with regular tennis training had a statistically significant ($p < 0.01$) effect on agility (modified 505 agility test). Kilit et al. (22) showed that dynamic and general static + dynamic stretching methods improved agility (T-drill test) significantly more than static and static + dynamic stretching sessions ($p < 0.05$). Additionally, dynamic and non-stretching approaches indicated a significant difference in performance between excellent and generally mediocre performers compared to static, static + dynamic, and dynamic + static stretching sessions ($p < 0.05$) (22). Kilit and Arslan (23) demonstrate that HIIT vs. OTT significantly improved agility performance (T-drill agility test; $p < 0.05$). Fernandez-Fernandez et al. (19) found that combining high-intensity training and sport-specific drill sessions had a statistically significant benefit on agility (505 agility test) when compared to solely sport-specific drill training. Fozia et al. (21) assessed the effects of core training on agility and the intervention group had a substantial improvement ($p = 0.001$) when compared to the CG.

Three studies found no significant difference in agility between the groups. Santos-Rosa et al. (25) compared an NWU to a DWU and found no significant improvement in agility (modified 5-0-5 change in direction evaluation; $p > 0.05$). Moya-Ramon et al. (24) examined the EG and CG using a resistant vs. normal sprint training program. The data indicate that agility, as measured by the modified 5-0-5 agility assessment (dominant and non-dominant limb), did not improve. In another study (20), the NMT before tennis-specific training group showed favorable benefits on agility (effect size 0.22), while the NMT after tennis-specific training group demonstrated negative effects on the modified 5-0-5 agility test (effect size −0.24).

Effect of Exercise Training on Power

In seven of the studies included, a speed test was examined. Kilit and Arslan (23) published results on HIIT vs. OTT; both training protocols significantly improved jumping performance (countermovement jumping, squat jumping, and drop jumping) from pre- to post-testing ($p < 0.05$). Moya-Ramon et al. (24) compared EG and CG using a resistant sprint training program. The results indicate that power (as measured by the vertical jump test) was significantly enhanced ($p < 0.05$). Fernandez-Fernandez et al. (17) revealed that combining explosive strength with repeated sprint training sessions resulted in a statistically significant ($p < 0.05$) increase in vertical jumping power.

Fernandez-Fernandez et al. (18) further found that combining plyometric exercise with traditional tennis training resulted in a statistically significant increase ($p < 0.01$) in power (vertical countermovement jump). Santos-Rosa et al. (25) found that NWU was associated with a statistically significant ($p < 0.05$) increase in power when compared to a DWU training program (vertical jumping). Fernandez-Fernandez et al. (19) observed no significant gain in power following a training intervention combining high-intensity training and sport-specific training (vertical jumping). There was a considerable increase in power (effect size 0.29) in the NMT before the tennis particular training group, but only a minor decrease in countermovement (effect size −0.03) in the NMT after tennis-specific training group was found (20).

Effect of Exercise Training on Strength

In four of the studies included, the strength test was examined. Fernandez-Fernandez et al. (18) adopted an intervention program that included plyometric exercise and regular tennis training. They found a statistically significant ($p < 0.01$) improvement in standing long jump test and overhead medicine ball throw. Moya-Ramon et al. (24) compared EG and CG using a resistant vs. normal sprint training program. They found that standing long jump strength was significantly improved (effect size 0.31).

Two studies concluded that there was no statistically significant difference in strength. Santos-Rosa et al. (25) found that NWU sessions had no effect on the backhand medicine ball throw test ($p > 0.05$), but had an effect on the forehand medicine ball throw test ($p = 0.004$) and overhead medicine ball throw test ($p = 0.014$). Another study conducted by Fernandez-Fernandez et al. (20) showed that the NMT before tennis-specific training group achieved favorable improvements in terms of strength (effect size 0.51) and the trivial overhead medicine ball throw (effect size 0.02).

Effect of Exercise Training on Flexibility

Flexibility was evaluated only in one study (25), which examined flexibility using the shoulder range of motion test (external rotation range of motion and total range of motion). Flexibility tests reveal that the NWU significantly increased ($p < 0.05$) shoulder external rotation range of motion and overall range of motion on the dominant side.

DISCUSSION

The purpose of this study was to examine the effects of exercise training interventions on the physical fitness components of young tennis players and to determine whether exercise training can have a beneficial effect on these components. Nine studies' preliminary data revealed substantial evidence that exercise training enhanced athletes' physical fitness in terms of speed, agility, strength, and flexibility. Meanwhile, there is conflicting evidence regarding the effect on power, and yet there is no evidence regarding the effect of exercise training on endurance. These studies' conclusions show the beneficial effect of exercise training on young tennis players. However, the methodological quality of these studies varied, and future research should aim to improve methodological quality in order to better explain the effect of exercise training on physical fitness.

Effect of Exercise Training on Speed

Running skills of the tennis players directly affect whether a game wins or loses (31). Tennis players run an average of 3 m each time they strike the ball. Athletes must run between 8 and 12 m to earn a ball score, which establishes a high threshold for athletes' movement speed. Notably, the majority of the research examined ($n = 8$) have concentrated on speed (strong evidence). Tennis players' speed was assessed using sprint test (20 m linear sprint test), repeated sprint shuttle test (RSA) (17, 24), 20 m dash (with 5 and 10 m split times) (18–20, 23, 25), 10 m sprint (17), 20 m (17, 22), 30 m sprint (17), and 400 m running test (23). The data indicated that resisted training (24), mixed high-intensity intermittent running sessions, tennis-specific training, tennis-specific drills (19), plyometric training (18), combined explosive strength and repeated sprint training (17), NWU, DWU training (25), NMT prior to tennis specified training, NMT post-tennis specified training (20), different stretching training (22), HITT, and OTT training (23) can help tennis players to improve their speed. Specifically, the four studies showed a statistically significant effect of exercise training on speed using various stretching programs (22), NWU vs. DWU training (25), plyometric training combined with regular tennis training (18), and HIIT vs. OTT training (22). Other studies examined the effect of their training programs on speed using a combination of explosive strength and repeated sprint training (17), resisted sprint training (24), NMT before or after a tennis session, combining HIIT and sport-specific drills vs. only sport-specific drill training (19) and found no statistically significant effect of their training methods on speed.

Effect of Exercise Training on Agility

Agility is a critical component of physical fitness (32), since it enables tennis players to quickly shift their direction of movement (33). It can be divided into three distinct categories: forward occurs approximately 47% of the time; sideways occurs ∼48% of the time; and backward occurs around 5% of the time (31). In the eight studies that reported on agility (strong evidence), agility was assessed using a modified variant (i.e., stationary start) of the 505 agility test (18–20, 24, 25) and T-drill test or T-test (21–23). The data showed that resisted training (24), core training (21), mixed high-intensity intermittent running sessions and tennis-specific training, tennis-specific drills (19), plyometric training (18), NWU training, DWU training (25), NMT (20), different stretching training (22), and HIIT vs. OTT (23) can help tennis players to improve their agility. Specifically, the five studies demonstrated a statistically significant effect of exercise training on agility when plyometric training was combined with traditional tennis training (18), different stretching programs were used (22), HIIT vs. OTT was used (23), combining HIIT and sport-specific drill sessions was used instead of sport-specific drill training alone (21), and core training was used (21). The other studies compared NWU to a DWU training program (25), resisted sprint training to

a conventional sprint training program (24), and NMT before or after a tennis session training program (20) and found no statistically significant effect of their training programs on agility.

Effect of Exercise Training on Power

Power is a subset of speed power, which is the foundation for numerous sports (34). Not only can it overcome resistance and cause the object to produce displacement, but it may also cause the object to produce a huge displacement speed (35). Seven studies (conflicting evidence) evaluated power using the vertical jump test (countermovement jumping) (17–20, 22, 24, 25). Only one study, however, included three vertical jump tests: countermovement jumping, squat jumping, and drop jumping (23). The types of exercises that can improve the power of young tennis players included resisted training (24), mixed high-intensity intermittent running sessions and tennis-specific training sessions, tennis-specific drills (19), plyometric training (18), combined explosive strength and repeated sprint training (17), NWU training, DWU training (25), NMT (20), and HIIT vs. OTT (23). Specifically, six studies indicated a statistically significant effect of exercise training on power using an HIIT vs. OTT protocol (23), a resisted sprint training program (17), a plyometric training program in combination with a regular tennis training program (18), and an NWU (25). The other studies used a combination of HIIT and sport-specific drill training sessions vs. only sport-specific drill training sessions alone (19), or NMT before or after a tennis session program (20) and found that their training programs had no statistically significant effect on power, but the NMT before tennis-specific training group achieved a positive effect from pre-test to post-test measures in power.

Effect of Exercise Training on Strength

Strength is the foundation for all other components of physical fitness (e.g., speed and endurance) (36). However, just four studies on strength have been published (limit evidence). Following the standing long jump test, the medicine ball throw, and the shoulder strength test, strength was assessed. However, there is only one study that evaluated strength using both the overhead medicine ball throw and the standing long jump (18). One study passed the shoulder strength test and the medicine ball throw test (i.e., overhead, forehand, backhand, and forehand and backhand) (25). The types of exercise training used to improve strength were resisted training (24), plyometric training (18), NWU training, DWU training (25), and NMT (20). Our analysis of the literature revealed that different types of exercise training have varying training effects. Specifically, two studies demonstrated a statistically significant effect of exercise training on strength when a plyometric training program was combined with regular tennis training (18) and when a resisted sprint training program was used (24). The other studies compared NWU to a DWU training program (25), and NMT before or after a tennis session program (20) and found that their training programs had no statistically significant effect on strength. These findings may be explained by the fact that growth and maturation can be connected with these increases in strength and power, as it has been indicated that adolescents should undergo a performance spurt in strength and power following the onset of puberty (37).

Effect of Exercise Training on Flexibility

Athletes should place a premium on flexibility development during training, as flexibility enhances muscle strength and movement range (38). However, just one study has examined the subject of flexibility (limit evidence). The results reveal that both groups, NWU and DWU, improved their shoulder external rotation and overall range of motion significantly. However, incorporating an NWU with a lower volume (i.e., 20–35 min) that involves general mobility, core, and shoulder strength routines in conjunction with neuromuscular-related exercises, such as plyometric and acceleration/deceleration/COD drills, has been shown to significantly improve the overall flexibility training of young tennis players (25). This study compared solely the NWU and DWU interventions (25); it made no comparisons to other forms of exercise training. As a result, additional research is required in the future to focus on flexibility.

Limitations

This systematic review has a number of limitations. To begin, there are no reports of endurance in the research included. Endurance is a critical component of physical fitness and a vital indicator of a tennis player's physical fitness (39). However, a lack of research on this physical fitness component may impair the study's completeness or create loopholes in the examination of athletes' physical fitness components. Second, three of the studies did not include information about the athletes' gender. If it exists, it may be significant because gender is a significant influencing factor when judging young tennis players' physical fitness. At the same time, there is no report on female athletes, suggesting that future studies should include female athletes. Thirdly, this review chose to include only English-language papers, which indicates that some pertinent empirical material may be omitted. Fourthly, this study focused exclusively on six components of physical fitness, omitting the effect of exercise training on other components of physical fitness. This is because the International Tennis Federation considers that the six physical fitness components provide complete representations of a tennis player's physical fitness level (9).

CONCLUSION

The review found compelling evidence that exercise training increased the physical fitness of young tennis players in terms of speed and agility, but there was insufficient evidence for strength and flexibility. Meanwhile, there is conflicting evidence regarding the effect of power, but no evidence regarding the effect of exercise training on endurance was found. These findings may give tennis practitioners with insight into the importance of considering the interplay between physical fitness components when measuring and developing talent, rather than focusing exclusively on the performance of a single physical fitness component. Additionally, there is a lack of studies in the research field that examines the relationship between exercise training and physical fitness in female tennis players. To gain a better understanding of the relationship and effect of

various exercise training methods on the multifactorial nature of physical fitness performance in young tennis players, high-quality, comprehensive evidence is required, covering athletes of various sports levels.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

The literature search, study selection, and study quality assessment were completed by WX and XB, and SG arbitrated the study to include any disagreements. OT, MN, and CZ participated in the review of the manuscript. TB and WL participated in the revision and reading of the manuscript. All the authors made contributions to the article and reviewed the submitted manuscript.

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Proteinuria as a Nascent Predictor of Frailty Among People With Metabolic Syndrome: A Retrospective Observational Study

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Frailty is a commonly occurring geriatric condition that increases the risk of adverse health outcomes. The factors and predictors behind frailty are not yet well understood. A better understanding of these factors can enable prevention of frailty in elderly patients. The objective of this study was to determine the association between proteinuria and frailty in US individuals with metabolic syndrome (MetS). Data from the National Health and Nutrition Examination Survey III (NHANES III, 1988–1994) conducted by the National Center for Health Statistics of the Centers for Disease Control and Prevention. This is a cross-sectional study, and proteinuria and frailty were measured only once at enrollment. The study included 2,272 participants with MetS aged 40–90 years from the NHANES III. The participants underwent assessments to evaluate frailty and frailty components (low body weight, weakness, exhaustion, low physical activity, and slow walking). Proteinuria was represented as albumin-to-creatinine ratio (ACR) (mg/g) and divided into tertiles: T1-normal range (ACR $<$ 30 mg/g), T2-microalbuminuria (ACR 30–299 mg/g), and T3-macroalbuminuria (ACR $\geq$ 300 mg/g). We applied multiple logistic regression to determine the odds ratios (ORs) of frailty for T2 vs. T1 and T3 vs. T1 in both sexes. In the adjusted analysis for male participants, the ORs of frailty for T2 and T3 vs. T1 were 3.106 (95% confidence interval [CI] = 1.078–8.948, $P = 0.036$) and 14.428 (95% CI = 4.231–49.193, $P < 0.001$), respectively. For female participants, the ORs of frailty for T2 and T3 vs. T1 were 1.811 (95% CI = 1.071–3.063, $P = 0.027$) and 2.926 (95% CI = 1.202–7.124, $P = 0.018$), respectively. The positive association between T2 and T3 vs. T1, and frailty were statistically significant. The trends of higher likelihood of every frailty component were also statistically significant across increasing tertiles of proteinuria after multiple levels of adjustment for covariates ($P < 0.05$). Increased proteinuria levels were positively associated with frailty and each frailty component. Proteinuria might be a useful maker for frailty in individuals with MetS.

Keywords: proteinuria, albumin to creatinine ratio, metabolic sybdrome, frailty, National Health and Nutrition Examination Survey

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INTRODUCTION

Metabolic syndrome (MetS) is defined as a collection of cardiovascular risk factors, including elevated levels of triglycerides, low concentrations of high-density lipoprotein cholesterol, impaired fasting glucose, central obesity, and elevated blood pressure (1). The prevalence rate of MetS is high and is increasing worldwide (2). MetS is a risk factor for developing diabetes and cardiovascular disease and raises the possibility of all-cause and cardiovascular mortality in aging individuals (3).

The ever-increasing average age of the population has increased the interest of researchers in frailty. Frailty is a widely prevalent geriatric syndrome that reflects a state of decreased physiological reserve and increased vulnerability to stressors. Frail, older adults are at an increased risk of adverse health outcomes such as institutionalization, comorbidity, and mortality. Developing a better understanding of indicators that can be used to identify high-risk individuals is a major step toward preventing frailty. A previous study suggested that frailty is associated with chronic kidney diseases (CKDs), and albuminuria is an early indicator of diabetic nephropathy (4–6). Although CKDs have been extensively documented as a crucial factor in frailty, data examining the associations of early indicators of CKDs, such as albuminuria, with frailty are relatively sparse. Albuminuria is associated with frailty among community-dwelling middle-aged and older people (7). Given the aging population, it may be beneficial to use laboratory data for the early screening of frailty. This study investigated the correlation between different levels of proteinuria, frailty, and each frailty component (slowing walking, weakness, exhaustion, low physical activity, and low body weight) among people with MetS. Representative samples were retrieved from the U.S. National Health and Nutrition Examination Survey III (NHANES III, 1988–1994).

MATERIALS AND METHODS

Data Source and Participants

The data were from NHANES III (1988–1994), a nationwide probability sample of 39,695 persons aged 2 months and older. The National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention (CDC) introduced this cross-sectional survey to assess the health and nutritional status of Non-institutionalized U.S. residents. The survey included all ethnicities, such as Non-Hispanic white, Non-Hispanic black, Mexican American and others of community-dwelling populations of the US. The retrieved data were used with informed consent, and the participants were examined in a mobile center. The institutional review board (IRB) exempted the protocol from a formal review owing to the anonymous nature of the data. The survey was executed in accordance with the Declaration of Helsinki and was based on a complex, multistage, stratified, clustered probability design. Detailed operations manuals, consent documents, and brochures of NHANES III are available online at http://www.cdc.gov/nchs/nhanes.htm. The study flowchart is shown in **Figure 1**. To eliminate the influence from possible confounding factors, we've determined exclusion criteria as follows: subjects lacking data on past medical history of cardiovascular (CV) diseases, hypertension, type 2 diabetes mellitus (DM) ($n = 7{,}502$); subjects lacking data on any disease or taking antidiabetic agents, antihypertensive medications, and lipid-lowering drugs that might affect biochemical parameters or lipid metabolism ($n = 8{,}534$). In addition, subjects lacking data on MetS components, lipid profile, and the results of laboratory as well as clinical examinations or lost follow-up ($n = 21{,}387$) were excluded. This study enrolled 2,272 participants aged 40–90 years.

Measurement: Proteinuria

A casual urine specimen was collected from each participant in sterile containers. The samples were stored in frozen conditions (-20°C). Dipstick methods are not effective at detecting low levels of urinary albumin; therefore, the study employed a solid-phase fluorescent immunoassay for the measurement. Urine creatinine was analyzed with the Jaffe reaction using a Beckman Synchron AS/ASTRA analyzer (Beckman Coulter, Fullerton, California) in which creatinine reacted with picrate in an alkaline solution to form a red creatinine–picrate complex. To measure urinary albumin excretion, the albumin-to-creatinine ratio (ACR) was calculated by dividing the urinary albumin value by the urinary creatinine concentration (8, 9). Proteinuria was divided into three tertiles. Those with ACR $<$ 30 mg/g were referred to as the normal range group (tertile 1, T1). Microalbuminuria (tertile 2, T2) and macroalbuminuria (tertile 3, T3) were defined as ACR of 30–299 mg/g and $\geq$ 300 mg/g, respectively.

Measurement: Frailty

A validated five-item frailty phenotype score proposed by Fried et al. was adapted (10). The frailty phenotype consists of the following five items:

1. Slow walking: defined as the slowest quintile adjusted for sex in a timed eight-foot walk.
2. Weakness: defined by "some difficulty, much difficulty," or "unable to do" when asked how much difficulty they have "lifting or carrying something as heavy as 10 pounds".
3. Exhaustion: defined by "some difficulty, much difficulty," or "unable to do" when asked how much difficulty they have "walking from one room to the other on the same level".
4. Low physical activity: defined as present if participants answered "less active" when asked "Compared with most (men/women) your age, would you say that you are more active, less active or about the same?"
5. Low body weight: defined by body mass index (BMI) $\leq$ 18.5 kg/m^2.

In this study, individuals were considered frail if they exhibited three or more of the mentioned items.

Measurement: Correlation Between Proteinuria and Frailty

Although low-grade albuminuria plays a role in frailty and may share common pathological mechanisms related to CV diseases

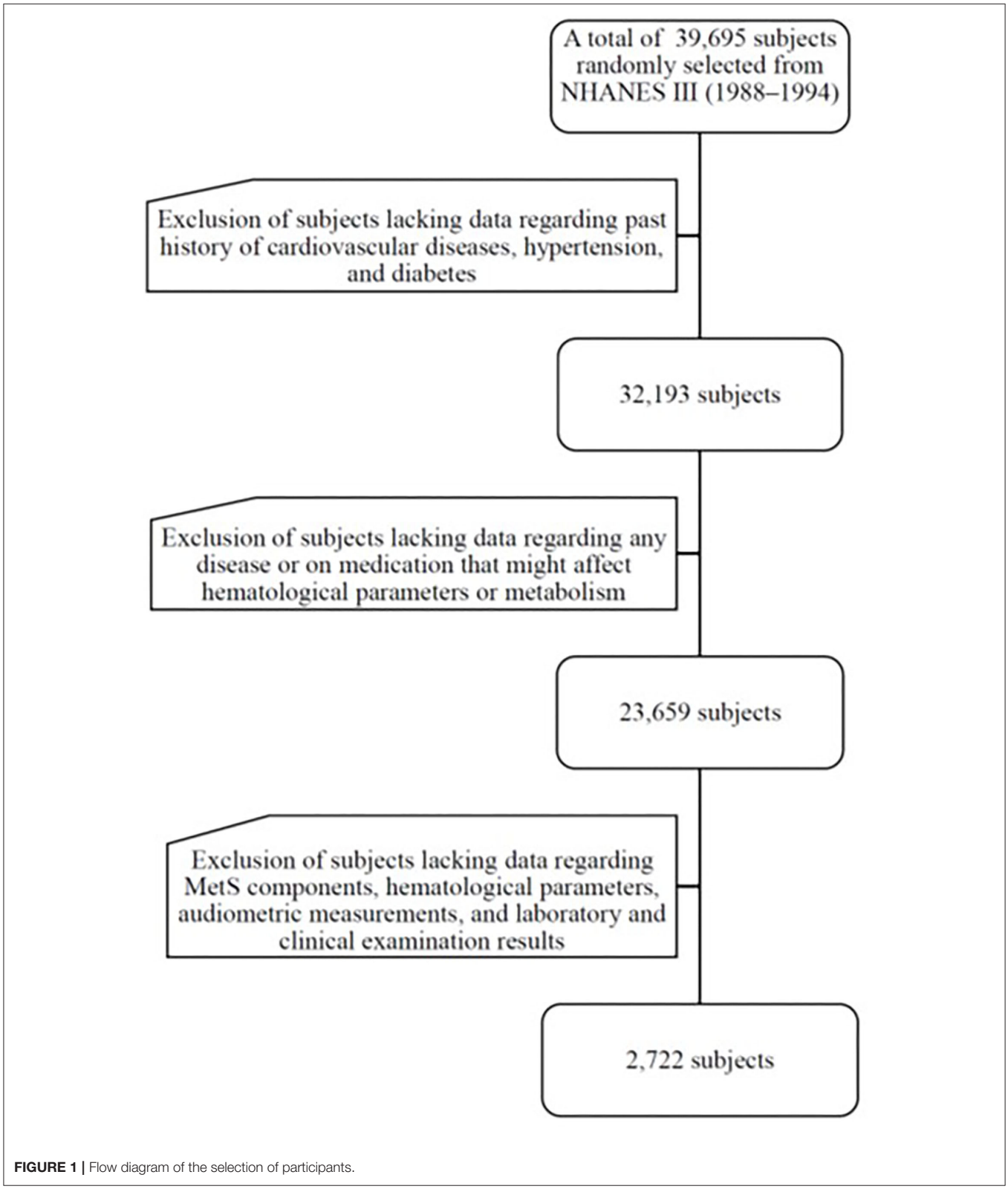

FIGURE 1 | Flow diagram of the selection of participants.

(7), the potential effect of increasing levels of proteinuria on frailty and each component of frailty remains unknown. Thus, we clarified the relationship between different degrees of proteinuria (normal range, microalbuminuria, macroalbuminuria), frailty, and frailty components in the study.

Measurement: Risk Variables

Self-report history was obtained for the following variables by asking the question "Has a doctor ever told you that you have (disease state) congestive heart failure (CHF), skin cancer, any other cancer, stroke, asthma, or DM?". The interviews were conducted by trained personnel. Questions were directed to the respondent or, if necessary, to their proxy. Physical activity was determined by asking, "Are you active compared to men/women your age?" Smokers were identified by asking, "Do you smoke cigarettes?" while "ever smokers" included subjects answering "yes" to "Have you ever smoked at least 100 cigarettes in your lifetime?"

Metabolic variables were obtained from blood samples. Plasma glucose was measured from fasting blood samples (fasted for 6 h or more) using the hexokinase enzymatic method. Serum total cholesterol (TC), serum total triglycerides (TG), serum high-density lipoprotein (HDL), and serum low-density lipoprotein (LDL) were measured using a Hitachi 704 analyzer (Roche Diagnostics, Indianapolis, IN, USA). Serum C-reactive protein (CRP) concentration was measured by latex-enhanced nephelometry with a Behring Nephelometer Analyzer System (Behring Diagnostics Inc.). This study utilized the Hitachi 737 Analyzer to measure other biochemical profiles, such as serum uric acid (UA), serum total bilirubin, aspartate aminotransferase (AST), alanine aminotransferase (ALT), serum creatinine, and serum total protein. Urinary creatinine and urinary albumin levels were measured using the Synchron AS/ASTRA Clinical Analyzer and fluorescent immunoassay, respectively. Age, BMI, systolic blood pressure (SBP), diastolic blood pressure (DBP), and blood and urinary samples were listed as continuous variables. The database had already been approved by the CDC and appropriate permissions and ethical clearance were obtained.

Statistical Analysis

All statistical analyses were conducted using the Predictive Analytics Suite Workstation Statistics (SPSS Inc., Chicago, IL, USA). The NHANES III is a database with complex designs. It was inappropriate to perform statistical analyses with the assumption of a simple random sample providing incorrect variance estimates. "Complex Sampling" was used to incorporate sample weights and adjusted for strata of the complex sample design. Basic statistics were used to describe the characteristics of the study participants. Continuous variables are presented as mean ± standard deviation (SD), while categorical variables are presented as counts and percentages (%). ANOVA was used for analyzing continuous variables, and the Chi-square test was used for categorical variables.

We used multiple logistic regression to determine the odds ratios (ORs) of frailty for increasing proteinuria levels. The participants in the lowest group being used as the reference group. The OR for frailty was obtained using multiple logistic regression by comparing each participant in the upper two tertiles of the proteinuria levels to those in the lowest tertile. For covariate adjustment, we used an extended-model approach: Model 1 was unadjusted by other variables; Model 2 was an adjusted Model 1, and was adjusted by the age, ethnicity, and BMI variables; Model 3 was an adjusted Model 2, and was adjusted by the SBP, serum fasting glucose, serum TG, and serum creatinine variables; Model 4 was an adjusted Model 3, and was adjusted by the history of congestive heart failure, stroke, diabetes mellitus, smoker, and physical activity variables. Trend tests were assessed by treating the tertiles of proteinuria levels from T1 to T3 as a continuous variable to observe the associations across increasing tertiles of proteinuria levels and OR of frailty.

RESULTS

Study Sample Characteristics

The study consisted of 2,272 adults aged 40–90 years whose frailty measures and laboratory examinations were available. The baseline characteristics of the subjects are presented in **Table 1**. The mean age was 72.07 years in women and 71.73 years in men, and 1,010 subjects (44.5%) were male. There were statistically significant differences in age, serum UA, serum creatinine, urinary albumin, history of CHF, DM, and physical activity between the frail and Non-frail groups in both sexes. There were also statistically significant differences in BMI, serum TG, serum glucose, serum total protein, and history of stroke in women, and DBP, serum HDL, and urinary creatinine in men between the frail and Non-frail groups.

Preliminary Analysis

To determine the relationship between proteinuria and frailty, a multivariable-adjusted logistic regression analysis was performed to demonstrate the effect of proteinuria. **Table 2** shows the significant positive associations between proteinuria tertiles and frailty. In the unadjusted analysis for male participants, the ORs of frailty for T2/T1 and T3/T1 were 3.152 (95% confidence interval [CI] = 1.120–8.870, $P = 0.030$) and 18.620 (95% CI = 6.980–49.674, $P < 0.001$), respectively. For female participants, the ORs of frailty for T2/T1 and T3/T1 were 2.203 (95% CI = 1.344–3.611, $P = 0.002$) and 5.296 (95% CI = 2.482–11.300, $P < 0.001$), respectively. After additionally adjusting for other covariates in Models 2–4, the positive association between T2/T1, T3/T1, and frailty remained essentially unchanged in both sexes. In the male group, the ORs of frailty for T2/T1 were 2.891 (95% CI = 1.035–8.297, $P = 0.041$), 3.217 (95% CI = 1.065–8.510, $P = 0.038$), and 3.106 (95% CI = 1.078–8.948, $P = 0.036$) from Models 2 to 4, respectively. In the female group, the ORs of frailty for T2/T1 were 1.872 (95% CI = 1.151–3.742, $P = 0.013$), 1.928 (95% CI = 1.163–3.191, $P = 0.011$), and 1.811 (95% CI = 1.071–3.063, $P = 0.027$) from Models 2 to 4, respectively. The ORs of frailty for T3/T1 were higher than those for T2/T1 in both sexes. For the male participants, the ORs of frailty for T3/T1 were 15.517 (95% CI = 4.926–48.940, $P < 0.001$), 14.845 (95% CI = 4.703–47.887, $P < 0.001$), and 14.428 (95% CI = 4.231–49.193, $P < 0.001$) from Models 2 to 4, respectively. For the female participants, the ORs of frailty for T3/T1 were 4.454 (95%

TABLE 1 | Metabolic syndrome participant characteristics by gender, frailty, and Non-frailty.

Variables	Male group *N* = 1,010				Female group *N* = 1,262			
	Non-frailty *N* = 971	Frailty *N* = 39	Total *N* = 1,010	*P* -value	Non-frailty *N* = 1,152	Frailty *N* = 110	Total *N* = 1,262	*P* -value
Continuous variables								
BMI (kg/m^2), mean (SD)	28.27 (4.10)	28.05 (4.99)	28.26 (4.14)	0.754	28.79 (5.48)	32.03 (7.00)	29.07 (5.70)	<0.001
Age (years), mean (SD)	71.54 (7.92)	76.38 (7.47)	71.73 (7.96)	<0.001	71.89 (7.97)	74.02 (8.24)	72.07 (8.01)	0.008
SBP (mmHg), mean (SD)	146.78 (20.89)	146.84 (24.08)	146.79 (21.00)	0.987	148.74 (22.45)	145.98 (21.39)	148.50 (22.36)	0.223
DBP (mmHg), mean (SD)	77.14 (12.25)	72.79 (19.11)	76.97 (12.60)	0.037	71.55 (14.72)	70.64 (13.34)	71.47 (14.68)	0.541
Serum TG (mg/dL)	163.23 (122.63)	169.90 (141.57)	163.49 (123.34)	0.741	165.70 (103.08)	220.55 (172.98)	170.48 (111.92)	<0.001
Serum cholesterol (mg/dL), mean (SD)	209.68 (43.00)	207.67 (45.73)	209.60 (43.08)	0.775	231.85 (44.24)	230.39 (47.43)	231.72 (44.51)	0.743
Serum LDL-cholesterol (mg/dL), mean (SD)	135.66 (35.72)	134.54 (30.26)	135.63 (35.56)	0.911	146.17 (40.03)	137.73 (34.69)	145.55 (39.69)	0.196
Serum HDL-cholesterol (mg/dL), mean (SD)	43.14 (13.29)	47.82 (18.48)	43.32 (13.55)	0.034	53.02 (16.98)	52.40 (17.54)	52.96 (17.03)	0.718
Serum CRP (mg/dL), mean (SD)	0.59 (0.96)	0.70 (0.61)	0.59 (0.94)	0.470	0.63 (0.97)	0.76 (0.89)	0.64 (0.97)	0.202
Serum total bilirubin (umol/L), mean (SD)	0.67 (0.35)	0.61 (0.23)	0.67 (0.34)	0.317	0.52 (0.24)	0.50 (0.31)	0.52 (0.25)	0.639
Serum UA (mg/dL), mean (SD)	6.24 (1.50)	6.81 (1.72)	6.26 (1.51)	0.021	5.45 (1.45)	5.89 (1.71)	5.49 (1.48)	0.003
Serum glucose (mg/dL), mean (SD)	121.46 (49.40)	126.74 (41.99)	121.66 (49.13)	0.510	117.11 (47.87)	145.04 (78.29)	119.55 (51.81)	<0.001
Serum total protein (g/dL), mean (SD)	7.38 (0.48)	7.44 (0.42)	7.38 (0.47)	0.391	7.32 (0.49)	7.46 (0.56)	7.33 (0.50)	0.005
AST (U/L), mean (SD)	22.34 (14.14)	21.79 (10.03)	22.32 (14.00)	0.812	21.21 (11.47)	21.07 (9.48)	21.20 (11.31)	0.902
ALT (U/L), mean (SD)	15.93 (12.71)	14.36 (9.25)	15.87 (12.60)	0.446	14.21 (9.40)	13.82 (8.51)	14.18 (9.32)	0.671
Serum creatinine (mg/dL), mean (SD)	1.33 (0.65)	1.56 (0.66)	1.34 (0.65)	0.030	1.09 (0.435)	1.21 (0.970)	1.10 (0.505)	0.019
Urinary albumin (ug/mL), mean (SD)	113.59 (495.40)	319.79 (649.43)	120.49 (502.27)	0.020	73.01 (561.04)	233.95 (903.47)	86.51 (598.49)	0.009
Urinary creatinine (mg/dL), mean (SD)	127.49 (66.60)	101.71 (49.32)	126.63 (66.24)	0.028	92.05 (60.69)	88.47 (51.24)	91.75 (59.94)	0.563
Categorical variables								
Non-hispanic white *N* (%)	200 (20.6)	6 (15.4)	206 (20.4)	0.375	224 (19.4)	35 (31.8)	259 (20.5)	0.006
Congestive heart failure, *N* (%)	99 (10.2)	10 (25.6)	109 (10.8)	0.025	77 (6.7)	17 (15.5)	94 (7.4)	0.003
Stroke, *N* (%)	68 (7.0)	6 (15.4)	74 (7.3)	0.267	71 (6.2)	22 (20.0)	93 (7.4)	<0.001
Asthma, *N* (%)	52 (5.4)	1 (2.6)	53 (5.2)	0.730	82 (7.1)	11 (10.0)	93 (7.4)	0.269
Skin cancer, *N* (%)	119 (12.3)	5 (12.8)	124 (12.3)	0.916	87 (7.6)	6 (5.5)	93 (7.4)	0.688
Other cancer, *N* (%)	70 (7.2)	4 (10.3)	74 (7.3)	0.759	82 (7.1)	8 (7.3)	90 (7.1)	0.952
Diabetes mellitus, *N* (%)	185 (19.1)	14 (35.9)	199 (19.7)	0.034	243 (21.1)	44 (40.0)	287 (22.7)	<0.001
Smoker, *N* (%)	350 (36.0)	15 (38.5)	365 (36.1)	0.758	7 (0.6)	0 (0)	7 (0.6)	0.412
Physical activity, n (%)				<0.001				<0.001
Ideal, *N* (%)	351 (36.1)	13 (33.3)	364 (36.0)		324 (28.1)	16 (14.5)	340 (26.9)	
Intermediate, *N* (%)	451 (46.4)	5 (12.8)	456 (45.1)		465 (40.4)	17 (15.5)	482 (38.2)	
None, *N* (%)	169 (17.4)	21 (53.8)	190 (18.8)		363 (31.5)	77 (70.0)	440 (34.9)	

N, number; SD, standard deviation; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; serum TG, serum triglycerides; LDL, low-density lipoprotein; HDL, high-density lipoprotein; serum CRP, serum C-reactive protein; serum UA, serum uric acid; AST, aspartate aminotransferase; ALT, alanine aminotransferase.

TABLE 2 | Association between the frailty and proteinuria in male and female participants with metabolic syndrome.

Models[a]	Tertiles	Male group			Female group		
		Odds ratio[b] (95% CI)	*P* Value	*P* for Trend	Odds ratio[b] (95% CI)	*P* Value	*P* for Trend
Model 1	T2 vs. T1	3.152 (1.120, 8.870)	0.030	<0.001	2.203 (1.344, 3.611)	0.002	<0.001
	T3 vs. T1	18.620 (6.980, 49.674)	<0.001		5.296 (2.482, 11.300)	<0.001	
Model 2	T2 vs. T1	2.891 (1.035, 8.297)	0.041	<0.001	1.872 (1.151, 3.742)	0.013	<0.001
	T3 vs. T1	15.517 (4.926, 48.940)	<0.001		4.454 (2.186, 9.673)	<0.001	
Model 3	T2 vs. T1	3.217 (1.065, 8.510)	0.038	<0.001	1.928 (1.163, 3.191)	0.011	<0.001
	T3 vs. T1	14.845 (4.703, 47.887)	<0.001		3.108 (1.247, 7.253)	0.014	
Model 4	T2 vs. T1	3.106 (1.078, 8.948)	0.036	<0.001	1.811 (1.071, 3.063)	0.027	<0.001
	T3 vs. T1	14.428 (4.231, 49.193)	<0.001		2.926 (1.202, 7.124)	0.018	

T1, normal range (ACR < 30 mg/g); T2, microalbuminuria (ACR 30–299 mg/g); and T3, macroalbuminuria (ACR ≥ 300 mg/g); ACR: albumin-to-creatinine ratio.

[a]*Adjusted covariates:*

Model 1 = Unadjusted.

Model 2 = Model 1 + age, ethnicity, body mass index (BMI).

Model 3 = Model 2 + systolic blood pressure (SBP), serum fasting glucose, serum TG, serum creatinine.

Model 4 = Model 3 + history of congestive heart failure, stroke, diabetes mellitus, smoker, physical activity.

[b]*Odds ratios were interpreted as change of frailty for each increase in different proteinuria levels.*

CI = 2.186–9.673, $P < 0.001$), 3.108 (95% CI = 1.247–7.253, $P = 0.014$), and 2.926 (95% CI = 1.202–7.12, $P = 0.018$) from Models 2 to 4, respectively.

Association Between Proteinuria and the Components of Frailty

Prominent frailty measures included the frailty phenotype (10) and the frailty index (11). This investigation adapted frailty phenotype as a measurement. **Table 3** shows that proteinuria was significantly positively associated with each frailty component. Participants in the higher tertiles of proteinuria tended to have higher ORs for each frailty component. The trends of higher likelihood of all frailty components were statistically significant across increasing tertiles of proteinuria after additionally adjusting for other covariates from Models 1 to 4 ($P < 0.05$ for all trends).

DISCUSSION

This study showed a statistically significant correlation between proteinuria and frailty. Proteinuria was strongly associated with every component of frailty in a Non-institutionalized, general population, even after adjustment for multiple covariates.

Frailty, conceptualized as a state of increased vulnerability to stress resulting from aging-related decline in physical function across multiple physiologic systems, predicts poorer outcomes in several medical specialties (10, 12, 13). Fried et al. proposed a phenotype to diagnose frailty (10). Another frailty measure is the frailty index, which operationalizes frailty as the fraction of 46 deficits present in an individual (11). The more health deficits an individual has, the frailer and more vulnerable the individual will be to adverse health outcomes. Research has described frailty from the perspective of people with chronic illnesses. Frailty is prevalent in patients with chronic obstructive pulmonary disease (COPD), and the strongest predictor of frailty among these patients was self-reported shortness of breath (14). The prevalence of frailty among those with CHF is high and presents a greater risk of adverse events, including hospitalization and mortality (15). Occasionally, in patients undergoing cardiac surgery, frailty is associated with an increased risk of morbidity, mortality, functional decline, and major adverse cardiac and cerebrovascular events (16). Elderly people with frailty who suffer from cancer are at an increased risk of chemotherapy intolerance, postoperative complications, and mortality (17). Thus, comprehensive geriatric assessment (CGA), a multidisciplinary diagnostic and treatment process that identifies psychosocial, functional, and medical limitations of a frail older person, is applied to develop individualized approaches toward cancer treatment (18). Patients with mild CKDs have a double risk of frailty, while moderate-to-severe CKD patients have an ∼ 6-fold risk (6). Moreover, the influence of moderate-to-severe CKD on frailty exceeds that of other chronic illnesses, such as cancer, vascular disease, and other degenerative diseases (6).

Proteinuria is characterized by the presence of excess protein in the urine. The two mechanisms leading to proteinuria are:

TABLE 3 | Association between the frailty components and proteinuria in male and female participants with metabolic syndrome.

Models[a]	Tertiles	Male group			Female group		
		Odds ratio[b] (95% CI)	*P* Value	*P* for Trend	Odds ratio[b] (95% CI)	*P* Value	*P* for Trend
Frailty (Slow walking)							
Model 1	T2 vs. T1	2.049 (1.282, 3.275)	0.003	<0.001	2.026 (1.474, 2.785)	<0.001	<0.001
	T3 vs. T1	5.423 (3.046, 9.654)	<0.001		6.133 (3.938, 9.553)	<0.001	
Model 2	T2 vs. T1	1.857 (1.187, 3.005)	0.006	<0.001	1.721 (1.257, 2.319)	0.001	<0.001
	T3 vs. T1	4.587 (2.714, 8.107)	<0.001		6.001 (4.003, 9.719)	<0.001	
Model 3	T2 vs. T1	1.918 (1.286, 3.180)	0.008	<0.001	1.778 (1.301, 2.517)	0.001	<0.001
	T3 vs. T1	4.514 (2.245, 8.359)	<0.001		4.457 (2.488, 7.963)	<0.001	
Model 4	T2 vs. T1	1.820 (1.125, 2.943)	0.015	<0.001	1.578 (1.133, 2.198)	0.007	<0.001
	T3 vs. T1	4.337 (2.188, 8.597)	<0.001		4.162 (2.471, 7.012)	<0.001	
Frailty (Weakness)							
Model 1	T2 vs. T1	1.942 (1.260, 2.993)	0.003	<0.001	1.964 (1.565, 2.465)	<0.001	<0.001
	T3 vs. T1	6.370 (3.961, 10.995)	<0.001		3.209 (2.127, 4.841)	<0.001	
Model 2	T2 vs. T1	1.465 (0.994, 2.268)	0.079	<0.001	1.747 (1.388, 2.194)	<0.001	<0.001
	T3 vs. T1	4.518 (2.637, 8.110)	<0.001		3.121 (2.024, 4.783)	<0.001	
Model 3	T2 vs. T1	1.453 (0.912, 2.253)	0.099	<0.001	1.826 (1.431, 2.276)	<0.001	<0.001
	T3 vs. T1	4.220 (2.263, 7.886)	<0.001		2.456 (1.593, 3.812)	<0.001	
Model 4	T2 vs. T1	1.398 (0.900, 2.171)	0.136	<0.001	1.642 (1.297, 2.080)	<0.001	<0.001
	T3 vs. T1	4.252 (2.267, 7.975)	<0.001		2.306 (1.467, 3.623)	<0.001	
Frailty (Exhaustion)							
Model 1	T2 vs. T1	1.895 (0.928, 3.871)	0.079	<0.001	2.035 (1.276, 3.247)	0.003	<0.001
	T3 vs. T1	7.850 (3.679, 16.752)	<0.001		3.553 (1.624, 7.771)	0.001	
Model 2	T2 vs. T1	1.424 (0.695, 2.978)	0.412	<0.001	1.627 (1.019, 2.613)	0.044	<0.001
	T3 vs. T1	5.277 (2.457, 11.335)	<0.001		2.869 (1.299, 6.338)	0.009	
Model 3	T2 vs. T1	1.462 (0.767, 3.122)	0.335	<0.001	1.657 (1.215, 2.647)	0.043	<0.001
	T3 vs. T1	4.817 (1.979, 12.121)	0.001		1.578 (0.613, 3.935)	0.304	
Model 4	T2 vs. T1	1.347 (0.649, 2.795)	0.423	<0.001	1.470 (0.899, 2.405)	0.124	<0.001
	T3 vs. T1	4.855 (1.950, 11.934)	0.001		1.544 (0.631, 3.780)	0.342	
Frailty (Low physical activity)							

(Continued)

TABLE 3 | Continued

Models[a]	Tertiles	Male group			Female group		
		Odds ratio[b] (95% CI)	*P* Value	*P* for Trend	Odds ratio[b] (95% CI)	*P* Value	*P* for Trend
Model 1	T2 vs. T1	1.947 (1.399, 2.711)	<0.001	<0.001	1.782 (1.388, 2.289)	<0.001	<0.001
	T3 vs. T1	3.300 (2.021, 5.390)	<0.001		3.713 (2.397, 5.753)	<0.001	
Model 2	T2 vs. T1	1.679 (1.206, 2.365)	0.002	<0.001	1.598 (1.290, 2.011)	<0.001	<0.001
	T3 vs. T1	3.323 (2.122, 5.396)	<0.001		3.206 (2.227, 4.995)	<0.001	
Model 3	T2 vs. T1	1.712 (1.328, 2.426)	0.002	<0.001	1.757 (1.357, 2.278)	<0.001	<0.001
	T3 vs. T1	3.257 (1.905, 5.601)	<0.001		3.084 (1.937, 4.932)	<0.001	
Model 4	T2 vs. T1	1.616 (1.150, 2.269)	0.006	<0.001	1.604 (1.237, 2.081)	<0.001	<0.001
	T3 vs. T1	2.994 (1.757, 5.102)	<0.001		3.154 (1.971, 5.047)	<0.001	
Frailty (Low body weight)							
Model 1	T2 vs. T1	1.935 (1.288, 2.906)	0.001	<0.001	1.864 (1.332, 2.608)	<0.001	<0.001
	T3 vs. T1	2.458 (1.240, 4.873)	0.010		1.355 (0.554, 3.313)	0.505	
Model 2	T2 vs. T1	1.975 (1.272, 3.075)	0.003	<0.001	0.839 (0.589, 1.234)	0.350	<0.001
	T3 vs. T1	2.227 (1.156, 4.467)	0.021		5.920 (2.364, 14.994)	<0.001	
Model 3	T2 vs. T1	1.729 (1.101, 2.715)	0.017	<0.001	0.837 (0.582, 1.204)	0.347	<0.001
	T3 vs. T1	1.563 (0.578, 3.718)	0.328		3.644 (1.297, 10.262)	0.011	
Model 4	T2 vs. T1	1.641 (1.035, 2.604)	0.035	<0.001	0.803 (0.557, 1.159)	0.242	<0.001
	T3 vs. T1	0.910 (0.421, 2.640)	0.910		2.934 (1.003, 8.587)	0.049	

[a]*Adjusted covariates:*
Model 1 = Unadjusted.
Model 2 = Model 1 + age, ethnicity, body mass index (BMI).
Model 3 = Model 2 + systolic blood pressure (SBP), serum fasting glucose, serum TG, serum creatinine.
Model 4 = Model 3 + history of congestive heart failure, stroke, diabetes mellitus, smoker, physical activity.
[b]*Odds ratios were interpreted as change of frailty components for each increase in different proteinuria levels.*

(1) the abnormal trans-glomerular passage of proteins due to changes in glomerular capillary permeability and (2) subsequent impaired reabsorption by the epithelial cells of the proximal tubuli (19). Urine dipsticks mainly detect albumin; however, light chains or other urine proteins can be missed even when they are present in significant quantities. The test becomes positive when proteinuria surpasses 15–30 mg/dL (300–500 mg/day, depending on urine volume) (20). Microalbuminuria is defined as an ACR of 30–300 mg/g, and macroalbuminuria is defined as ACR $\geq$ 300 mg/g (8, 9). High levels of urinary albumin excretion are associated with an increased all-cause mortality rate in the general population and high-risk patients, such as elderly subjects and those with hypertension, DM (21, 22). A community-based study conducted in Japan indicated that proteinuria is the most potent predictor of end-stage renal disease (ESRD), while the next most powerful predictor is hematuria (23). Furthermore, it can be a predictor of ESRD risk in all ethnic groups, including white, black, Hispanic, and Asian (24). Proteinuria is also implicated in CV mortality, risk of incident stroke, and atherosclerotic events. Proteinuria can be used as a marker to evaluate the therapeutic effects of CV medicine (25). Sarcopenic individuals have a higher proportion of albuminuria than those without sarcopenia after stratification based on the presence of hypertension, DM, MetS, and a higher homeostasis model assessment of insulin resistance (HOMA-IR) (26). Sarcopenia is defined as the involuntary loss of skeletal muscle mass that occurs with advancing age

(27). Previous studies on sarcopenia included study populations that were community-dwelling (28–30) whereas frailty is more widely applied in institutionalized people. Therefore, this study evaluated the correlation between frailty and proteinuria among middle-aged and older people with MetS.

A consequence of MetS is endothelial dysfunction (31). The endothelium regulates the growth, tone, hemostasis, and inflammation in the circulation. Insults to the endothelium result in inflammation and endothelial dysfunction (32, 33). Proteinuria is a manifestation of endothelial dysfunction and inflammatory cell infiltration in the kidneys (34). A study indicated that frailty occurs at a high frequency among Pre-dialysis patients and is correlated with aging, obesity, and endothelial dysfunction (35).

Insulin resistance (IR) is one of the components of MetS. Podocytes attach to the basement membrane of the glomeruli and share a slit-pore membrane with each other, forming a filter for plasma water and solutes (36). Podocytes are insulin-sensitive cells, and the IR of podocytes may be related to cell death and contribute to proteinuria (37). DM increases the risk of frailty and is a leading cause of disability in older adults. MetS and IR are strong risk factors for DM and could lead to frailty (38).

Activation of the renin-angiotensin-aldosterone system (RAAS) is common in patients with MetS (39). The clinical use of angiotensin-converting enzyme inhibitors (ACEIs) or angiotensin II receptor blockers (ARBs) to improve proteinuria suggests that activated RAAS plays an important role in proteinuria (40). Emerging evidence confirms the role of RAAS in the activation of inflammatory pathways, which may lead to frailty (41).

From previous literature, one can speculate that MetS, proteinuria, and frailty are associated and share common pathological mechanisms. A cohort study found a 15% overall rate of frailty among people with elevated serum creatinine concentrations (42). Sarcopenia and frailty are two geriatric syndromes with partly overlapping phenotypes, and sarcopenia usually precedes frailty (43). A Korean survey suggested that the close relationship between sarcopenia and albuminuria may be due to mechanisms such as RAAS, inflammation, and IR (44). In a recent cross-sectional study, Yang et al. have reported the correlation between frailty and albuminuria in elderly Chinese inpatients through multiple regression analysis (45). Another study conducted by Chang et al. revealed that the degree of microalbuminuria relates to frailty in middle-aged and elderly individuals (7). The authors proposed that the pathophysiological link between albuminuria and frailty is attributed to shared CV risk factors. Taken together, the finding of our study may be related to various complex mechanisms, such as CV diseases, sarcopenia, IR and RAAS.

This study has several limitations. First, the cross-sectional design limited the conclusions regarding the causality between proteinuria and frailty. The association between proteinuria and frailty over time was not analyzed because these clinical variables were measured only once at enrollment. Second, the survey revealed an independent association between proteinuria and frailty but did not observe mortality or comorbidities. Third, the relationship between proteinuria and frailty may vary among different ethnic groups. Fourth, although the analyses were adjusted for potential confounding factors, some residual confounders cannot be ruled out. Fifth, the study utilized frailty phenotype to classify individuals as frail; however, there is still a debate on the conceptual and operational definition of frailty (46).

CONCLUSION

In conclusion, the level of proteinuria has an independent positive correlation with the severity of frailty, and proteinuria affects all the components of frailty, including slow walking, weakness, exhaustion, low physical activity, and low body weight. For patients with proteinuria and metabolic syndrome, it is necessary to pay attention to the risk of frailty. For these high-risk groups, physical activity examination can detect frailty at an early stage, allowing to promptly provide relevant treatment.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/**Supplementary Material**.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by National Center for Health Statistics https://www.cdc.gov/nchs/nhanes/irba98.htm. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

P-KC: conceptualization, data curation, writing original draft, formal analysis, and methodology. Y-PC: writing original draft, investigation, project administration, resources, supervision, and validation. L-WW: conceptualization, data curation, methodology, formal analysis, writing review, and editing. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

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The Association Between the China's Economic Development and the Passing Rate of National Physical Fitness Standards for Elderly People Aged 60–69 From 2000 to 2020

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Objective: According to the seventh demographic census, China's elderly population reached 260 million, accounting for 18.7% of the total population, indicating that China is on the verge of transitioning from a relatively mild aging to a moderately aging society, and an aging society inevitably brings concerns about the elderly people's health. The purpose of this study was to better understand the effect of economic development on the physical fitness of the elderly people aged 60–69 in China during the first two decades of the twenty-first century, as well as to establish a correlation between China's gross domestic product (GDP) and changes in the elderly people's passing rate of national physical fitness standards.

Methods: A linear regression analysis was performed on the data of GDP and the passing rate of national physical fitness standards of Chinese elderly people aged 60–69 in 2000, 2005, 2010, 2014, and 2020.

Results: The passing rate of national physical fitness standards for elderly people aged 60–69 increased linearly ($R^2 = 80.56\%$, $p < 0.05$), indicating that the physical fitness of the elderly tends to increase steadily with GDP expansion.

Conclusions: Between 2000 and 2020, the annual improvement in the physical fitness of the elderly people in China is inextricably linked to rapid economic development. Increased financial investments in public sports services and a corresponding national fitness plan all contribute to an overall improvement in the physical fitness of the elderly people. This outcome is the effect of fiscal and policy coordination, which may represent a distinctive Chinese model and contribution to the global effort to manage and improve population physical fitness.

Keywords: GDP, population aging, public financing, public health, sports industry, policy coordination, spillovers

INTRODUCTION

Physical fitness can be broadly defined as the state of being physically capable of performing one's daily tasks as well as performing at a satisfactory level in sports (1). Physical fitness is associated with morbidity and mortality and is also highly associated with health outcomes (2). Thus, physical fitness is critical for healthy life in all age groups. Due to the age-associated decline in physical fitness (3), it is critical to enhance involvement in physical activity and related physical fitness, particularly among the elderly people (4). Diets (5), cigarette smoking (6), and genetics (7) all function as mediators of an individual's physical fitness, and the economic environment has an effect on the population's level of physical fitness. It has been found that children and adolescents with a lower socio-economic status engage in less physical exercise and thus have lower levels of physical fitness than children with a higher socio-economic position (8). Similarly, it was discovered through secondary analysis of health and fitness survey data from 15 European countries that lower-income countries had lower levels of fitness in persons aged 50 and above when compared to higher-income countries (9). Increased economic wellbeing among the population may boost opportunities for physical activity, hence increasing physical fitness levels. Given that economic status might be a barrier for the elderly people, it would be quite advantageous to assist them in this area. It is a well-known fact that the world's elderly population is growing in many countries (10). One of those countries is China.

Between 2000 and 2020, China's society accelerated its aging. China's old population over the age of 60 reached 260 million in the seventh demographic census, accounting for 18.7% of the overall population (11). This shows that China is on the verge of transitioning from a relatively mild aging to a moderately aging society, and the resulting physical fitness of the elderly population becomes critical. To gain a comprehensive understanding of the national physical fitness situation, assist in completing the assessment of the national fitness plan, and supervise and promote the construction of a healthy China, the General Administration of Sport of China and the Ministry of Education and other relevant departments began cooperating in 2000.

The passing rate for elderly people's physical fitness standards was 86.3% in the 2000 National Physical Fitness Monitoring Bulletin (12). In the 2005, Second National Physical Fitness Monitoring Bulletin (13), a total of 27,125 elderly people were surveyed, and the passing rate for elderly people's physical fitness standards was 84.4%, a decrease of 1.9% from 2000. The 2010 National Physical Fitness Monitoring Bulletin (14) examined 25,712 adults nationally and reported an elderly passing rate of 86.4%, a 2% improvement from 2005. The 2014 National Physical Fitness Monitoring Bulletin (15) was published in November 2015. The bulletin used stratified random whole-group sampling to poll the elderly people aged 60–69, and a total of 25,719 people were surveyed nationwide. The results indicated that 87.1% of the elderly people passed the national physical fitness standards, an increase of 0.7% over 2010. According to the Fifth National Physical Fitness Monitoring Bulletin (16), the proportion of elderly people who earned a passing rate of the national physical fitness standards was 91.4%, up 4.3% from 2014.

Stable public financing is a critical aspect in ensuring the long-term and coordinated development of public sports services in China. To encourage public sports services to gradually transition to a "sports-oriented and diversified" model, the government has enacted policies such as the "Interim Measures for Contracting the Budgets of Public Sports Services Under the State Sports Commission" and implemented a graded accountability system for public expenditure on sports, with sports expenditure gradually shifting from the state to a combination of the state and society (17). In 1995, China enacted the People's Republic of China's Sports Law (18), which stipulates unequivocally that people's governments at or above the county level should incorporate sports funding and capital construction funds into their financial budgets and capital construction investment plans, and gradually increase investment in public sports services as the national economy develops. It also establishes a legal framework for the formulation and improvement of public sports services.

Government investment in physical fitness programs for the elderly is critical for the overall health of the population. In developed countries, the United States, the United Kingdom, and South Korea all invest more than 1% of their gross domestic product (GDP) in sports, the Swiss government invests 4.3% of its budget in sports and recreation, and the Russian Federation's State Sports Fund receives 2% of its budget (19). Although China's public financial investment in public sports services has increased, the proportion of public financial investment in sports to national GDP remains low (**Table 1**) (20), and the proportion of financial expenditure on sports in other developed nations remains a gap.

There have been few research published to date examining the association between national GDP and physical activity levels, and the current evidence is conflicting. According to data collected from the 27 European Union member states, there is a statistically significant correlation (regression coefficient, 0.599; $p < 0.10$) between GDP and leisure-time physical activity (measured indirectly *via* surveys) (21). Another research of 76 nations discovered that more economically developed and urbanized countries (indirectly measured *via* the Human Development Index) have a higher proportion of their population (aged 15 and above) that does not get enough physical activity (measured indirectly *via* surveys) (22). Whereas, another study of 38 nations found a negative correlation between GDP and population physical activity (measured indirectly *via* surveys), with the highest levels of physical activity occurring in countries with a relatively low GDP (23). In short, there are no conclusive findings about the relationship between economic environment and physical activity levels or fitness, and there is no data on the elderly population.

China's economy has made significant achievement since the beginning of the twenty-first century, growing at an average annual rate of more than 8.65% from 2000 to 2020 (24). The GDP steadily increased from 10.028 trillion Chinese Yuan in 2000 to 101.599 trillion Chinese Yuan in 2020 (24). Meanwhile, as China's population ages, future risks related with demographic disorders, economic volatility, and an increase in chronic diseases

TABLE 1 | List of China's public financial investments in sports as a percentage of gross domestic product (GDP).

Year	Public financial investments in sports (billion Chinese Yuan)	GDP (trillion Chinese Yuan)	Percentage of GDP (%)
2000	8.16	9.921	0.08
2001	10.82	11.086	0.09
2002	14.18	12.171	0.11
2003	15.53	13.742	0.11
2004	17.38	16.184	0.11
2005	18.02	18.731	0.10
2006	21.57	21.943	0.10
2007	26.01	27.009	0.10
2008	33.27	31.924	0.10
2009	31.35	34.851	0.09
2010	33.42	41.211	0.08
2011	36.52	48.794	0.07
2012	38.84	53.858	0.07
2013	31.58	59.296	0.05
2014	33.38	64.356	0.05
2015	35.50	68.885	0.05
2016	40.66	74.358	0.05
2017	46.90	82.075	0.06

are possible. When it comes to addressing the social issue of how to improve the physical fitness of the elderly people, more rigorous and comprehensive planning is required in order to promote the elderly people's physical fitness while encouraging the synergistic development of China's economy.

There is currently no research on the relationship between national economic development and physical fitness among China's elderly people. As a result, this study sought to determine this correlation in order to gain a better understanding of their relationship and to influence future national policies aimed at promoting the sustainable development of both the elderly population's physical fitness and economic policy in China.

METHODS

Between 2000 and 2020, GDP data for China Mainland were retrieved from the World Bank (24). The national physical fitness standards for elderly people aged 60–69 were collected from the National Physical Fitness Monitoring Bulletin to determine the passing rate. In China, national physical fitness standards are explored in depth using a multi-category comprehensive index capable of efficiently assessing the development of physical condition (25). The index system includes a total of 20 indications divided into three categories: body morphology, body function, and physical function, with six to nine indicators chosen for each category based on the physical features of various age groups of people. Indicators of body morphology represent the state of development of the human body, including body shape, posture, and nutritional status. Height, body weight, chest circumference, waist circumference, hip circumference, skinfold thickness (i.e., triceps, scapula, and abdomen), and body fat percentage are all used as body morphology markers in national physical fitness monitoring of elderly people aged 60–69. To address the needs of a broad national sample, the national physical fitness monitoring program can utilize only a few straightforward and easy-to-use body function indicators. The national physical fitness monitoring program for elderly people aged 60–69 uses blood pressure, resting heart rate, lung capacity, and a 2-min high knees as measures of body function. Physical function indicators refer to the ability of the human body to display speed, strength, agility, balance, and flexibility in sports. The national physical fitness monitoring program for elderly people aged 60–69 includes indicators for forward bend test in sitting position, grip strength, single-leg stance test with eyes closed, choice reaction time test, and 30-s of sit to stand test. The standards use the individual indicators' physical fitness test scores, followed by a holistic assessment of all indicators, to classify an individual's physical fitness within the same population into four categories: excellent, good, pass, and fail.

Due to the fact that the linear function gave the same results as the first-order polynomial function, linear regression was employed to investigate the association between GDP and the passing rate of national physical fitness standards. Pearson's correlation coefficient was used to quantify the relationship between the total value of GDP and the elderly people's passing rate in the five corresponding years: 2000, 2005, 2010, 2014, and 2020. The obtained linear regressions enabled us to forecast trend changes in the elderly people's physical fitness. $p < 0.05$ was considered statistically significant. The analyses in this work were conducted using prism 9 (GraphPad Software, San Diego).

RESULTS

Between 2000 and 2020, five national physical fitness monitoring bulletins were published. **Tables 2**–**4** present a summary of single indicators of national physical fitness standards in 2010, 2014, and 2020. Individual indicators of physical fitness are generally above the passing norm, with the overall passing rate of national physical fitness standards for elderly people ranging from 86.3% in 2000 to 84.4% in 2005, 86.6% in 2010, 87.1% in 2014, and 91.4% in 2020.

The correlation coefficient model is summarized in **Figure 1**. The Pearson correlation coefficient between the total value of GDP and the elderly people's passing rate of national physical fitness standards is 0.8976, indicating a positive association between the two. With a significant *p*-value of 0.0388, it can be concluded that GDP has a positive significant effect on the elderly people's passing rate of national physical fitness standards.

DISCUSSION

This is the first study in China to demonstrate a strong positive correlation between the total value of GDP and the passing rate of national physical fitness standards among the elderly in the corresponding year. China's average GDP growth rate over the last two decades has been as high as 9%, and the overall GDP has

TABLE 2 | Indicators of body morphology average test results in national physical fitness standards.

Sex	Year	Age group (yrs)	Height (cm)	Body weight (kg)	Chest circumference (cm)	Waist circumference (cm)	Hip circumference (cm)	Skinfold thickness (mm)			Body fat percentage (%)
								triceps	scapula	abdomen	
Male	2000	60–64	165.4	64.5	89.5	83.0	92.6	12.3	17.7	21.9	/
		65–69	164.8	63.7	89.0	83.4	92.5	12.2	17.5	21.5	/
	2005	60–64	165.3	65.0	90.5	83.9	92.1	11.3	17.4	21.3	/
		65–69	165.0	63.9	89.8	83.5	91.9	11.5	17.2	20.9	/
	2010	60–64	165.7	66.6	91.5	85.4	93.0	11.0	16.8	20.6	/
		65–69	164.9	65.3	91.2	85.3	92.8	11.2	16.6	20.3	/
	2014	60–64	166.1	67.6	92.6	87.0	94.2	12.0	17.6	22.2	/
		65–69	165.4	66.6	92.2	86.8	94.0	12.3	17.5	21.9	/
	2020	60–64	165.9	69.0	/	89.3	96.4	/	/	/	23.3
		65–69	165.4	68.1	/	89.3	96.3	/	/	/	23.3
Female	2000	60–64	154.2	57.6	87.8	81.5	93.5	18.8	21.6	28.7	/
		65–69	153.4	56.5	87.1	81.8	93.0	17.9	20.3	27.4	/
	2005	60–64	154.1	58.0	88.4	82.9	93.2	19.8	21.9	28.9	/
		65–69	153.2	56.4	86.8	82.4	92.3	18.8	20.8	27.9	/
	2010	60–64	155.3	59.7	90.6	84.7	94.7	19.8	21.2	27.4	/
		65–69	154.4	59.2	90.4	85.5	94.5	19.5	20.8	27.0	/
	2014	60–64	154.5	59.2	89.5	84.0	94.1	20.0	21.1	26.9	/
		65–69	153.4	57.7	88.6	84.0	93.4	19.2	20.0	25.9	/
	2020	60–64	155.1	60.3	/	85.5	95.3	/	/	/	32.9
		65–69	154.4	59.8	/	86.4	95.4	/	/	/	33.0

TABLE 3 | Indicators of body function average test results in national physical fitness standards.

Sex	Year	Age group (yrs)	Systolic blood pressure (mm Hg)	Diastolic blood pressure (mm Hg)	Resting heart rate (beats·min^{-1})	Lung capacity (mL)	2-min high knees (times)
Male	2000	60–64	130.7	81.2	78.1	2649.9	/
		65–69	132.8	80.9	78.5	2441.3	/
	2005	60–64	129.2	80.5	77.4	2,565	/
		65–69	131.1	79.6	77.3	2,364	/
	2010	60–64	130.2	81.6	76.0	2,611	/
		65–69	132.0	81.2	75.7	2,407	/
	2014	60–64	129.4	81.0	77.2	2,563	/
		65–69	131.0	80.2	76.8	2,432	/
	2020	60–64	/	/	/	2,509	51.8
		65–69	/	/	/	2,342	50.7
Female	2000	60–64	129.2	79.5	77.9	1861.0	/
		65–69	131.1	79.3	78.2	1761.6	/
	2005	60–64	127.6	78.2	76.8	1,725	/
		65–69	129.5	77.9	77.3	1,617	/
	2010	60–64	126.8	77.7	76.4	1,829	/
		65–69	129.5	78.0	76.8	1,747	/
	2014	60–64	128.1	79.4	75.6	1,766	/
		65–69	130.4	79.2	75.6	1,645	/
	2020	60–64	/	/	/	1,785	55.1
		65–69	/	/	/	1,679	52.3

TABLE 4 | Indicators of physical function average test results in national physical fitness standards.

Sex	Year	Age group (yrs)	Forward bend test in sitting position (cm)	Grip strength (kg)	Single-leg stance test with eyes closed (s)	Choice reaction time test (s)	30-s of sit to stand test (times)
Male	2000	60–64	3.4	37.4	12.0	0.7	/
		65–69	1.6	34.9	9.4	0.8	/
	2005	60–64	1.9	37.5	10.8	0.66	/
		65–69	0.5	35.0	8.7	0.72	/
	2010	60–64	1.8	37.4	10.1	0.7	/
		65–69	0.5	34.6	8.2	0.7	/
	2014	60–64	2.1	37.3	9.4	0.67	/
		65–69	1.5	35.0	8.2	0.70	/
	2020	60–64	2.4	36.5	11.3	0.72	12.0
		65–69	1.7	35.1	10.3	0.74	11.7
Female	2000	60–64	8.4	23.9	9.7	0.8	/
		65–69	7.1	22.8	8.4	0.8	/
	2005	60–64	7.8	23.5	9.1	0.73	/
		65–69	6.4	22.2	7.9	0.78	/
	2010	60–64	7.9	23.2	8.5	0.71	/
		65–69	7.2	22.3	7.7	0.75	/
	2014	60–64	7.9	23.3	9.2	0.7	/
		65–69	6.7	21.8	7.4	0.8	/
	2020	60–64	7.9	22.8	109	0.74	11.8
		65–69	7.1	21.6	9.9	0.78	11.3

increased by nearly 1,085% (24). Rapid economic development has resulted in the development of health care and public sports services, laying the groundwork for the elderly people's physical fitness to continue to improve year after year.

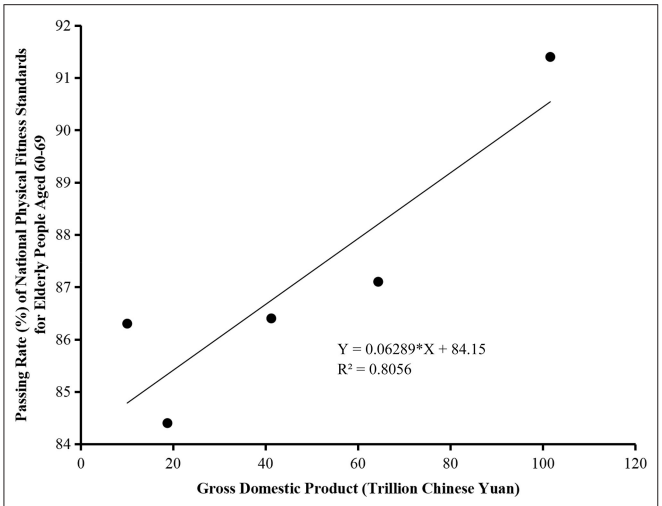

FIGURE 1 | Linear regression of gross domestic product and elderly people's passing rate of national physical fitness standards in the five corresponding years: 2000, 2005, 2010, 2014, and 2020.

Previous research on the relationship between economic development and physical fitness has primarily relied on indirect measures of the economic environment (e.g., Human Development Index) or indirect measures of physical fitness (e.g., surveys). This is the only study we are aware of that establishes a direct association between national economic development and large-scale, population physical fitness by measuring each activity directly (i.e., GDP and actual physical fitness tests). Particularly, lower body strength and grip strength, which are included in national physical fitness standards, are closely correlated with frailty, an age-related condition characterized by a vulnerability status that impairs the elderly people's quality of life and independence (4). Thus, the current findings provided the first direct analysis demonstrating how rapid economic expansion has impacted the physical fitness of the elderly population in the world's second largest economy.

China's financial expenditure on public sports services increased from 8.16 billion Chinese Yuan in 2000 to 46.90 billion Chinese Yuan in 2017 (20), an increase of approximately 5.75 times in 15 years. The absolute scale of financial expenditure on public sports services has steadily increased, but a stable growth mechanism has not yet been established. From 2000 to 2015, China's financial expenditure on public sports services hit its peak in 2012 (**Table 1**). However, it decreased by 19.7% in 2013 and by 5.9% following the 2008 Beijing Olympic Games, indicating that China's financial expenditure on public sports services has been impacted by the Olympic Games and other major international sports events. China spent 145.61 billion Chinese Yuan on public sports services during the 11th Five-Year Plan period (2006–2010), and 175.82 billion Chinese Yuan on public sports services during the 12th Five-Year Plan period (2011–2015) (20), an increase of 21% over the 11th Five-Year Plan period. Meanwhile, China's overall fiscal expenditure for the 11th Five-Year Plan period (2006–2010) was 31,897.08 billion Chinese Yuan, and during the 12th Five-Year Plan period (2011–2015), the total fiscal expenditure was 70,306.71 billion Chinese Yuan (20), a 220% increase over the 11th Five-Year Plan period. Thus, it can be observed that sports expenditures are growing at a slower rate than fiscal expenditures. However, as financial investment in public sports services increases year after year, China continues to establish comprehensive circumstances for physical fitness and exercise for the elderly population, while simultaneously improving the state of the public sports and fitness environment.

China's old population has been growing since the millennium's turn. The government's year-on-year increase in public funding on sports is certain to boost the elderly population's physical fitness. Under the policy framework of the National Fitness Plan (26), the Chinese government has gradually improved public sports and fitness facilities at three levels—counties (cities and districts), townships (streets), and administrative villages (communities)—and has increased support for senior sports clubs and other related organizations to provide practical assistance in improving the elderly population's physical fitness. Meanwhile, the General Administration of Sport of China, in collaboration with the National Office for the Aging and the China Senior Citizens Sports Association, has organized a series of more influential senior sports activities in China, including the National Senior Citizens Sports and Fitness Conference and group fitness and recreation activities. Government-sponsored sports events are rigorously developed to serve as a model for elderly population's engagement in physical fitness and sports (27). In the summer, more than 70% of elderly population in North, East, South Central, Southwest, and Northwest China engage in physical activity, and more than 60% of elderly population in North, Northeast, East, and South Central provinces engage in physical activity more than five times per week for a total of 30–60 min each session (28). Under the guidance of the National Fitness Plan (26), various departments in China have provided strong support for the elderly population's fitness, including instruction and teaching, fitness venues, medical protection, and activity organization, and have vigorously promoted the elderly population's active participation in sports and fitness activities, as well as made concerted efforts in a variety of areas to assist the elderly in improving their physical fitness.

China's governmental financial expenditure on sports has increased year after year in lockstep with GDP development, ensuring both a continuous increase in the pace at which physical fitness standards for the elderly population in China are passed and a high level of convenience for the elderly people to exercise and stay healthy. While China still lags behind other countries in terms of state expenditure on public sports services (19), it has achieved substantial outcomes and assisted the elderly people in developing their physical health in accordance with China's national development. In the future, China's state expenditure on public sports service shall continue to grow at a steady rate consistent with the national circumstances, and could significantly support the elderly people's ability to exercise and enhance their physical fitness.

We should caution that, current findings in China as a result of fiscal and policy coordination, may not necessarily

be extrapolated to other countries, i.e., economic growth does not always result in an increase in population physical fitness. This phenomenon has been documented in previous research, where a negative correlation exists between GDP and levels of physical activity (22, 23). This discrepancy may be explained by the fact that China is a socialist country, which means that national policy is highly regulated and has a substantial impact on social and economic outcomes. Following the National Fitness Plan (26), the Chinese government establishes national physical fitness monitoring centers and exercise guidance stations throughout the country, utilizes big data to expand population-wide physical fitness monitoring, and develops local fitness exercise programs for the elderly people based on regional characteristics. Additionally, the Chinese government expands training and allocation of social sports management personnel and establishes a network of sports and fitness volunteers around the country to provide scientific counsel and help to the elderly population regarding fitness and exercise. These socialist-leaning policies ensure that public financial investments in sports reach the elderly population effectively. On the other hand, countries characterized by a free market economy may not achieve the same level of fiscal and policy coordination as China (29). Over the last four decades, China has enacted a series of fundamental market reforms to open up trade routes and investment flows, ultimately lifting hundreds of millions of family out of poverty and into the middle class. Its economic expansion is unlikely to be replicated by any country, both in terms of relative growth rate and absolute base effect. Likewise, other countries are less likely to emulate its centralized government policies. This steady rise in physical fitness among the Chinese elderly is a result of both impressive economic development and an efficient policy transmission channel, an unique Chinese phenomena.

In conclusion, China's ongoing economic expansion in tandem with fiscal expenditures between 2000 and 2020 has resulted in the continual provision and support of fitness activity for the elderly people within the context of national physical fitness standards. Additionally, the continuous increase in the passing rate of physical fitness standards for the elderly people in China over the last two decades is due not only to the rapid growth of China's GDP and the continuous expansion of China's public expenditure on sports, but also to the elderly people's growing awareness of exercise as a result of state, society, and public media education. As a result of the National Fitness Plan (26), the proportion of elderly people participating in physical activity has grown massively in China. The percentage of elderly people participating in fitness activities has been increasing, as has the rate of elderly people passing national physical fitness standards. By examining the rate and pattern of China's population growth, it is clear that the China's population is beginning an accelerated aging trend. It has been projected that (30), China will have approximately 180 million people aged 65 and over in 2020, accounting for ∼13% of the total population, and more than 310 million in 2035, accounting for ∼22.3% of the total population. The increasing age of society's population, as well as the gradual slowing and fluctuation of China's economic growth, would have an effect on the elderly population's health and fitness. The nation's financial funding for public sports services must continue to rise in the future to keep pace with the aging population's growth and to ensure the elderly people's physical fitness.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

ZL, A, and TB: conceptualization and methodology. ZL: formal analysis. ZL and A: writing—original draft preparation. TB, SA, and BJ: writing—review and editing. ZL and TB: project administration. TB: funding acquisition. All authors have read and agreed to the published version of the manuscript.

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Lifestyle, Physical Activity, Eating and Hygiene Habits: A Comparative Analysis Before and During the COVID-19 Pandemic in Student Population

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Background: Changing daily habits such as diet, hygiene and physical activity may be some of the consequences of the COVID-19 pandemic. The aim of the study was to analyze the effect of this pandemic on lifestyle, physical activity, eating and hygiene habits among students.

Methods: This cross-sectional study involved 171 students from the Faculty of Medical Sciences, University of Kragujevac, Serbia. Data were statistically analyzed using Wilcoxon Signed-Rank test, Marginal homogeneity test and Chi-square test. The differences were considered statistically significant when $p \leq 0.05$.

Results: In this study, it was observed that the most common physical activity before the pandemic was walking, while during the pandemic was home exercising. Compared to the period before the pandemic, there was no difference in the time spent engaging in daily physical activity ($p = 0.334$). However, there was a significant increase in sitting time during the pandemic ($p = 0.005$). Difference was noticed in the use of breakfast, the number of meals, and the type of fat in the diet before and during the pandemic ($p = 0.000$). During the pandemic, there was an increase in the use of fruits ($p = 0.000$), vegetables, and nuts ($p = 0.001$), while the use of fast food and alcohol have decreased. During the COVID-19 pandemic, a significant increase in the use of dietary supplements was observed (40.2%), ($p = 0.008$).

Conclusions: Given that the COVID-19 pandemic is ongoing, certain changes in lifestyle observed in this study should be confirmed in more extensive population studies.

Keywords: coronavirus, lockdown, sedentary behavior, nutrition, personal hygiene habits

INTRODUCTION

The Coronavirus Disease 2019 (COVID-19) is a severe acute respiratory syndrome caused by SARS coronavirus 2 (SARS-CoV-2). The first series of pneumonia cases were described in Wuhan, Hubei Province, China in December 2019. COVID-19 has rapidly spread to other parts of the world causing the pandemic (1). With the growing case notification rates at Chinese and other international locations, and Serbia was also affected, with the first confirmed case on March 6, 2020 (2, 3). The government of Serbia declared a state of emergency on March 15, 2020, implementing some of Europe's strictest measures to combat the pandemic (such as 12 h and weekend police-enforced curfew, strict bans on movement, and shutting borders) (4).

Due to the introduction of various measures to bring the pandemic under control, sudden and radical changes in the habits and lifestyle of the population occurred, with a significant reduction in any form of socialization. Educational institutions such as kindergartens, schools and universities were completely suspended, and students were staying indoors for months and learning via TV and online platforms (4). Self-isolation and physical distance have affected the lives of citizens, especially their daily behavior and eating habits. Although restrictions such as social distancing, reduced group gatherings, closed gyms, etc. are efficient in reducing the infection rate, such restrictions result in limiting participation in normal daily activities, travel, and physical activity. The prolonged homestay may lead to increased sedentary behaviors, such as spending excessive amounts of time sitting or lying down that consequently makes it difficult to fight infection, and lead to immunological and cardiopulmonary complications of more severe outcomes (5).

Optimal level of nutrition, food choices as well as eating habits have long-term benefits on disease prevention, including COVID-19, and may affect the course and outcome of COVID-19 infection. Studies show that consuming healthy foods has a rapid anti-inflammatory effect, even in the presence of obesity pathology (6).

Given the ease and speed of human-to-human transmission of the virus, Non-pharmaceutical measures such as wearing face masks and washing and disinfection hands play an important role in the risk of transmission because they establish a barrier to aerosol spread and protect vulnerable populations (7, 8). Evidence from the literature showed that frequent hand-washing would reduce the risk of viral transmission by 55% (7).

Although the COVID-19 pandemic and the lockdown have induced changes in all aspects of life and the living habits of people of all ages, young people were particularly affected by these changes. However, not enough research has been conducted to investigate the effect of the pandemic on student population in Serbia. The aim of this study was to analyze the differences in lifestyles, eating, and hygiene habits before and during the pandemic among the students (aged $\geq$ 19) of the Faculty of Medical Sciences in Kragujevac, Serbia.

METHOD

This study is designed as a cross-sectional study in the period from June 1st until August 1st, 2020. It included 171 students from the Faculty of Medical Sciences, University of Kragujevac, Serbia (128 female respondents and 43 male respondents, aged $\geq$ 19). The study comprised a structured questionnaire which was available on the online platform of the faculty, disseminated through institutional networks, accessible through any device with an Internet connection from June 1st until August 1st, 2020. The questionnaire was also provided in paper form for students who came to the faculty during this period to take exams, who did not complete the online questionnaire. Students agreed to participate in an anonymous survey. The study was approved by the institution where the research was conducted. The questions were divided into different sections: socio-demographic data (age, gender); anthropometric data (weight and height, waist circumference); information on eating habits (regularity of breakfast, number of daily meals, type of bread used, frequency of use of dairy products, type of fat used for food preparation, type of meat, salting, type and frequency of fruit and vegetable consumption, method of food preparation); information on life habits (alcohol use; physical activity–form and time period of physical activity) and hygiene habits. The questionnaire was in online format and paper form. Body mass index value (BMI) was used to assess nutritional status and divide respondents into weight status categories–underweight, normal weight, overweight, and obesity. After completing the questionnaire on the Google platform, the data were downloaded to the Microsoft Excel sheet. These data are combined with the data from the questionnaire in the paper version.

Statistical analyzes were performed using the SPSS program, version 20.0. The analysis of the normality of the distribution of continuous variables was performed using the Kolmogorov-Smirnov test. The significance of differences between continuous variables before and during the COVID-19 pandemic was determined using the Wilcoxon Signed-Rank test, as the variables did not follow the normal distribution. The Marginal homogeneity test was used to determine the difference between these two periods for categorical variables. The Chi-square test was used to determine the difference between the sexes in certain variables. Statistical significance existed when $p \leq 0.05$.

RESULTS

The average age of the respondents was 22.53 ($SD = 2.477$), and the average height of the respondents was 161.86 cm

TABLE 1 | Data on age, height, weight, BMI, and waist circumference of respondents, differences before and during the COVID-19 pandemic (Wilcoxon Signed Rank test).

	N	Minimum	Maximum	Mean	Std. deviation	*p*-value
Age	171	19	37	22.53	2.48	
Grade Point Average	167	7	10.00	8.44	0.79	
Weight before pandemic (kg)	171	42	108	65.04	12.63	0.755
Weight during the pandemic (kg)	172	43	110	65.02	12.90	
Height (cm)	153	2	193	163.69	36.50	
BMI before the pandemic (kg/m^2)	144	16.33	29.75	21.77	2.91	0.568
BMI during the pandemic (kg/m^2)	145	16.16	30.85	21.69	2.87	
Waist circumference before the pandemic (cm)	120	50	125	73.85	13.89	0.979
Waist circumference during the pandemic (cm)	119	50	128	73.45	14.16	

($SD = 36.807$). During the pandemic, there was no significant change in average values for body weight (Wilcoxon Signed Rank test $p = 0.755$) and waist circumference (Wilcoxon Signed Rank test $p = 0.979$) compared to the period before the pandemic (**Table 1**). A significant percentage of male subjects were overweight both before (Pearson chi-square value = 10.518, $df = 2$, $p = 0.005$) and during the pandemic (Pearson chi-square value = 14.106, $df = 3$, $p = 0.003$) compared to female subjects. No significant difference in BMI ($p = 0.568$, Wilcoxon Signed Rank test) was found before and during the pandemic (**Tables 1**, **2**).

When it comes to eating habits, there was no difference in the use of bread before and during the pandemic (Marginal homogeneity test $p = 0.881$), there was a significant difference in the consumption of breakfast, and the number of meals, type of fat used by respondents before and during the pandemic ($p = 0.000$) (**Table 3**). Before the pandemic, 64% of respondents had breakfast every day, and during the pandemic 84.3% of respondents. The percentage of respondents who had 5 or more meals during the day increased from 15.6 to 28.9% of respondents. The use of lard increased from 16.4 to 27.5%. There was no difference in the consumption of pork ($p = 0.752$), beef ($p = 0.515$), poultry ($p = 0.285$), fish ($p = 0.782$) and cured meat products ($p = 0.913$) before and during the pandemic.

There was a significant increase in the consumption of fruits ($p = 0.000$), vegetables, and nuts ($p = 0.001$) during the pandemic. Daily consumption of fruits increased from 25 to 33.7%, vegetables from 40.6 to 45%, and nuts from 37.1 to 44.1% of respondents (**Table 3**). No difference was observed in the consumption of certain types of fruit, except in the case of the use of lemon ($p = 0.000$), which was previously used by 39.6% of respondents, and during the pandemic by 50.6%.

The method of food preparation before and during the pandemic differed significantly. There was a significant difference in food processing by baking ($p = 0.000$), cooking ($p = 0.002$), frying ($p = 0.041$), stewing ($p = 0.025$), use of raw food ($p = 0.016$) and use of fast food ($p = 0.000$). The percentage of all types of food processing increased, with cooking being the most common, food frying increased from 66.1 to 72%, while the consumption of fast food decreased from 35.7 to 17.9%. There was no difference in the consumption of coffee ($p = 0.891$) and carbonated beverages ($p = 1.00$), while the consumption of alcohol decreased significantly ($p = 0.022$).

During the COVID-19 pandemic, a significant increase in the use of dietary supplements, which was not prescribed by a physician, was observed (40.2%), compared to the period before the pandemic (33.7%, $p = 0.008$) (**Table 3**). In particular, an increase in the use of supplements containing vitamins C ($p = 0.028$), D ($p = 0.002$) and zinc ($p = 0.000$) was observed. Before the pandemic, 66% used vitamin C, 12.8% vitamin D, and 30.8% zinc, while during the pandemic the use of vitamin C was recorded in 73.3%, vitamin D in 21.1%, and zinc in 47.2% of respondents. However, there was no difference in the use of B vitamins ($p = 0.239$) and calcium ($p = 0.096$).

During the pandemic, more frequent thinking about health was observed when choosing food and planning a diet ($p = 0.000$).

Compared to the period before the pandemic, there was no significant difference in the time spent engaging in physical activity during the day ($p = 0.334$). The most common activity before the pandemic was walking, and during the pandemic, home exercising. Walking decreased from 40.7 to 24.2% of respondents during the pandemic. There was a significant increase in sitting time (average 5.73 h) compared to the Pre-pandemic period (average 5.29 h), (Wilcoxon test, $p = 0.005$).

When it comes to hygienic habits that help protect against coronavirus infection, it was found that during the pandemic, 90.9% washed their hands before meals, 93.9% after using the toilet, 89% after coming home, and 38.4% of respondents before putting on masks. The largest percentage of respondents used soap and hot water for handwashing (97%), while 2.4% of respondents used alcohol-based products for dry hand washing. About 30% of respondents touched their nose, mouth, and eyes outside the house with unwashed hands. In public, 31.1% of respondents always wore a mask, while 53.4% respondents wore a mask often, 13% of them wore it rarely, and 2.5% of respondents never wore it. The largest percentage of respondents (81%) used medical-surgical masks, 39.9% of respondents wore masks made of cotton, linen or other materials, while epidemiological masks N95 were used by 9.2% of respondents. The highest percentage of respondents (40.7%) used the same mask (single or multiple without washing and disinfection) only 1 day, 32.1%

TABLE 2 | Nutritional status (BMI), χ^2 test by gender before COVID-19 (Pearson chi-square value = 10.518, $df = 2$, $p = 0.005$) and during COVID-19 pandemic (Pearson chi-square value = 14.106, $df = 3$, $p = 0.003$).

COVID-19 pandemic	Before	During	Before	During	Before	During	Before	During
BMI (m/kg^2)	Underweight %		Normal weight %		Pre-obesity %		Obesity %	
Total	11.8	9	74.0.3	77.8	13.9	11.8	0	1.4
Males	2.9	2.9	68.6	68.6	28.6	28.6	0	0
Females	14.7	11	76.1	80.7	9.2	6.4	0	1.8

of respondents used the mask for up to 3 days, more than 5 days used the same mask 9.3% of respondents, while 2–4 h the same mask was used by 7.4% of respondents. There were 76.1% of respondents who used alcohol to disinfect their hands when they were away from home, 57.7% after shopping, 46% after using an ATM, and 27.6% after visiting a pharmacy. 33.7% of respondents have never used surgical gloves outside the home when handling money and shopping.

During the pandemic, a significantly higher percentage (50.3%) of respondents cleaned and disinfected their shoes after returning home ($p = 0.001$) compared to the period before the pandemic (11%). During the pandemic, a significant percentage (50%) of respondents took showers and changed clothes upon returning home, compared to the Pre-pandemic period (27.8%) ($p = 0.000$).

Compared to the period before the pandemic, there was a significant difference in cleaning, washing, and disinfection of food after purchase ($p = 0.000$), before the pandemic 6.1% of respondents treated food in this way, and during the pandemic 35.6% of respondents.

The recommendation to maintain the required social distance was always followed by 30.7% of respondents, often 55.2%, rarely 12.9%, and never 1.2% of respondents.

Respondents obtained the information on the COVID-19 pandemic through the Internet (89.2%) and television (78.4%).

During the pandemic, a significant decrease in household income was observed compared to the period before the pandemic ($p = 0.049$, Wilcoxon Signed Rank Test).

DISCUSSION

The COVID-19 pandemic encouraged researchers to examine what eating habits, physical activity, and hygiene habits were before and whether there were changes during the pandemic, taking into account the socioeconomic and sociodemographic characteristics of the respondents.

The study observed a significant decrease in household income during the pandemic compared to the Pre-pandemic period, which is probably due to job loss or lower-income during the isolation period. Although the COVID-19 pandemic affects populations around the world, there are numerous reports documenting a greater impact of the pandemic on lower socioeconomic groups (9). The risk of unemployment is higher for those with atypical and precarious employment conditions, whose financial income is already minimal. While unemployment as a whole is rising, low-income people are more likely to work in the sectors hardest hit by the pandemic and have fewer economic reserves to maintain a period of lost income, and the negative impact of unemployment is reflected in health. The prevalence of the disease is inversely related to socioeconomic status (10).

Nutritional status can have a significant impact on an individual's general health (11, 12). These changes in dietary patterns during quarantine can potentially lead to changes in body weight as a result of lower physical activity, changes in food consumption, and stress, which may be due to adaptation to the new situation (13). Following the bodyweight of the student population, there is no significant deviation in the average values of body weight, but it is noted that a significant percentage of male respondents were overweight before and during the pandemic compared to female respondents, which is consistent with previous studies which examined gender differences in the prevalence of overweight and obesity among university students (14, 15).

When it comes to eating habits, during the COVID-19 pandemic, there is a noticeable increase in respondents who ate breakfast every day and had more meals during the day. Similar findings are evident in a study conducted in Poland, where the majority of respondents, 65.5%, stated that they practice breakfast every day. Numerous studies document that skipping breakfast can be associated with an increased risk of various diseases, and given that this information is available in various sources for health promotion that are more commonly reached by individuals with higher education, it is not surprising the frequency of breakfast (13).

There was also a significant difference in food preparation before and during the pandemic, with an increase in the percentage of all food processing, where cooking was the most common form of preparation, while the consumption of fast food decreased dramatically from 35.7 to 17.9%. It is assumed that one of the reasons for choosing this method of food preparation is greater information of the population about the importance of healthy food preparation, as a preventive measure to prevent various diseases. During the pandemic, the study showed a significant increase in consumption of fruits, vegetables, and nuts, which is documented by the findings of research conducted in the regions of Spain, Brazil, Chile (16), and Italy, where 37.4% of the population said they increased consumption of healthy food (17). Improving the quality of nutrition was also noted by Grant et al. in their extensive study of 2,678 people (18). These results are not surprising given that due to confinement, families have had more time to improve their eating habits by increasing

TABLE 3 | Overview of the percentage of respondents' responses regarding eating habits and supplementation in which a significant difference was found before and during the COVID-19 pandemic (Marginal homogeneity test).

	% of respondents with a certain answer		
COVID-19 pandemic	**Before the COVID-19 pandemic (%)**	**During the COVID-19 pandemic (%)**	**Marginal homogeneity test *p*-value**
1. Breakfast			$p = 0.000$
Every day	64	84.3	
Sometimes	30.8	13.4	
Never	5.2	2.3	
2. Number of meals during the day			$p = 0.000$
<3	28.9	15.6	
3	34.7	31.8	
4	20.8	23.7	
5	11.6	23.1	
>5	4	5.8	
3. The type of fat used in the diet			$p = 0.000$
Lard	16.4	27.5	
Butter	1.8	1.2	
Vegetable fat	7.6	6.4	
Margarine	3.5	2.9	
Oil	68.4	59.6	
None	2.3	2.3	
4. Consumption of fruit			$p = 0.000$
Once or more a day	25	33.7	
4–6 times a week	23.3	28.5	
1–3 times a week	37.2	29.1	
<1 per week	13.4	7.6	
Never	1.2	1.2	
5. Consumption of vegetables			$p = 0.001$
Once or more a day	40.6	45	
4–6 times a week	32.9	36.7	
1–3 times a week	24.1	16.6	
<1 per week	2.4	1.8	
Never	0	0	
6. Consumption of nuts			$p = 0.001$
Yes	37.1	44.1	
Not	12.4	15.3	
Sometimes	50.6	40.6	
7. Method of food processing			
Baking	50.6	64.3	$p = 0.000$
Cooking	72.6	82.7	$p = 0.002$
Frying	66.1	72	$p = 0.041$
Stew	27.4	33.3	$p = 0.025$
Raw food	29.2	35.7	$p = 0.016$
Fast food	35.7	17.9	$p = 0.000$
8. Alcohol use			$p = 0.022$
Once or more times a day	1.2	1.2	
4–6 times a week	1.2	2.5	
1–3 times a week	11.7	9.8	
<1 per week	42.9	33.7	
Never	42.9	52.8	
9. Consumption of dietary supplements			$p = 0.008$
Yes	33.7	40.2	
Not	66.3	59.8	

their intake of legumes, fruits, and vegetables and the fact that the WHO recommends fruits and vegetables as the best food during self-quarantine or longer stays at home (16). However, some people have reduced their use of fruits and vegetables, citing difficulties in finding open food stores in the immediate area, Scarmozzino et al. point out in their study. When it comes to determining the difference in the use of beverages such as coffee and carbonated beverages, it is not recorded during the pandemic compared to the previous period. However, there is a significant reduction in alcohol use, which is probably a consequence of the inability to go to cafes and nightclubs where younger individuals are surrounded by other peers who consume alcohol. Similar findings were reported in a study conducted in Italy (19).

Food and micronutrients, especially vitamins C, D, and zinc, support the body in the fight against viral agents (20). Thus, in this research, during the pandemic, a significant increase in the use of dietary supplements was observed, especially those that contain vitamins C, D, and zinc, without being prescribed by a doctor, but were the choice of the respondents. Vitamin C deficiency impairs immune function and increases susceptibility to infections (21). The results of meta-analyses of 39 studies from around the world document an increased risk of SARS-CoV-2 infection and a more severe clinical outcome due to vitamin D deficiency (22). Improved immunity, support in the fight against infection, and inflammation are thought to have been the main reasons for increasing the use of these supplements (23).

Following the time spent in physical activity during the day in the period before and during the pandemic, no significant difference is observed. The most common activity before the pandemic was walking, while during the pandemic there was an exercise at home. In our research, during the pandemic, a significant decrease in walking was observed. These findings are in line with the results of the previous studies (24, 25). Despite the fact that there were restrictions on movement, the results of the research by López-Valenciano et al. indicate that students who were previously active continued to be during quarantine (25). However, the research shows an increase in sitting time compared to the period before the pandemic, which is confirmed by the

research of Ammar et al., which shows an increase in daily sitting time by more than 28%, probably due to the negative impact of COVID-19 home confinement (5).

Numerous studies have been conducted with the aim of examining hygiene habits and the existence of changes in them in order to prevent further development of the COVID-19 pandemic. The student population of this study followed the recommended anti-epidemic measures. The largest percentage of respondents (81%) used medical-surgical masks while epidemiological N95 masks were used by 9.2% of respondents, with 53.4% of respondents often wearing a mask in public. Hand hygiene is one of the important interventions in the prevention of infectious diseases. In order to maintain hand hygiene, 97% of respondents used soap and warm water, while 76.1% of respondents used alcohol to disinfect their hands when they were away from home. It is assumed that public awareness of the importance of hygiene habits during this pandemic will have an important impact on global hygiene habits and that the habit of using hand sanitizers will remain after the COVID-19 pandemic as an integral part of proper personal hygiene (26).

Given that the COVID-19 pandemic is ongoing, certain changes in lifestyle observed in this study should be confirmed in more extensive population studies.

The main limitation of this study is the self-reported questionnaire, which can lead to actual misreporting of data related to independent assessment of body weight, height and waist circumference of the respondents. Measuring the physical activity of the respondents could also be done with more objective assessment tools, but due to the pandemic reasons, there have been limitations in more accurate and general collection of these data. The strength of our research was the fact that the research was conducted quickly after the lockdown, in the most critical period of the epidemic in Serbia.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Relationship Between Old-Aged Preferences Regarding Various Types of Physical Activity and Chronic Disease Status: A Cross-Sectional Study in Shanghai, China

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Background: A lack of physical activity (PA) is a threat to public health. However, for the elderly, most PA abilities are limited. By focusing on the types and intensity of PA that the elderly can bear, this study aimed to reveal whether preferences regarding types of PA (including housework, transportation, and recreational activities) and their intensity were associated with health status. The main forms of PA include shopping, cooking, cleaning, walking, cycling, various fitness activities and other activities with a certain intensity.

Methods: Surveillance data on chronic diseases and their risk factors were collected from one district of Shanghai in 2017-2018. A Kish table was used for sampling 500 older adults, including the diagnosed group (chronic diseases diagnosed by physicians, $n = 119$), the abnormal group (not diagnosed but abnormal indicators detected in this investigation, $n = 287$) and the healthy group ($n = 94$). Multiple regressions were used to test the relationship between the various types, durations and intensities of PA the elderly individuals participated in and their health status.

Results: All three groups included a large proportion of older adults who participated in housework- and transport-related PA. The diagnosed group had the largest proportion (63.06% for housework-related PA; 87.39% for transport-related PA) and median minutes (17.14 min of housework-related PA per day; 30.00 min of transport-related PA per day). The diagnosed group had more metabolic equivalents (METs) of moderate-intensity PA than the two other groups ($H = 33.01$, $P < 0.01$), and more people met the WHO recommendation ($\chi^2 = 34.71$, $P < 0.01$). Diagnosis was associated with performing housework- and transport-related PA and moderate-intensity PA and with meeting the WHO's recommendation. Higher education levels were a positive factor for elderly individuals to participate in PA.

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Conclusions: Transportation and housework activities are good targets for increasing PA in older adults. Diagnosis is associated with older adults' more PA.

Keywords: physical activity, older adults, chronic disease, moderate-intensity physical activity, housework-related physical activity, transport-related physical activity

INTRODUCTION

Physical activity (PA) has significant health benefits and contributes to the prevention and treatment of non-communicable diseases (NCDs), such as diabetes, cardiovascular disease, hypertension, and some cancers (1–4). Patients with chronic diseases need more regular PA than healthy residents to increase the effect of treatment and avoid adverse disease consequences (5, 6). According to the World Health Organization (WHO), PA is regarded as an important strategy for preventing or treating some chronic diseases and refers to any part of work, transport (walking, wheeling and cycling), sport and leisure, as well as every day and household tasks (7). Elderly individuals were less likely to conduct the exercises but more likely to perform moderate-intensity PA (8).

This is because increased age involves declining PA and increased chronic disease risk (9). A study of older European people's PA showed that nearly half of the elderly population was not adequately active (10). Another study that examined the PA levels of adults over 50 in 6 low- and middle-income countries reported that of the 34,129 respondents, only 23.5% met the recommended PA level (11). With a further increase in age, the amount of PA will gradually decrease. The recent update to the US National Health Interview Survey provides sobering evidence indicating that age continues to be a prominent factor in engaging in recommended aerobic PA levels. Younger adults (18–24 years) report the highest compliance rate (62.2%, CI 59.33–65.05%), while older adults (≥75 years) report the lowest compliance rate (30.2%, CI 27.9–32.61%) (12).

The worldwide epidemic of chronic diseases is strongly linked to population aging (13). A cohort study from China showed that one-third of Chinese adults had hypertension, and the prevalence increased with age (from 12.6% at 35–39 years of age to 58.4% at 70–74 years of age) (14). Elderly individuals may suffer from chronic diseases accompanied by physical inactivity. Not meeting the WHO recommendations of PA (at least 600 MET-minutes per week) is associated with obesity, diabetes, hypertension and metabolic syndrome (15). Therefore, the health status of elderly people is also an important factor in their participation in PA.

Obviously, not every type of PA is suitable for elderly individuals or elderly individuals with chronic diseases. This raises an interesting question that considers elderly people's PA ability: what PAs are preferred by elderly individuals? Currently, guidelines predominantly focus on healthy age-stratified target groups of children and adolescents, adults, and older adults, but the target group of individuals with NCDs has received scant consideration (16). Studies have shown that the types of PA most popular among older adults were consistently of moderate intensity (walking, gardening, golf, low-impact aerobic activities) compared with those of younger adults (17, 18).

Shanghai, a metropolitan city, was the first city in China to enter the aging society and is a large city with the highest degree of aging in China (19). In 2018, it had 14.6 million registered residents, including an estimated 5.02 million elderly people who were over 60 years old (20). Because of the rapidly aging population, Shanghai began to explore community elderly care services in 2000. The development of community services includes improving the living environment of elderly people, facilitating their daily travel, enriching their cultural life, and expanding their social participation. The construction of a supportive environment in Shanghai is also developing. By the end of 2018, the total length of fitness trails and cycling trails for citizens in Shanghai was 1,415 km, including 240 km of cycling trails and 671 km of greenways. The city has built 16,307 community fitness points, 2,208 citizen courts, 84 community citizen fitness centers, 35 citizen swimming pools, 181 citizen gyms, and many sports fitness facilities to achieve full coverage of the community (21). Compared with 2017, the proportion of people aged 60 and over who often take part in PA has increased (21). However, the statistics do not show the health status of older people who increase their PA. In Shanghai, where the proportion of elderly people who suffer from chronic diseases is 22.52∼62.58%, it is particularly important to analyse the PA preferences of elderly individuals with chronic diseases. Identifying the preferences of elderly individuals for PA may help in designing community guidance for PA for elderly residents.

This study aimed to reveal whether resident's preferences regarding types of PA (including activities at work, transportation, recreational activities) and their duration and intensity were associated with resident's health status. It is believed that this study will provide information to improve the guidelines for elderly people.

METHODS

Data Source and Data Screening

The data came from the Shanghai Centres for Disease Control and Prevention's Regular Monitoring of Chronic Diseases in Yangpu District from October 2017 to March 2018. This survey included 1,004 residents from 240 households in all 12 community streets in Yangpu District, Shanghai. Twenty households were randomly selected from each street. A Kish table was used for sampling, and a household survey was conducted. The questionnaire was administered by professional investigators, who input the investigation results into the

Abbreviations: PA, Physical activity; NCDs, Non-communicable diseases; WHO, World Health Organization; BMI, Body mass index; TC, Total cholesterol; HDL, High-density lipoprotein; LDL, Low-density lipoprotein; TG, Triglycerides; OR, Odds Ratios.

information collection system at the same time as inquiry. In addition to answering the questionnaire, the selected people received a unique bar code and went to a designated medical institution to participate in the physical examination, which included height, weight, blood pressure, and blood and urine tests. The examination results were recorded in the body measurement table and entered into the database by the investigators. This analysis was approved by the research ethics committee of Tongji University (ref: LL-2016-ZRKX-017).

The survey was divided into three sections: i) basic personal information, including age, sex, education level, marital status, and occupation; ii) personal PA habits, including the self-reported frequency of PA in a typical week and the self-reported cumulative minutes of PA per day; and iii) personal health status: the body mass index (BMI), fasting glucose, glycosylated hemoglobin, total cholesterol (TC), high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglycerides (TG), urinary protein-to-creatinine ratio, aSBP and aDBP were tested in a health institution; the self-reported history of chronic diseases diagnosed by doctors. In part ii, the data were collected using the Global Physical Activity Questionnaire (GPAQ) (22). In the GPAQ, PA was divided into work (moderate- and vigorous-intensity), transportation and recreational activities (moderate- and vigorous-intensity).

In total, 1,004 people were invited to participate, and 28 people whose physiological indicators were missing were eliminated (the effective response rate was 97.21%). If an individual had a disease that may cause movement restriction, such as heart disease, lung disease, or cerebral infarction, their records were eliminated. Those who were under 60 years old and those over 60 who were still working were also eliminated. Finally, a total of 500 older adults were included, of whom 119 had self-reported chronic diseases diagnosed by doctors (diagnosed group), 287 had some abnormal indicators on our survey but did not have a doctor's diagnosis since the indicators did not support disease status (abnormal group), and 94 were healthy (healthy group).

Measurements

According to the *GPAQ Analysis Guide* (22), we calculated the total minutes spent on all types of PA per day and the minutes spent on 3 types of activities (housework-, transport-, and recreation-related) per day. Transport-related activity included transportation necessary for commuting, shopping and field work but did not include necessary transportation at work. For example, a courier's riding during delivery is not a transport-related activity, although his or her commute is a transport-related activity. Recreation-related activities included sports and exercises not for the purpose of competition, which refers specifically to activities that occur frequently, not occasionally.

According the guideline, metabolic equivalents (METs) are commonly used to express the intensity of PA. One MET is defined as the energy cost of sitting quietly and is equivalent to a caloric consumption of 1 kcal/kg/h. When calculating a person's overall energy expenditure using GPAQ data, 4 METs are assigned to time spent in moderate activities and 8 METs are assigned to time spent in vigorous activities. The minimum time that adults need in order to benefit from PA is at least 150–300 min of moderate-intensity PA, at least 75–150 min of vigorous-intensity PA, or an equivalent combination of moderate- and vigorous-intensity activity throughout the week (7, 23). We select the lowest value and calculated the cut-off point of METs as 600.

Outcome Variables

We examined the binary outcome variables of i) performing various types of PA or not (did PA, 1; did no PA, 0) and ii) meeting WHO recommendations on PA for health or not (MET- minutes/week $\geq$ 600,1; MET- minutes/week $<$ 600,0) and examined the continuous outcome variable of total minutes spent on various types of PA per day.

Independent Variables

The demographic variables in the data were age, sex, education, marital status, and occupation. According to the WHO statistics (24), age was divided into four categories: 60–64, 65–69, 70–74 and $\geq$75 years old. Education level was divided into primary school or below, junior high school, senior high school, and bachelor's degree or above. BMI was grouped as $<$18.5, 18.5–23.9, and $>$23.9.

Statistical Analysis

Basic demographic characteristics and binary outcome variables are presented as percentages for each group. Continuous outcome variables of the duration of various PAs are presented as medians. Statistical significance was determined by Pearson's chi-square test or Kruskal-Wallis H test. GraphPad Prism 8 (GraphPad Software, San Diego, CA, USA) was used to draw a scatter bar chart of minutes spent on PA per day. Logistic regression models were constructed to analyse the relationship between the types of various PAs and independent variables (models 1 to 3 and models 7 to 9). Linear regression models were used to analyse the relationship between the continuous outcome variables and independent variables (models 4 to 6 and models 10 to 12). All statistical tests were conducted using Stata 14 (StataCorp LLC, College Station, TX, USA). A *p-value* below 0.05 was considered statistically significant.

RESULTS

Descriptive and Somatotype Statistics

As shown in **Table 1**, the proportion of each group aged 60–69 was 59.70% and above. There were more women (55.50–61.70%) than men (38.30–44.50%). The diagnosis group had a higher proportion of bachelor's degrees or above (23.50%), and the difference in educational background distribution was statistically significant ($P < 0.01$). The proportion of married older adults was over 90.00%. The three groups had a higher proportion of normal BMI and overweight, and the two proportions were close in the diagnosed and healthy groups. The differences in the proportions of age group, sex, marital status and BMI level in the three groups were not statistically significant.

TABLE 1 | Descriptive statistics of all included participants ($N = 500$, %).

	Diagnosed group ($N = 119$)	Abnormal group ($N = 287$)	Healthy group ($N = 94$)	χ^2	*P*-value
Age (years)					
60–64	35.30	42.50	38.30	10.81	>0.05
65–69	24.40	29.30	27.70		
70–74	16.80	11.50	21.30		
≥75	23.50	16.70	12.80		
Sex					
Male	44.50	40.40	38.30	0.94	>0.05
Female	55.50	59.60	61.70		
Education					
Primary school or below	5.90	12.50	10.60	40.28	**<0.01**
Junior high school	37.80	42.50	31.90		
Senior high school	32.80	41.10	43.60		
Bachelor's degree or above	23.50	3.80	13.80		
Marital status					
Unmarried	5.90	5.20	8.50	1.36	>0.05
Married	94.10	94.80	91.50		
BMI*					
<18.5	1.70	1.00	3.30	6.76	>0.05
18.5–23.9	49.60	41.10	50.50		
>23.9	48.70	57.80	46.20		

The BMI index of three people in the healthy group was missing. Bold numbers indicate that the differences were statistically significant.

Types of PA

Figures 1A–C shows that the proportion of older adults in the diagnosed, abnormal and healthy groups who performed housework-related PA was 63.06, 38.33, and 42.55%, respectively ($\chi^2 = 21.01$, $P < 0.01$), while the proportion of older adults who performed transport-related PA was 87.39, 54.01, and 57.45%, respectively, in the three groups ($\chi^2 = 41.37$, $P < 0.01$). The proportion of recreation-related PA was lower than 17%, and the difference among the three groups was not statistically significant ($\chi^2 = 0.18$, $P > 0.05$). **Figures 1D–F** shows the minutes older adults spent on housework-, transport- and recreation-related PA. The median time for housework-related PA was 17.14 min per day in the diagnosed group, which was more than the other groups (median = 0.00 min for abnormal group; median = 0.00 min for healthy group) (H = 19.36, $P < 0.01$). A median of 0 does not mean that everyone did not participate in housework-related PA but that more than half of people spent 0 min on housework-related PA. The median times of transport-related PA were 30.00, 8.57, and 13.58 min, respectively, in the three groups (H = 28.00, $P < 0.01$). The older adults in the three groups spent little time on recreational PA, and the difference among the three groups was not statistically significant (H = 0.18, $P > 0.05$).

Intensity of PA

Figures 2A–C shows the proportion of participation in moderate- and vigorous-intensity PA and the proportion of meeting WHO recommendations. A total of 90.76% of older adults in the diagnosed group performed moderate-intensity PA, which was larger than the other two groups ($\chi^2 = 41.74$, $P < 0.01$). The proportion of vigorous-intensity PA was lower than 7%, and the difference among the three groups was not statistically significant ($\chi^2 = 0.07$, $P > 0.05$). The diagnosed group also had the largest proportion (79.83%) of older adults who met the WHO's recommendation for PA per week ($\chi^2 = 34.71$, $P < 0.01$). **Figures 2D–F** shows the METs of participation in moderate-, vigorous-intensity and total PA. The METs median of moderate-intensity PA per week was 1,680 in the diagnosed group, which was higher than the other two groups (H = 33.01, $P < 0.01$). The median MET of vigorous-intensity PA in the three groups was 0.00, and the difference among the three groups was not statistically significant (H = 0.08, $P > 0.05$). The total METs of PA in the diagnosed group was 1,800, higher than the other two groups (H = 28.85, $P < 0.01$).

Multiple Regression Analysis of the Types of PA

Table 2 shows that older adults in the abnormal and healthy groups were associated with housework-related PA (OR = 0.39, $P < 0.01$ for the abnormal group; OR = 0.47, $P < 0.05$ for the healthy group in model 1) and transport-related PA (OR = 0.20, $P < 0.01$ for the abnormal group; OR = 0.21, $P < 0.01$ for the healthy group in model 2) more than those in the diagnosed group. Performing PA was associated with higher education levels in models 1 to 3. However, the abnormal and healthy groups were not associated with recreation-related PA (OR = 1.34, $P > 0.05$ for the abnormal group; OR = 0.96, $P > 0.05$ for

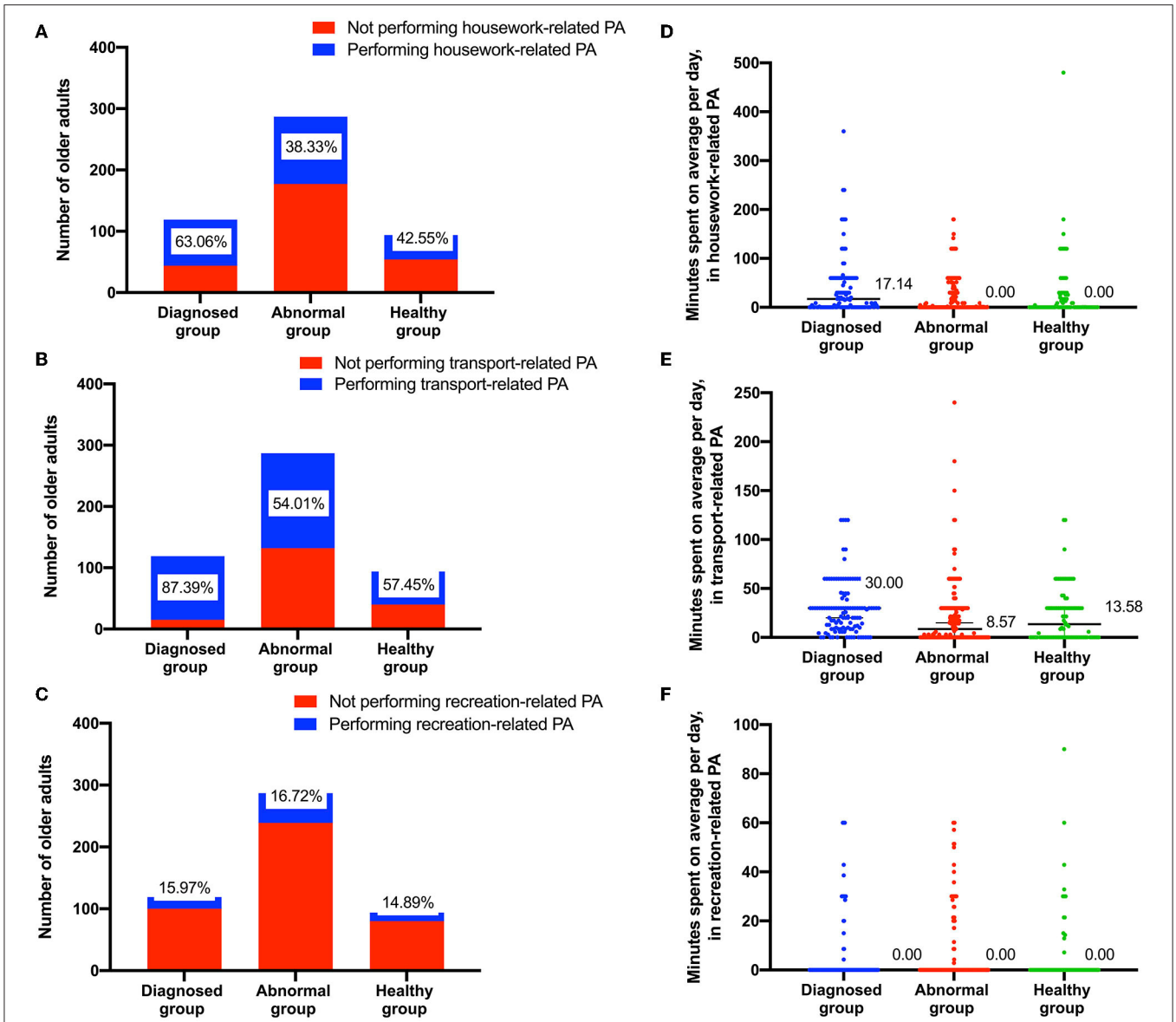

FIGURE 1 | Elderly individuals engaged in three types of PA in three health status groups. **(A–C)** count the number and proportion of older adults participating in the specific type of PA. **(D–F)** show the minutes each older adults spent on the specific type of PA.

the healthy group in model 3). The older adults in the diagnosed group spent more minutes on housework-related PA (beta = −0.19, $P < 0.01$) and transport-related PA (beta = −0.16, $P < 0.05$) than the older adults in the abnormal group but not more than the older adults in the healthy group. The association was not statistically significant in model 6. The minutes older adults spent on the three types of PA were associated with higher education levels in models 4 to 6.

Multiple Regression Analysis of the Intensity of PA

The results of the multiple regression (**Table 3**) showed that older adults in the diagnosed group were more likely to participate in moderate-intensity PA (OR = 0.16, $P < 0.01$ for the abnormal group; OR = 0.19, $P < 0.05$ for the healthy group in model 1) and meet WHO recommendations (OR = 0.27, $P < 0.01$ for the abnormal group; OR = 0.30, $P < 0.01$ for the healthy group in model 3). Moderate-intensity PA and meeting WHO recommendations were associated with higher education levels in models 7 and 9. More METs of moderate-intensity PA were associated with healthy status (beta = −0.20, $P < 0.01$ for the abnormal group; beta=-0.11, $P < 0.05$ for the healthy group) in model 10, as in model 12. Females in the diagnosed group (beta = 0.13, $P < 0.05$) with higher education levels (beta = 0.32, $P < 0.01$ for junior high school; beta = 0.21, $P < 0.01$ for senior high school; beta = 0.21, $P < 0.01$ for bachelor's degree or above) reported more METs of moderate-intensity PA, as did model 12.

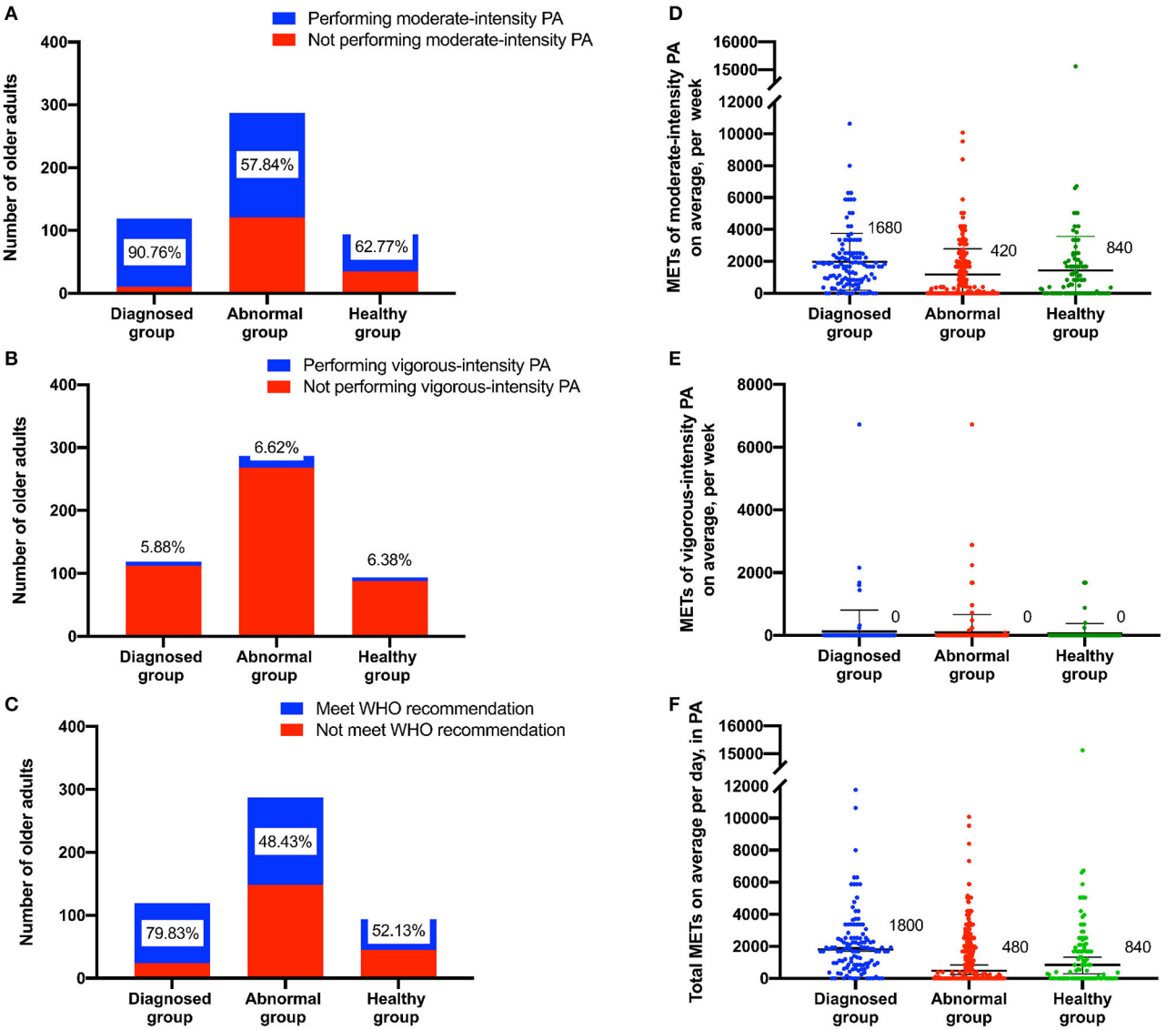

FIGURE 2 | Elderly individuals performing moderate- or vigorous-intensity PA in the three health status groups. **(A,B)** count the number and proportion of older adults participating in the different intensity of PA. **(C)** counts the number and proportion of older adults who met the WHO's recommended level. **(D)** shows the METs of moderate-intensity PA. **(E)** shows the METs of vigorous-intensity PA. **(F)** shows the total METs.

DISCUSSION

In this study, we were concerned about the preference of elderly patients with chronic diseases for three types of PA. We found that elderly individuals, regardless of whether they suffered from chronic diseases, spent the longest average time on transport-related PA per day, which is a type of PA they enjoy. Elderly people were likely to prefer slower-paced PA compared to younger adults, who preferred fast-paced PA (25). Transportation can address this preference. Shanghai has built sufficient pedestrian, cycling and greenway areas for elderly people, and retired elderly individuals have sufficient space for transport-related PA. According to the *Shanghai Resident Fitness Development Report 2018,* Shanghai residents enjoy walking and cycling. Aging is associated with a progressive loss of bone-muscle mass and strength (26, 27). Walking is an important way to maintain muscle function (28, 29) and reduce the risk of related diseases. Another PA that occupies a large amount of time is housework activities, which are unavoidable. One of the characteristics of aging in Shanghai is that there are many families in which all members are over 60 years old. By the end of 2018, the number of elderly people in "families with only elderly" in Shanghai reached 1.33 million (30). In addition to the need for care, housework is done by elderly people themselves. In addition, under the influence of fast-paced urban life, even in families with young people, housework is performed

TABLE 2 | Multiple regression of three types of PA.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Performing housework-related PA or not		Performing transport-related PA or not		Performing recreation-related PA or not		Minutes of housework-related PA per day		Minutes of transport-related PA per day		Minutes of recreation-related PA per day	
	OR	*P*-value	OR	*P*-value	OR	*P*-value	Beta	*P*-value	Beta	*P*-value	Beta	*P*-value
Group												
Diagnosed group	Reference						Reference					
Abnormal group	0.39	**<0.01**	0.20	**<0.01**	1.34	0.36	−0.19	**<0.01**	−0.16	**<0.05**	0.04	0.47
Healthy group	0.47	**<0.05**	0.21	**<0.01**	0.96	0.91	−0.10	0.06	−0.08	0.14	−0.01	0.93
Age (years)												
60–64	Reference						Reference					
65–69	1.38	0.18	1.25	0.37	1.22	0.52	0.02	0.73	0.03	0.56	0.02	0.65
70–74	1.26	0.43	0.89	0.70	1.80	0.10	0.01	0.90	−0.05	0.27	0.05	0.28
≥75	1.70	0.06	1.34	0.35	0.60	0.22	0.03	0.51	0.13	**<0.05**	−0.07	0.17
Sex												
Male	Reference						Reference					
Female	1.43	0.07	1.16	0.48	0.95	0.84	0.14	**<0.01**	0.05	0.24	0.00	0.97
Education												
Primary school or below	Reference						Reference					
Junior high school	5.72	**<0.01**	5.18	**<0.01**	10.57	**<0.05**	0.22	**<0.01**	0.32	**<0.01**	0.16	**<0.05**
Senior high school	5.00	**<0.01**	5.78	**<0.01**	13.05	**<0.05**	0.20	**<0.05**	0.21	**<0.01**	0.22	**<0.01**
Bachelor's degree or above	5.16	**<0.01**	12.12	**<0.01**	22.40	**<0.01**	0.07	0.26	0.17	**<0.01**	0.22	**<0.01**
Marital status												
Unmarried	Reference						Reference					
Married	0.88	0.76	0.47	0.11	0.48	0.16	−0.06	0.16	−0.08	0.08	−0.04	0.40
BMI												
<18.5	Reference						Reference					
18.5~23.9	1.34	0.70	0.73	0.72	0.36	0.25	−0.03	0.85	−0.04	0.83	0.01	0.97
>23.9	1.08	0.92	0.67	0.65	0.44	0.34	−0.08	0.67	−0.08	0.63	0.01	0.94

Bold numbers indicate that the differences were statistically significant.

TABLE 3 | Multiple regression of the intensity of PA and meeting WHO recommendations.

	Model 7		Model 8		Model 9		Model 10		Model 11		Model 12	
	Performing moderate-intensity PA or not		Performing vigorous-intensity PA or not		Meeting WHO recommendation or not		Mets of moderate-intensity PA per week		Mets of vigorous-intensity PA per week		Mets of PA per week	
	OR	*P*-value	OR	*P*-value	OR	*P*-value	Beta	*P*-value	Beta	*P*-value	Beta	*P*-value
Group												
Diagnosed group	Reference						Reference					
Abnormal group	0.16	**<0.01**	1.31	0.58	0.27	**<0.01**	−0.20	**<0.01**	−0.01	0.93	−0.19	**<0.01**
Healthy group	0.19	**<0.01**	1.38	0.59	0.30	**<0.01**	−0.11	**<0.05**	−0.03	0.60	−0.11	**<0.05**
Age (years)												
60–64	Reference						Reference					
65–69	1.13	0.64	1.59	0.31	1.34	0.22	0.02	0.65	0.05	0.29	0.04	0.45
70–74	1.00	1.00	1.64	0.37	0.96	0.90	−0.01	0.85	0.01	0.92	−0.01	0.89
≥75	1.43	0.26	0.72	0.60	2.10	**<0.05**	0.07	0.14	−0.04	0.47	0.06	0.24
Sex												
Male	Reference						Reference					
Female	1.08	0.71	0.50	0.07	1.22	0.34	0.13	**<0.05**	0.00	1.00	0.12	**<0.05**
Education												
Primary school or below	Reference						Reference					
Junior high school	6.20	**<0.01**	1.00	0.99	7.69	**<0.01**	0.32	**<0.01**	0.10	0.20	0.34	**<0.01**
Senior high school	5.74	**<0.01**	0.51	0.26	7.02	**<0.01**	0.27	**<0.01**	0.07	0.36	0.28	**<0.01**
Bachelor's degree or above	13.93	**<0.01**	1.00	-	9.67	**<0.01**	0.16	**<0.05**	0.07	0.26	0.18	**<0.01**
Marital status												
Unmarried	Reference						Reference					
Married	0.59	0.27	1.00	-	0.56	0.20	−0.10	**<0.05**	0.03	0.49	−0.08	0.07
BMI												
<18.5	Reference						Reference					
18.5~23.9	0.91	0.92	0.18	0.15	1.44	0.65	−0.05	0.79	0.03	0.86	−0.03	0.85
>23.9	0.86	0.86	0.35	0.37	1.08	0.93	−0.10	0.59	0.03	0.89	−0.08	0.64

Bold numbers indicate that the differences were statistically significant.

by elderly family members as long as their health allows. The preference of the elderly for PA may thus be a passive choice. Studies have confirmed a positive association between time devoted to housework activities, total housework and health status among elderly men and women (31) that can help prevent the deterioration of disability (32). This result suggests that health guidance can indicate the preferred items of elderly individuals who are physically inactive and diagnosed with chronic diseases.

We were also concerned about whether older adults with a diagnosis of chronic diseases are active in PA. This study found that the proportion of older adults with chronic diseases who participated in both housework- and transport-related PA was higher than the other two groups; they also spent more time on the two types of PA than other groups. The preference of older adults in the abnormal group was similar to those in the healthy group and lower than the diagnosed group. Unlike the abnormal group, patients with chronic diseases were usually instructed by doctors to increase their activity. Many studies have confirmed the effectiveness of regular physical activity in the primary and secondary prevention of several chronic diseases (e.g., cardiovascular disease, diabetes, cancer, hypertension, obesity, depression and osteoporosis) and premature death (33–37). Publicity, notification and health education for patients with chronic diseases are listed in the catalog of community health service projects in Shanghai. However, elderly individuals in the abnormal group may ignore their own health, and they are unable to obtain more information and support from the outside world. Therefore, identifying older adults in the early stage of chronic diseases may be a first step in implementing PA strategies in the community. These differences in preference among different groups may be related to diagnosis information. Studies have shown that a diagnosis can act as an important catalyst to prompt health behavior changes (38, 39). Because this paper is a cross-sectional study, it is impossible to determine whether the diagnostic information is related to the increase of PA.

This study shows that nearly 80% of the older adults in the diagnosed group meet the WHO's recommendation (7, 23), and only approximately 50% of the other two groups meet this standard. The WHO's recommendation is the minimum PA level needed to maintain health. In 2018, the per capita consumption expenditure in Shanghai was 43,351 yuan (20), while the per capita monthly pension for enterprise retirees was 3,851 yuan (46,212 yuan per year), which was received by 4.49 million retirees (89.33% of the elderly population) (40). Therefore, under normal circumstances, elderly people do not need to continue to engage in livelihood activities after retirement. The lack of PA may be caused by the personal fitness literacy of elderly people. In 2018, the fitness literacy scores of citizens aged 50 and above were significantly lower than the scores of those under 50 (21). However, this phenomenon is not unique to China. In the UK, despite much publicity, the overwhelming majority of elderly people still do not meet the minimum levels (41). Although PA is an intervention strategy to improve quality of life, manage symptoms and extend survival, its popularization has great resistance in practice (42). Some studies suggest that necessary interventions may change the activities of the elderly, such as health apps (43) and social support (44).

We also observed that education has a positive effect on whether older adults participate in PA. In this study, the mean age of the group observed was 68.64 ± 7.43 years, and higher education was related to more time spent in PA. Earlier studies showed that high physical activity is related to a higher educational level (45, 46). Individuals with high educational achievement are more likely to tolerate and be open to diverse perspectives and to assimilate external information constructively (47). People with higher education recognize to a greater extent the importance of nutrition, diet, and the role of physical activity in treating their disease (48). Research has shown that education affects personal self-control, which affects PA and even health. There is a positive mediating effect of self-reported PA on the relationship between personal control and health when an individual's educational level is high, and there is a negative mediating effect of self-reported PA when an individual's educational level is low (49). Therefore, educational differences may have an effect on the results of PA in elderly populations.

Limitations

First, given the self-reported nature of the questionnaire, it is possible that reporting bias led to some data distortion. To better meet social expectations, patients with chronic diseases may report values that are longer than the actual PA time. Second, because this study was cross-sectional, the results of this study only showed that at the time point considered, the diagnosis group spent more time on PA than the other two groups. The correlation between diagnosis and PA needs to be further explored. Finally, the proportion and time of older adults participating in recreational activities were the lowest. Encouraging the participation of older adults with chronic diseases is worth further exploration. We will continue to explore this direction in future research.

CONCLUSIONS

In conclusion, our results of representative data from Shanghai showed that elderly people generally participated more in transportation and activities at housework. A diagnosis of chronic disease was associated with time spent on PA and PA MET-minutes. This finding suggests that the possibility for older adults, especially those with abnormal health indicators, to participate in PA should be considered in the prevention and control of chronic diseases. When carrying out community-based chronic disease prevention in Shanghai that promotes PA for elderly people, priority can be given to recommending moderate-intensity housework or transportation (such as walking or cycling), which are preferred by elderly people. More research is needed to understand the mechanisms

of diagnostic information on the participation in PA among residents with chronic diseases.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary materials, further inquiries can be directed to the corresponding authors.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Research Ethics Committee of the Tongji University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

XH, WZ, JS, and ZW designed the study. XH, DY, HJ, and WY conduct literature analysis. JH, XG, XH, and JS conducted the data analysis, YL, LZ, JH, and JS made all tables. YY, NC, and XH produced all figures. DY, JS, and ZW guarantee access to research resources. All authors participated in the writing, revision, final review of the manuscript, read, and approved the final manuscript.

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Gender Differences in the Associations Between Physical Activity, Smartphone Use, and Weight Stigma

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Background: Physical activity (PA) is important for health. However, there is little evidence on how weight stigma, time spent on sedentary activities (including smartphone, social media, online learning), time spent on outdoor activity, and nomophobia associate with PA among Chinese individuals with consideration of gender. The present study examined the aforementioned associations in the COVID-19 pandemic era.

Methods: University students (N = 3,135; 1,798 females, 1,337 males) with a mean age of 19.65 years (SD = 2.38) years completed an online survey from November to December, 2021. The online survey assessed weight stigma (using the Perceived Weight Stigma Scale and Weight Bias Internalization Scale), PA (using the International Physical Activity Questionnaire Short Form), time spent on different activities (using self-designed items for time on smartphone, outdoor activity, social media, and online learning), and nomophobia (using the Nomophobia Questionnaire). Parallel mediation models were constructed (dependent variable: PA; mediators: perceived weight stigma, weight-related self-stigma, time spent on smartphone, time spent on outdoor activity, time spent on social media, and time spent online learning; independent variable: nomophobia) and evaluated using Hayes' Process Macro Model 4 (IBM SPSS 20.0).

Results: Weight-related self-stigma ($\beta = -0.06$; $p = 0.03$), time spent on outdoor activity ($\beta = 0.21$; $p < 0.001$), time spent on social media ($\beta = 0.07$; $p = 0.02$), time spent on online learning ($\beta = 0.06$; $p = 0.03$), and nomophobia ($\beta = -0.07$; $p = 0.01$) were all

significant factors explaining the PA among female participants. Perceived weight stigma ($\beta = -0.07$; $p = 0.01$), time spent on outdoor activity ($\beta = 0.27$; $p < 0.001$), and time spent on online learning ($\beta = 0.10$; $p = 0.002$) were all significant factors explaining PA among male participants.

Conclusion: Chinese healthcare providers should design programs on weight stigma reduction and outdoor activity improvement to enhance PA among university students.

Keywords: gender, nomophobia, physical activity, smartphone use, weight stigma

INTRODUCTION

Physical activity (PA) is important given the robust evidence on its benefits, including (i) cognitive function improvement; (ii) bone health improvement; (iii) weight management; (iv) health risk reduction, such as cancer and diabetes; (v) psychological distress reduction; (vi) sleep quality; (vii) quality of life enhancement; (viii) fall prevention; and (ix) increase in life expectancy (1–4). In contrast, physical inactivity has been found to be associated with increased risk of mental health problems such as depression and physical problems such as cardiovascular diseases (5, 6). Given that university students are at a critical transition moment of human development (e.g., typically moving from high school to university with environment changes), they are likely to decrease their PA as they engage in efforts to cope with the new environment (7, 8). Indeed, a recent survey conducted by the Ministry of Education in mainland China reported that 30% of the university students do not engage in sufficient PA (9). Therefore, it is important for healthcare providers to promote PA among university students and to understand the potential factors contributing to their PA engagement (e.g., weight stigma, time spent on sedentary activities, and time spent on outdoor activities).

Weight stigma has been suggested to be a primary contributor of physical inactivity via lowered motivation to exercise caused by this type of stigma (10–13). Most evidence regarding the effects of weight stigma on physical inactivity is supported by data from Western populations. However, recent studies on Eastern populations (e.g., Chinese) have reported similar effects of weight stigma on physical inactivity (14–16). Moreover, three types of weight stigma have been identified: experienced weight stigma (i.e., individuals experience unfriendly treatment due to their weight), perceived weight stigma (i.e., individuals perceive weight is their problem of causing stigmatized treatment), and weight-related self-stigma (i.e., individuals endorse, agree, and accept that the stigmatized treatments toward them are justified and appropriate) (17). However, effects of different weight stigma types (i.e., perceived weight stigma, experienced weight stigma, and weight-related self-stigma) on physical inactivity have rarely been investigated separately. Therefore, more empirical evidence regarding the different effects of different types of weight stigma on PA (or physical inactivity) is needed.

Apart from weight stigma, time spent on sedentary activities, especially smartphone use and time on social media/learning, may decrease time spent on PA and/or exercise (18–22). It is postulated that when individuals spend more time on sedentary activities (e.g., engaging in social media, using smartphone, or learning), the time spent on physical activities (e.g., exercise) may decrease. However, some evidence indicates that university students may simultaneously be physically active and engaging in substantial sedentary behaviors (23). As a result, mixed findings in the associations between PA and sedentary behaviors have been reported. For example, Fennell et al. (24) found no associations between smartphone use and PA; Towne et al. (25) found positive associations between smartphone use and PA; Grimaldi-and Puyana et al. (26) and Kwok et al. (18) found negative associations between smartphone use and PA using objective measures. Moreover, Lin et al. (19), Shi et al. (20), Van der Velde et al. (21), and Yang et al. (22) all used subjective measures and reported an association between screen time (or problematic smartphone use) and physical inactivity. Therefore, the findings concerning screen use (including smartphone use) and university students' PA are inconsistent and the effects of different type of sedentary screen-based activities may also differ.

Given that university students are grown-ups who are fully in charge of their daily activities and have access to the modern technology, they tend to engage a substantial proportion of daily activities on smartphones (27, 28). In other words, university students depend on smartphone substantially in their daily activities, they are therefore likely to develop nomophobia, a new concept of anxiety resulting from no mobile phone use (i.e., phobia of no mobile phone access) (29, 30). Nomophobia may induce individuals to engage in more smartphone activities (e.g., greater smartphone and social media use) to relieve their anxiety of craving smartphone use (31, 32). Therefore, it is possible that nomophobia serves as a trigger of some sedentary activities and subsequently turns into physical inactivity among university students. Moreover, nomophobia itself may directly decrease PA because evidence shows that anxiety is associated with physical inactivity (33). However, to the best of the present authors' knowledge, no previous study has ever explored the effects of nomophobia on PA or physical inactivity. Therefore, further investigation on this issue is warranted.

Moreover, the COVID-19 pandemic has indirectly increased sedentary behaviors among students given that they have been required to study online instead of studying in a physical classroom (34, 35). In other words, university students have been forced into sedentary lifestyles because of COVID-19. Indeed, most policies to prevent COVID-19 transmission (e.g., lockdowns, quarantining, and public facility closure) decrease individuals' time spent on outdoor activities and increased time on online activities (34, 35). Nevertheless, it is unclear

whether individuals have maintained their PA during COVID-19 pandemic. More specifically, individuals' outdoor activity patterns may have changed due to COVID-19 pandemic. Therefore, it is also important to investigate whether the positive relationship between outdoor activity and PA has remained during the COVID-19 pandemic.

Although evidence has shown that PA (or physical inactivity) is associated with weight stigma (10–13), sedentary activity (19–22), and outdoor activity (36), the associations might vary between genders. Prior evidence shows that females as compared with males enjoy PA less and has fewer positive effects on their quality of life (37). Moreover, with the considerations of culture and regulation, especially in East Asia countries (38), females as compared with males are more concerned about their weight in social interaction (39–41). Therefore, it is possible that weight stigma and time spent on social media would be different between genders as evidence showing that girls as compared with boys are more addicted to social media (42). Consequently, the associations between PA and its contributors (i.e., weight stigma, time spent on smartphone, time spent on social media, time spent on online learning, and time spent on outdoor activity) might not always be consistent between genders (43).

In order to provide contemporary evidence regarding PA engagement among university students, the present study utilized a cross-sectional survey study design to investigate whether weight stigma (including perceived weight stigma and weight-related self-stigma), time on different daily activities (including smartphone use, outdoor activities, social media use, and online learning), and nomophobia were factors contributing to PA (or inactivity during the COVID-19 pandemic). Based on the extant literature, the following hypotheses were proposed: (i) weight stigma would be negatively associated with PA; (ii) time spent on smartphone, social media, and online learning would be negatively associated with PA; (iii) time spent on outdoor activity would be positively associated with PA; (iv) nomophobia would be negatively associated with PA directly and indirectly via weight stigma and time spent on different activities; and (v) the aforementioned associations would be different between male and female participants (**Figure 1**).

METHODS

Participants and Data Collection Procedure

The online survey included measures including the Perceived Weight Stigma Scale (PWSS), Weight Bias Internalization Scale (WBIS), International Physical Activity Questionnaire Short Form (IPAQ-SF), and Nomophobia Questionnaire (NMPQ) based on research objectives. Before a formal survey was launched, a pilot study was conducted with 30 university students to assess if the content addressed in the scales were fully understood. In the pilot study, all the students verified that the readability of the survey questions and items were appropriate and understandable. More specifically, the 30 students rated the readability of the survey questions and items and all indicated that the readability was good or very good for all the questions and items used in the survey. Next, an online survey was conducted from November to December 2021 with a total of 26 Chinese universities (Nanchang University, Hangzhou Dianzi University, East China Normal University, Northeast Normal University, Fujian Normal University, Zhengzhou Normal University, Jilin Engineering Normal University, Guangzhou Sport University, Minnan University of Science and Technology, Baoji University of Arts and Sciences, Kaili University, Harbin Cambridge University, Communication University of Shanxi, Guangdong University of Science and Technology, Shanxi Vocational and Technical College, Shenzhen Polytechnic, Shanwei Institute of Technology, Zhejiang Yuying College of Vocational Technology, Ganzhou Teachers College, Guangxi Eco-Engineering Vocational and Technical College, Guangzhou South China Business Trade College, Software Engineering Institute of Guangzhou, Guangzhou College of Commerce, Xiamen Huatian International Vocation Institute, Jiangxi Environmental Engineering Vocational College, and Guizhou Vocational and Technical College of Water Resources and Hydropower). Convenience sampling was utilized which resulted in data being collected from 3,158 participants. All the participants were recruited in the same period (i.e., between November and December 2021). The inclusion criteria for participation were (i) being a university student, (ii) being aged 18 years or above, and (iii) currently residing in mainland China. There were no exclusion criteria. All the data were collected through the online questionnaire *Star* application in China and the *Star* application ensured that each student only completed the survey once. After data cleaning, 3,135 surveys remained for data analysis. The present study was approved by the Human Experimental Ethics Committee in Guangzhou Sport University (Ref no. 2021LCLL-23).

Demographics

The participants were asked the following demographics information: (a) age in years; (b) height in cm; (c) weight in kg; (d) marital status reported using single or other; and (e) current disease reported using "yes" or "no". Self-reported body mass index (BMI) was then calculated using the formula of weight in kilograms divided by squared height in meters.

Weight Stigma

Two types weight stigma (i.e., perceived weight stigma and weight-related self-stigma) were assessed using the Perceived Weight Stigma Scale (PWSS) and Weight Bias Internalization Scale (WBIS). The PWSS comprises 10 dichotomous items rated as 1 (*yes*) or 0 (*no*). The 10 item scores are summed (therefore, the maximum score on the PWSS is 10) to represent the level of perceived weight stigma and a higher score indicates a higher level of perceived weight stigma. A sample item for the PWSS is *"People behave as if you are inferior because of your weight status"*. Good psychometric properties of the PWSS have been reported in its factor structure (i.e., unidimensionality is supported) and internal consistency ($\alpha = 0.84$) (42).

The WBIS contains 11 five-point Likert-scale items rated from 1 (*strongly disagree*) to 5 (*strongly agree*). After reverse coding two item scores (i.e., Items 1 and 9), the 11 item scores are summed (therefore, the maximum score on the WBIS is 55) to represent the level of weight-related self-stigma and a higher

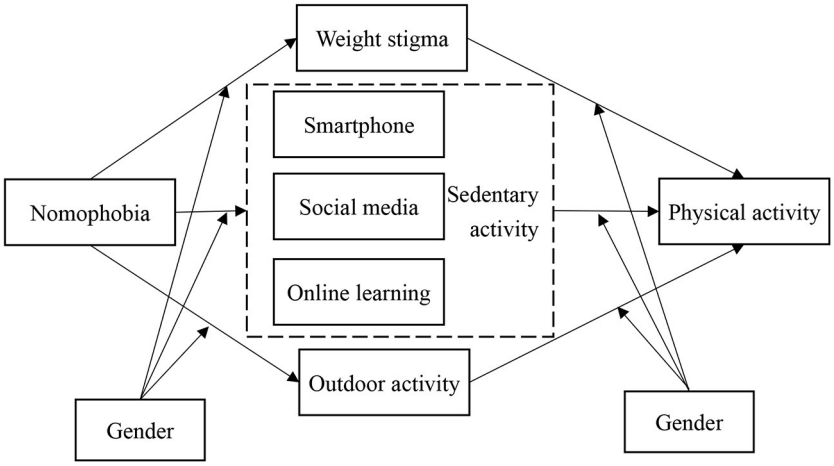

FIGURE 1 | Proposed model in the present study. Nomophobia impacts on physical activity via weight stigma, sedentary activity, and outdoor activity; gender serves as a moderator.

score indicates a higher level of weight-related self-stigma (44). A sample item for the WBIS is *"I hate myself because of my weight"*. Good psychometric properties of the WBIS have been reported in its factor structure (i.e., unidimensionality is supported) and internal consistency ($\alpha = 0.90$) (45, 46).

Physical Activity (PA)

PA was assessed using the International Physical Activity Questionnaire Short Form (IPAQ-SF). The IPAQ-SF contains seven items asking how much time in minutes an individual engages in the past week (47). A sample item for the IPAQ-SF is *"During the last 7 days, on how many days did you do vigorous physical activities?"*. Metabolic equivalent of task (MET) was then calculated using the seven IPAQ-SF items and a total MET-minutes in a week. According to the IPAQ-SF guidelines, a specific MET value is given for walking (MET = 3.3), moderate level of PA (MET = 4), and vigorous level of PA (MET = 8). Then, time on each activity is multiplied by the given MET to calculate the MET-minutes per week. For example, if an individual spent (i) one hour swimming (PA at vigorous level) on 3 days, (ii) one hour jogging (PA at moderate level) on 1 day, and (iii) one hour walking on 3 days, the individual would have 2,274 MET-minutes: $(8 \times 60\,\text{min} \times 3\,\text{days}) + (4 \times 60\,\text{min} \times 1\,\text{day}) + (3.3 \times 60\,\text{min} \times 3\,\text{days}) = 2{,}274$. Higher MET-minutes in a week indicate higher levels of PA. Psychometric properties of the IPAQ-SF have been supported by the good test-retest reliability (intraclass correlation coefficient = 0.79) (48).

Time Spent on Activities

The participants were asked how much time per day they spent on the following four activities in the past week: time spent on smartphone, time spent on outdoor activity, time spent on social media, and time spent on online learning. They were instructed to answer numerically to indicate how many hours and minutes were spent on each activity. A sample item was: *"How much time on average did you spend on your smartphone per day in the last week? Please answer in hours and minutes"*.

Nomophobia

Nomophobia was assessed using the Nomophobia Questionnaire (NMPQ). The NMPQ comprises 20 seven-point Likert-scale items rated from 1 (*strongly disagree*) to 7 (*strongly agree*). The 20 item scores are summed (therefore, the maximum score on the NMPQ is 140) to represent the level of nomophobia and a higher score indicates a higher level of nomophobia (49). A sample item for the NMPQ is *"I would feel uncomfortable without constant access to information through my smartphone"*. Good psychometric properties of the NMPQ have been reported in its factor structure (i.e., a four-factor structure is supported) and internal consistency ($\alpha = 0.97$) (29, 50).

Data Analysis

First, descriptive statistics (i.e., means and frequencies) were used to understand the participants' characteristics, including their time spent on each activity and the measure scores (e.g., perceived weight stigma and weight-related self-stigma). Independent *t*-tests and $\chi 2$ tests were used to examine whether male participants and female participants had significant differences in their characteristics. Two sets of multivariate linear regression models were constructed to examine the potential predictors on PA for different genders separately. In the multivariate linear regression models, the dependent variable was PA (i.e., weekly MET-minutes); the independent variables included perceived weight stigma, weight-related self-stigma, time spent on smartphone, time spent on outdoor activity, time spent on social media, time spent on online learning, and nomophobia. The confounders were age and BMI.

Because it was hypothesized that nomophobia would explain PA via different mediators and such mediation effects might be different between genders, a parallel mediation model (**Figure 1**) was constructed and tested on male and female participants

separately. More specifically, PA was the dependent variable; perceived weight stigma, weight-related self-stigma, time spent on smartphone, on outdoor activity, social media, and online learning were the parallel mediators; nomophobia was the independent variable; and age and BMI were confounders in the parallel mediation models. The mediation effects were examined using the 95% lower limit confidence interval (LLCI) and upper limit confidence interval (ULCI) in the 1,000 bootstrapping resamples conducted using the Hayes' Process Macro Model 4 (51). When the 95% LLCI and ULCI do not cover 0, the mediation effect of that specific mediator is supported (52). All the statistical analyses were performed using the IBM SPSS 20.0 and the level of significance was set at $p < 0.05$ (IBM Corp. Armonk, NY).

RESULTS

The participants' characteristics are reported in **Table 1**. The sample ($N = 3,135$) was relatively young (mean age = 19.65 years; $SD = 2.38$) and comprised more female participants ($n = 1,798$; 57.4%). The mean BMI was 23.90 ($SD = 7.88$) for the entire sample. On average, the participants spent 8.27 h daily on their smartphone ($SD = 4.57$), 2.99 h daily on outdoor activities ($SD = 3.08$), 4.04 h daily on social media ($SD = 3.81$), and 3.64 h daily on online learning ($SD = 3.33$). The MET-minutes in a week for the sample was 5,359.25 ($SD = 4,913.15$). Their mean scores were 1.02 for perceived weight stigma ($SD = 2.22$); 26.60 for weight-related self-stigma ($SD = 8.17$); and 75.56 for nomophobia ($SD = 26.51$). In addition, male participants as compared with female participants spent significantly more time on outdoor activity ($p < 0.001$) and had significantly more PA ($p < 0.001$). Female participants as compared with male participants spent significantly more time on smartphone ($p < 0.001$) and social media ($p < 0.001$); and had a higher level of nomophobia ($p < 0.001$). No gender differences were found in the BMI, time spent on online learning, disease, perceived weight stigma, and weight-related self-stigma.

Multivariate linear regression model ($R^2 = 0.12$; adjusted $R^2 = 0.11$; $F = 16.42$; $p < 0.001$ [male]; $R^2 = 0.09$; adjusted $R^2 = 0.09$; $F = 16.18$; $p < 0.001$ [female]) indicated that male and female participants had different predictors for their weekly PA (**Table 2**). More specifically, weight-related self-stigma (standardized coefficient [β] = −0.06; $p = 0.03$), time spent on outdoor activity (β = 0.21; $p < 0.001$), time spent on social media (β = 0.07; $p = 0.02$), time spent on online learning (β = 0.06; $p = 0.03$), and nomophobia (β = −0.07; $p = 0.01$) were significant factors explaining the PA among female participants. Perceived weight stigma (β = −0.07; $p = 0.01$), time on outdoor activity (β = 0.27; $p < 0.001$), and time on online learning (β = 0.10; $p = 0.002$) were significant factors explaining the PA among male participants.

Given that nomophobia was not a significant factor explaining PA among male participants, the mediation model was only tested for female participants (**Table 3**). The mediation model additionally showed that nomophobia had indirect effects on female participants' PA via weight-related self-stigma (unstandardized coefficient [B] = −3.19; 95% CI = −6.2906, −0.4450), time spent on outdoor activity (B = −3.17; 95% CI = −5.4244, −1.4345), and time spent on social media (B = 1.12; 95% CI = 0.0638, 2.4677). Moreover, nomophobia had direct effects on female participants' PA (B = −10.42; 95% CI = −18.6101, −2.2204).

TABLE 1 | Participants' characteristics for the entire ($N = 3,135$), female ($n = 1,798$), and male samples ($n = 1,337$).

Variable	*n* (%) or M (SD)			*t* or χ^2 (*p*-value)
	Entire sample	Female	Male	
Age (year)	19.65 (2.38)	19.45 (1.95)	19.92 (2.83)	5.14 (<0.001)
Height (cm)	166.05 (8.33)	161.31 (5.89)	172.44 (6.71)	48.32 (<0.001)
Weight (kg)	66.08 (22.80)	61.70 (21.38)	71.98 (23.32)	12.79 (<0.001)
Body mass index (kg/m^2)	23.90 (7.88)	23.71 (8.15)	24.15 (7.49)	1.54 (0.12)
Marital status				4.14 (0.04)
Single	2,785 (88.8)	1,615 (89.8)	1,170 (87.5)	
Others	350 (11.2)	183 (10.2)	167 (12.5)	
Time on smartphone (hour/day)	8.27 (4.57)	8.60 (4.46)	7.83 (4.67)	4.53 (<0.001)
Time on outdoor activity (hour/day)	2.99 (3.08)	2.63 (2.85)	3.47 (3.29)	7.29 (<0.001)
Time on social media (hour/day)	4.04 (3.81)	4.50 (3.87)	3.42 (3.64)	7.79 (<0.001)
Time on online learning (hour/day)	3.64 (3.33)	3.60 (3.16)	3.69 (3.55)	0.76 (0.45)
Physical activity in a week (MET-minutes)	5,359.25 (4,410.28)	4,913.15 (3,850.41)	5,941.25 (4,359.94)	6.45 (<0.001)
Disease (no)				2.17 (0.14)
No	2,916 (93.0)	1,662 (92.4)	1,254 (93.8)	
Yes	219 (7.0)	136 (7.6)	83 (6.2)	
Perceived weight stigma	1.02 (2.22)	0.96 (2.11)	1.09 (2.36)	1.57 (0.12)
Weight-related self-stigma	26.60 (8.17)	26.45 (7.76)	26.79 (8.68)	1.13 (0.26)
Nomophobia	75.56 (26.52)	80.02 (25.01)	69.55 (27.32)	11.00 (<0.001)

DISCUSSION

The first hypothesis in the present study was partially supported given that weight stigma was negatively associated with PA engagement in different ways. More specifically,

TABLE 2 | Multivariate linear regression model in explaining physical activity for female and male participants separately.

	DV: physical activity in a week (MET-minutes)	
	Female	**Male**
IV	B (SE)/ β (*p*-value)	B (SE)/ β (*p*-value)
Age	**−163.40 (50.60)/ −0.08 (0.001)**	**−176.87 (57.78)/ −0.09 (0.002)**
Body mass index	5.67 (11.86)/ 0.01 (0.63)	−9.52 (16.37)/ −0.02 (0.56)
Perceived weight stigma	−62.31 (45.72)/ −0.04 (0.17)	**−133.86 (53.62)/ −0.07 (0.01)**
Weight-related self-stigma	**−29.44 (13.51)/ −0.06 (0.03)**	−16.92 (17.99)/ −0.03 (0.35)
Time on smartphone	33.55 (25.09)/ 0.04 (0.18)	17.06 (29.59)/ 0.02 (0.56)
Time on outdoor activity	**280.68 (35.89)/ 0.21 (<0.001)**	**363.10 (40.57)/ 0.27 (<0.001)**
Time on social media	**72.14 (30.00)/ 0.07 (0.02)**	−10.44 (40.62)/ −0.01 (0.80)
Time on online learning	**71.31 (32.67)/ 0.06 (0.03)**	**125.25 (40.38)/ 0.10 (0.002)**
Nomophobia	**−10.42 (4.18)/ −0.07 (0.01)**	−5.88 (5.78)/ −0.04 (0.31)

DV, dependent variable; IV, independent variable.
Significant coefficients are in bold.

PA was negatively associated with perceived weight stigma but not weight-related self-stigma among male participants; PA was negatively associated with weight-related self-stigma but not perceived weight stigma among female participants. The second hypothesis was not supported given that time spent on smartphone was not associated with PA; time spent on social media was positively associated with PA among female participants; and time spent on online learning was positively associated with PA among both genders. The third hypothesis was fully supported because outdoor activity was positively associated with PA. The fourth hypothesis was partially supported because nomophobia was negatively and directly associated with PA among females but not among males. Moreover, nomophobia was negatively associated with PA via weight-related self-stigma and time spent on outdoor activity but not other proposed mediators among females. The fifth hypothesis was fully supported because different associations were found between males and females.

Consistent with prior literature findings (10–13), weight stigma in the present study was found to be negatively associated with PA. Previous research suggests that weight stigma is a variable that lowers individuals' motivations to exercise and subsequently results in low levels of PA among individuals (10–13). Indeed, Cheng et al. (14) and Fung et al. (15) found that Hong Kong university students were likely to have weight stigma effects in relation to their intention to engage in PA. Because individuals having weight stigma (either weight-related self-stigma or perceived weight stigma) may want to escape from other individuals' judgements, one coping strategy that is employed is not to exercise in front of them (10–15). More specifically, those who have weight stigma issues may feel like they are being laughed at and/or derided by others when they exercise. Therefore, they may consider that PA engagement may increase their risk of being laughed at and/or derided. As a result, their weight stigma may result in increased physical inactivity.

The present findings extend the knowledge regarding the association between weight stigma and PA in relation to gender differences. Female university students were impacted more by their weight-related self-stigma on their PA, while male students were more impacted by the perceived weight stigma on PA. The gender differences may be explained by the features of gender such as females have more internalizing problems (e.g., depression) and males having more externalizing problems (e.g., aggressive behaviors) (53–59). Internalizing problems among females may maximize their feelings of weight-related self-stigma, which in turn, are associated with their lowered PA (59). Externalizing problems among males may make them share the attitudes and behaviors of their peers, which strengthens the effects of their perceived weight stigma on PA (53–58).

Contrary to the hypothesis, the present study found that time spent on smartphone did not associate with PA. Inconsistent findings have previously been found for the associations between time spent on smartphone and PA (24–26). Several reasons may explain the inconsistent findings. First, objective measures and subjective measures assessing time spent on smartphone and PA may result in different findings. Indeed, the present study used self-reports and have similar findings to another study using self-reports (24). Second, Peterson et al. (23) noted that university students may use smartphone apps to record and monitor their PA. Moreover, they may also use smartphone apps to help them facilitate PA (e.g., use of a "reminder" function to help them to engage in PA, calculating energy expenditure in exercising). Therefore, some smartphone use may be directly associated with PA. Therefore, it is possible that some participants in the present study used smartphones and were physically active, which resulted in the nonsignificant association between time spent on smartphone and PA. Third, some university students may use smartphone apps to engage in exercise given many exercise apps have been developed (60, 61). Therefore, the association between time spent on smartphone and PA could be varied depending on how university students used their smartphone.

Contrary to two other hypotheses, time spent on online learning (for both genders) and time spent on social media (for females) were positively associated with PA. A possible explanation for the positive association between time spent on online learning and PA is that the students who spent time on online learning may be more diligent, which could be an important factor in pushing them to do exercise. However, the present study does not have evidence to support this speculation and future studies are needed to verify this. Regarding the positive association between time spent on social media and PA among female participants, the explanation may be that female participants use social media to relieve their emotional distress (62), which in turn puts them in a better mood to exercise. However, this speculation also needs further study to corroborate.

The positive associations between outdoor activity and PA among both genders supported the hypothesis. These findings echo previous PA advocators that it is important to push university students to go outdoors instead of staying indoors (36). Given that the present findings were obtained during COVID-19 pandemic, the implication is that government and policymakers may consider implemented initiatives allowing citizens to go outdoors if lockdown and closures are needed for controlling COVID-19 transmission. However, such initiatives

TABLE 3 | Mediation model in explaining physical activity for female participants.

			Coeff. (SE)/ Std. Coeff.	*p*-value	LLCI, ULCI
IV	Mediator	DV			
Nomophobia	Perceived weight stigma	–	**0.01 (0.002)/ 0.10**	**<0.001**	**0.0040, 0.0128**
Nomophobia	Weight-related self-stigma	–	**0.11 (0.008)/ 0.35**	**<0.001**	**0.0937, 0.1232**
Nomophobia	Time on	–	**0.02 (0.005)/ 0.12**	**<0.001**	**0.0120, 0.0302**
Nomophobia	Time on outdoor activity	–	**−0.01 (0.003)/ −0.10**	**<0.001**	**−0.0170, −0.0056**
Nomophobia	Time on social media	–	**0.02 (0.004)/ 0.10**	**<0.001**	**0.0040, 0.0128**
Nomophobia	Time on online learning	–	**−0.01 (0.003)/ −0.11**	**<0.001**	**−0.0195, −0.069**
–	Perceived weight stigma	Physical activity	−62.31 (45.72)/ −0.04	0.17	−151.9896, 27.3609
–	Weight-related self-stigma	Physical activity	**−29.44 (13.50)/ −0.06**	**0.03**	**−55.9312, −2.9499**
–	Time on smartphone	Physical activity	33.55 (25.09)/ 0.04	0.18	−15.6757, 82.7720
–	Time on outdoor activity	Physical activity	**280.68 (35.89)/ 0.21**	**<0.001**	**210.2792, 351.0792**
–	Time on social media	Physical activity	**72.14 (30.00)/ 0.07**	**0.02**	**13.2963, 130.9878**
–	Time on online learning	Physical activity	**71.31 (32.67)/ 0.06**	**0.03**	**7.2218, 135.3995**
Nomophobia	–	Physical activity	**−10.42 (4.18)/ −0.07**	**0.01**	**−18.6101, −2.2204**
Nomophobia	Perceived weight stigma	Physical activity	−0.53 (0.46)/ −0.003	–[a]	−1.3777, 0.4363[a]
Nomophobia	Weight-related self-stigma	Physical activity	**−3.19 (1.50)/ −0.021**	**–[a]**	**−6.2906, −0.4450**[a]
Nomophobia	Time on smartphone	Physical activity	0.71 (0.65)/ 0.005	–[a]	−0.3737, 2.1419[a]
Nomophobia	Time on outdoor activity	Physical activity	**−3.17 (1.06)/ −0.021**	**–[a]**	**−5.4244, −1.4345**[a]
Nomophobia	Time on social media	Physical activity	**1.12 (0.62)/ 0.007**	**–[a]**	**0.0638, 2.4677**[a]
Nomophobia	Time on online learning	Physical activity	−0.94 (0.58)/ −0.006	–[a]	−2.1970, 0.0982[a]

Age and body mass index were controlled in the model.

[a]*Calculated using bootstrapping method (1,000 bootstrapping resamples); therefore, no p-values reported.*

IV, independent variable; DV, dependent variable; Coeff., coefficient; Std., standardized; SE, standard error; LLCI, lower limit confidence interval at 95%; ULCI, upper limit confidence interval at 95%.

Significant coefficients are in bold.

would need to be carefully discussed so that public health safety is maintained.

Negative effects of nomophobia on PA were found among females but not among males, which partially supported the hypothesis. The effects among females but not males may again be explained by the fact that females as compared with males are more likely to (i) have internalizing problems (e.g., depression) (60, 61), and (ii) use more social media to express emotions (62). Female participants in the present study may have relied more on smartphones than male participants as evidenced by their higher NMPQ score (**Table 1**). As a result, nomophobia may have effects on PA among females but not males. Additionally, mediated roles of weight-related self-stigma, time spent on outdoor activity, and time spent on social media in the association between nomophobia and PA engagement were only found among females.

There are some limitations in the present study. First, the present study only used subjective measures to assess all the factors. Prior evidence shows that there could be some differences between objective measures and subjective measures in PA and time spent on smartphone (26, 34). Moreover, social desirability and recall bias may make participants report better performance in PA and smartphone use. Therefore, the present findings are subject to the biases caused by self-reports (42). Second, the present study was conducted using online survey with convenience sampling. Therefore, the present findings were not from a representative sample. Third, the cross-sectional study design used in the present study provides weak evidence in causality between nomophobia, weight stigma, time spent on different activities, and PA engagement. Therefore, the directions and mediations proposed and examined in the present study need future studies to corroborate using a longitudinal study design.

CONCLUSION

The present study found that factors regarding PA engagement were different among male and female mainland Chinese university students. More specifically, younger age, more time spent on outdoor activity, and more time spent on online learning were significantly associated with higher levels of PA for both genders. Among female participants, PA engagement was negatively associated with weight-related self-stigma and nomophobia but positively associated with time spent on social media. The positive association between PA engagement and time spent on social media suggests that social media platforms could be motivational tools in promoting a physically active lifestyle among young female adults. Moreover, the effect between nomophobia and PA engagement was indirect via weight-related self-stigma, time spent on outdoor activity, and time spent on social media. Among male participants, PA engagement was negatively associated with perceived weight stigma. Therefore, Chinese healthcare providers should design programs for weight stigma reduction and outdoor activity improvement to enhance PA among university students.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Human Experimental Ethics Committee in Guangzhou Sport University (Ref no. 2021LCLL-23). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

PX, J-SC, XW, and Y-LC contributed to the study conception and design. PX, Y-LC, and C-YL performed material preparation. PX, XW, and XJ collected data. Y-LC analyzed data. PX, J-SC, MG, AP, and C-YL interpreted data. PX and Y-LC wrote the first draft of the manuscript. J-SC, XW, XJ, Y-LC, MG, AP, and C-YL critically reviewed the manuscript. MG was responsible for all final editing. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors. All authors contributed to the article and approved the submitted version.

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Role of Sociodemographic Variables and the Mother's Active Behavior on Active Commuting to School in Children and Adolescents

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The main objective of the current study was to analyze how parents' sociodemographic characteristics, mode of commuting and physical activity (PA) act as indicators of active commuting to school (ACS) in their children and adolescents. A total of 684 paired parents (52.8% mothers) and their respective offspring (33.7% girls) were included. The participants self-reported their sociodemographic characteristics, mode of commuting, and PA. Logistic regression analyses were performed using a stepwise approach, including, as indicators, parental characteristics, mode of commuting and PA. The main outcome was child and adolescent ACS. The odds ratio (OR) and R^2 of Nagelkerke were obtained for each step. Parental sociodemographic characteristics were greater indicators of child ACS than the parental mode of commuting and PA. In children, the greatest predictive variables of ACS explained 38% of the variance and were as follows: car availability (OR = 0.24), father's educational level (OR = 0.47), mother's educational level (OR = 1.95), mother's active commuting to work (OR = 4.52) and mother's salary/month (OR = 0.67). In adolescents, the greatest predictive variables of ACS explained 40% of the variance and were as follows: socioeconomic level (OR = 0.43) and father's active commuting (OR = 10.6). In conclusion, sociodemographic factors are better indicators of ACS than parents' physical activity and active commuting to work.

Keywords: active transport, physical activity, youth, parents, school

INTRODUCTION

Physical activity (PA) in young people has been associated with numerous physical and psychosocial health benefits (1, 2). To obtain these benefits in children and adolescents, the World Health Organization – WHO (3) recommended performing at least 60 daily minutes of moderate-to-vigorous physical activity (MVPA). However, only a small proportion of children and adolescents meet these daily MVPA recommendations (4–6).

On the other hand, the socioecological model has been broadly used to explain the determinants of physical activity (7). This model includes family and people close to the family as highly influential factors for developing these behaviors (8).

Accordingly, it has been shown that children's PA habits are associated with their parents' physical activity, especially in younger children (9). Children with active parents are more active than children with inactive parents (10). For instance, a positive association has been found between mother's sport participation and children's out-of-school PA (11). Mothers play a greater role in planning and organizing children's PA, while fathers are more likely to model children's PA (12). According to the previous evidence, the family, and especially, the mothers play an important role in maintaining levels of PA in children, which are worth studying. The educational style of parents and its influence on PA has also been studied. Evidence has found that permissive mothers are associated with higher PA practice by their children than authoritarian mothers (13, 14). In addition, higher levels of care and personalized education for the mother favored athletes and PA practitioners who perceived better support from her parents (15).

Moreover, previous research has demonstrated that active commuting to/from school (ACS), such as walking or cycling, is an opportunity to reach daily PA levels (16–18). Additionally, ACS has been proposed as a strategy where boys and girls are 42% and 66% more likely to attain PA recommendations, respectively (19). However, many children and adults commute to school and work, respectively, using passive modes (20, 21). Furthermore, a general decline in ACS has been observed in recent decades in different countries (22–24) and even in Spain (25). The decline in ACS is partially explained by rising commuting distances and car ownership (26), but other factors may be influences, such as safe routes to school and policies that encourage schools to be placed within neighborhoods to ensure an acceptable walking distance (27). In this regard, different family factors, such as the parent's educational level (15), socioeconomic status (28) and professional levels (29), may influence ACS. However, it is not clearly defined which family factors "are more powerful" to influence this type of active behavior.

In recent years, several studies focused on the established parent-child relationship on ACS have emphasized parental barriers to ACS (30–32). The findings have indicated that parents perceived more barriers in children than adolescents (30, 31, 33). However, few studies have analyzed the influence of parental sociodemographic factors on ACS in offspring (29, 34, 35), which has already been mentioned as relevant. Unfortunately, the studies including in these associations the effect of gender (mothers vs. fathers; boys vs. girls) and including both children and adolescents are lacking. Nevertheless, in the current study the gender variable is included to answer the question about a greater influence of the father or mother. Additionally, fewer studies have investigated the interaction between the active commuting to work (ACW) of parents and the active commuting to/from school (ACS) of their offspring. Recently, Brand et al. (36) found associations between mothers and their children, and Rodríguez-Rodríguez et al. (37) showed a stronger association with children than with adolescents. However, more studies in this regard are needed to elucidate the parental variables and interactions that affect ACS in both children and adolescents.

According to the last, the hypothesis of this study suggests that active behaviors such as PA and ACW have a greater influence on ACS in children and adolescents. At the same time, the influence of fathers and mothers would be different. In this way, understanding how parental factors interact with the ACS of their offspring could offer us key information about how to guide school interventions to achieve successful results, increasing the PA in children and adolescents. Consequently, according to the previous information, the main objective of the current study was to analyze how parental sociodemographic characteristics, mode of commuting, and PA predict ACS in their children and adolescents, highlighting the differences by gender of parents.

MATERIALS AND METHODS

Study Design and Participants

This is a cross-sectional study of schoolchildren and parental participation that was carried out in Granada (Spain) and Valparaíso (Chile). Data were obtained as part of the "Cycling and Walk to School" (PACO, for its Spanish acronym) study, focused on promoting PA and, particularly, active commuting to and from school. The sampling has been obtained for convenience, where initially a total of 2,526 children and adolescents and 1,959 of their parents were invited to participate in the study. Participants came from 20 schools as a nonrandomized sample. From the total sample of children, 1,807 participants could not be paired with parental data, and 34 did not report their gender and were excluded (72.8% of the sample). A total of 572 parents could not be paired with their children's data, and 703 parents without gender data were excluded (65% of the sample). Finally, a total of 684 paired parents (52.8% mothers) and their respective offspring (33.7% girls) were included. These child-parent pairs belonged to 15 schools in Granada, Spain ($n = 492$) and five schools in Valparaíso, Chile ($n = 192$). The age (mean $\pm$ standard deviation) of each group was as follows: parents 43.4 $\pm$ 6.5 years old, children 9.7 $\pm$ 1.7 years old, and adolescents 14.0 $\pm$ 1.7 years old.

Procedures

The student questionnaire was administered to children and adolescents between 2015 and 2018 by the research staff during physical education lessons and lasted $\sim$30 min. The research staff and schoolteachers were present to answer the students' questions (offspring). The parent's questionnaire was delivered to students and completed at home by their parents (mother/father or guardian). Additionally, the parents signed an informed consent form that explained the aims and characteristics of the study and allowed their offspring to participate. The ethical principles for medical research involving human subjects were followed based on The World Medical Association Declaration of Helsinki 2002 revised in 2013. Additionally, the study was reviewed and accepted by the Ethical Committee of the University of Granada, Spain (No. 162/CEIH/2016), and the Ethical Committee of the Pontificia Universidad Católica de Valparaíso, Chile (CCF02052017) to be applied in both countries.

Parental Sociodemographic Characteristics

The participants self-reported their sociodemographic characteristics, including age, school grade, gender, and full postal address. Additionally, the parent's questionnaire included questions about the highest educational level attained (no study, primary school, secondary school, bachelor's degree, professional degree, and university degree) and income per month (None; <499€; 500–999€; 1,000–1,499€; 1,500–1,999€; 2,000–2,499€; 2,500–2,999€; 3,000–4,999€; >5,000€) dichotomized in <1,000 € and ≥1,000 € according to the minimum salary in Spain which is around 1,000 euros and it has been homogenized for the Chilean sample, where the sample was dichotomized according to the minimum salary in Chile (≅ $350.000). The socioeconomic level was asked using the Family Affluence Scale (FAS) defined with the following questions: "Does your family own a car?" (No [0 point]; Yes, one [1 point]; Yes, two or more [2 points]), "How many computers does your family own?" (None [0 point]; One [1 point]; Two [2 points]; More than two [3 points]), "Do you have your own bedroom for yourself?" (No [0 point]; Yes [1 point]) and "Do you have internet access?" (No [0 point]; Yes [1 point]). A score was assigned for each answer and then summed to obtain the total points. Participants were classified into three categories regarding the FAS: low (0–3 points), medium (4–5 points) and high (6–7 points) (38). In addition, car availability in the family from the FAS was reported as an independent variable.

Parent's Active Commuting to Work and Physical Activity

To determine the parental mode of commuting to work, two reliable questions (39) were used: (1) "How do you usually get to work?" and (2) "How do you usually get home from work?" The response options for all the questions were walk, bike, car, motorcycle, public bus, metro/train, and other. The usual mode of commuting was categorized as "active" when the parents went to or from to work in "active" mode (walk or bike) and "passive" when the parents went to work in motorized modes (car, motorcycle, public bus, and metro/train). The answer, "Other mode," was excluded since it was not able to be categorized. In addition, the distance from home to work was asked with the following question: "How far do you live from work? The answer options were <0.5 km, 0.5 to <1 km, 1 to <2 km, 2 to <3 km, 3 to <5 km and >5 km.

The International Physical Activity Questionnaire (IPAQ, short version) was used to determine parental PA levels. The IPAQ shows acceptable psychometric properties to measure MVPA levels in 1 week (40, 41). Additionally, this instrument determines the time in different intensity categories as sedentary, light PA, moderate PA, and vigorous PA in minutes in the last seven days. Regarding MVPA recommendations for adults (≥ 150 min/week), parents were classified as meeting MVPA recommendations (i.e., physically active) and not meeting MVPA recommendations (i.e., physically inactive) (3).

Active Commuting to School

The children's questionnaire, which included the mode and frequency of commuting to and from school information, was self-reported by the children and adolescents, and has been previously validated (42) and is considered reliable (43) for use in Spanish-speaking children and adolescents. This questionnaire is a 4-item self-report instrument designed to evaluate the mode and weekly frequency of ACS in children and adolescents. Four questions were included in the questionnaire: (1) "How do you usually get to school?"; (2) "How do you usually get home from school?"; (3) "How did you get to school each day?"; and (4) "How did you get home from school each day?"; and the choice of answers to the questions was as follows: walk, bike, car, motorcycle, school bus, public bus, metro/train/tram and other (44). The whole questionnaire is available at http://profith.ugr.es/pages/investigacion/recursos. The mode of commuting was categorized as "active" (walk and bike) or "passive" (car, motorcycle, school bus, public bus, or metro/train/tram). The answer "Other mode" was excluded since it was not able to be categorized. The final dependent variable to predict was the usual active modes of commuting to and from school.

Statistical Analysis

The mean and standard deviation (SD) for continuous variables and absolute and relative frequency (%) for categorical variables were calculated. The differences in sociodemographic characteristics, mode of commuting to work and PA between mothers and fathers, and the differences in ACS between boys and girls in children and adolescents were calculated using the chi-square test. The results were analyzed separately by country, but not all were calculated due to lack of data. Nor did it show any differences when joining both countries. Therefore, the indicators were calculated from a single group (Chile-Spain together).

Logistic regression analyses were performed stepwise along with three models, including the ACS (passive vs. active) of the children and adolescents as the main outcome variable (passive commuting was used as a reference). The three models were performed separately for children and for adolescents. In the first model, all sociodemographic variables were included as explanatory variables. In the second model, parents' active commuting to work and PA were included as explanatory variables. In the third model, the significant variables from the first two individual models were included as new explanatory variables (all variables) to determine the variables explaining ACS. The odds ratio (OR) and 95% confidence interval of each variable as well as the correlation (Nagelkerke R^2) were obtained for each step. The confidence interval (CI) values were used to establish the association with ACS. All analyses were performed using SPSS® v21 (IBM, New York, NY, USA). Additionally, a $p < 0.05$ value was considered significant.

RESULTS

Parental sociodemographic characteristics, mode of commuting to work and PA variables are presented in **Table 1**. Gender differences were found for educational level, monthly salary, car

TABLE 1 | Parental sociodemographic characteristics, mode of commuting and physical activity variables, overall, and for mothers and fathers.

	Overall		Mothers		Fathers		*p-value*
	N	(%)	*N*	(%)	*N*	(%)	
Participants	684 (100)		361 (52.8)		323 (47.2)		
Age (Mean ± SD)	43.4 ± 6.5		42.7 ± 6.5		45.7 ± 6.0		0.094
Educational level (*N* = 631)							
No studies	9	(1.4)	5	(1.6)	4	(1.3)	[b] <0.001
Primary school	46	(7.3)	32	(10.2)	14	(4.4)	
Secondary school	156	(24.7)	70	(22.3)	86	(27.1)	
Bachelor's	131	(20.8)	47	(22.6)	84	(26.5)	
Professional	122	(19.3)	71	(19.9)	51	(16.1)	
University degree	167	(26.5)	89	(28.3)	78	(24.6)	
Salary/month (*N* = 419)							
Unemployed	33	(7.9)	14	(6.4)	19	(9.5)	
<1,000 €	160	(38.2)	60	(27.3)	100	(50.2)	
1,000 to <2,000 €	182	(43.4)	123	(56.0)	59	(29.6)	[a] 0.001
2,000 to <3,000 €	39	(9.3)	18	(8.2)	21	(10.6)	
≥3.000 €	5	(1.2)	5	(2.3)	0	(0.0)	
Car availability (*N* = 575)							
None	123	(21.4)	36	(11.5)	87	(33.3)	
Only one	290	(50.4)	167	(53.2)	123	(47.1)	[b] <0.001
Two or more	162	(28.2)	111	(35.4)	51	(19.6)	
Socioeconomic level (*N* = 381)							
FAS Score (Mean ± DS)	7.26 ± 1.09		7.25 ± 1.11		7.32 ± 1.03		0.608
Mode of commuting to work (*N* = 419)							
Active commuting	82	(20.9)	51	(26.3)	31	(15.6)	0.074
Passive commuting	310	(70.1)	143	(73.7)	167	(84.4)	
MVPA Recommendation (*N* = 519)							
<150 min in MVPA	195	(37.6)	93	(29.9)	102	(49.0)	[b] <0.001
≥150 min in MVPA	324	(62.4)	218	(70.1)	106	(51.0)	[b] <0.001

MVPA, moderate-vigorous physical activity;, SD, standard deviation; [a]p < 0.05; [b]p < 0.001.

availability and reaching the MVPA recommendations (mothers: 70.1% and fathers: 51.0%; $p < 0.001$). No significant differences in socioeconomic level or mode of commuting were found between mothers and fathers.

The children's and adolescents' sociodemographic characteristics and mode of commuting to school are shown in **Table 2**. No significant differences between children and adolescents were found, except for age.

The parental sociodemographic characteristics (Model 1) as explanatory variables of ACS in children and adolescents are shown in **Table 3**.

Regarding children, four-step logistic regressions were obtained in Model 1 of parental sociodemographic characteristics (see **Figure 2**). In the first step, "car availability" was included and explained 18% of the variance; in the second step, "father's educational level" was added and explained 23% of the variance (+5%); in the third step, "age" was added, increasing the explained variance to 28% (+5%); and in the last step, "socioeconomic level" was included, increasing the explained variance to 32% (+4%). In this last model, an OR = 1.894 was obtained, increasing the probability that children are active.

In adolescents, only one step was obtained, which included socioeconomic level (OR = 0.534), which explained 14% of the variance.

Model 2 of parental mode of commuting to work and PA variables as explanatory variables of ACS in children and adolescents are shown in **Table 4**.

In children, three steps were calculated to predict ACS (see **Figure 2**). The first step included a higher "father ACW," explaining only 9% of the variance, but a greater odds value (OR = 4.430). As a second step, lesser "mother ACW" was included in the model, increasing the variance explanation by 14% (+5%). The third step included a higher "mother ≥150 minutes in MVPA," slightly increasing the variance explanation toward 16% (+2%). In adolescents, only one step was used to predict ACS. Higher "Father ACW" explained 5% of the variance.

Every previous parental explanatory variable was included in Model 3, separately, for children and adolescents (**Figure 1**), and higher variance values were obtained. Regarding children, five stepwise models, which included "car availability," less "father's educational level" (+6%), higher "mother's educational level" (+4%), "mother ACW" (+4%) and less mother salary/month

TABLE 2 | Sociodemographic characteristic and mode of commuting to school between children and adolescents.

	Overall ($n = 684$)		Children ($n = 438$)		Adolescents ($n = 246$)		*p-value*
Sociodemographic factors	***N***	**(%)**	***N***	**(%)**	***N***	**(%)**	
Age (Mean ± SD)	11.3 ± 2.7		9.7 ± 1.7		14.0 ± 1.7		[a] <0.001
Gender							
Girls	386	(56.4)	243	(55.5)	143	(58.1)	0.521
Boys	298	(43.6)	195	(44.5)	103	(41.9)	
Mode of commuting ($n = 673$)							
Active	263	(39.1)	169	(39.0)	94	(39.2)	0.518
Passive	410	(60.9)	264	(61.0)	146	(60.8)	

SD, standard deviation; [a]$p < 0.001$.

TABLE 3 | Associations between parental sociodemographic characteristics and their child's or adolescent's ACS (Model 1).

Group	Steps	Predictors	*OR*	CI 95%	*p*-value	R^2
Children	1	Car availability	0.248	0.126–0.489	<0.001	0.18
	2	Car availability	0.282	0.141–0.566	<0.001	0.23
		Father's educational level	0.682	0.507–0.918	0.012	
	3	Car availability	0.290	0.144–0.583	0.001	
		Father's educational level	0.617	0.449–0.847	0.003	0.28
		Age	1.86	1.011–1.166	0.024	
	4	Car availability	0.113	0.037–0347	<0.001	0.32
		Father's educational level	0.571	0.407–0.802	0.001	
		Age	1.088	1.012–1.169	0.022	
		Socioeconomic level	1.894	1.088–3.298	0.024	
Adolescents	1	Socioeconomic level	0.534	0.309–0.924	0.025	0.14

OR, odds ratio; CI, confidence interval; R^2, Nagelkerke correlation.
Parent variables included in the model were as follows: age, educational level (mother and father), salary/month (mother and father), car availability, and socioeconomic level.

TABLE 4 | Associations between parental mode of commuting to work and PA with their child's or adolescent's ACS (Model 2).

Group	Steps	Predictors	*OR*	CI 95%	*p*-value	R^2
Children	1	Father Active Commuting	4.430	2.258–8.691	<0.001	0.09
	2	Father Active Commuting	3.672	1.826–7.381	<0.001	0.14
		Mother Active Commuting	3.363	1.580–7.161	0.002	
	3	Father Active Commuting	4.269	2.064–8.828	<0.001	
		Mother Active Commuting	3.247	1.509–6.987	0.003	0.16
		Mother >150 min in MVPA	1.961	1.079–3.563	0.027	
Adolescents	1	Father Active Commuting	3.142	1.108–8.913	0.031	0.05

OR, odds ratio; CI, confidence interval; R^2, Nagelkerke correlation.
Included parent variables in the model: MVPA (mother and father) and mode of commuting (mother and father).

(+4%) as explanatory variables of ACS (see **Figure 2**). Overall, the model explained 38% of the variance.

Regarding adolescents, two steps were calculated to predict ACS. The first step included less "socioeconomic level" and explained 23% of the variance, while the second step included the higher "Father ACW" (+17%) and increased the variance explanation toward 40%.

Figure 2 shows the differences between the three models stratified by children and adolescents. In addition, the increases in the percentage of variance explained can be seen when adding each variable (steps).

DISCUSSION

Physical Activity and Commuting to Work of Parents

The main objective of the current study was to analyze how parental sociodemographic characteristics, mode of commuting,

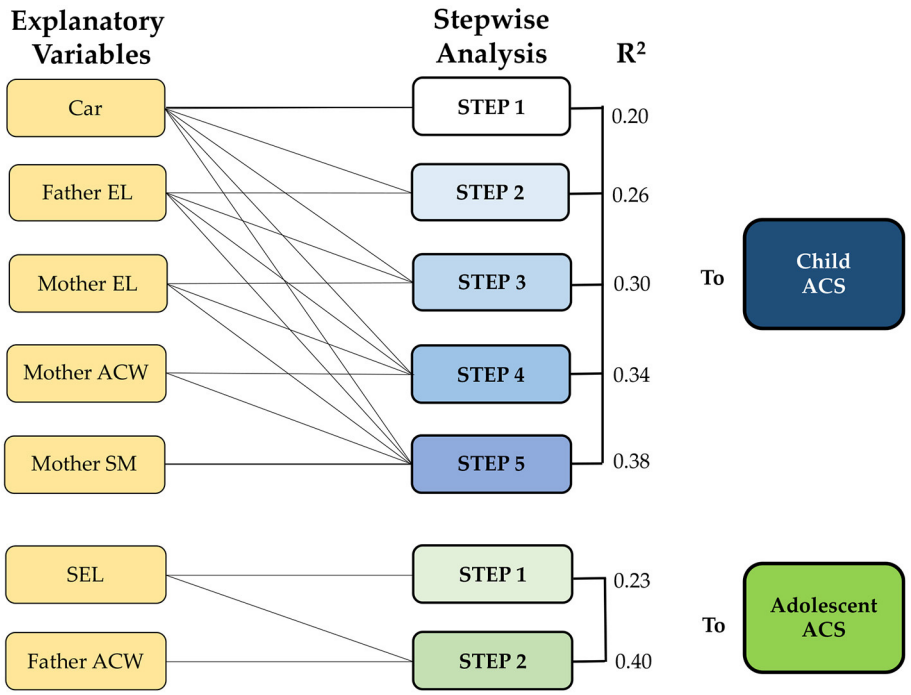

FIGURE 1 | Nagelkerke correlation (R^2) in combined stepwise model analysis (Model 3) on active commuting to school in children and adolescents. Car, car availability; EL, educational level; ACW, active commuting to work; SM, salary per month; SEL, socioeconomic level; ACS, active commuting to school.

and PA predict ACS in their children and adolescents, highlighting the differences by gender of parents. Moreover, the main results of the current study were that parental sociodemographic characteristics, such as car availability, mother's and father's educational levels, mother's salary, and socioeconomic level, explained significantly more the ACS than ACW and parent' PA. In accordance with this, the hypothesis is rejected, which stated that active behaviors such as PA and ACW have a greater influence on ACS in children and adolescents.

According to the above, only the mother's PA was incorporated into the Model 2 to explain ACS in children. But it only improved the variance from 14 to 16%. An important implication of these findings is that the weak association between parental PA and ACS can be explained because the questionnaire (IPAQ) applied in the parents tends to overestimate the amount of physical activity reported compared to an objective device (45). In this way, any association could be lost and, consequently, these results must be analyzed with caution. In addition, this could be explained by the low number of parents who met the PA recommendations (37).

Parental behavior affects children's behavior, and the importance of the family in the development of children's active behaviors has been previously demonstrated (46). Regarding active commuting to work, mothers' active commuting to work in children and fathers' active commuting to work in adolescents were important variables for explaining ACS. Recently, a study conducted in North America with 344 parents suggested that ACS among children was directly influenced by the commuting behaviors of their parents (10). In another study in Brazil, strong associations between children's and adolescents' ACS with the mother's active commuting to work were found (36). Additionally, greater positive associations were found for mothers actively commuting to work and their offspring's ACS and stronger associations between parents and children than adolescents were found (37). To our knowledge, few studies have associated the active commuting of parents with children with ACS, and future studies should continue to explore and to describe new relationships.

Sociodemographic

Model 3, which included the sociodemographic variables, active commuting, and PA, was the more efficient explanatory model. In the case of children, four of the five variables that best predicted ACS were sociodemographic factors (car availability, father's educational level, mother's educational level and mother's salary/month).

Car availability usually represents a high socioeconomic level and has regularly been associated with lower ACS (29, 44, 47, 48). In addition, families without a car increase their active commuting options (49). However, parents can conveniently drive to school because trips can often be combined with work commutes (50). Additionally, a long distance to commuting home to school or home to work typically involves car use (51), and thus negatively affects ACS. A study conducted in New Zealand showed that 32.3% of schoolchildren enrolled in the closest school were driven to school by car, compared to 57.2% not enrolled in the closest school that were driven by car (52).

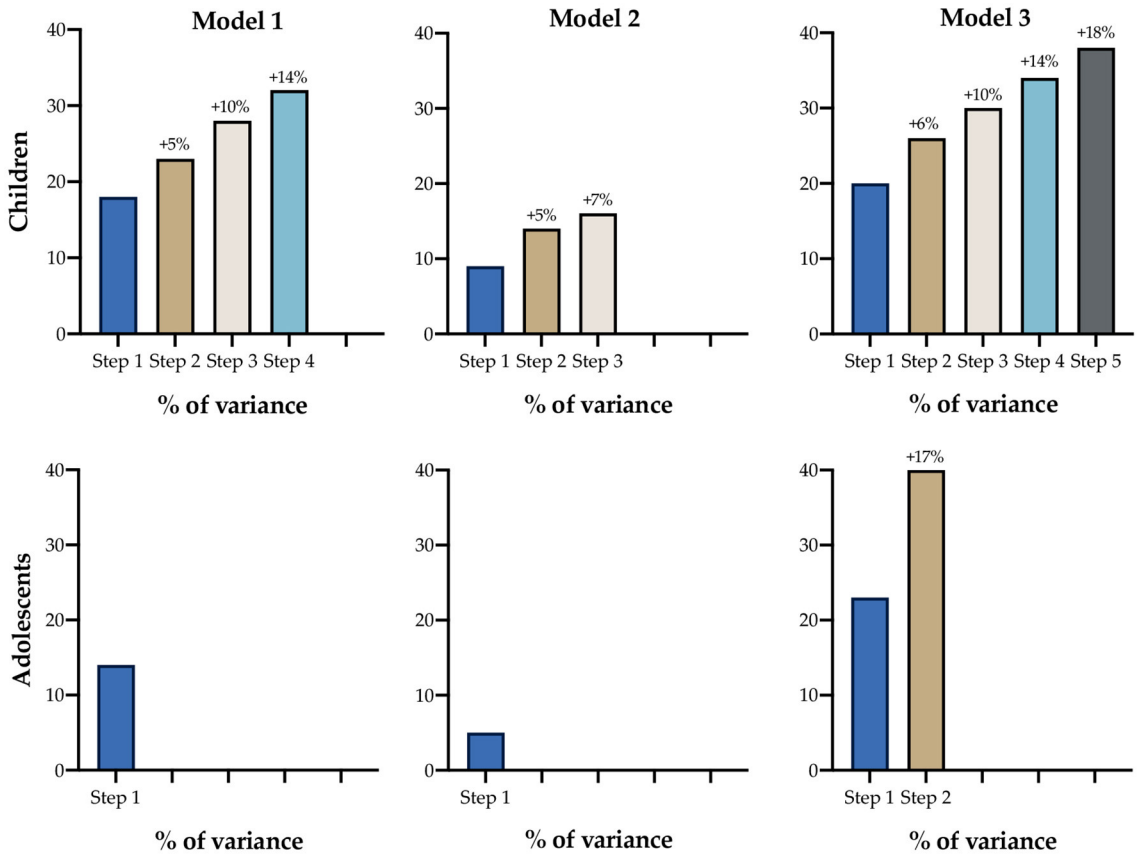

FIGURE 2 | Increase in the percentage of variance explained in each model in children and adolescents.

In another sense, our findings demonstrated that children's ACS can be explained by the educational levels of fathers and mothers. A previous study showed that parents with lower levels of education drove cars less to work (38.8 vs. 46.6%), and they walked more often (19.1 vs. 16.9%) than parents with high educational levels (21).

In adolescents, parental educational level was not an explanatory variable for ACS. However, socioeconomic level was an important sociodemographic variable included in the model. A Spanish study showed that adolescents from families with high socioeconomic levels had lower levels of ACS than their peers from families with low socioeconomic levels (44). It should be considered that sociodemographic variables are less modifiable and cannot be intervened. Therefore, interventions must identify the factors that may influence the increase or decrease in ACS. Therefore, our results indicate that parental and familial sociodemographic factors have the most important role in the ACS of children and adolescents.

Our study has described several parental factors that can explain ACS and help to focus future intervention strategies.

STRENGTHS AND LIMITATIONS

The large sample of parents and their offspring stand out as one of the strengths of the study, reaching 1,368 participants. Data from two Spanish-speaking countries were enrolled with their respective language adaptations, providing instruments that can be used by other Latin American countries. Additionally, the novelty of the study was to have included sociodemographic and PA variables in the same model, which provided new evidence on parents and their offspring.

The main limitation of the study was the cross-sectional design; therefore, no cause-and-effect relationship can be established in the associations. Indeed, a longitudinal study is required to determine the causal direction of the relationship. There was a relevant loss of sample data regarding the initial data collection because there were many incomplete questionnaires. Additionally, a nonrandomized sample was included; therefore, it is not possible to generalize to other populations. In addition, a self-reported questionnaire was used, which has a lower objectivity to determine PA than devices such as accelerometers.

CONCLUSION

The most explanatory variables for children's ACS, ordered from more to less relevance, were the parents' car availability, father's educational level, mother's educational level, mother's salary/month and mother's active commuting to work. The most explanatory variables for adolescents' ACS, ordered from more to less relevance, were socioeconomic level and father's

active commuting. In conclusion and according to our objective, it can be stated that parental sociodemographic factors are more related to active commuting to school in children and adolescents than parents'physical activity and active commuting to work. In addition, more factors from the mother influence this active behavior.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Bioethical Committee of the Pontificia Universidad Católica de Valparaíso, Chile (CCF02052017). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

FR-R, PS-U, JM, MA-B, YB-R, and PC have made substantial contributions to the conception of the study and drafted the work and substantively revised it. FR-R and PS-U in design of the work and analysis of data. MA-B in acquisition of data. FR-R, PS-U, JM, and PC interpretation of data. All authors contributed to the article and approved the submitted version.

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STUDY PROTOCOL
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The First United Arab Emirates National Representative Birth Cohort Study: Study Protocol

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Background: In recent years, the prevalence of non-communicable diseases (NCDs) has escalated. Evidence suggests that there are strong associations between nutrition in early life and the risk of disease in adulthood. This manuscript describes the study protocol of the First United Arab Emirates National Representative Birth Cohort Study (UAE-BCS), with the objective of investigating nutrition and lifestyle factors in the first 1,000 days of life. The main aims of the study are (1) to address critical issues relating to mother and child nutrition and their effect on growth and development, (2) to profile maternal nutrition, child growth, health, and development outcomes in early life, and (3) to study the associations between these factors among the Emirati population in the UAE.

Methods/Design: In this study, a multidisciplinary team of researchers was established including credible researchers from the UAE, Lebanon, Australia, and the United Kingdom to launch the First United Arab Emirates 3-year birth cohort study. We aim to recruit 260 pregnant Emirati women within their first trimester, which is defined by the study as from 8 to 12 weeks pregnant, from obstetrics and gynecology clinics in the UAE. Participants will be recruited via face-to-face interviews and will receive a total of 11 visits with 1 visit in each trimester of pregnancy and 8 visits after delivery. Maternal data collection includes, socio-demographic and lifestyle factors, dietary intake, anthropometric measurements, physical activity, maternal psychological state, and blood samples for biochemical analysis. Post-partum, visits will take place when the child is 0.5, 4, 6, 9, 12, 18, and 24 months old, with data collection including infant anthropometric measurements, young child feeding practices, dietary intake, supplement use and the eating environment at home, as well as all maternal data collection described above, apart from blood samples. Additional data collection for the child includes early child developmental assessments taking place at three timepoints:

(1) within 2 weeks of birth, (2) at 10–14 months and (3) at 22–26 months of age. Early child developmental assessments for the infant include vision, hearing, cognition, motor skills, social-emotional reactivity, neurodevelopmental, and sleep assessments.

Discussion: The United Arab Emirates Birth Cohort study protocol provides a standardized model of data collection methods for collaboration among the multisectoral teams within the United Arab Emirates to enrich the quality and research efficiency in early nutrition, thereby enhancing the health of mothers, infants, and children.

Keywords: nutrition, pregnancy, feeding practices, development, United Arab Emirates

INTRODUCTION

Globally the impact of NCDs continues to grow, and they have become the leading cause of mortality, with type T2DM being the fourth most deadly NCD (1, 2). During the past three decades, the global prevalence of T2DM has doubled and now presents a significant public health challenge in almost every country. In 2019, the International Diabetes Federation (IDF) estimated the global prevalence of T2DM to be 9.3%; however, it is thought that around 50.1% of people with diabetes remain undiagnosed. Additionally, the prevalence is estimated rise to 10.2% by 2030 resulting in 115 million new cases between 2019 and 2030. The Middle East and North Africa (MENA) region is ranked the highest region for the prevalence of diabetes accounting for 54.9 million of the global prevalence (3), the United Arab Emirates (UAE) part of the three countries with the highest prevalence of diabetes in the MENA region with 12.3% of the population living with the disease (4, 5). In the UAE, four NCDs are responsible for 65% of all deaths; cardiovascular disease, cancer, diabetes, and chronic respiratory disease (6). A 2010 study in the UAE showed the prevalence of prediabetes to be 31% and undiagnosed diabetes mellitus 14.6%. Another significant health issue is metabolic syndrome (MetS), the concurrent existence of prediabetes, dyslipidemia, elevated blood pressure, and obesity (7).

It is widely acknowledged that most NCDs identified in adults have their origins in early life. The theory of the developmental origins of adult diseases, commonly known as the Barker hypothesis, associates nutrition during pregnancy, and risk of chronic disease in later life (8). Accumulating evidence shows that a balanced and varied diet plus a healthy lifestyle in the months leading up to conception, throughout pregnancy, during infancy, and to the second birthday, collectively known as the first 1,000 days of life, are influential to health and risk of disease later in life. For instance, full-term infants who are small-for-gestational age have an increased risk of cardiovascular disease (CVD) and T2DM in adulthood, and this is a known consequence of fetal undernutrition (9). Studies on the relationships of nutritional imbalances in early life with birth outcomes, growth patterns, and early determinants of NCDs, have revealed direct associations between limited maternal weight gain during pregnancy and both impaired fetal growth, and low birth weight (10). Also, excess maternal weight gain correlates with high birth weight and fetal growth (large-for-gestational age) (11, 12), as well as adverse cardiometabolic profiles in the offspring (13). In addition to maternal weight gain, maternal diet composition and micronutrient status during pregnancy seem to be associated with birth outcomes and child health status.

The first 1,000 days of life are a vital period that play a crucial role in the development of the immune, endocrine, metabolic, motor, and other developmental pathways. Maternal nutrition and lifestyle choices in preconception and during pregnancy have significant influences on the health, growth, and development of the fetus. Research shows that a maternal diet low in protein is connected to changes in the structure of the liver of the fetus and low birth weight (14), while a diet rich in fat effects adipocyte metabolism, fetal growth, and fat mass in the offspring (15, 16). Maternal anemia and iron, folate, or vitamin B12 deficiency during pregnancy is associated with an increased risk of fetal growth restriction, premature birth, and low birth weight (17–19). The effect of maternal nutrition on the cognitive capability and neurodevelopment of offspring is well established, particularly in the context of micronutrient deficiencies. Vitamin B12 deficiency is associated with spina bifida and infant insulin resistance (20), and maternal iodine deficiency with hypothyroidism. Prenatal maternal iron deficiency is associated with decreased myelination, disturbance in monoamine neurotransmitter synthesis and hippocampal energy metabolism in offspring (21), and there is evidence of an association between increased consumption of essential long-chain omega -3 fatty acids during pregnancy and better infant performance in development assessments, verifying the link between prenatal and postnatal diet to specific aspects of the brain development (22). The effect of prenatal maternal nutrition on neurodevelopment outcomes in children is not exerted solely through the effect of maternal nutrition on fetal growth and birth outcomes. It persists into the postnatal period, by impacting the quality and quantity of breast milk, maternal mood, and infant feeding practices.

Maternal and infant nutrition may influence the risk of later disease due to its critical associations with immunological development of the fetus and young infant (23). Adequate nutrition is necessary both for establishment of the immune system, normal organogenesis and development, and development of an adequate immune response. Undernutrition

during early childhood exerts a concomitant effect on cognitive and developmental milestones through mid- and late- childhood and into adolescence. Studies consistently identify associations between stunting at ages 2 and 3 years with later cognitive deficit, as well as school achievement, even after controlling for socio-demographic confounders (24).

Global estimates of stunting and wasting in children under the age of five for 2018 were reported to be 21.9% (149 million) and 7.3% (49 million), respectively, and obesity in children of the same age group was reported to be 5.9% (40 million). The MENA region has the second highest rate of under 5 years overweight children, with an increase from 8.9% in 2,000 to 11.2% in 2018 (25). According to the UNICEF, in 2020 the UAE mortality rate for children under five was 6.6 per 1,000 live births, for infants was 5.6 per 1,000 live births, and neonatal mortality rate was 3.6 per 1,000 births (26). The percentage of overweight school and adolescent children (5–9 years) was estimated to be 37% in 2016 (27). However, there are no records for malnutrition, stunting and wasting of children in the country.

In some research from the UAE, the overall prevalence of global development delay and pervasive development disorder among 3-year old children was reported to be 2.44% and 29 in 10,000 for severe development delay/disorder with a prevalence of 8.4% and 58 in 10,000 for mild to moderate delay/disorder (28). Currently, there are no reports of the neurodevelopmental abilities of young children during the first 1,000 days of life from the UAE. These indicators are considered key public health factors, which contribute independently to mortality and burden of disease.

Objectives

The objective of the first UAE -BCS is to recruit 260 pregnant Emirati women and to profile the maternal nutrition, child growth and developmental outcomes during the first 1,000 days of life in the UAE. This 3-year, prospective observational study seeks to address critical issues relating to mother and child nutrition and its effect on growth and development. Specifically, given that maternal and paternal health has a transgenerational impact on the development and health of offspring, this cohort study aims to profile maternal nutrition, child growth and development outcomes, and to study the association between these in the UAE. Accordingly, the establishment of a body of evidence through this cohort study is of paramount importance to inform future strategies regarding optimal dietary intake and consequent nutrition-related health of women in childbearing age and their offspring. The objectives of this cohort study involve:

- Characterization of the *in utero* environment through assessment of antenatal maternal and paternal factors such as, weight gain, abnormal gestational glucose tolerance, pregnancy-induced hypertension, preterm births, and new-born small- and large—for gestational age birth weight on new-born body composition, birth outcomes, and growth patterns.
- Studying the association between early feeding practices including breastfeeding, weaning, and complementary feeding patterns, as well as postnatal growth and adiposity for the first 1,000 days of life.
- Studying the association between specific maternal micronutrient status (vitamin B12, vitamin A, vitamin D, hemoglobin, ferritin, folate, lead, and zinc) and gestational weight gain with offspring body composition, birth outcomes and growth patterns.
- Determining the impact social and environmental conditions, including family structure, socioeconomic status, health behaviors (i.e., dietary intake and physical activity), and maternal psychological stress factors on the development of adiposity of the growing offspring in the first 1,000 days of life.
- Developing and validating the Neonatal Neurodevelopment Assessment (Neo-NDA) for the measurement of neurological status and maturity in new-borns, which will ultimately serve clinical and academic research purposes.

METHODS AND ANALYSIS

Ethical Approval

The UAE-BCS protocol was approved by the United Arab Emirates University Human Research Ethics Committee, (ref. ERH-2020-61442020-12). Additional approval was granted from the Ministry of Health and Prevention (Approval Reference No: MOHAP/DXB-REC/NDD/No.162/2020.) and the Department of Health Abu Dhabi (ref: DOH/CVDC/2021/510). This study is registered at clinicaltrials.gov (NCT04928898).

Study Design

The UAE-BCS is a prospective, observational, population-based 3-year cohort study of expecting Emirati females and their children living and attending obstetrics and gynecology (OB-GYN) clinics in the UAE. In 2021, the UAE population was reported to be 10 million, however, the expatriates constitute the majority of the population, and the Emirati population was estimated to account for almost 1 million of the entire population in 2010 (29, 30). The UAE has seven Emirates in which the Emirati population is reported to be a s follows; Emirate of Abu Dhabi was estimated to have 551,353 Emiratis in 2016; the Emirates of Dubai was estimated to have 233,430 in the same year, and most recently 271,050 in 2020; Ras Al Khaimah had 127, 000 Emiratis in 2015. However, data for Ajman, Umm Al Quwain and Fujairah estimated 42, 186, 17,482 and 64,860 Emiratis in 2010, respectively. Additionally, in all Emirates males account for most of the Emirati population in all Emirates with the exception of Umm Al Quwain in which 8, 811 of the 17, 482 were female in 2010 (31–34).

For this study, the UAE will be stratified into three geographic areas based on population density and socioeconomic factors: Abu Dhabi, Dubai, and the Northern Emirates. Approximately 40% of participants will be recruited from Kanad Hospital, Al Ain, Abu Dhabi; 30% of participants from facilities in Dubai, and 30% from clinics across the Northern Emirates.

Study Participants

The study aims to recruit a total of 260 pregnant Emirati females during their first trimester (8–12 weeks of gestation) through face-to-face recruitment at OB-GYN clinics in selected health care facilities across the Emirates of the UAE. The participants will be provided with both verbal and written information (Participant Information sheet) about the study aims, data collection activities, and duration of the study. Mothers will consent to the study on behalf of their children to be included in the study, by signing a form, after meeting the following inclusion and exclusion criteria.

Inclusion Criteria:

- Emirati Nationality
- Within first trimester of pregnancy (between 8–12 weeks of gestation)
- Singleton pregnancy
- Absence of major illness preconception (Diabetes mellitus, hypertension, kidney disease, cancer, epilepsy, severe psychiatric illness, and other chronic diseases of infections such as autoimmune disorders, human immunodeficiency virus, and hepatitis).

Exclusion Criteria:

- Non-Emirati Nationality
- Unconfirmed viable, intrauterine pregnancy at first obstetric ultrasound during first trimester
- Twin or multiple gestation pregnancy and a history of multiple gestations
- History of chronic illness (i.e., T2DM, hypertension, etc.)
- Previously given birth to babies with malformation, intellectual disability, or inborn errors of metabolism.
- Experience of a miscarriage before 28 weeks of gestation
- Use of significant regular medications, including insulin, anti-hypertensive agents, psychotropic medications, anti-epileptic drugs, steroids, immune-suppressive agents, and chemotherapeutic agents.

Study Protocol

The study protocol is summarized in **Figure 1**. Each mother/child will be assessed over 3 years, at 11 separate study visits.

During Pregnancy

Pregnant females will be recruited during their first trimester (8–12 weeks of gestation) in OB-GYN clinics and perinatal health facilities in the UAE. There will be one visit during each trimester of pregnancy, and an additional eight visits postpartum. The initial prenatal assessment screening will aim to measure key factors such as diet and supplement use, physical activity and lifestyle practices, maternal psychological, sociodemographic, and socioeconomic characteristics, through anthropometric measurements and validated questionnaires. Blood samples will be collected from participants during the first and third trimester for biochemical analysis of several biomarkers. Maternal exposure, knowledge, attitudes, and intention toward infant feeding practices will be assessed during the third trimester through questionnaires. Information on fetal growth from ultrasound will be collected during the second and third trimester.

Post-partum

The participants' hospital records will be used to obtain information about the delivery, as well as birth outcomes data. Postnatal visits will take place when the child is 0.5, 4, 6, 9, 12, 18, and 24 months old. These visits will consist of anthropometric measurements and assessment of child feeding practices (breastfeeding and complementary feeding practices, dietary intake, supplement use, and the eating environment at home). Developmental assessments will take place at three points: (a) within 2 weeks of birth, (b) at 10–14 months, and (c) at 22–26 months of age. In addition, the mothers will undergo postpartum assessment at each postnatal visit. This will consist of anthropometric measurements, collection of dietary intake data, supplement use, lifestyle habits, physical activity, and psychological state.

Data Collection Instruments and Methods

Culture specific and English and Arabic questionnaires were developed for the purpose of data collection for this study. In addition, questionnaires for infant neurological development and neonatal forms were provided by an expert in the field and translated into Arabic. The content and validity of all questionnaires was confirmed by experts in each respective field. A pilot study was conducted to test the wording, cultural appropriateness of the questionnaires, and to ensure they would yield the required data. The questionnaires will be administered by trained research nutritionists through face-to-face interviews.

Sociodemographic and Lifestyle Questionnaires

This questionnaire will be used to collect sociodemographic information about the parents, including age, education, employment status, income, dietary, and lifestyle influences and choices, and household details including information about living arrangements, such as type of accommodation. Additional paternal information collected in this questionnaire include brief questions about general health.

Maternal Dietary Intake Assessment Questionnaire

Maternal dietary intake information will be collected through Food Frequency Questionnaires (FFQ) and multiple pass 24 h food recalls and will be used to assess energy, nutrient intake, and dietary patterns. The FFQs contain 130 culture-specific food items, and supplement use will also be collected during the 24-h recall. The FFQs were specifically created for population studies in the UAE and will include foods traditionally consumed during pregnancy. Additionally, the FFQs will contain questions about the weekly consumption frequency of different foods and food groups. The United States Department of Agriculture Multiple Pass Food Recall (MPFR), which is a 24-h recall method used to collect detailed dietary intakes and supplement use of participants to allow capture of all food and beverage consumption during the 24 h preceding the interview, and is validated for accurate measurement of food intake (35). The 24-h

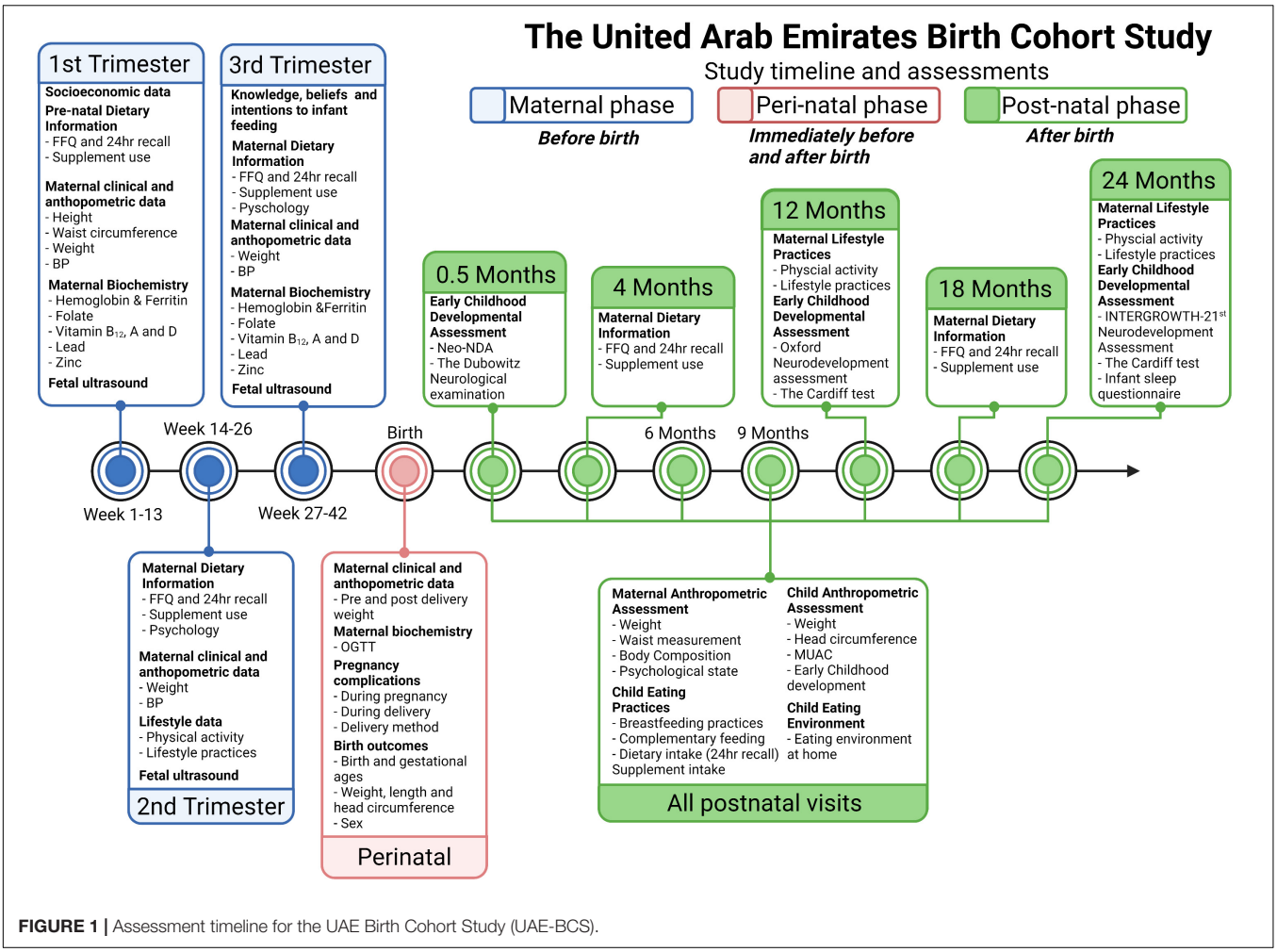

FIGURE 1 | Assessment timeline for the UAE Birth Cohort Study (UAE-BCS).

food recalls will be analyzed with the ESHA Food Processor, SQL (ESHA Research, V. 11. 0) to calculate energy and nutrient intake in the participants (36). During the study, both the FFQs and the 24-h recalls will be conducted during the first, second and third trimester, and 4 months post-partum.

Physical Activity Questionnaire

A pregnancy-specific physical activity questionnaire used in a similar study in Qatar and Lebanon will be used to assess the physical activity levels of the participants during their second trimester (37). The International Physical Activity Questionnaire (IPAQ) will be used to collect physical activity levels of the mother at each child follow up visit (38).

Infant and Young Child Feeding Practices and Dietary Intake

The WHO indicators will be used as benchmarks to assess child breastfeeding and complementary feeding practices and will include questions related to breastfeeding and complementary feeding (39). A 24-h recall using the mother as a proxy for the child's dietary intake and supplement use will be used for evaluation at each of the visits post-partum.

Anthropometric Assessments

Anthropometric measurements of the mothers, infants and young children will be obtained at different stages throughout the study.

Anthropometric Assessment of Mothers

Maternal anthropometric measurements will be taken during pregnancy and will follow standard techniques for obtaining height in centimeters (cm) using a stadiometer during the first trimester, weight in kilograms (kg) using Tanita scale (Tanita BC-418, Tanita Corp., Tokyo, Japan) at all visits, waist circumference in centimeters using a non-stretchable measuring tape during the first trimester and percentage body fat which will be assessed by bioelectrical impedance analyzer (Tanita BC-418, Tanita Corp., Tokyo, Japan) during the first trimester and during all postnatal visits.

Anthropometric Assessment of Infants and Young Children

Anthropometric assessment of infants and young children will be taken at each of the six visits after birth and will include measurement of weight, length, head circumference

and mid-upper arm circumference (MUAC). Anthropometric measurement protocols and quality control procedures will follow the WHO MGRS INTERGROWTH-21st Project protocol (40–42). Study equipment will include portable electronic weighing scales (Seca model 376; Seca, Hangzhou, China); recumbent length will be measured using a Harpenden Infantometer (range 300–1,100 mm; Chasmors Ltd., London, United Kingdom), flat metal tape measure will be used for head circumference measurement (CMS ref.3105; Chasmors Ltd., London, United Kingdom). MUAC will be measured using a tape around the arm at the level of the midpoint (42).

Early Child Development Assessments

For this study, a set of formal validated questionnaires and developmental assessment tools will be used to assess the child's growth milestones and development, such as vision, hearing, attainment of certain reflexes and motors kills, social-emotional behaviors, and language.

Assessment of early child development (ECD) will occur at three timepoints: (i) within 2 weeks of birth; (ii) at 10–14 months of age; and at 22–26 months.

The first developmental assessment will take place within 2 weeks and consist of a brief examination of the newborn for color, posture, tone, reflexes, suck, behavior and dysmorphic features using a novel tool, the Neonatal Neurodevelopment Assessment (Neo-NDA). In a sub-sample of 30 participants, the Dubowitz's neurological examination (43), a clinical examination of neonatal tone, reflexes and behavior will be administered together with the Neo-NDA.

The second developmental assessment will occur at 10–14 months of age, using the Oxford Neurodevelopment Assessment (OX-NDA). The OX-NDA is a 57-item measure and assesses nine domains: cognition (15 items); fine and gross motor (8 items); language (8 items); behavior (7 items); executive function (3 items); attention (5 items); social-emotion reactivity (9 items); and positive affect (2 items). The instrument has a combination of directly administered, concomitantly observed, and maternally reported items. The child's performance on each item is reported on a five-point scale. The OX-NDA was designed to be an international, population-based screening measure for assessing early child neurodevelopment without the need for specialist professionals or infrastructure and has been validated against the Bayley Scales of Infant Development in a sample of 522 from Pelotas, Brazil (44). Hearing will be assessed by mapping 11 items on the OX-NDA onto 4 auditory milestones for the 10–14 months age group (45). Vision outcomes in the infants will be evaluated using the Cardiff Tests, which measure visual acuity and contrast sensitivity (46, 47). Mothers will report on the sleep of their infants using a modification of the brief infant sleep questionnaire (48).

The final developmental assessment will occur at 22–26 months of age, using the INTERGROWTH-21st Neurodevelopment Assessment (INTER-NDA) (49, 50). The INTER-NDA is a 53-item assessment of cognition, expressive and receptive language, gross and fine motor skills, behavior, attention, and social-emotional reactivity in children 2 years old. Outcomes are reported on a 5-point scale characterizing the child's performance in each domain across a spectrum. Like the OX-NDA, it designed to be free from cultural biases and is based upon objective reporting (rather than subjective judgment) of the child's performance. It consists of directly administered, concurrently observed, and caregiver reported items. It's inter-rater and test-retest reliability are $k = 0.70$, 95% CI: 0.47–0.88 and $k = 0.79$, 95% CI: 0.48–0.96, respectively (49), and the INTER-NDA shows good agreement with the Bayley Scales of Infant Development III edition (intraclass correlations for domains ranging between 0.745 and 0.883; $p < 0.001$). The INTER-NDA has been used to assess ECD outcomes in over 5,000 children from 12 countries.[1] Hearing will be assessed by mapping 6 items on the INTER-NDA onto 3 auditory milestones for the 22–26 months age group (45). Vision outcomes in the infants will be assessed using the Cardiff Tests, and mothers will report on infant sleep outcomes on a modification of the brief infant sleep questionnaire.

Biochemical and Blood Pressure Assessments

During pregnancy, fasting blood samples will be obtained from the mother twice, in the first and third trimester to assess maternal micronutrient status. The blood samples will be collected by a certified phlebotomist into appropriate test tubes (with or without ethylenediaminetetraacetic acid (EDTA) appropriate for the biomarker to be analyzed. Iceboxes will be used to store the test tubes temporarily until ultimate centrifugation and analysis. The following are the biomarkers that will be examined and with corresponding analytical method:

- Hemoglobin (HemoCue® Glucose 201 + System)
- Ferritin (Electrochemiluminescent assay, RocheCobas E 411; Roche Diagnostics, Indianapolis, IN, United States)
- Folate (Electrochemiluminescent assay, Roche Cobas E 411)
- Vitamin B12 (Electrochemiluminescent assay, Roche Cobas E 411)
- Vitamin A (High-Performance Liquid Chromatography)
- Vitamin D (Electrochemiluminescent assay, Roche Cobas E 411)
- Lead [Inductive Captured Plasma (ICP)]
- Zinc [Inductive Captured Plasma (ICP)]

Blood pressure will be measured with a validated and calibrated digital automated sphygmomanometer (Omor Hem-907, Omron Healthcare, Kyoto, Japan) with participants seated after a 5-min rest. These measurements will be obtained at the three visits during pregnancy.

Delivery and Birth Outcome Data

Delivery and birth outcome data will be obtained from the records of the hospital at which the birth takes place with the participant's consent. The data includes occurrence of complications during pregnancy, date and method of delivery, gestational age, sex of newborn, birthweight, length, and head

[1] www.inter-nda.com

circumference all of which will be measured by a trained researcher or clinician.

Reliability of Data Collection

The questionnaires to be used in the study were reviewed by the experts in the field. Additionally, the validity of questionnaires will be tested using a pilot group of the study population, however, the FFQ and IPAQ have been validated and used in the UAE population in recent studies (51, 52). Considering that the data will be collected by trained research assistants across the different states of the UAE, several quality assurance activities will be implemented to ensure consistency and reliability standards of the collected information. The principal investigators have compiled a data collection training program with a certification process and detailed operations manual describing the procedures before, during and after data collection to be given to each research assistant. The manual will contain checklists to be followed before and after each visit, including a section on Frequently Asked Questions (FAQs). The instruments used in data collection were carefully chosen and will be identical in each of the facilities where data will be collected, such as measuring tapes, stadiometers, scales, etc. Additionally, there will be regular meetings between the principal investigators and personnel involved in data collection in which probing and interviewing techniques will be standardized to minimize interviewer bias. The principal investigators will regularly visit participating healthcare centers to observe data collection activities, discuss emerging situations and ensure that all procedures are standardized.

Statistical Analysis and Sample Size Calculation

The data collected will be checked for accuracy and completeness and will be entered into the Statistical Package for Social Science (SPSS) software, using the most current version. The primary aim of the study is to examine the associations between maternal nutrition (e.g., weight gain, micronutrient status, etc.) and infant health outcomes (e.g., growth rate, dietary diversity score, feeding practice score, etc.). Given the somewhat limited data on the above-mentioned relationships, for power calculation an $r = |0.2|$ was chosen, as it yields the largest sample size. Using the UCSF sample size calculator, the sample size needed to detect a correlation as small as $|0.2|$, at 80% power and 5% type I error, is determined at 194. For this study, correlations less than 0.20 would be too small to be considered clinically significant (37). Given the high attrition rate seen in previous birth cohorts (37), we estimate that roughly 15% of the participants will drop out after the first visit. An additional 10% was factored into for losses due to preterm delivery or still birth. More participants (∼10% of sample) are also required to test for simple interactions in our study (e.g., Emirati, Sex, and Timing). Thus, the original sample size was increased by 35% and the intended sample size was determined at 260 pregnant women.

Frequencies and percentages will be used to describe categorical variables and mean, and standard deviations will be used to describe continuous variables. The chi-square test ($\chi 2$) or Fisher' s exact test will be used to calculate the association between categorical variables. Independent *t*-tests and Mann-Whitney tests will be used to chart comparisons for normal and non-normal continuous variables, with normality of variables evaluated using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Associations among the variables of the cohort study (i.e., maternal factors, birth outcomes, breastfeeding, complementary feeding, growth patterns, etc.) will be examined using simple linear and logistic regressions. The two main dependent variables in this study are related to birth outcomes and growth patterns of the child. Variables showing statistical significance in the univariate analysis will be included in the multivariate models as covariate factors in order to control for potentially confounding variables that have been used in the model. Parameter estimates and their respective 95% confidence intervals will be calculated for linear regression analyses, whilst for logistic regression analyses odds ratios and their respective 95% confidence intervals will be calculated. Tests for linearity (tolerance > 0.4) of the covariates included in the regression models will be performed. Normality of the residuals will be assessed using the histogram of standardized residuals and normal probability plot in all linear regression models. *P*-values less than 0.05 will be considered to indicate statistical significance.

DISCUSSION

The design for the 3-year birth cohort study of pregnant Emirati women and their offspring has been thoroughly described in this study protocol. The study investigates relationships between nutrition and lifestyle factors with birth and growth outcomes in the UAE and explores the early determinants of NCDs. Existing studies of the UAE population has focused mainly on the determinants of obesity and NCDs in adults, with some studies focusing on investigating the prevalence of obesity and its determinants in adolescent children. There is a scarcity of detailed research on the dietary practices during pregnancy or infant and young child feeding practices in the UAE with previous studies mainly cross sectional in design, with small sample sizes which are not nationally representative (53–56).

Research has established that growth and development in early life is crucial to longer-term health status, wellbeing, and behavior across the lifespan (57). Nutrition and lifestyle behaviors are similarly critical for maternal and offspring health from preconception, through pregnancy and into early postnatal life (58). Given the rapidity of the development of the obesity epidemic and increased prevalence of related NCDs, particularly in the UAE, the changes cannot be explained by genetics alone but rather in key environmental factors (59, 60). Accordingly, optimal nutrition during pregnancy has important implications for fetal development and growth and may be protective for the long-term health outcomes of both the mother and child. Prenatal genetic and environmental factors that can affect the first 1,000 days of life have recently been shown to play a pivotal role in early childhood development including cognitive, social-emotional skills and motor development. Moreover, the global double burden

of malnutrition is increasing, and the UAE lacks data for malnutrition, stunting and wasting of children. Undernutrition during early childhood exerts a concomitant independent effect on the cognitive and developmental abilities developing through mid- and late-childhood and into adolescence (61). Prospective cohort studies consistently show significant associations between stunting at age 2 or 3 years and later cognitive deficits, school achievement, and dropout, after controlling for socio-demographic confounders (24).

The overall prevalence of global developmental delay and pervasive developmental disorder among 3-year-old children in the UAE in 2016 was reported to be 2.44% and 29/10,000 for severe delay/disorder with a prevalence of 8.4% and 58/10,000 for mild to moderate delay/disorder, respectively, with no reports profiling the neurodevelopment abilities of young children during the first 1,000 days of life from UAE (28). Therefore, the importance of the first few years of a child's life to decreasing the risk of disease morbidity, mortality, and later risk of chronic disease, and to promoting healthy growth and development, is important. Moreover, nutrition during the first 1,000 days of a child's life has been identified as one of the significant modifiable factors, during this critical window of opportunity, to influence optimal growth, promote optimal neurodevelopment and reduce disease vulnerability later in life (61). In addition, the data obtained in this study will support the development and validation of a new tool, the Neo-NDA, to be used for the measurement of neurological status and maturity of new-borns in the UAE; explore the association between early childhood development (ECD) outcomes using the three inter-related tools: Neo-NDA, the OX-NDA and the INTER-NDA at < 5, 12, and 24 months of life; and use holistic and standardized measures of ECD, importantly including measure of vision, hearing and sleep at all developmental assessments. Prenatal maternal nutrition is an important predictor of fetal and child brain development, exerting its effect in both intrauterine (fetal growth and birth outcomes) and extrauterine (parenting, child feeding practices, maternal mood, quality, and quantity of breast milk) environments. There is limited understanding on what constitutes optimal ECD, with most studies employing heterogeneous methodologies for ECD assessment and being carried out in high-income western settings. This has limited both the comparability and generalizability of neurodevelopmental evaluations, between studies, and to other populations. It also restricts their scalability for measuring and monitoring ECD at a population level with routine ECD screening programs lacking in many parts of the world. To our knowledge, there are no studies profiling neurodevelopmental outcomes during the first 1,000 days of life in the UAE, and therefore our findings will fill this gap. There is a need for high quality data to be collected in country/geography-specific large birth cohorts, using standardized methodologies, to guide understanding of what constitutes optimal and sub-optimal child development in these contexts, to permit comparability between populations, representing a scalable solution to the application of ECD surveillance in these settings. Birth cohort studies that commence either during pregnancy or preconceptionally and then follow the offspring and the wider family into later life, can make a significant contribution to the development of dietary recommendations to expectant mothers during pregnancy to maximize the health and development of the offspring while simultaneously contributing to the understanding of optimal and sub-optimal ECD outcomes in the context of maternal nutrition. Maternal and infant nutrition, as well as early child growth, health, and development, should be a priority for health policy implementation, health promotion activities, and interventions.

The findings of this study will not only provide evidence and data for the UAE population that has never been collated before, but it will also survey infant and maternal body composition and contribute to reproductive health policy. In addition to laying the foundations for culture specific health policies and interventions for pregnant women, infants and young children, this study will provide the first database for the UAE and highlight gaps in the current evidence while identifying avenues for further research. The hallmark of the UAE birth cohort study protocol includes intersectoral collaborations and a versatile research team, and the comprehensive assessment of maternal and infant nutrition and lifestyle exposures. An important aspect of the study is the collaboration between OBYGYN clinics and selected health care facilities across the UAE with a panel of experts and research personnel in this study, particularly in recruitment, data collection and follow up. Importantly, the team of researchers involved in this study are experts in obstetrics, neonatal development, and nutrition epidemiology. Another key aspect of the study is the methodical observation, monitoring and examination of dietary intake lifestyle practices, body composition, and growth of mothers and their off springs from conception to 2 years of after birth.

CONCLUSION

The UAE-BCS will provide a key platform of evidence and skill to inform future strategies to optimize dietary and consequent nutrition-related health of women in child-bearing age and their children, and thereby, the health of the nation. It will also provide critical data to inform policy decisions, and public health interventions in the region, providing a path to reduce the growing impact of obesity and NCDs in the UAE and MENA region more broadly.

AUTHOR CONTRIBUTIONS

LS, AA, LC, AH, HA, MF, NH, RA, AS, and HK: conceptualization. SM and JF: writing—original draft preparation. LS, AA, LC, AH, HA, SK, MF, NH, RA, and AS: writing—review and editing. JF: visualization. LS and AA: supervision. All authors contributed to the article and approved the submitted version.

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Epidemiology of Campus Football Injuries in Ningxia, China: Occurrence, Causes, and Management

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Objective: By 2022, the Chinese government intends to have more than 30 million primary-, middle- and high-school children and adolescents regularly participate in campus football. In contrast, epidemiology of campus football injuries is completely missing. The goal of this descriptive epidemiological study was to determine the current state of campus football injuries and then to recommend appropriate prevention and management strategies.

Methods: This retrospective epidemiological study conducted a survey of students, physical education and football teachers in primary, middle and high schools in the Ningxia Autonomous Region to determine the campus football injuries that occurred throughout the preceding 12-month period. The survey comprised questions on demographic characteristics, the occurrence, causes, and management of campus football injuries.

Results: A total of 1,285 students and 200 teachers returned eligible surveys. 25.7% of students had encountered injury accidents while participating in campus football activities. 31.3% of high school students, 23.8% of middle school students, and 19.2% of primary school students have sustained injuries. Football competition, accounting for 45.4% of all injuries, is the leading cause of injury. Football class teaching, which accounted for 3.0% of all injuries, had the lowest injury rate of any campus football activity. Students and teachers reported that a lack of safety awareness and injury prevention education were the primary causes of injuries. Only 18.7% and 11.4% of students are familiar with first aid basics and cardiopulmonary resuscitation, respectively. 10.6% and 7.5% of students lack any first aid basics and skills, respectively. 43.9% of students lack insurance coverage for athletic injuries. 62.5% and 38.5% of teachers reported that schools lack first aid training and an emergency plan for injuries, respectively.

Conclusion: Students in Ningxia's campus football programs have a high injury risk. Injury prevention and management strategies lag significantly behind the mainstream nationwide promotion of campus football in China.

Keywords: soccer, youth athletes, injury prevention, first aid, risk factors, healthcare

INTRODUCTION

Football (soccer) is the most popular sport in the world, with an estimated 4 billion fans worldwide (1). Despite concerns about the safety of youth football training, a growing body of evidence indicates that regular participation in well-designed, rationally advanced, and professionally instructed football training programs can provide children and adolescents with substantial health and fitness advantages (2, 3). On March 16, 2015, the State Council announced the "General plan of Chinese football reform and development" (4), ushering in a new age of "Campus Football 2.0" in China. Since the Chinese government implemented a series of comprehensive plans and guidelines, campus football has grown rapidly in China. In Chongqing for example, the number of students who participate in campus football activities on a regular basis has nearly doubled from <20,000 in 2014 to more than 400,000 in 2016, a nearly 20-fold increase (5). On August 28, 2020, the Ministry of Education published a "Notice of Action Plan for the Construction of the Eight Major Systems of National Youth Campus Football" (6). The Action Plan establishes a working target of more than 30 million primary-, middle-, and high-school students participating in football on a regular basis by 2022. After establishing the framework for campus football, the directive objectives and improvement plans for the construction of the "Eight Major Systems" were presented. China has essentially finished the five-in-one national campus football promotion pattern of "distinctive schools + high-level football teams in colleges and universities + pilot counties (districts) + reform pilot zones + Man Tian Xing training camps." By 2021, the "multiple pillar" of campus football reform had been largely completed, with 2,038 schools, 2,030 kindergartens, 40 pilot zones, five pilot counties (districts), and 28 "Man Tian Xing" training camps established for campus football nationwide (7). Campus football activities are gaining huge popularity throughout China.

Apart from the increased interest and engagement in campus football across the nation, the game itself is a confrontation sport that requires rapid acceleration and deceleration, direction changes, and jumping and landing challenges. Due to the frequent physical contact involved, the risk of injury is significant (8). Injury risk is especially significant in youth sports, where the growth and maturation of children and adolescents may predispose youth players to an increased risk, and football has been shown to have the highest occurrence and severity of injuries among popular youth sports (9). As campus football activities have grown in popularity, an increasing number of injuries have occurred (10). On the one hand, high incidence rates impose significant socioeconomic consequences on the public healthcare system (11, 12). On the other side, major injuries can have a long-term effect on an individual player's health (11). Children and adolescents who sustain sports injuries may experience significant reductions in their current and future participation in physical activities (11), which is directly contrary to the promotion of campus football in China. As a result, it is critical to assess epidemiological data during campus football participation. A systematic examination of occurrence and risk factors enables the development of effective preventative measures, ensuring the healthy development of youth and youth sports as a whole.

Athletic injuries have severely hampered the growth of campus football in China (13, 14). With the rapid growth of campus football, it is vital to analyze epidemiological data in order to design appropriate safety education programs tailored for Chinese youth and schools. Using a representative sample who participated in campus football programs in Ningxia, this study aimed to determine the occurrence, causes, and management of campus football injuries. The discussion and findings are likely to aid in the long-term development of campus football.

METHODS

Participants

The Ningxia Autonomous Region in China was chosen as a sample region for campus football injuries in this study. The sample was drawn from a convenience sample who participated in the Ministry of Education certified campus football programs in the preceding year. This study included students, physical education (PE) teachers and football coaches (hereafter, referred as teachers) from primary, middle and high schools. The ethics committee of Ningxia University approved the study.

Instrument

The data collection instrument was a self-administered, anonymous paper-and-pencil survey ("Research Questionnaire on Campus Football Safety Prevention System," in Chinese). Two versions were developed to meet the research aims for students and teachers, respectively. An injury in the surveys was defined as one that required a teacher to enter the field to assess a player's condition, or one that required a player to withdraw from participation, or one that required any type of first aid during an incident that occurred throughout the preceding 12-month period. Existing football injuries survey modules from the literature (15–17) were used to construct the surveys.

Occurrence of campus football injuries was assessed by one item: "Have you ever been hurt while participating in campus football activities? A. Yes B. No" (students survey).

Causes of campus football injuries were assessed by five items: (1) "Which of the following activities resulted in your injuries while playing campus football? How many times has each activity resulted in an injury in the past academic year? (multiple choice) A. Football class teaching (on-campus, supervised sessions) B. Football competition (on-campus, supervised sessions) C. Extra-curricular activities (on-campus, unsupervised sessions) D. After-school football training (off-campus, supervised sessions) E. After-school football activities (off-campus, unsupervised sessions)" (students survey); (2) "What, in your opinion, are the safety factors affecting the development of campus football activities? (multiple choice) A. Lack of safety knowledge on the part of students B. Inadequate safety awareness and behavior among students C. Poor physical characteristics of students D. Lack of safety knowledge on the part of teachers E. Inadequate safety awareness of teachers F. Inadequate classroom

management by teachers G. Teachers' lack of seriousness and accountability in class H. Teachers' exercise schedules are excessive J. Sports equipment and pitch present safety issues K. Inclement weather L. Inadequate safety management of the school" (students survey); (3) "What factors do you believe contribute to acute injuries among students? (multiple choice) A. Inadequate warm-up B. Inclement weather C. Poor physical characteristics of students D. Excessive risk-taking among students E. Errors in technical movement of students F. Sports equipment and pitch present safety issues G. Lack of self-protection skills and safety knowledge on the part of students H. Lack of professional knowledge on the part of teachers I. Inadequate safety awareness of teachers" (teachers survey); (4) "Have your teachers taught you the methods of self-protection in sports? A. Often taught B. Occasionally taught C. Rarely taught D. Did not teach" (students survey); and (5) "Is the pitch and equipment sufficient for your campus football activities? A. Fulfill the requirements B. Fulfill only the basic requirements C. Could not fulfill the requirements" (students survey).

Management of campus football injuries was assessed by six items: (1) "Do you know first aid basics in the event of an athletic injury accident? A. Clear understanding B. Partial understanding C. No understanding" (students survey); (2) "Is there a first aid course offered at your school? A.Yes B.No" (teachers survey); (3) "Do you know how to administer the following first aid skills (multiple choice): A. Ice compression B. Simple bandage C. Immobilization of the torso and limbs D. Cardiopulmonary resuscitation E. No knowledge of basic first aid" (students survey); (4) "If a financial disagreement emerges as a result of an athletic injury sustained while participating in campus football activities, who do you believe should be held accountable: A. The school B. Personal responsibility C. A third party, such as a healthcare insurance" (students survey); (5) "Do you have insurance for athletic injuries? A.Yes B.No" (students survey); and (6) "Is there an emergency plan in place at your school for athletic injuries sustained during campus football activities? A.Yes B.No" (teachers survey).

Data Collection

In classrooms at the schools, research assistants contacted potential volunteers. To those who expressed an interest, a consent letter and survey instrument were distributed. Each participant provided written consent. In order to collect as accurate data as possible, research assistants explicitly explained all items in the survey to the participants. If participants had any queries concerning the items in the surveys, researcher assistants and/or students' parents clarified them before they responded. Students and teachers who agreed to participate completed a paper survey and returned it to a classroom research assistant.

Statistics

Two researchers independently entered the data into Excel (Microsoft Corporation, USA), and if there were discrepancies, a third researcher verified the accuracy of the data. Descriptive statistics were performed (SPSS, IBM, USA) to describe the characteristics of survey items.

RESULTS

Participants

A total of 1,362 surveys were sent out to students, all of which were returned and 1,285 were effective, with an effective rate of 94.3%. **Table 1** shows the demographic data of students participating in campus football injuries survey. A total of 213 surveys were sent out to teachers, all of them were returned, and 200 were effective, with an effective rate of 93.9%.

Occurrence of Campus Football Injuries in Ningxia

According to the results of an effective survey distributed to 1,285 students in Ningxia (**Table 2**), 330 students sustained injuries while participating in campus football activities, accounting for 25.7% of the total respondents. Risks of injury tend to increase as a student progresses through primary school, middle school, and high school campus football activities.

Causes of Campus Football Injuries in Ningxia

Table 3 summarizes football activities that resulted in campus football injuries. Football competition is the primary activity among the five forms of football activities in which injuries occur to students of all school grades. Football class teaching had the lowest proportion of injuries.

According to a student survey, 80.9% believed that the cause of injury accidents was students' own lack of safety knowledge, 71.2% believed that students' lack of safety awareness and behavior contributed to the occurrence of injury accidents, and 54.8% believed that students' poor physical characteristics contributed to the occurrence of injury accidents.

According to a teacher survey, 61.0% believed that the cause of injury accidents was students' lack of self-protection skills and safety knowledge, 42.0% believed that inadequate safety awareness of teachers contributed to student injuries, and 33.0% believed that teachers' lack of professional knowledge contributed to student injuries. Additionally, 62.0% of teachers often taught students self-protection techniques during campus football activities, 30.5% occasionally taught students self-protection techniques, and 7.5% seldom or never taught students self-protection techniques.

According to the surveys on the causes of student injuries, 32.2% of students and 38.0% of teachers cited safety issues on sports equipment and pitch as the cause of injury accidents. According to a survey of students' satisfaction with the pitch and equipment used for campus football activities, 42.7% of students believed the school pitch and equipment could meet the needs of sports, 46.7% believed they could only meet the basic needs of sports, and 10.6% believed they could not meet the needs of sports.

Management of Campus Football Injuries in Ningxia

First aid is applicable to a wide variety of medical circumstances and entails both specialized knowledge and skills as well as the ability to assess and make appropriate decisions. Only 18.7% of

TABLE 1 | Demographic data of students of various grades.

Grade	Male		Female		Missing sex data		Overall	
	Age (years)	N	Age (years)	N	Age (years)	N	Age (years)	N
High school	16.0 ± 1.2	336	15.6 ± 1.2	187	15.9 ± 1.2	11	15.9 ± 1.2	534
Middle school	13.6 ± 1.0	239	13.6 ± 1.0	164	13.0 ± 0.0	4	13.6 ± 1.0	407
Primary school	11.3 ± 1.1	192	11.4 ± 0.8	146	12.0 ± 0.0	6	11.3 ± 1.0	344

Data are expressed as means ± standard deviations.

TABLE 2 | Injury occurrence during campus football activities.

Whether or not injuries had occurred	High school (n_1)		Middle school (n_2)		Primary school (n_3)		Overall (n_4)	
	YES	NO	YES	NO	YES	NO	YES	NO
N	167	367	97	310	66	278	330	955
%	31.3	68.7	23.8	76.2	19.2	80.8	25.7	74.3

$n_1 = 534$, $n_2 = 407$, $n_3 = 344$, $n_4 = 1{,}285$.

TABLE 3 | Football activities that result in campus football injuries.

Forms of football activities	High school (n_1)		Middle school (n_2)		Primary school (n_3)		Overall (n_4)	
	N	%	N	%	N	%	N	%
Football class teaching	16	3.0	16	4.0	6	1.8	38	3.0
Football competition	274	51.6	169	42.7	132	38.9	575	45.4
Extra-curricular football activities	98	18.5	64	16.2	76	22.4	238	18.8
After-school football training	38	7.2	37	9.3	49	14.5	124	9.8
After-school football activities	105	19.8	110	27.8	76	22.4	291	23.0

$n_1 = 531$, $n_2 = 396$, $n_3 = 339$, $n_4 = 1{,}266$.

TABLE 4 | Students' proficiency of first aid skills.

First aid proficiency	N	%
Ice compression	669	52.1
Simple bandage	515	40.1
Immobilization	155	12.1
Cardiopulmonary resuscitation	147	11.4
Know nothing	96	7.5

students are aware of first aid basics, while 10.6% are completely unaware. 70.7% of students have a hazy understanding of first aid basics. The results of a teacher survey indicate that 62.5% of schools lack first aid training.

According to the results of a student survey (**Table 4**), 52.1% of students knew how to apply ice compression in the event of an injury, 40.1% knew how to apply simple bandage techniques, and 12.1% knew how to immobilize the torso and limbs when treating severe injuries. Only 11.4% of students are familiar with cardiopulmonary resuscitation (CPR). 7.5% of students are unaware of any first aid skills.

According to the survey of solutions to campus football injuries, 16.4% of students believe that the school should bear responsibility, 23.3% believe that students should bear responsibility, and 60.2% believe that a third party, such as an insurance company, should bear responsibility. Additionally, 43.9% of students lack health insurance coverage for athletic injuries. Finally, 38.5% of teachers reported that schools lack an emergency plan for student injuries sustained during campus football activities.

DISCUSSION

This retrospective epidemiological study was conducted to identify football injury situations in Ningxia, China. To our knowledge, this is the first study in China to examine the epidemiology of campus football injuries in a systematic manner. Our findings indicate that there is a high occurrence of student injuries associated with both independent student participation in campus football activities and instructor participation in campus football activities during teaching sessions. Injuries sustained during campus football activities have a direct impact on the development of campus football in China as well as the health and growth of children and adolescents. Therefore,

enhancing the prevention and management of campus football injuries should become a priority for organizing campus football.

First, our results indicate that campus football injuries occur at a rate of 25.7% among 1,285 students in Ningxia, which are relatively higher than those as a result of general PE classes. For example, Ding surveyed 1,300 students in 26 middle schools from Wuxi, China (18). It was discovered that athletic injuries occurred at a rate of 18.1% during PE classes. Likewise, Wu and Zhang (19) surveyed 1,570 students in middle schools in Zhejiang Province. Their findings indicated that students who had sustained athletic injuries during PE classes accounted for 16% of the total. In general, youth football exposes a greater risk of injury than many other sports (9, 20), because the game itself demands a higher level of playing intensity, a greater volume of training, stronger players, heightened competitiveness, and an aggressive playing style. As a result, we recommend designing campus football injury prevention education programs that incorporate practical injury prevention training to children and adolescents, in order to raise awareness about injury risk and minimize injury occurrence.

Second, our results indicate that the risk of injury tends to increase with increasing school grade levels. This is consistent with results from developed football nations indicating age-related disparities in injury patterns. A prospective descriptive epidemiological research of football injuries over two seasons in the Czech Republic and Switzerland found that injury occurrence rose with increasing age among youth players aged 7 to 12 years (21). A recent prospective cohort study conducted at a national youth football academy (U13–U18; age range: 11–18 years) also discovered that injury occurrence was greater among older players and more than doubled between the U13 and U18 age groups (22). Middle- and high-school students' athletic ability has increased with age, and they participate in more intensive physical activities than primary-school students (23, 24), which adds to the higher injury occurrence among middle- and high-school students. It should be noted that injury occurrence could have a lasting impact on the youth growth as well as the promotion of campus football. It was shown that having a history of injury in youth was associated with a higher likelihood of injury (recurrent injury) as children and adolescents grow (25, 26), which could result in youth's increased financial obligations (27) and an earlier end to football participation (11). In light of this characteristic, all segments of society should take appropriate steps to mitigate youth injury in campus football activities.

Third, our results discover that campus football injuries occurred, regardless of whether students participate in football activities alone or with the guidance of teachers. The highest number of injuries happened during football competition, followed by after-school football activities, while the lowest percentage occurred during football class instruction. Due to the intensity of the game and the fierce competition, students are subjected to a greater athletic load and the likelihood of injury increases, particularly when the competition's success or failure is at stake. Thus, it's unsurprising that football competition is the leading cause of campus football injuries, which is consistent with the existing literature demonstrating that injury occurrence is higher during competitions than during practice (28). Because after-school football activities are not supervised and restrained by teachers, students' safety awareness is low, making it simple to undertake risk-taking maneuvers and therefore increasing the likelihood of injury. In contrast, the football class has a united structure and administration of teachers, and the teacher's discipline and monitoring improves students' safety awareness, successfully lowering the injury occurrence. According to these findings, more qualified professionals, such as community-based football coaches capable of supervising after-school football activities, should be available to oversee training sessions and design exercise programs that match the needs, interests, and abilities of youth players.

Fourth, our results suggest a lack of safety awareness and injury prevention education is the primary cause of campus football injuries, and students and teachers alike should improve their safety knowledge and profession training. To our knowledge, injury prevention education in China is primarily delivered through lectures rather than practical training, and it is typically delivered infrequently, for example, once throughout an academic year via a classroom lecture. Proper education and adequate instruction are paramount in athletic injury prevention. As a result, we recommend that all campus football programs in China offer practical and need-based safety training for youth players and teachers in order to raise their safety knowledge. Relevant governing bodies of campus football programs could consider to adopt youth-tailed, proven effective injury prevention programs, such as FIFA "11+ Kids" (29) [note. FIFA 11 is not recommended (30)] and neuromuscular training (31). A nationally implemented injury prevention education program would not only benefit youth health while participating in campus football, but would also be monetarily beneficial to both youth and society (32, 33).

Fifth, our results reveal that that students' current level of first aid knowledge is concerning, with only 18.7% of students knowledgeable with basic first aid and only 11.4% familiar with CPR. The majority of students lack adequate first aid knowledge and skills, which corresponds to findings from other study of children and adolescents in China (34). This is not unrelated to the school's decision to offer first aid training to students and the quality of the training provided. According to a teacher survey, 62.5% of schools do not offer specialized first aid training, a trend that has also been observed in other regions of the world (35). It should be underlined that everyone, even children and adolescents, should be familiar with basic first aid and advanced first aid techniques such as CPR (36), which has been endorsed by the World Health Organization (37). As a result, schools should strengthen the development of first aid training courses, popularize first aid knowledge among students, and essentially require students and teachers to master pertinent first aid skills as a prerequisite to participate in campus football. Age-appropriate CPR teaching for children and adolescents should also be integrated into the school curriculum and relearned on a yearly basis. Recently, the Ministry of Education has decided to include first aid and CPR training in compulsory courses in middle and primary schools in China (38). A comprehensive emergency preparedness could enhance students', teachers', and schools' capability, resilience,

and efficacy in the case of accidents and injuries during campus football activities.

Sixth, our results indicate that there is no clear solution in the event of campus football injuries. Campus football injuries are mostly the result of three distinct bodies of responsibility: students, teachers, and schools. Because sports injury can lead to emergency room visits and hospitalizations, lawful rights, interests, and liability arising from campus football injuries become a challenging legal issue (39, 40). While determination of the legal responsibility for athletic injuries is beyond the scope of the present study, we recommend seeking out third-party entities that would pay the school and its students' losses incurred as a result of athletic injuries. In principle, a commercial sports injury insurance covering school-related accidents could benefit students by easing financial burden imposed by the risk of campus football injuries and negotiating for follow-up care (41, 42).

There are a few limitations in this study. Because there is no national injury surveillance system for campus football, this study investigated epidemiological data using a survey approach. However, due to the retrospective nature of the injury data collection, the results may be skewed by recall bias. We would like to take this opportunity to urge that a national framework be established to monitor campus football injuries. Furthermore, because the study's participants were children and adolescents aged 9 to 18, and because kids in lower school grades had a poorer understanding of different types of injuries, we did not examine the injury severity. Both the occurrence and severity of injuries are critical for developing campus football programs, and hence we urge that future research employ systematic ways to analyze injury severity profiles and more detailed information about injuries from a clinical point of view.

Despite these limitations, we believe that our findings are applicable to youth participants from other regions of China because they were collected from a large student sample size participating in the Ministry of Education certified campus football programs in Ningxia. This is the first systematic investigation on the epidemiology of campus football injuries, and we envision that the findings would be carefully reviewed by schools, sports governing bodies (e.g., the Chinese Football Association), commercial entities, and the Ministry of Education in order to develop evidence-based injury prevention and management strategies that will promote the long-term development of Chinese youth football.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by College of Education, Ningxia University, Yinchuan, China. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

HL, TB, and WJ: conceptualization, methodology, and project administration. HL, SH, TF, and LZ: formal analysis and writing—original draft preparation. TB and WJ: writing—review and editing and funding acquisition. All authors have read and agreed to the published version of the manuscript.

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Equalisation of Children's Various Levels of Physical Activity Using Increased Physical Activity at School Among Ninth Graders

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The purpose of this study was to examine whether 60 min of physical activity implemented during school hours, would have an impact on 15-year-olds' MVPA (moderate to vigorous physical activity) throughout the school day, and what effect it would have on low-, average-, and high- physically-active students. The intervention study included a sample of every 93 students in the ninth grade from a school in Trøndelag, Norway. Data on the students' physical activity levels during schooltime were measured using accelerometers and analyzed using the Actilife program. A significant higher change in MVPA was found in the intervention group compared to the control group, with an average increase of 25 min in MVPA in the pre-test to 42 min in post-test. Further analyses showed that the that both the low-active and the high-active had a significant increase in MVPA, taking the results of the control group into consideration. However, the low-active participants had the largest increase, with a 123% increase in MVPA during schooltime. The implication of the study is that PA interventions in school have the largest percentage effect among the low-active students in the study, which indicates that school-based interventions can be important in bridging social differences in MVPA among adolescents.

Keywords: physical activity, school, children, accelerometer, intervention

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INTRODUCTION

Today's society is characterized by inactivity and sitting still more than before, and physical inactivity has, in a long-term perspective, a negative effect on children and young people, bringing disadvantages from both a public health and a socio-economic perspective (1, 2). The positive effect of physical activity (PA) for children and young people has led, in recent years, to many interventions focusing on raising young people's activity level, and school has been an important arena for such interventions and measures (3).

International (and Norwegian) health recommendations say that children and young people should engage in PA for a minimum of 60 min moderate to hard intensity (MVPA) each day (2, 3). The results from recorded measurement of the PA of Norwegian 6-, 9- and 15-year-olds show clear signs that the level of activity is too low in relation to the recommendation (4–6). Among 15-year-olds, only 40% of the girls and 51% of the boys met the recommended level (4). Studies indicate that the level of adolescents' PA has been relatively stable in recent years, but with a small downturn between 2005 and 2018 (4–6). Longitudinal studies have pointed to a decrease in children's and

young people's activity during their adolescent years (4, 7, 8). On a world basis, it is estimated that more than 80% of young people get insufficient moderate to hard PA (9).

The falling level of PA has, in light of the consequences it brings, led to an increased focus on PA and health promotion work in the western world, with school being seen as a particularly suitable arena for interventions to increase children and young people's activity level (10–12). School's infrastructure is very well suited to trying out such interventions (1, 11, 13), and given that school (as opposed to sport) is a place where all children can be reached, it is particularly well-suited, in terms of adolescents' level of PA, to leveling out social disparities. A central and underlying aim of Norwegian education policy is that school should have a leveling effect on society: it is about reducing the differences and inequalities between the various classes in society (14). Social leveling means that the possibility of succeeding will be the same irrespective of one's family background. In this way, school will not necessarily create equal students, but rather give all students an equal opportunity for both learning and development. Several studies have seen a positive correlation between socio-economic status, and children and young people's level of activity (15–17). By using school as an arena for intervention to raise the level of PA among children and young people, all children are reached, and their socio-economic status does not need to be a crucial factor (11). Another important, positive factor of school-based interventions is that the total time spent at school is continuous over a long period, which is relevant and importance when an intervention takes place (18). Trudeau and Shepars (19) see school as an important arena for achieving greater PA in line with the recommendations and argue that incorporating PA into the theoretical subjects does not adversely affect academic performance.

The USA is one of the countries with a clear recommendation in relation to school's accountability in relation to children's total PA. The recommendation is that school take responsibility for activating the children for 30 of the recommended minutes of activity (20). In Norway, on the other hand, there is, for the moment, no comparable recommendation regarding school's responsibility, but in 2017 a proposal, which received majority assent, was put before parliament in which the proposers referred to a minimum of 1 h PA each day for everyone in grades 1–10. The proposal read as follows: "Parliament begs the government to introduce a measure guaranteeing pupils in grades 1–10 at least an hour's PA each day and within the school timetable, and that this be funded as a public health measure." (21). The proposers used as a basis the well-documented connection between health and PA, with the activity level in Norway being considered to be low, as with other Western countries. The call was that the hour be planned, adapted and led by a competent teacher (21).

Many intervention studies have been conducted with the intention of increasing knowledge about PA. Most have been directed toward adults and children, while studies aimed at adolescents are largely absent (1). This is paradoxical when one considers that it is precisely in adolescence that PA falls away (often related to "drop-out" from organized sport), and that it is during this period that most people form habits that they often maintain throughout the rest of their life. Kristiansen et al. (22) found that schooltime for 12–13-year-olds accounted for 31 and 26% respectively of boys' and girls' total weekly MVPA, with a mean of 13 minutes MVPA. Andersen (23) found a mean MVPA of 19 min during schooltime. It is very important that the least active increase their activity.

A number of intervention studies into increased PA in school have been conducted. In Active Smarter Kids, 60 min a day of teacher-led PA was implemented. The effect, which was measured as aerobic endurance, proved to be considerable, leading to the school management continuing to use the model (24). The effect of such interventions has, however, shown itself to be variable, which may be a result of methodology and strategies during the period of intervention (24–26). Resaland et al. (24) have, in addition to sound planning and organization, pointed to communication, supervision and teacher training as important factors in the eventual success of an intervention. Tillaar et al. (26) mention lack of significant follow-up, procedures and organization as being possible reasons for lack of effect. Inchley et al. (27) argue that the implementation of PA in schools should receive greater recognition to achieve the desired changes. School management, parents and teachers should be both motivated and engaged in implementing, preferably over a longer time, the measure designed to raise the pupils' level of activity (28, 29).

On the basis of the above discussion, this study will look closely at the effect of an intervention intended to implement 60 min of PA every day during schooltime. The research question is as follows: What effect will the implementation of 60 min PA, as a part of school's academic curriculum, have on 15-year-olds' MVPA in schooltime, and to what extent will such an intervention even out differences among students with different activity levels?

METHODS

The study uses data from a larger study concerning the introduction of daily PA in middle school, and where, also, pupils' activity levels were measured by accelerometer. These measurements took the form of a pre-test and a re-test. In advance of the project, approval was granted by the Norwegian Centre for Research Data for data collection to be carried out. Both pupils and teachers gave their assent to participation in the study, and the pupils and their parents gave written consent.

Participants

The participants in the study came from a middle school, chosen by means of a stratified selection, in Trøndelag county. The school had four 9th grade classes, consisting of 93 pupils (14 years of age) and, in all, 12 teachers. 91 pupils had valid accelerometer data. One of the four classes was randomly selected as a control group ($N = 21$, 12 girls and 9 boys). This class was used as a control group throughout the entire project. The other three classes carried out the intervention and became an intervention group ($N = 70$, 38 girls and 32 boys).

Procedures

Ahead of pre-testing, all the pupils received instruction from the project leader (one of the authors) in the use of the activity

meter. The training included guidance on where it should be placed, when it should be on, and they were able to try out for themselves how to attach and place it. This was done to ensure correct use of the equipment. Pre-testing was carried out during a 2-week period (10 teaching days), during which both the control group and the intervention group received their normal teaching with their 12 teachers. Re-testing was carried out during a 2-week intervention period (10 teaching days), during which the intervention group was offered a teaching programme aimed at 60 min of PA each day, while the control group had their normal teaching. The measures that were implemented in everyday school life were PA used as a teaching method within traditional academic subjects, such as languages and mathematics. During the intervention period, the 12 teachers were to implement PA as part of the academic content of their teaching using a strategy called physical active learning (PAL), which falls under what is known as "movement integration" (30), implying that PA is implemented in regular teaching hours, in the classroom or elsewhere (31). Research related to "movement integration" has led to positive results related to increasing children's MVPA at school (12, 32, 33). During this intervention period, more time was given to PA by reallocating time within other subjects. Sixty minutes of PA were carried out each day, the sessions being at class level, and led by the same 12 teachers as in the control period. The strategy involves PA being incorporated into the normal lessons, in the classroom or elsewhere (31). The subjects involved was Norwegian, Mathematics, Science, Social Science, Arts, English and Christianity. The sessions were at class level, and teacher led. The teaching plan was put together and discussed jointly, with guidance from one of the authors. The emphasis during this period was active learning, with the teacher using PA as a way of communicating the material in the theory lesson.

Data Collection

Level of PA was measured using Actigraph GT1M (ActiGraph LLC, Pensacola, FL, USA) accelerometers. ActiGraph is known to be highly effective, and is widely recognized in studies related to PA (34, 35). Migueles et al. (36) show that more than 50% of all published articles of PA have used Actigraph in their studies to acquire objective measures of PA.

On initialization, an EPOCH-length of 60 s was chosen. This little meter records the student's PA (13). The same type of accelerometer, as well as procedures used in this study, were deployed in line with procedures from the largest population studies done on measurements of children and adolescents' degree of activity (4, 6). All movement to which it is exposed is registered, and all activity outside normal human movement filtered out (6). The activity monitor registers acceleration, which is converted into digital signals, known as "counts". These counts describe the level of acceleration that the accelerometer itself was subject to. A low level of counts per minute indicates a low average level of activity, while a large number of counts per minute indicates a high average level of activity. These counts are recorded continuously and saved at a pre-set time interval (epoch). This time interval is usually between 5 and 60 s (37). The limit value used in the analysis of moderate intensity was set, in this study, at 2000 counts, in line with other, large Norwegian surveys (6). In this way, activity during schooltime can be isolated, so that the actual activity level of the participants at different points in the school day was measured. This can contribute to a clearer picture of children and adolescent's level of activity in schooltime, break periods and physical education (38).

According to the protocol, each individual pupil should have had the accelerometer on them for two consecutive weeks (10 school days), in two periods. In line with the procedure (6), the pupils placed their accelerometer on their right hip each morning as school started and took it off at the end of the school day. School activity was isolated, so that the actual activity level of the students was measured. The teachers, throughout the project, were responsible for handing out and collecting in the accelerometers. The teachers had their own suitcases, which were marked each with their own number for each student. In this way, errors were avoided, in which, for example, the wrong tape was delivered to the wrong person. Training in the use of the accelerometers was introduced in advance of the intervention period, to ensure that the equipment was used correctly. The project leader was present during this period and during the first 2 days of the control period. This approach increases reliability. After the 14 days (10 school days), the accelerometers were collected in, and the data downloaded in the program Actilife, and analyzed. The same procedure was repeated after the 2 weeks of the intervention period.

Statistical Analyses

On the basis of the pre-test measurements from the control period, the pupils were categorized into three groups based on the MVPA values; low-active: 0–20 min, medium-active: 20.01–30 min and high-active: 30.01–50 min. The statistical analyses performed were made using the statistical program SPSS version IBM SPSS 27. The descriptive statistics used in this study are presented as average and standard deviance (SD). To evaluate the difference in size of the changes between the control and intervention groups (post-test minus pre-test), independent *t*-tests were used, and to explore the changes between pre- and post-tests, paired sample t-tests were used. The statistical significance was set at <0.05.

RESULTS

Effect on MVPA of the Introduction of 60 min PA

In **Figure 1**, the daily contribution of MVPA during school time (minutes) is presented for the control group and the intervention group, tested by both pre-test and post-test of the pupils. The results show that the control group reached 23 min MVPA during the school day at pre-test, and 30 min at post-test. This is an increase of 30%. In the intervention group's case, they reached an average of 25 min at pre-test, but post-test showed an average of 42 min, a 66% increase. The Figure shows that the increase from pre-test to post-test was significant for both the control group ($t = -4.2$, $p < 0.05$) and the intervention group (t 0–16.8, $p < 0.05$), but the intervention group had a significantly higher increase than the control group in this period ($t = -4.2$, <0.05).

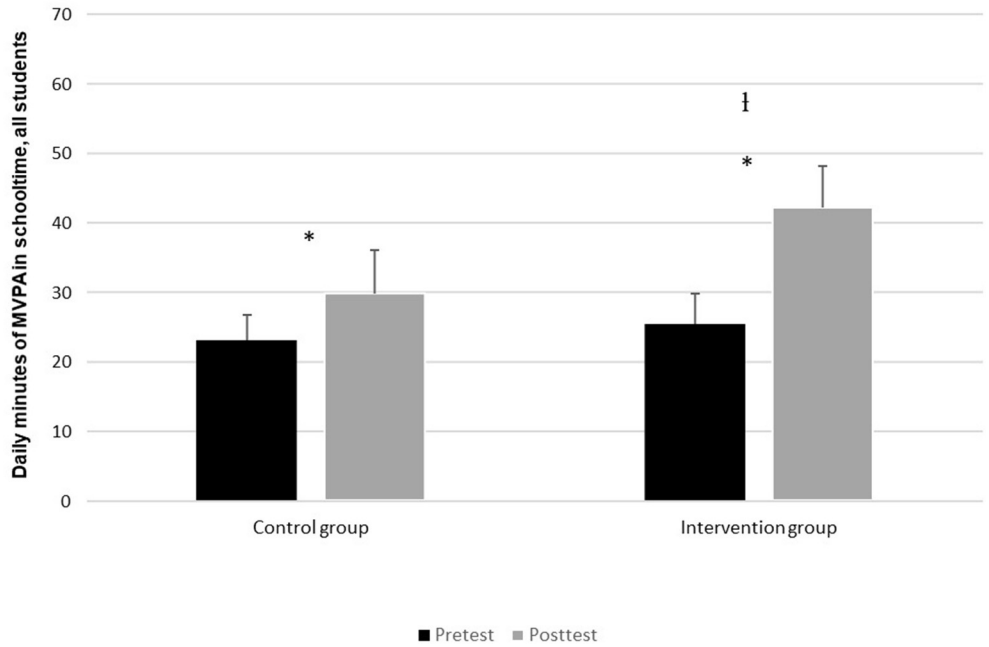

FIGURE 1 | Average daily contribution of MVPA (min) in school time at pre-test and post-test. *Indicates a significant difference ($p < 0.05$) between pre-test and post-test in daily MVPA in school time. [I]Indicates a significant difference ($p < 0.05$) in MVPA development between the control group and the intervention group.

Changes in MVPA for the Low-, Middle and High-Active

Figure 2 shows that the average MVPA per day in schooltime among the low-active in the intervention group is significantly higher in the post-test than in the pre-test ($t = -15.9, p = <0.05$). The percentage change here is 123% based on the results from the pre-test which showed an average of 14 min, and a post-test average of 32 min. In the control group there is also significant change from pre-test to post-test ($t = -4.6, <0.05$). The pre-test showed an average of 15 min, giving a percentage-wise change of 31%. The change in the intervention group is, however, significantly greater than the control group ($t = -7.9, p < 0.05$).

In **Figure 3**, one also finds a significant increase among pupils in the intervention group categorized as medium-active ($t = -10.3$, $p < 0.05$), with a 67% increase from the pre-test average measurement of 24 min and the post-test measure of 40 min. There was also a significant difference in the control group ($t = -4.2$, $p < 0.05$). The pre-test in this group showed an average of 26 min, while the post-test showed 40 min, amounting to a difference of 56%. There was however no significant difference between the change in the control group and the intervention group ($t = -0.4, p = 0.07$).

Figure 4, like the other figures, shows a significant increase in the intervention group from pre-test to post-test ($t = -7$, $p = <0.05$), with a percentage increase of 44% from pre-test to post-test. In the control group, however, there was no significant difference between pre-test and post-test ($t = -1, p = 0.391$).

DISCUSSION

Effect on MVPA of Implementation of 60 min PA in School

The results have shown that 2 weeks with daily implementation of 60 min PA in different academic subjects led to a significant increase in the pupils' PA, where the intervention group had a significantly higher change in PA compared to the control group. The total percentage increase was 66% from pre-test to post-test in total MVPA for the intervention group, compared to the control group where the increase pre-test to post-test was 30%. As with Larsen et al. (39), the intervention appears to have been successful in our study. Larsen et al. emphasize that the pupils in their study had an extremely positive experience from the combination of academic studies and PA, finding this a highly motivating and stimulating combination. Our findings support earlier studies which have shown school to be an arena well-suited to testing different implementations (10–12, 20).

At the time of writing, it is 5 years since a majority in Parliament supported a proposal that all children have the opportunity to have 1 h PA at school (21), but the measure has still not come into effect on account of, among other matters, a lack of research, together with questions concerning its cost. This research, in common with that done earlier into children and young people's PA in school (24) is indicates strongly that the initiative has a positive effect on pupils. Research has shown that PA among children and young people affects their social life and represents an important prerequisite for them being able to master both school and life in general (40). Against this background, there is reason to think of the time spent at school as

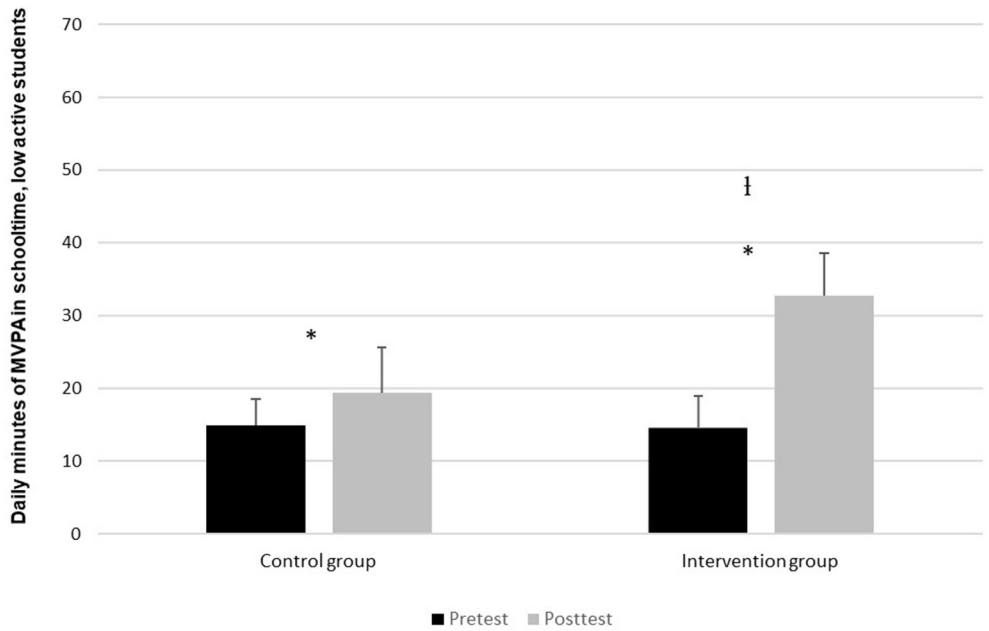

FIGURE 2 | Daily contribution of MVPA in schooltime for pupils in the low-activity group, divided between pre-test and post-test. *Indicates a significant difference ($p < 0.05$) between pre-test and post-test in the daily MVPA during schooltime. [I]ndicates a significant difference ($p < 0.05$) in MVPA development between the control group and the intervention group.

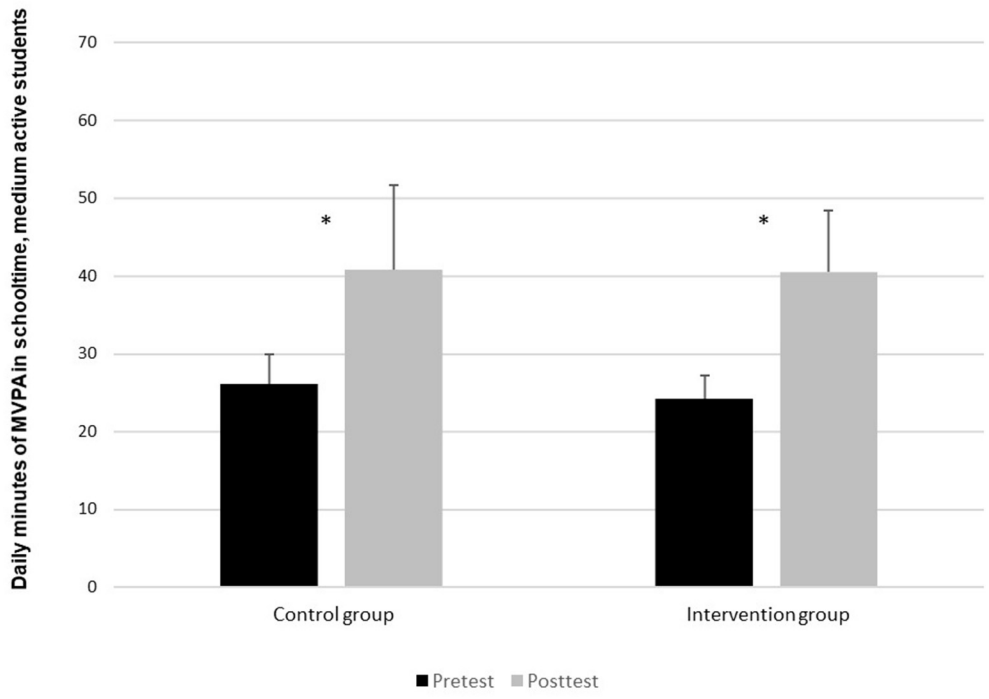

FIGURE 3 | Daily contribution of MVPA in schooltime for pupils in the medium-active group, divided between pre-test and post-test. *Indicates a significant difference ($p < 0.05$) between pre-test and post-test in daily MVPA in schooltime.

being especially important for children and adolescents as it gives them the possibility of learning good lifelong habits regarding PA, which, in that way, represents a good long-term investment. And, when it comes to finance, there is also good reason to believe that inactivity will carry a greater cost in the long run. The positive results from this study also reinforce the previously mentioned

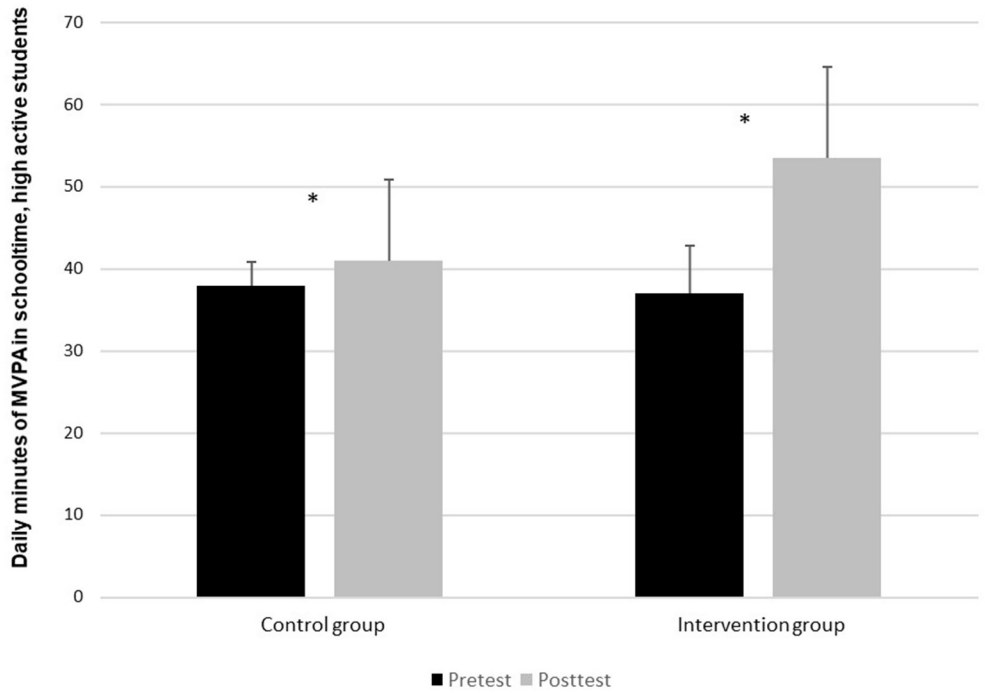

FIGURE 4 | Daily contribution of MVPA in schooltime for pupils in the high-active group, pre-test and post-test.*Indicates a significant difference ($p < 0.05$) between pre-test and post-test in the daily MVPA in schooltime of the intervention group.

research indicating that implementation of PA in schools ought to be given greater recognition in respect of achieving the desired change (27). An implementation making use of school as an implementation arena can offer pupils a safe environment and mean that all pupils, regardless of differences in motivation for PA, can readily take part (13).

The findings of this study show from the pre-test an average of 25 min of MVPA achieved in school time across all the pupils participating in the study (control group and intervention group). This is somewhat more than in an earlier study of Norwegian 15-year-olds (23), which found an average of 19 min MVPA in schooltime. Kristiansen (22) found an average of 14 min MVPA in schooltime among 12–13-year-olds. These studies included relatively many students from quite many schools. It can appear, therefore, that the school chosen in our study, is a school with relatively physically active pupils.

Against the background of a large percentage of children and adolescents in Norway not fulfilling the recommended healthy level of 60 min of PA per day, the findings in this project can give a clear indication that raising the level of activity at school will also raise children's MVPA level, which is highly desirable from a health perspective. This in the hope of satisfying the health recommendations to a greater extent than previous research has shown young people to be doing at present (4–6). If the recommended American level of 30 min MVPA during schooltime (41), was linked to the results following the intervention in our study, all the pupils would, on average, have attained this level. The results indicate, nonetheless, that despite such an implementation, there will still be some pupils who will fall short of the recommended level of PA. Our findings suggest that school isn't able to assume full responsibility for their pupils' MVPA, and that other things such as sport, leisure activities and, not least, parents and carers, are important in respect of contributing to young people's PA.

Equalization of Difference in Activity Level Through the Implementation of 60 min PA

The results show the clear positive effect of the intervention, particularly among low-active pupils. The results showed that the low-active in the intervention group had an increase in minutes of MVPA of 123% between pre-test and post-test. The medium-active members of the intervention group had an increase in minutes of MVPA of 67%, while the high-active members of the intervention group had an increase in minutes of MVPA of 44%. There were also significant changes for the low-active and medium-active in the control group. The changes were, however, significantly greater in the intervention group than in the control group. Among the high-active, there was no significant change in the control group, only in the intervention group. From these findings, one can claim that both the low-active and the high-active profit from the intervention, but that the intervention has the greatest effect among the low-active pupils. There are therefore grounds to say that such strategies have a positive effect in equalizing differences in activity level among the pupils. This is beneficial given that research has shown that children from families with low socio-economic status have a lower level of activity (17, 42), and pointed to school as a suitable arena for equalizing differences in PA (5).

Our results have shown that there are big differences among pupils in activity level in schooltime, but that school can succeed in evening these out. By using school as an intervention arena, one is able to reach all the children, irrespective of social inequalities, and contribute, thereby, to reducing these inequalities (43, 44). Using school as an arena for PA interventions ensures that all children have the possibility of PA to a much greater extent than do similar measures involving, for example, sport. Our findings appear to show school to be a highly suitable arena for leveling out differences in MVPA among the pupils. This is in agreement with earlier research (45, 46). These findings suggest there may, therefore, also be grounds for seeing school as a particularly suitable arena for equalizing social inequality in health. Increased PA in schooltime will also, according to Bastian et al. (47), affect the activity level of pupils in their leisure time, which is, again, an important factor in leveling out social inequalities in health in the longer term. This is because school-based interventions, through facilitation and structural measures, also had a positive effect on the activity level of children and young people in leisure time.

Looking at it critically, one can argue that even though the increases in MVPA are large with such an intervention—especially among students in the low-activity group, one is still not reaching the target set by the health recommendation of 60 min daily MVPA (4). At least not if one looks only at the figures for schooltime. For the high-active, we find an average of 54 min MVPA, which should be seen and interpreted as almost achieving the goal set by the health recommendations, The pupils categorized as medium-active achieved an average of 41 min MVPA, while the low-active came out with an average of 33 min MVPA. Previous research has shown that those students who are not so physically active during school time have problems in "catching up" with those who are sufficiently active in their free time, and, in this way, it becomes difficult both to establish good activity habits, and to provide good coping experiences for these children (48).

Strengths and Weakness of the Study

A very high participant adherence of 98% and 91 students who used the accelerometer for 20 schooldays, can be thought of as a strength. The use of a control group in the intervention as was done here, represents a strength in comparison to studies not using one (13, 49).

An epoch length of 60 s was chosen at the initialization of this study. There is room for discussion as to whether this is a strength or a weakness, but on the basis of previous research it is difficult to either disprove or confirm a "correct" formula. It can be seen as beneficial to have a storage interval of 10 s for children and adolescents due to a sporadic activity level (6, 50), while several studies of adults have used an epoch length of 60 s (51, 52). A Norwegian study of nursery children nonetheless used an epoch length of 60 s (53). There is a considerable difference in activity-rhythm between 6-year-old children and 15-year-olds who have a much less sporadic rhythm, closer to that of adults. On that basis, the choice of an epoch length of 60 s can still very likely be appropriate.

The study also has certain weaknesses. It would have been advantageous to have had more schools in the study, to have had an even larger sample that would have given greater reliability to the study (54). Random sampling would have been more representative, making it easier to generalize the results. Another potential weakness of the method used in this study can be the accelerometers and their limited ability to not register non-ambulatory activities such as climbing, cycling and strength-training (55–59). This may lead to certain activities being overlooked as they are not recorded accurately (37, 56, 58). Also, a further weakness of the accelerometers is that they cannot be in contact with water, leading to swimming not being registered. In the case of this study, neither swimming, nor cycling or strength-training were a part of schooltime during this study. Finally, the inequality of the groups and the small control group is a weakness of the study.

CONCLUSION

The results of this study show that the implementation of 60 min PA in schooltime, raises the pupils' MVPA by 68%. This gives a clear indication that school is both an effective and important arena for interventions aimed at increasing children and adolescent's PA. Further, this study finds that implementation of 60 min of PA in schooltime has a positive effect in equalizing differences in activity level among children during schooltime. In the study, we found that it is low-active children who gain the most, relatively, from such an intervention. For this reason, we argue that school is not only an important societal mandate when it comes to equalizing differences in activity in school, but also seems to be a good arena for leveling out the large differences in PA level among children and young people. This is because school, unlike sport, reaches all children, and, not least, that PA interventions like this are found to equalize differences in adolescents' PA levels. Further research should include a larger number of young people, using randomized selection supplemented by qualitative interviews and questionnaires gathering in the pupils' and teachers' reflections concerning PS interventions in school.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Norwegian Centre for Research Data. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

HH has written most of the article, especially the introduction, discussion, and conclusion. SL has participated in the design

and data collection and has also participated in some of the writing. PL has participated in the design, data collection, analyses of the data, writing the results, has also participated in some of the writing of the introduction, discussion, and conclusion. All authors contributed to the article and approved the submitted version.

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Relationship Among Motor Behavior, Motor Development, and Motor Performance in Children Aged 7–8 Years in China

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For children aged 7–8 years in China, "immobility" is a key problem hindering their physical and mental development in recent years. It is widely accepted that motor performance development in children is accompanied by physical and mental growth and development. However, few studies have clarified the relationship among motor behavior, motor development and motor performance. To bridge this knowledge gap, an empirical analysis of children aged 7–8 years in China was conducted. This study developed scales for testing motor performance, motor behavior and motor performance, respectively, and collected data of these tests on children aged 7–8 years in China. Canonical correlation analysis was used to analyze the correlations among motor performance, motor behavior and motor performance, and partial least squares regression was used to evaluate the relationship between dependent and independent variables. It was found that, for the children aged 7–8 years in China, there were significant positive correlations among the motor performance, motor behavior, and motor development. The three tests were closely related and could be applied to promote children's sports performance through improved training activities for targeting specific indicators. The study found there was no significant differences in the application of the three tests for children with different age and gender. This finding lays a foundation for further testing in older children and meets the measurement requirements of modern medicine's "bio-psycho-social model of health promotion". Additionally, the theoretical motional quotient model of "The Bio-Behavior-Task" is constructed as a comprehensive motor performance evaluation system, aligning with students' physical and mental development standards.

Keywords: motor behavior, motor development, motor performance, physical activity, health, motional quotient

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INTRODUCTION

Physical inactivity and sedentary behavior issues are increasing in modern society, carrying health risks for humans, i.e., disease, disability, and even death (1). In childhood, this poor lifestyle manifests as a lack of exercise ability, insufficient physical activity, increased risk during exercise behavior, stiff and weak movement, motor retardation, a high obesity rate, poor social adaptation, and even cardiovascular-related diseases, etc. (2, 3). For Chinese children aged 7–8 years, "immobility" is also a key problem affecting their physical and mental health development.

Only 8.9% of children and adolescents engage in 1 h of high-intensity physical exercise more than three times a week. According to the eight Reports on the Physical Fitness and Health Research of Chinese School Students from 1985 to 2019, the living standards have improved significantly, while the physical health conditions in children have not increased as expected. What's worse, the physical fitness level specific to endurance, strength, and speed have continued to decline (4). For promoting the physical health conditions, Chinese government has implemented annual physical health test for children students. However, the uniformly-used national standard for students' physical health test ignores the concepts of individual development, environmental impact, experience acquisition and sports development, rendering it impossible to formulate educational and practical programs based on the test. Thus, developing the scales for testing motor behavior, motor development, and motor performance, respectively, and clarifying their relationships is highly needed for the children's physical health test.

Along with the motor development, the structure and function of human tissues and organs change over time, which directly leads to changes in motor performance (5–7). Accordingly, the physical education in China has emphasized being "in line with the law of students' physical and mental development", while the understanding of this developmental relationship is still in the preliminary exploration and empirical speculation stage. Additionally, with the goal of promoting the children's physical health, previous studies have focused on children's physical activity, physical fitness, motor performance, physical literacy, sports intelligence, sports behavior, movement development, fitness exercise, behavioral risk, physical fitness monitoring, and health promotion (8–17). For example, Phillip (14) and David (15) found that regular physical activity was an important factor for promoting health at any age (18, 19). Newell (5) proposed an action development model for "how individuals, environment and action tasks interact" based on social ecology. However, most of these studies ignore the effect of environment and task on evaluating physical activities and behaviors of an individual (20). Namely, few studies clarified the relationship among motor behavior, motor development, and motor performance.

To bridge the aforementioned research gaps, this study aims to explore the relationship among motor performance, motor behavior and motor development, and facilitate their cooperative development for children. Targeting at the children aged 7–8 years, we firstly developed the scales for testing the children's motor behavior, motor development, and motor performance, respectively, on basis of the requirements for health promotion education and environmental support conducive to health change. After collecting the test data, we analyzed the results of surveyed children's motor performance, motor behavior and motor development, and constructed the comparative analysis in consideration of the variance in children's age and gender. Finally, this study further discussed several specific findings in relation to correlation analysis, impact relationship analysis, and the development of the Motional Quotient scale as well as its theoretical model.

MATERIALS AND METHODS

Sample Design and Selection

After the literature review and policy analysis on the existing physical health tests, this study conducted an expert interview to develop the scales for testing the children's motor performance, motor behavior and motor development. Twelve experts (three researchers with more than 3 years' professional experience in the field of physical health and behavior development, three researchers with more than 5 years' professional experience in the field of children psychology, three researchers with more than 3 years' professional experience in the field of behavior development, and three experts with more than 5 years' working experience in motor development) were invited to be interviewed together *via* the on-line meeting. Each interviewed expert will be asked several open questions, such as "please show your opinion about the relationship between the children's motor performance and their physical and mental growth and development," "please explain your opinion in detail," "please show your opinion about our primarily selected items for testing the motor performance, motor behavior, and motor development," and "please list the concerns during the test". Notably, during the interview, we firstly provided the list of the primarily selected test items regarding the motor performance, motor behavior, and motor development, which we have selected *via* systematic literature review and policy analysis. All the experts confirmed the relationship between the children's motor performance and their physical and mental growth and development, and they finally achieved consistence for the scales of testing motor performance, motor behavior, and motor development through discussion. That is, the initial three test scales were developed.

Based on the preliminarily determined test scales, we provided a series of supporting files to the testers and testees, including test manual, test demonstration video, and scale recording form. Notably, these supporting files were confirmed by the invited 12 experts. Prior to the test, we performed the unified training for the testers regarding the test methods. During the test, the tester first presented one-time correct demonstration for each tested item, and then the testee practiced one time. Each testee performed the formal test one time for each tested item, and the testers recorded the test results. The formal test period was March 2018 to September 2020.

For performing the pretest, 10 boys and 10 girls in each age group (aged 7 and 8 years) were randomly selected in Jiangsu, China, for conducting the pretest. According to the pre-test results and the testees' feedback, the test scales for each dimension, i.e., motor performance, motor behavior, and motor development, were revised appropriately.

For performing the formal test, a total of 400 children testees aged 7–8 years were randomly selected from 4 provinces (cities) in China (Jiangsu, Shanghai, Zhejiang, and Shandong). There were 100 boys and 100 girls in the testee group of aged 7 years and aged 8 years, respectively.

TABLE 1 | Motor performance scale.

No.	Item	Unit	No.	Item	Unit
x1	Height	cm	x5	Rope skipping (1 min)	count
x2	Weight	kg	x6	Sitting body flexion	cm
x3	Turn back run (2 * 30 m)	s	x7	Throw solid ball in place (1 kg)	m
x4	Plate support	s	x8	Reverse run (20 meters)	s

TABLE 2 | Motor behavior scale.

No.	Item	No.	Item
y11	Average daily steps over 28 days	y21	Effective strategies are used in sports
y12	Number per week of medium and high intensity exercise sessions of more than 1 h	y22	Moderate activities strengthen the will and regulate sleep
y13	Number per week of interactive activities of more than 20 min	y23	Recognize that you have shortcomings in sports
y14	More than 10 min of action/skill learning per week	y24	Exercise only under the influence of partners, and do not take the individual initiative to exercise
y15	Skill at 1–2 sports to meet individual needs	y25	Ability to concentrate on activities
y16	People who feel that they are good at sports are popular	y26	Examples of health knowledge
y17	Fear of injury in sports games	y27	Understanding of physical activity
y18	Sports games are more interesting than computers (mobile phones, TV)	y28	Understanding of actions/skills
y19	You can learn movements more easily	y29	Understanding of activity time and environment
y20	Cannot improve the exercise level in the necessary time	y30	Understanding of body posture

The item y17, y20, and y24 were reverse items with Five-Likert scale.

Variables and Rating Scale

Motor Performance

It refers to the ability of an individual to perform a physical motor skill, which comprehensively representing the individual body shape, physical function, and physical qualities. Following the National Standard for Students' Physical Health (21), FITNESSGRAM (22), and ACSM (American College of Sports Medicine) guidelines for exercise testing and prescription (23), several test items relating to BMI, speed, strength, endurance, flexibility, sensitivity and balance were selected to represent the motor performance dimension. All these test items were summarized in **Table 1**.

Motor Behavior

It's aim is to explore the environmental interaction experience of the individuals when they participated in sports, including the measures of motor behavior, motor motivation, sports performance, and sports cognition. Based on the systematic review of the IPAQ (International Physical Activity Questionnaire) (24, 25), AHKC (Active Healthy Kids Canada) (26); internal motivation questionnaire, motor behavior scales, motor motivation scales; sports situational motivation scales, exercise attitude scales, tennis performance evaluation scales, sports performance strategy scales, athlete stress scale (27), and CAPL (Canadian Assessment of Physical Literature) (12), this study developed the motor behavior scales relating to daily exercise behavior (28), motivation and the psychological experience of participating in sports, psychological skills and applied strategies in sports, and basic knowledge and understanding of sports literacy. All these test items were summarized in **Table 2**. Notably, the motor behavior test was conducted through question-and-answer format.

Motor Development

It is used to test the ability of individuals to complete motor tasks. Through developmental evaluation, such as motor development tests, motor skill improvement and motor function evaluation during individual development (29), we can scientifically understand the relation of motor development to the physical and mental growth and development of Chinese children. With reference to the PMDS (Peabody Motor Development Scale) (30), and TGMD (Testing of Big Muscle Group Development) (31), the test items of motor development include posture, operation, hand-eye coordination, and reaction (32–34). In specific, the posture (Item z31), being widely-used by NASM (National Academy of Sports Medicine, USA), is a classic action for evaluating dynamic posture, with which the dynamic flexibility and muscle control are assessed. The operation (Item z32) include tapping, catching, kicking, throwing and dribbling, aiming to testing the gross movement development. The hand-eye coordination (Item z33) includes swinging, rotating, bouncing, catching, and throwing for testing the fine movement development. According to the characteristics of children's periodically development, we developed the test items in relation to imitation, specific skills static control, and dynamic scenes. Specifically, behavior (Item z34) is the performance of life experience acquisition, specific skills (z35) involve changes in physical education and learning, the squat control (z36) is the

effect of fitness and training, and dynamic scenario (z37) is the intelligent level of action processing. The reaction actions (Item z38) consists of walking on a balance beam, stepping on a five-pointed star, crawling in all directions and rotating in place to test the abilities of movement, climbing and balance. The detailed action procedure and scoring criteria for each item of the motor development scales are provided in **Appendix 1**, and the corresponding schematic figures are provided in **Appendix 2**.

Statistical Analyses

The collected data were analyzed by SPSS 28.0. The significance level of the hypothesis test using a two-sided test was 0.05. Canonical correlation analysis was used to analyze correlations, and the Spearman correlation coefficient was used to evaluate the possible correlations among the dimensions of motor performance, motor behavior, and motor development. Partial least squares regression was used to evaluate the relationships between dependent and independent variables.

RESULTS

Test Results

The mean ± standard deviation for each tested item (x1-x8, y11-y30, and z31-z38) regarding the motor performance, motor behavior, and motor development of the children with different age and gender are shown in **Table 3**.

Canonical Correlation Analysis

Table 4 and **Figure 1** show the results of the canonical correlation analysis of motor performance and motor behavior tests. The results show that a total of 8 typical variables are extracted. The *F*-test indicates that the first pair of typical variables are significant at the 0.01 level with a correlation coefficient of $0.557 > 0.5$, which is a very high value. There is a close positive correlation between the first pair of typical variables (U_{11} represents the first typical variable of motor performance, and V_{11} represents the first typical variable of motor behavior). Focusing on the intragroup difference analysis of the typical variables U_{11} and V_{11}, the load coefficients of x3 and x5 for typical variable U_{11} and Group X are 0.791 (absolute value) and 0.704, indicating a strong relationship; that is, typical variables extract more information from x3 and x5. The load coefficients of y13 and y16 for typical variable V_{11} and Group Y are 0.416 and 0.482 (absolute value), indicating a strong relationship; that is, typical variables extract more information from y13 and y16. Therefore, the main factors of motor performance, i.e., turning back and running (x3) and rope skipping (x5), are closely related to the main factors of motor behavior, i.e., "the number per week of interactive activities of more than 20 min" (y13) and "the people who feel that they are good at sports are popular" (y16). There is a very close positive correlation between motor performance (Group X) and motor behavior (Group Y).

Table 5 and **Figure 2** show the results of the canonical correlation analysis of motor performance and motor development tests. The results show that a total of 8 typical variables are extracted. The *F*-test shows that the first pair of typical variables is significant at the 0.05 level with a correlation coefficient of $0.459 > 0.3$, which is a high value. There is a close positive correlation between the first pair of typical variables (U_{21} represents the first typical variable of motor performance, and V_{21} represents the first typical variable of motor development). Focusing on the intragroup difference analysis of typical variables U_{21} and $V_{21,}$ the x5 and x7 load coefficients of typical variable U_{21} and Group X are 0.756 and 0.829, indicating a strong correlation, that is, typical variables extract more information from x5 and x7. The load coefficients of z35 and z38 of typical variable V_{21} and Group Z are 0.628 and 0.945 (absolute value), indicating a strong correlation, that is, typical variables extract more information from z35 and z38. Therefore, the main factors of motor performance, i.e., rope skipping (x5) and throw solid ball in place (x7), are closely related to specific skills (z35) and reactions (z38). Namely, there is a very close positive correlation between motor performance (Group X) and motor development (Group Z).

Table 6 and **Figure 3** show the results of the canonical correlation analysis of motor behavior and motor development tests. The results indicate that a total of 8 typical variables are extracted. The *F*-test finds that the first pair of typical variables is significant at the 0.05 level with a correlation coefficient of $0.507 > 0.5$, which is high. There is a close positive correlation between the first pair of typical variables (U_{31} represents the first typical variable of motor behavior, and V_{31} represents the first typical variable of motor development). Focusing on the intragroup difference analysis of typical variables U_{31} and V_{31}, the y13 load coefficient of typical variable U_{31} and Group Y is 0.489, indicating a strong relationship, that is, typical variables extract more information from y13. The load coefficients of z33 and z35 of typical variable V_{31} and Group Z are 0.771 and 0.616, indicating a strong relationship, that is, typical variables extract more information from z33 and z35. Therefore, the number per week of interactive activities of more than 20 min (y13) in motor behavior is closely related to the main factors of motor development, i.e., hand-eye coordination (z33) and specific skills (z35). Namely, there is a very close positive correlation between motor performance (Group Y) and motor development (Group Z).

Partial Least Squares Regression Analysis of the Tests for Participants With Different Age and Gender

Figures 4, **5** show the results of the partial least squares regression analysis of the motor behavior and motor performance tests. The results show that the environmental interaction experience of a 7-year-old boy, 7-year-old girl, 8-year-old boy, and 8-year-old girl participating in sports, namely, motor behavior, has a relatively high ability to cumulatively explain motor performance. The explained cumulative variance (R-square) values are 0.852, 0.889, 0.893, and 0.925, respectively, and the adjusted R-square values are 0.750, 0.812, 0.819, and 0.872, respectively. According to the cross-validity analysis, when the Qh^2 value is >0.0975, the best principal component is one. In this analysis, the most significant indicator of 7-year-old boys' motor performance is y17, followed by y24, y22, y11, y23, and y30. The most significant indicator

TABLE 3 | Test results categorized by the age and gender.

No.	Item	7 years old		8 years old	
		Boys ($n = 100$) Mean ± SD	Girls ($n = 100$) Mean ± SD	Boys ($n = 100$) Mean ± SD	Girls ($n = 100$) Mean ± SD
x1	Height	125.56 ± 4.93	123.17 ± 5.12	131.27 ± 4.76	129.46 ± 6.04
x2	Weight	25.72 ± 5.12	24.36 ± 5.85	30.68 ± 7.12	26.90 ± 5.95
x3	Turn back run (2 * 30 m)	15.79 ± 1.39	16.49 ± 1.48	14.80 ± 0.89	15.61 ± 1.12
x4	Plate support	19.12 ± 10.92	9.92 ± 5.29	27.52 ± 13.33	29.76 ± 13.81
x5	Rope skipping (1 min)	17.18 ± 16.12	9.48 ± 9.28	53.24 ± 32.15	60.38 ± 31.63
x6	Sitting body flexion	7.86 ± 3.68	10.86 ± 4.26	7.59 ± 3.45	11.50 ± 3.92
x7	Throw solid ball in place (1 kg)	2.35 ± 0.63	1.74 ± 0.55	3.15 ± 0.59	2.26 ± 0.57
x8	Reverse run (20 m)	11.90 ± 1.66	10.74 ± 1.58	9.79 ± 1.44	10.90 ± 1.82
y11	Average daily steps over 28 days	3.46 ± 1.11	3.32 ± 1.10	3.44 ± 1.30	3.72 ± 1.18
y12	Number per week of medium and high intensity exercise sessions of more than 1 h	3.46 ± 1.01	3.50 ± 0.99	3.48 ± 1.09	3.52 ± 0.99
y13	Number per week of interactive activities of more than 20 min	3.34 ± 1.02	3.26 ± 1.01	3.98 ± 0.96	3.74 ± 1.16
y14	More than 10 min of action/skill learning per week	3.04 ± 1.12	3.30 ± 1.22	3.94 ± 1.88	3.58 ± 1.09
y15	Skill at 1–2 sports to meet individual needs	4.10 ± 1.07	3.98 ± 1.12	4.20 ± 1.09	4.20 ± 0.97
y16	People who feel that they are good at sports are popular	4.42 ± 1.11	4.32 ± 1.04	3.84 ± 1.15	4.00 ± 1.14
y17	Fear of injury in sports games®	2.04 ± 1.47	2.48 ± 1.53	1.92 ± 1.19	2.14 ± 1.29
y18	Sports games are more interesting than computers (mobile phones, TV)	4.30 ± 1.33	4.16 ± 1.40	3.78 ± 1.37	3.82 ± 1.40
y19	You can learn movements more easily	4.06 ± 0.96	4.00 ± 1.03	3.86 ± 1.07	4.12 ± 0.94
y20	Cannot improve the exercise level in the necessary time®	2.76 ± 1.60	2.72 ± 1.41	2.50 ± 1.49	2.54 ± 1.37
y21	Effective strategies are used in sports	3.98 ± 1.52	3.60 ± 1.59	3.44 ± 1.53	3.36 ± 1.50
y22	Moderate activities strengthen the will and regulate sleep	4.30 ± 1.20	4.54 ± 0.99	4.14 ± 1.16	4.16 ± 1.15
y23	Recognize that you have shortcomings in sports	3.22 ± 1.71	3.36 ± 1.59	3.80 ± 1.32	3.96 ± 1.26
y24	Exercise only under the influence of partners, and do not take the individual initiative to exercise®	2.28 ± 1.67	2.32 ± 1.66	2.26 ± 1.55	1.92 ± 1.44
y25	Ability to concentrate on activities	4.08 ± 1.31	4.02 ± 1.22	4.04 ± 1.26	4.06 ± 1.19
y26	Examples of health knowledge	3.92 ± 1.21	4.14 ± 1.13	4.24 ± 0.85	4.20 ± 1.03
y27	Understanding of physical activity	3.38 ± 1.35	4.04 ± 1.07	3.86 ± 1.20	3.72 ± 0.95
y28	Understanding of actions/skills	3.40 ± 1.21	3.72 ± 1.07	3.74 ± 1.10	3.60 ± 1.16
y29	Understanding of activity time and environment	3.26 ± 1.21	3.42 ± 1.33	3.42 ± 1.20	3.22 ± 1.17
y30	Understanding of body posture	3.16 ± 1.50	3.10 ± 1.40	3.60 ± 1.12	3.34 ± 1.38
z31	Posture	3.30 ± 1.02	3.36 ± 1.01	3.36 ± 0.90	3.50 ± 1.04
z32	Operation	2.54 ± 0.93	2.80 ± 0.99	2.88 ± 1.02	3.18 ± 1.08
z33	Hand-eye coordination	2.06 ± 0.74	1.78 ± 1.00	2.24 ± 0.96	1.98 ± 0.87
z34	Behavior	3.44 ± 0.91	3.34 ± 1.00	3.32 ± 0.98	3.40 ± 0.88
z35	Special skills	4.28 ± 0.97	3.80 ± 1.14	4.70 ± 0.79	4.72 ± 0.67
z36	Squat control	3.28 ± 0.97	3.20 ± 0.93	3.18 ± 0.96	3.58 ± 1.05
z37	Dynamic scenario	3.06 ± 1.00	3.38 ± 1.09	2.92 ± 1.01	3.50 ± 1.07
z38	Reaction	54.32 ± 8.06	54.70 ± 8.84	45.86 ± 6.30	49.73 ± 7.14

of 7-year-old girls' motor performance is y16, followed by y19, y15, y30, y24, y17, and y26. The most significant indicator of 8-year-old boys' motor performance is y24, followed by y17, y20, y18, y26, and y11. The most significant index of 8-year-old girls' reaction to motor performance is y26, followed by y19, y12, y11, y14, y29, and y27. Therefore, the main common indicators of 7- to 8-year-old children's motor behavior reflecting motor performance are y11, y17, y19, y24, y26, and y30.

Figures 6, **7** show the results of the partial least squares regression analysis of motor development and motor performance tests. The results show that the ability of a 7-year-old boy, 7-year-old girl, 8-year-old boy, and 8-year-old girl to complete motor tasks is related to motor development. The cumulative explanation of motor performance is moderate. The explained cumulative variance (R-square) values are 0.325, 0.308, 0.383, and 0.369, respectively, and the adjusted R-square values

TABLE 4 | Typical correlation coefficients and significance between motor performance and motor behavior.

Typical variable pair	Canonical correlation coefficient	Wilks' lambda	*df*1	*df*2	*F*	*p*
1	0.557	0.304	160.000	1,291.300	1.397	0.001**
2	0.453	0.440	133.000	1,147.082	1.142	0.141
3	0.421	0.553	108.000	998.650	1.006	0.467
4	0.378	0.672	85.000	845.565	0.852	0.824
5	0.284	0.784	64.000	687.370	0.687	0.970
6	0.238	0.853	45.000	523.632	0.638	0.968
7	0.234	0.904	28.000	354.000	0.651	0.915
8	0.208	0.957	13.000	178.000	0.620	0.836

*$^{**}p < 0.01$.

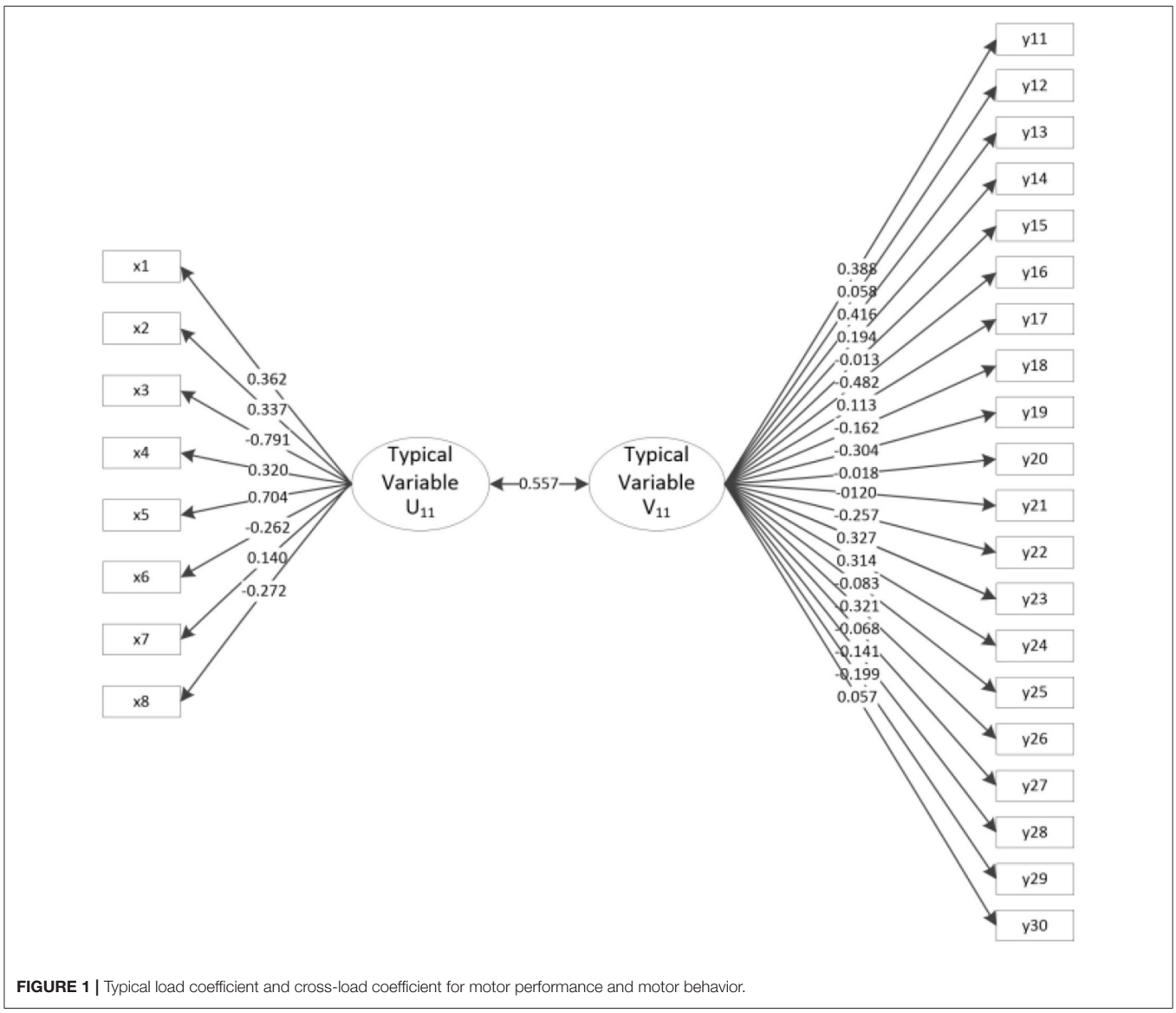

FIGURE 1 | Typical load coefficient and cross-load coefficient for motor performance and motor behavior.

TABLE 5 | Typical correlation coefficients and significance of motor behavior and motor development.

Typical variable pair	Canonical correlation coefficient	Wilks' lambda	*df*1	*df*2	*F*	*p*
1	0.459	0.638	64.000	1,062.011	1.344	0.040*
2	0.304	0.809	49.000	938.559	0.817	0.811
3	0.217	0.891	36.000	815.153	0.601	0.970
4	0.181	0.935	25.000	692.461	0.503	0.980
5	0.152	0.967	16.000	571.932	0.393	0.984
6	0.076	0.990	9.000	457.693	0.210	0.993
7	0.051	0.996	4.000	378.000	0.200	0.938
8	0.041	0.998	1.000	190.000	0.315	0.575

*$p < 0.05$.

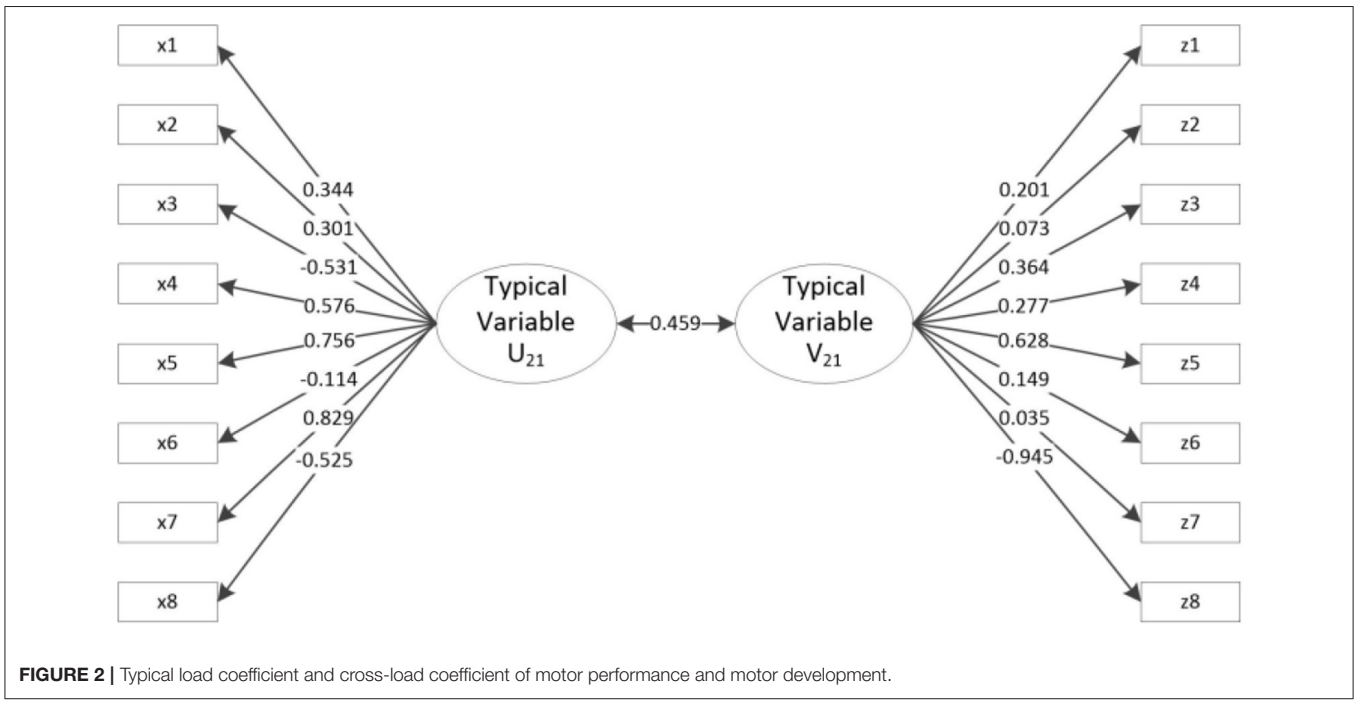

FIGURE 2 | Typical load coefficient and cross-load coefficient of motor performance and motor development.

TABLE 6 | Typical correlation coefficients and significance of motor behavior and motor development.

Typical variable pair	Canonical correlation coefficient	Wilks' lambda	*df*1	*df*2	*F*	*p*
1	0.507	0.395	160.000	1,298.768	1.076	0.047*
2	0.428	0.532	133.000	1,153.690	0.870	0.846
3	0.352	0.651	108.000	1,004.381	0.723	0.984
4	0.305	0.743	85.000	850.399	0.633	0.996
5	0.273	0.820	64.000	691.285	0.563	0.998
6	0.242	0.886	45.000	526.603	0.488	0.998
7	0.176	0.941	28.000	356.000	0.393	0.998
8	0.170	0.971	13.000	179.000	0.411	0.965

*$p < 0.05$.

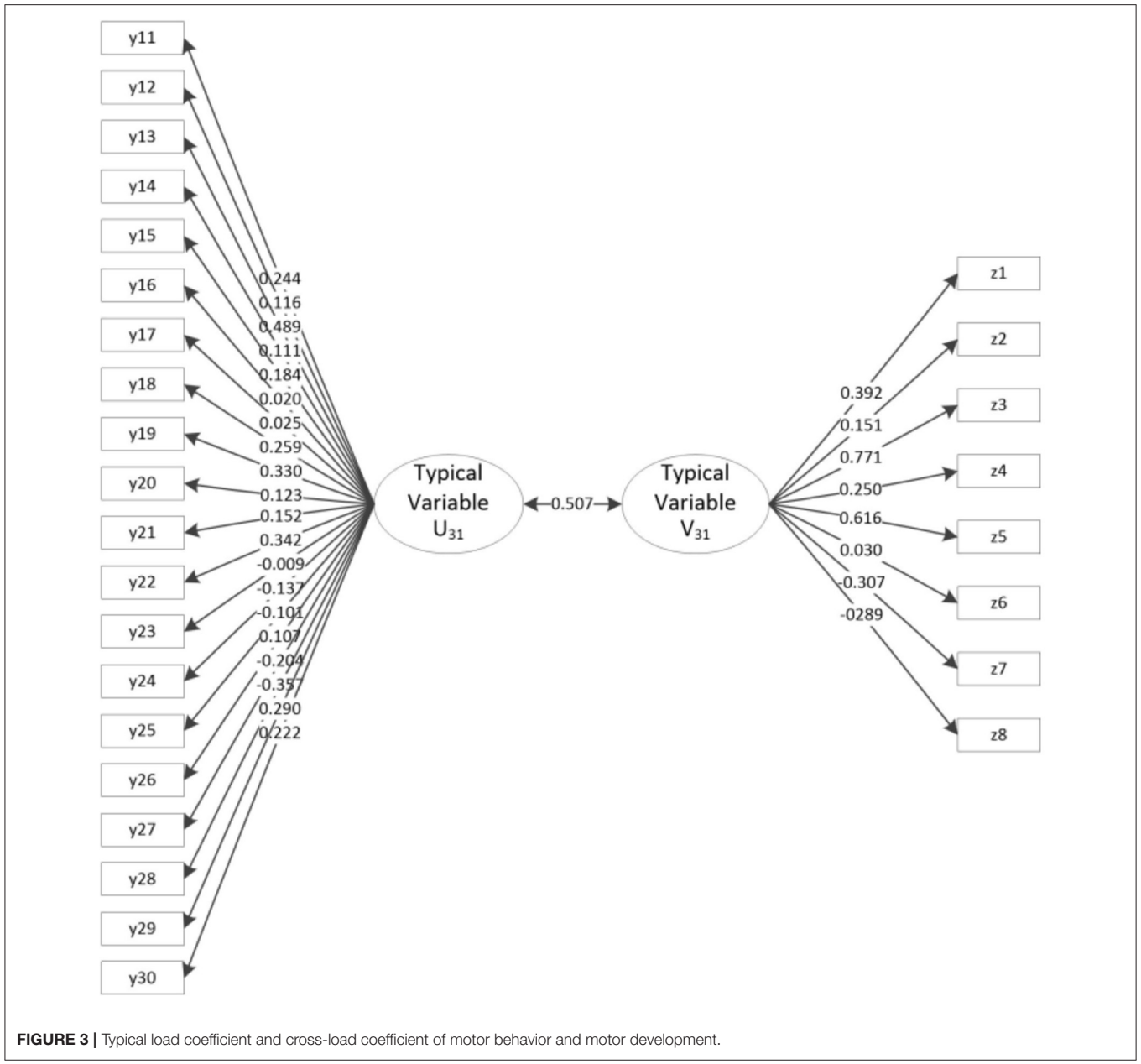

FIGURE 3 | Typical load coefficient and cross-load coefficient of motor behavior and motor development.

are 0.193, 0.173, 0.263, and 0.243, respectively. According to the cross-validity analysis, when the Qh^2 value is >0.0975, the best principal component is 1. In this analysis, the most significant index reflecting the motor performance of 7-year-old boys is z34, followed by z31 and z33. The most significant index of a 7-year-old girl's reaction to motor performance is z31, followed by z33. The most significant index of an 8-year-old boy's reaction to motor performance is z34, followed by z31 and z37. The most significant index of an 8-year-old girl's reaction to motor performance is z38, followed by z33 and z31. Therefore, z31, z33, and z34 are the main common indicators reflecting the motor performance of children aged 7–8 years.

Figures 8, **9** show the results of the partial least squares regression analysis of motor behavior and motor development. The results show that the environmental interaction experience of a 7-year-old boy, 7-year-old girl, 8-year-old boy, and 8-year-old girl participating in sports is motor behavior, and the cumulative interpretation of the ability to complete action tasks for motor development is relatively high. The explained cumulative variance R-square values are 0.712, 0.688, 0.720, and 0.735, respectively, and the adjusted R-square values are 0.513, 0.473, 0.526, and 0.553, respectively. According to the cross-validity analysis, when the Qh^2 value is >0.0975, the best principal component is one. In this analysis, the most significant

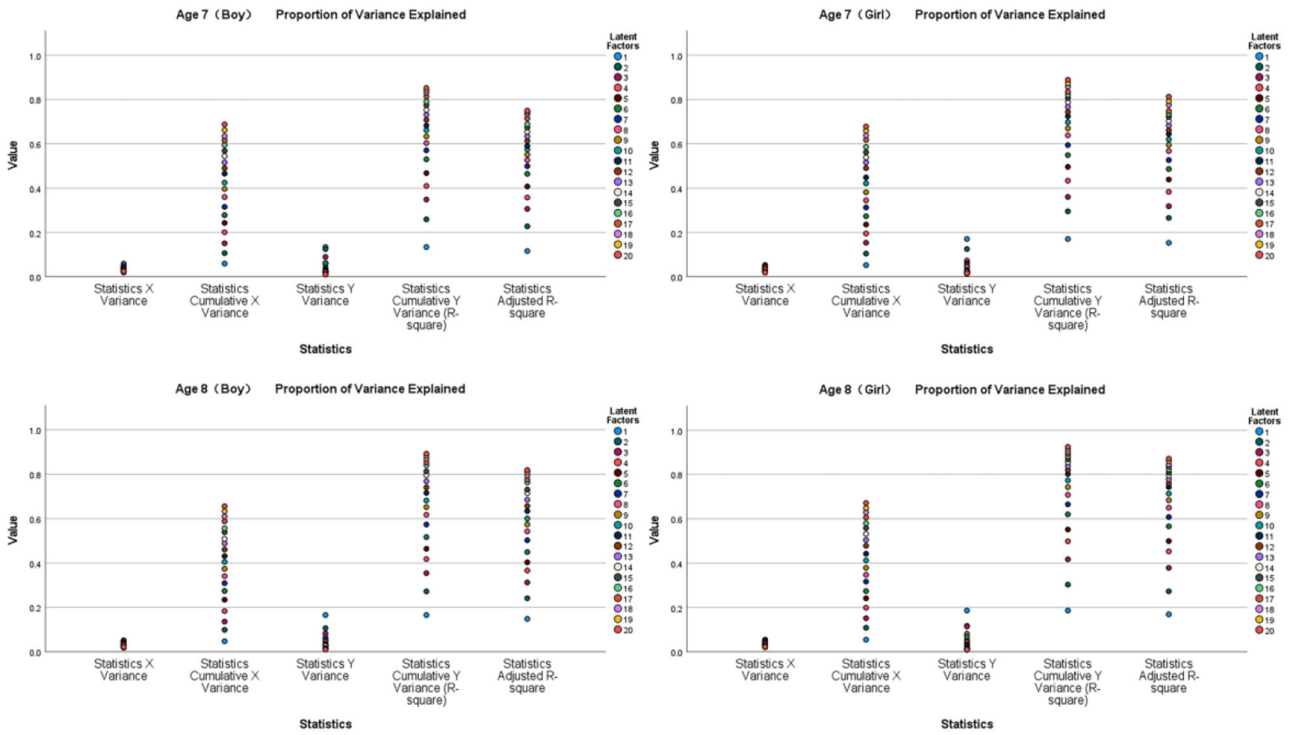

FIGURE 4 | Explanation and analysis of motor behavior on motor performance.

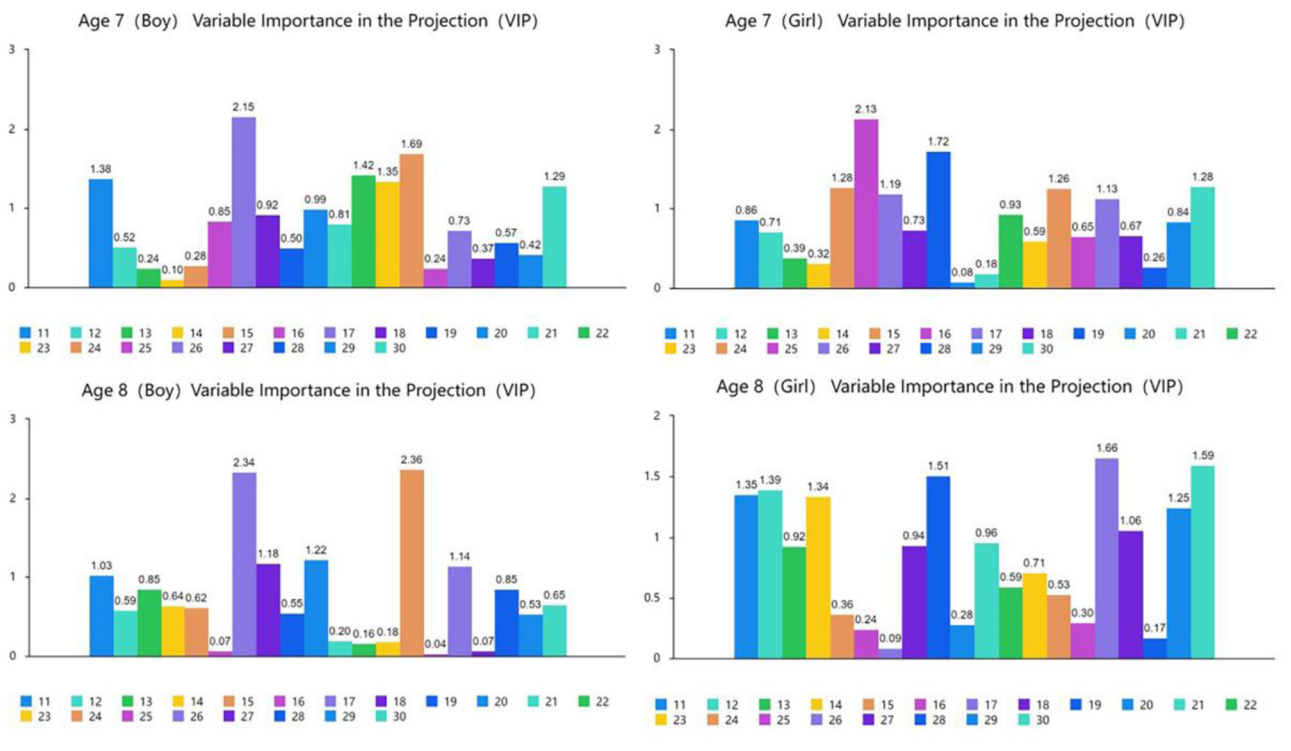

FIGURE 5 | VIP chart of the projection importance index of motor behavior to motor performance.

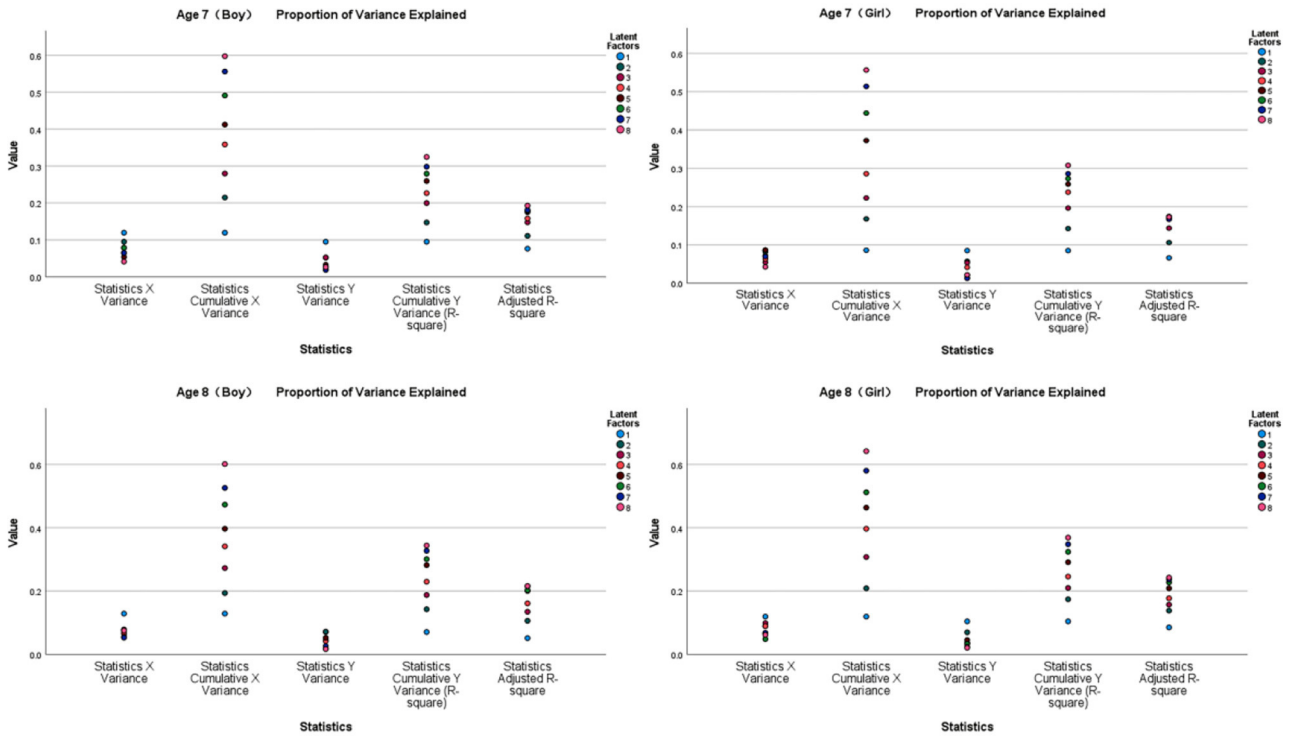

FIGURE 6 | Explanation and analysis of motor development on motor performance.

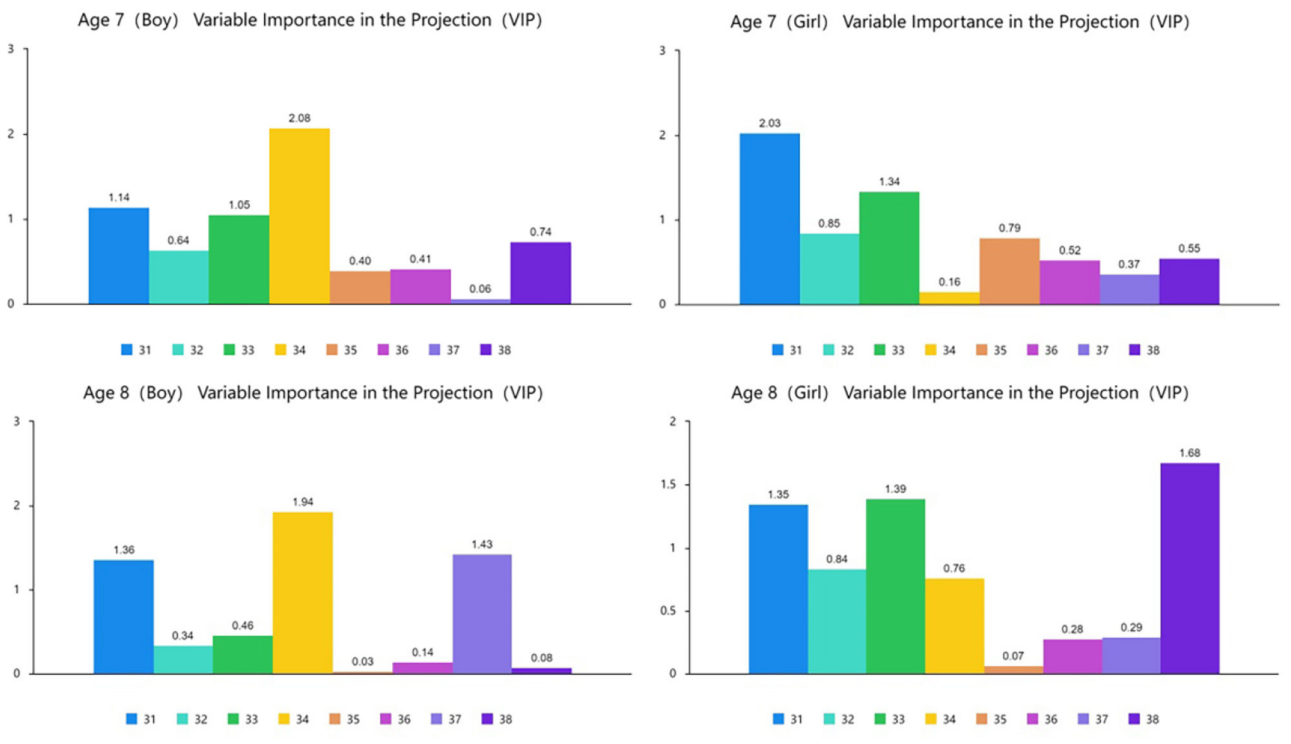

FIGURE 7 | VIP chart of the projection importance index of motor development to motor performance.

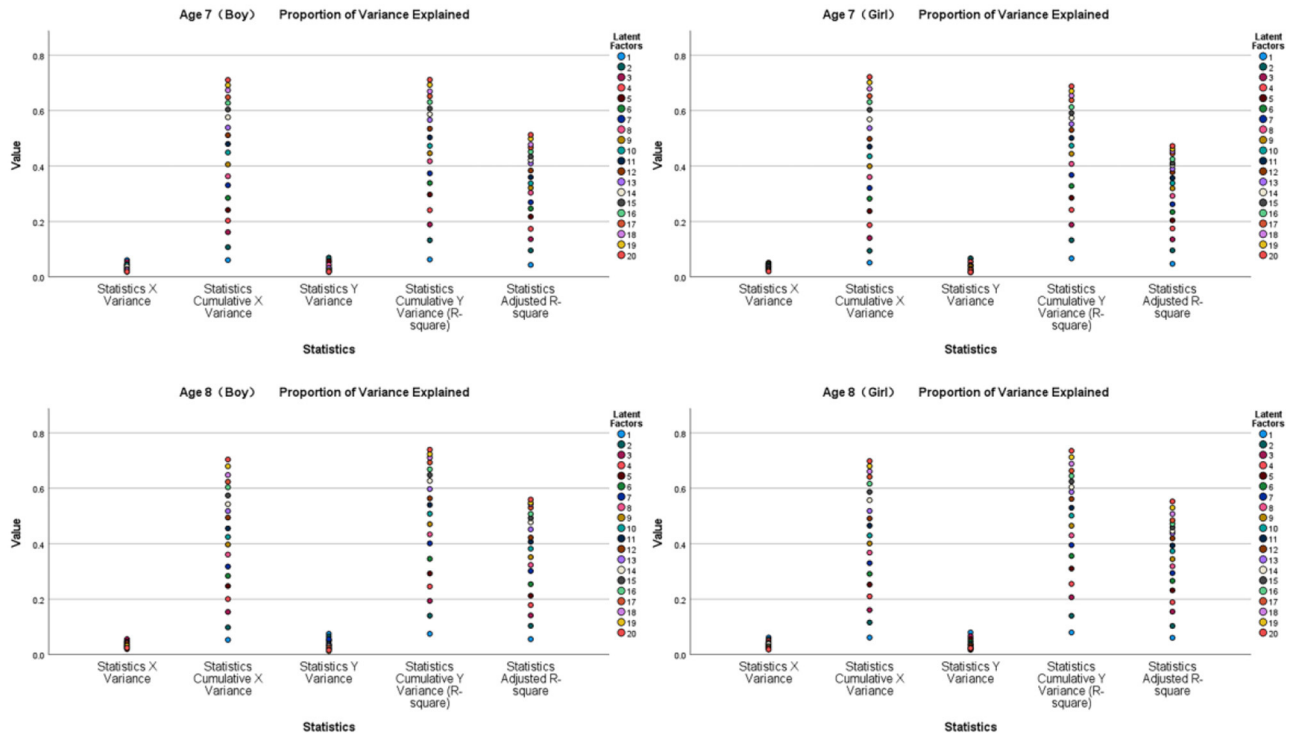

FIGURE 8 | Explanation and analysis of motor behavior on motor development.

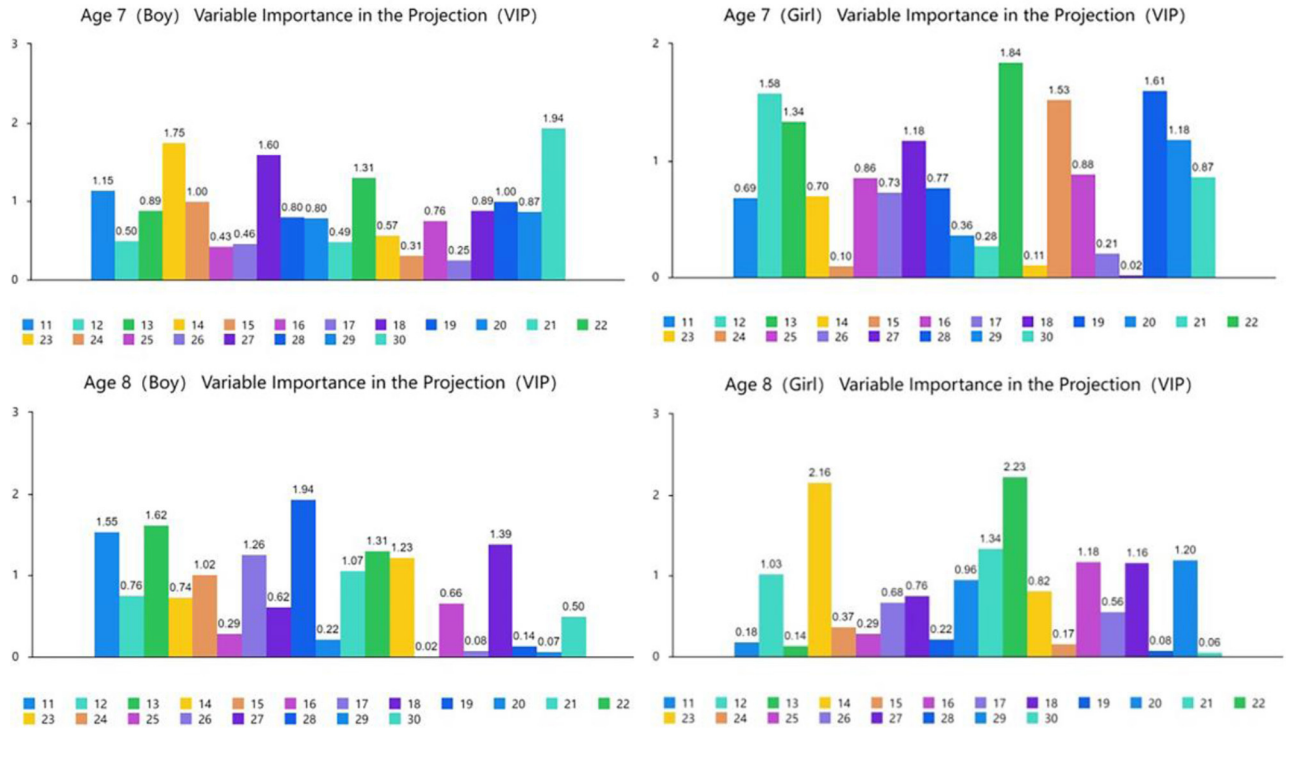

FIGURE 9 | VIP chart of the projection importance index of motor behavior on motor development.

index reflecting the motor development of 7-year-old boys is y30, followed by y14, y18, y22, y11, y15, and y28. The most significant index reflecting the motor development of 7-year-old girls is y22, followed by y28, y12, y24, y13, y18, and y29. The most significant index reflecting the motor development of 8-year-old boys is y19, followed by y13, y11, y27, y22, y17, y23, y21, and y15. The most significant index of 8-year-old girls' motor development is y22, followed by y14, y21, y29, y25, y27, and y12. Therefore, the main common indicators of 7- to 8-year-old children's motor behavior reflecting motor development are y11, y12, y13, y14, y15, y18, y21, y22, y27, y28, and y29.

DISCUSSION

The goal of this study is to design the scales for testing motor performance, motor behavior and motor development of children aged 7–8 years, carry out comparison analysis, and explore the comprehensive evaluation of motor performance and motor development. The canonical correlation analysis results show that there are significant-close positive correlations among the motor behavior, motor development, and motor performance. And the partial least squares regression analysis clarifies that the cumulative interpretation of the motor behavior to motor performance is high, the cumulative interpretation of the motor development to motor performance is moderate, while the cumulative interpretation of the motor behavior to motor development is high. Notably, these findings are applicable for the children in any age (7–8 years) and gender (boy and girl).

Based on the aforementioned overarching results, we further discussed several specific results relating to correlation analysis, impact relationship analysis, and the development of the Motional Quotient scale as well as its theoretical model as follow.

Correlation Analysis

Most of previous studies focused on the pairwise comparison analysis of motor performance, motor behavior and motor development, while few studies concerned the relationships among these three dimensions. Through the canonical correlation analysis in this study, it's noted that X3 (turning back and running), x5 (rope skipping), x7 (throwing a solid ball in place), y13 (the number of interactive activities per week lasting more than 20 min), y16 (People who feel that they are good at sports are popular), z33 (hand-eye coordination), z35 (special skills), and z38 (reaction) in motor development are the main representative factors. This finding aligns with the physical and mental growth and development standards for Chinese children aged 7–8 years. For example, rope skipping is beneficial to children's fitness, body composition, body health, and body immunity (35–40). Additionally, the rope skipping also have other advantages, such as the improvements in dynamic balance, explosive power (35), speed, agility (38), timing and rhythm, coordination (40, 41) and the contribution to building good self-confidence in sports activities (40). Additionally, after excluding the influence of the data trend, these representative indicators promote each other and are positively correlated; thus, they can be explored as a simplified measurement tool. In particular, x5 (rope skipping), y13 (the number of interactive activities per week lasting more than 20 min) and z35 (specific skills) appeared twice in the correlation analysis, which are more representative. We should pay more attention to these representative indicators for facilitating the physical health conditions of the children aged 7–8 years. Moreover, as previous studies stated, testing the rope skipping helps to identify motor problems in young children, because this skill relies on overall body coordination, and motor Performance (42, 43).

According to Trecroci et al., there are positive changes in balance and motor coordination among preadolescent soccer athletes (41). More and more studies began to link rope skipping with physical education and special training. In practical applications, these indicators focus on improving sports ability through training correct rope skipping and appropriate special technical learning and training to improve the number of interactive activities per week lasting more than 20 min, which is conducive to sports and promotes healthy development. At the same time, education and training related to a child's physical activity (such as speed, strength and sensitivity), motor development and physical skills, as well as the cultivation of self-confidence in activity participation, should be strengthened. The three tests are closely related and can be applied to promote children's sports performance through improved training activities for some indicators. This is consistent with the evidence provided by PDMS for the effectiveness of developmental activities at promoting motor development (30). Moreover, these findings show that continuing to deepen the evaluation of motor performance and development in older children can help provide appropriate education, training and services.

Impact Relationship Analysis

At the time of childhood, as boys and girls grow, the consequent longer levers and increased muscle tissue have the benefits to increase their strength. Both the boys and girls have the same ability to perform motor skills prior to puberty (44).This study found that the motor behavior of children of different age and gender generally has a high effect of motor performance and motor development, while the effect of motor development on motor performance is moderate. Most of the indicators selected in this study were derived from popular authoritative scales in China and other countries, but it is obvious that some indicators do not play a particular role, rather the cumulative effect of the motor development test on motor performance is moderate. It is assumed that the influence of motor development on motor performance is moderate, but the results of the canonical correlation analysis show that they have a very close positive correlation, and the influence of motor development on motor performance cannot be denied. Therefore, the hypothesis is not reliable. The reason for this result may be that this aspect has not attracted much attention from Chinese children.

It's critical to develop the motor performance for the children (45). For example, successful participation in the structured and non-structured activities, games, and sports demands a certain degree of competence in many fundamental motor skills (46). The main indicators of physical and mental growth reflecting exercise ability are y11 (average daily steps within

28 days), y17 (fear of injury in sports games), y19 (ability to readily learn actions), y24 (exercise only under the influence of partners and not taking the initiative), y26 (examples of health common sense), y30 (understanding of body posture), z31 (posture), z33 (hand-eye coordination), and z34 (behavior). A positive relationship exists between physical and mental growth and motor performance across childhood. These indicators can be used to predict children's motor performance and to focus the formulation of exercise prescriptions for improving motor performance.

The main common indicators of significant motor development reflected by motor behavior are y11 (average daily steps over 28 days), y12 (the number of medium and high intensity exercise sessions per week lasting more than 1 h), y13 (the number of interactive activities per week lasting more than 20 min), y14 (the number of action/skill learning sessions per week lasting more than 10 min), y15 (the amount of action/skill learning for more than 10 min per week), y18 (sports games are more interesting than computers [mobile phones, TV)], y21 (effective strategies are used in sports), y22 (moderate activities enhance will and regulate sleep), y27 (understanding of physical activities), y28 (understanding of movements/skills), and y29 (understanding of activity time and environment). Previous studies clarified that the essence of motor development is behavior development (28), and they also stated the importance of the bodily context in motor development (33). These aforementioned indicators can be used to predict children's motor development. Of these indicators, only y11 is the main indicator of sports behavior reflecting sports ability, which suggests that motor behavior reflects sports development and sports ability with good independence. It is necessary to focus on improving physical activities and behaviors in the environment and tasks to promote behavior and living conditions that are beneficial to sports and health and that meet the measurement requirements of modern medicine's bio-psycho-social health promotion model (47).

Development of the Motional Quotient Scale and Its Theoretical Model

The ACSM exercise testing and exercise prescription guide is committed to the promotion and integration of sports medicine and sports science in scientific research, education and practical application to maintain and improve physical function, physical fitness, health and quality of life (23). It provides good comprehensive exercise and medical guidance. Currently, the fields of public health and psychology in China mainly focus on the diagnosis of disorders in children, while the field of sports science focuses on the evaluation of teenagers. Physical activities, which are part of the traditional evaluation, generally lack a comprehensive evaluation of sports ability and development.

It is assumed that the three tests can be combined into three dimensions in a comprehensive evaluation scale of motor performance and development.

Cronbach′s alpha internal consistency reliability coefficient was used to evaluate the reliability of the hypothesis scale; the hypothesis scales for 7-year-old boys, 7-year-old girls, 8-year-old boys, and 8-year-old girls were tested. The α coefficients were 0.68, 0.60, 0.67, and 0.64, respectively, suggesting that the internal consistency of the scale was acceptable. The evaluation items of the hypothetical scale were derived from mature scales with good reliability and validity in China and elsewhere, and these items are representative, appropriate and reasonable within the defined scope. Actual measurements, questionnaires and observations yield a reflection of the basic motor performance, motor behavior, psychology and skilled motor performance of individuals, and the evaluation data are accurate and effective. Through expert interviews, 12 experts in related fields agreed that the content of the scale is relatively independent and can comprehensively reflect the development of motor performance in the process of motor development. Therefore, the content validity of the scale is good. The three dimensions of the hypothetical scale, motor performance, motor behavior and motor development, are significantly correlated with each other and have a very close positive correlation.

Therefore, the hypothesis scale is composed of topics with similar content and high statistical correlation. The topics have high correlation and high internal unity. The hypothesis is tenable.

According to the three dimensions of the hypothesis scale, the connotation of the representation hypothesis scale is that "the individual ability to carry out physical exercise, the environmental interactive experience of participating in exercise and the ability to complete action tasks". Blanche proposed the concept of the "Physical Quotient" in 1930 in addition to the concept of "Physical Age" (48). Mecloy proposed the "Motor Skill Quotient" in 1934 (49), and Anderson identified the "Motor Skill Quotient" in 1948 and applied it to grade evaluation in physical education teaching, which verified the research of the Motor Skill Quotient, however, there was no further explanation (50). Gesell proposed the concept of the "Developmental Quotient" in 1940, which mainly diagnoses the adaptive behavior, gross motor, fine motor, language and personal social behavior of children aged 0–6 years (51). Folio and Fewell published the first commercial PDMS in 1983 (30), which was mainly expressed by the Gross Motor Quotient, Fine Motor Quotient and Total Motor Quotient. In the "Theory of Multiple Intelligences" proposed by Gardner in 1983, Bodily-kinesthetic intelligence was defined as "the coordination and balance ability of human body and the strength, speed and flexibility of movement, which is characterized by the use of physical communication and problem-solving, skilled object operation and activities requiring good motor skills" (52). Craig proposed "Motor Intelligence" in 1990. Research has found that the cognitive processes directly affect the operation efficiency of athletes (53). Linda evaluated physical fitness with the Physical Fitness Quotient in ACSM in 2013 (23). The Physical Fitness Quotient is a comprehensive reflection of healthy physical fitness and skill physical fitness. Most people do not lack IQ (intelligence quotient) and EQ (emotional quotient), but do lack a body awareness 'quotient"'. Drawing on the research results of the quotient, we explored and extended the research results of many scholars and termed the hypothetical scale the Motional Quotient scale, with an innovation of the physical and motor skills that correspond to the "Emotional" aspect of EQ. The Motional Quotient represents the comprehensive motor ability level of individuals in their

age group. From the perspective of the health promotion model, motor performance, as one of the dimensions of evaluation, is comprehensively affected by other dimensions. According to "the bio-psycho-social health promotion model" and children's cognitive development standards (54), the theoretical Motional Quotient model of "The Bio-Behavior-Task" was further constructed to comprehensively evaluate motor performance.

CONCLUSIONS

Through interviews, investigations and quantitative tests, this study designed and validated the scales for testing motor performance, motor behavior, and motor development, respectively, aligning with the physical and mental growth and development standards for Chinese children aged 7–8 years. The three tests are significantly correlated with a very close positive correlation, and, for their high correlations, there are no significant differences in children's age and gender. Moreover, the three tests can be combined and compiled into an MQ (motional quotient) scale to build a theoretical MQ model of "The Bio-Behavior-Task", which can be a comprehensive motor performance evaluation system in consistent with the standards for students' physical and mental development.

The developed MQ scale helps clarify movement development standards, predict the motor performance and level, achieve predictable development sequence learning, and tailor appropriate sports development plans. In addition, it can be used to set goals and directions for individual sports development, produce highly effectiveness materials to promote sports participation, and provide implementable strategies for promoting health through children's sports.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Scientific Ethics Committee of Nanjing University of Science and Technology. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. Written informed consent was obtained from the minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

HZ contributed to data collection and manuscript writing. JC contributed to data interpretation and critical revisions. ZW contributed to the study design. HZ and JC contributed to data analysis. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.898266/full#supplementary-material

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Physical Activity Impacts of an Activity-Friendly Community: A Natural Experiment Study Protocol

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Background: Stakeholders from multiple sectors are increasingly aware of the critical need for identifying sustainable interventions that promote healthy lifestyle behaviors. Activity-friendly communities (AFCs) have been known to provide opportunities for engaging in physical activity (PA) across the life course, which is a key to healthy living and healthy aging.

Purpose: Our purpose is to describe the study protocol developed for a research project that examines: (a) the short- and long-term changes in total levels and spatial and temporal patterns of PA after individuals move from non-AFCs to an AFC; and (b) what built and natural environmental factors lead to changes in PA resulting from such a move, either directly or indirectly (e.g., by affecting psychosocial factors related to PA).

Methods: This protocol is for a longitudinal, case-comparison study utilizing a unique natural experiment opportunity in Austin, Texas, USA. Case participants were those adults who moved from non-AFCs to an AFC. Matching comparison participants were residents from similar non-AFCs who did not move during the study period. Recruitment venues included local businesses, social and print media, community events, and individual referrals. Objectively measured moderate-to-vigorous PA and associated spatial and temporal patterns served as the key outcomes of interest. Independent (e.g., physical environments), confounding (e.g., demographic factors), and mediating variables (e.g., psychosocial factors) were captured using a combination of objective (e.g., GIS, GPS, Tanita scale) and subjective measures (e.g., survey, travel diary). Statistical analyses will be conducted using multiple methods, including difference-in-differences models, repeated-measures linear mixed models, hierarchical marked space-time Poisson point pattern analysis, and hierarchical linear mixed models.

Conclusion: Natural experiment studies help investigate causal relationships between health and place. However, multiple challenges associated with participant recruitment, extensive and extended data collection activities, and unpredictable intervention schedules have discouraged many researchers from implementing such studies in community-based populations. This detailed study protocol will inform the execution of future studies to explore how AFCs impact population health across the life course.

Keywords: physical activity, obesity, activity-friendly community, natural experiment, healthy aging, healthy community, active living, study protocol

INTRODUCTION

Policy-relevant and sustainable health-promoting interventions have the potential to improve population health and support healthy living across the life course leading to healthy aging. However, it is not always feasible to conduct experimental studies on such interventions (e.g., policy changes, environmental modifications), especially when the intervention involves large-scale changes in community environments (e.g., residential relocation). Natural experiments allow researchers to overcome such feasibility challenges and better understand the effectiveness of such interventions using advanced research designs and methodological approaches that aim to strengthen cases for causal inference (1, 2). This paper presents the study protocols used to execute a natural experiment that assessed a policy-relevant and health-promoting intervention, the implementation of an activity-friendly community (AFC) design, to assess its impact on residents' physical activity (PA).

Obesity is a growing public health problem globally, with nearly a third of the world population being overweight or obese (3). In the USA, obesity has increased even more dramatically, now reaching over 40% of American adults (4). Obesity is a major risk factor for the onset or exacerbation of many chronic conditions such as heart diseases, diabetes, and cancer (5, 6). PA can help combat the obesity epidemic and brings many other health benefits (7). Guidelines from the US Centers for Disease Control and Prevention (CDC) recommend most adults engage in at least 150 min of moderate-intensity or 75 min of vigorous-intensity aerobic PA per week, or a combined equivalent to at least 150 min of moderate-to-vigorous physical activity (MVPA) per week (7). Staying physically active throughout the life course is also a key factor for healthy aging (8). However, in 2018, 46% of American adults did not meet these PA guidelines (9), and older adults (65+ years of age) are among the least likely to meet PA guidelines with less than a quarter meeting the recommendation as of 2019 (10, 11).

There has been a recent paradigm shift from individual-focused behavior change models to ecological models that consider the complex system of personal, social, and physical environmental factors that affect one's decision and ability to be physically active (12–16). Moderate and utilitarian/lifestyle PA (e.g., walking for transportation) integrated into the daily routine is often more attractive, sustainable, and cost-effective than purely recreational or structured PA, especially among those at high risk for obesity (16–19). That stated, lifestyle PA requires supportive living environments for viability. This is especially true for children and older adults and people with limited resources to access other PA amenities (e.g., paid gym membership) (16, 20).

The built and natural environments of residential communities have become increasingly recognized as important venues for promoting PA at the population level (20, 21). Living in AFCs with mixed and compact land uses, well-connected street networks, complete pedestrian and bicycle infrastructure, diverse recreational facilities, and slow/managed traffic has been associated with increased PA among adults (15, 17, 21–27). Such communities bring everyday destinations and homes closer to each other and make physically active travel modes (e.g., walking) viable and attractive. The natural environmental features of the neighborhood such as parks, lakes, trails, trees along streets, and visually appealing natural scenery, have also been linked with health benefits such as increased PA, reduced stress and depression, and improved overall well-being (12, 23, 28–31).

Personal attitudes (e.g., personal beliefs, self-efficacy, and perceived barriers) and social influences related to social support, social capital, safety, and social norms, have also been linked to PA (32–39). Social support for PA (e.g., having someone to exercise with) has been reported to be the most clearly established interpersonal determinant of PA (36–39). Limited studies have also suggested that AFCs facilitate social interactions among neighbors and help increase a sense of community (40–44). Perceived safety is recognized as an important barrier to PA, with safety concerns constraining PA (35, 45). More recent ecological models are positing a host of psychosocial factors as mediators between the physical environment and PA (32, 46–48).

Despite the substantial body of evidence on the association between the physical environment and PA, most cross-sectional studies do not address the potential self-selection bias (e.g., residents interested in PA intentionally choosing to live in an AFC). A limited number of studies have utilized proxies of self-selection (attitudinal and residential preference variables) and provided promising results supporting the significant roles of the built environment on PA even after accounting for self-selection (49, 50). Moreover, a systematic review identified 23 studies on the effects of residential relocation on PA, walking, and travel behavior (51). The findings were encouraging, especially for the relationship between residential relocation to more activity-friendly locations and increased walking, but somewhat weak

among prospective studies or other outcomes (e.g., total PA, cycling, transit use, and driving).

Overall, despite the growing body of literature, most previous studies on environment-PA relationships are cross-sectional, thus limiting the ability to understand complex pathways among multi-level factors and establish causal relationships between environmental interventions and increases in PA (17, 52–56). Also, many studies on PA promotion have focused on the changes in the total amount of PA, but did not explore the "when," "where," and "why" of those changes for total and specific types of PA, and the potential short- and long-term PA impacts of environmental interventions (52–55, 57). Another key limitation of some prior studies is the sole reliance on self-reports of PA, which have been shown to have significant measurement errors (58). These methodological limitations and unanswered questions prevent a full understanding of underlying mechanisms about how environmental interventions may promote PA (12, 15, 57).

On the other hand, the demands and market acceptance for AFCs have been growing. Urban planning trends such as New Urbanism, Smart Growth, and the Leadership in Energy and Environmental Design-Neighborhood Development (LEED-ND) advocate AFCs for their benefits not only on health but also on sustainability, economy, and equity (59–61). However, the traditional urban planning and land development process does not fully integrate the health benefits of their practices into the decision-making process. Recently, there have been growing efforts to overcome policy barriers to the development of AFCs. Agencies such as the Environmental Protection Agency and the American Planning Association have identified possible policy solutions such as revisions of local zoning codes (62–64). More research is needed to provide more confirmatory evidence about the health benefits of AFCs, and thereby help inform future environmental/policy interventions and overcome existing regulatory barriers.

To help address the relative gaps in the existing literature identified above and support rigorous environment-PA studies, this paper provides a comprehensive description of the study protocol developed to execute a quasi-experimental study (natural experiment) using a pre-post, case-control design. This approach allows researchers to assess the implementation of an AFC design, and to test causal inference using a difference-in-differences framework (65, 66). We also summarize lessons learned from a transdisciplinary team approach used in this study, which allowed us to formulate research questions and implement the research with insights from multiple disciplines, informed by the diverse methods and approaches from different fields.

METHODS AND ANALYSIS

Study Design and Aims

This paper describes the study protocol for the Active Living Austin (ALA) study, which is funded by the National Institutes of Health (Grant ID: R01CA197761, 2015-2022). ALA investigates a timely and understudied topic—the causal relationships between changes in physical environments and PA, utilizing a natural experiment with residents moving to and living in an AFC (Mueller community in Austin, Texas, USA). It is designed to make several substantive and methodological innovations in studying environmental approaches toward PA promotion across the life course. With a longitudinal, case-comparison study design, ALA aimed to examine the short- and long-term impacts of the residential relocation, while capturing both the total amount and the spatial and temporal patterns (frequency, timing, type, location) of PA. To better understand the complex causal pathways at multiple levels (personal, social, physical environment), ALA examines both the direct and indirect impacts (through the psychosocial mediators) of the residential relocation on PA. A common challenge for these types of real-life studies is the possible self-selection bias because researchers cannot randomly assign participants to different living environments. To assess and reduce the impact of self-selection bias, we also included validated self-selection-related items (e.g., residential preferences, reasons for the household relocation, and attitudes and preferences related to PA) in the survey component of this study.

The specific aims and corresponding hypotheses are drawn from existing literature and practice and summarized below.

Aim 1

Examine the short- and long-term changes in total PA levels and spatial and temporal patterns of PA, after individuals move from non-AFCs to an AFC.

Hypothesis 1

Compared to the pre-move baseline and comparison participants, case participants will (1A) achieve greater short-term increases in PA levels after moving to the AFC; (1B) maintain increased PA levels over baseline at long-term, post-move follow-ups; and (1C) have a higher proportion out of total PA that takes place within the community, a higher proportion of walking out of total PA, and more PA bouts/sessions throughout the day indicating PA is more integrated into daily routines, at post-move follow-ups.

Aim 2

Determine what built and natural environmental factors lead to changes in PA among individuals moving from non-AFCs to an AFC, either directly or indirectly (by affecting psychosocial factors related to PA).

Hypothesis 2

Environmental factors in the AFC such as increased density, land use mix, sidewalks, walking/hiking paths, water features, and parks, will lead to increased PA both directly and indirectly (by improving attitudes toward and community support for PA) among case participants, while the absence of such environmental changes for comparison participants (non-movers staying in their non-AFCs) is associated with lack of increases in their PA levels.

Conceptual Framework

Drawing on the ecological model as the conceptual basis to understand PA behaviors (54), we developed a logic

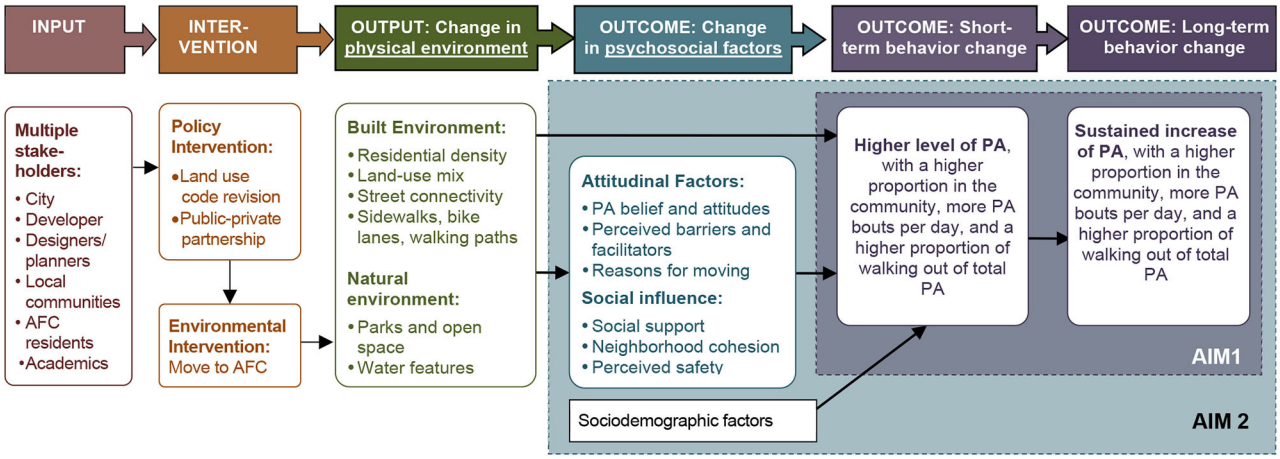

FIGURE 1 | Logic model for the Active Living Austin study.

model (**Figure 1**) to illustrate the relationships among the resources (input), program activities (interventions), outputs, and short- and long-term outcomes of the intervention (moving to an AFC) (67–70). Psychosocial factors, including personal attitudes and social influences, are the hypothesized mediators between the environmental intervention and PA changes.

Study Setting: Case and Comparison Communities

The case community (AFC) is the 700-acre Mueller community in Austin, Texas, USA. It will accommodate about 16,400 residents and 16,000 employees upon completion (estimated to be around the end of 2024). The community has reserved about 25% of the housing units as affordable homes for households with incomes lower than the area's median. Mueller's activity-friendly environment represents a departure from typical community developments in the city. Compact and mixed land uses, well-connected street networks, complete sidewalks, and rich PA amenities (e.g., green/open spaces, trails, and greenways), as well as diverse housing types, are notable features (see **Figure 2** and **Table 1**).

Examining available data during our pilot study (2013) revealed a similarity in Mueller's population characteristics at that time to the citywide average (**Table 1**) (71). As of February 2014, when we started planning this study, Mueller had approximately one-quarter of its construction completed, with about 4,750 residents living in its 1,900+ homes (859 single-family homes and 1,000+ apartments), and about 4,850 employees working in the community. According to the latest Mueller Community Report from December 2018 (mid-point of our study period), Mueller housed about 8,500 residents in 3,500 housing units and served as a workplace for about 5,500 employees. Comparison communities for this study are non-AFCs where case participants lived before moving to Mueller and other similar non-AFCs in Austin.

Study Population

Two types of participants were recruited for the study: case and comparison participants. Case participants are those moving from non-AFCs to this AFC and additional inclusion criteria include: (a) being 21+ years of age; (b) not a full-time student; (c) having no physical impairment or disability preventing engagement in PA; and (d) planning to live in this AFC for at least 1 year. Utilizing similar inclusionary criteria, comparison participants were recruited from case participants' pre-move communities and other communities in Austin with similar physical environmental features in terms of lack of support for PA. They were matched with case participants in the data analysis stage using propensity score matching considering covariates such as sex, age, race, ethnicity, income, baseline weekly minutes of MVPA, and Walk Score of the participant's home location.

Recruitment

Recruitment presented one of the most significant challenges due to the need to recruit case participants before they moved to Mueller for the baseline data collection. We developed a multi-channel recruitment strategy based on our experiences from the pilot study (75). Considering the varying locations from which case participants moved and the unpredictable times of move, we had to maintain a flexible, multi-phased approach, recruiting participants on a rolling basis. Venues for the case participant recruitment included local businesses such as the leasing offices of apartment buildings and the developer's office, home builders, and realtors; online messaging *via* social media, community online newsletters, and project website; print media (e.g., study flyers, local newspaper); individual referral by local residents who knew of someone moving to Mueller; and community venues such as the Mueller Neighborhood Association meetings and local events. Comparison participants were recruited through case participants' referrals, local neighborhood organizations, and media advertisements.

FIGURE 2 | Land use map and photos of the Mueller Community in Austin, Texas, USA. [Source of images: Catellus Development Corporation. Note: An older version of the land use map was published earlier in the journal of World Health Design (71)].

Study Variables and Data Collection

Table 2 lists the study variables and their corresponding data sources and measurement methods. One baseline and two follow-up assessments were conducted. For case participants, the baseline was operationally defined as 0.5–6 months before moving to the AFC, and follow-up was operationally defined as short-term (first follow-up at about 6–12 months post-move) and long-term (about 12–24 months post-move) (**Figure 3**). Follow-up measurements for comparison participants were conducted at about 6–12 months and 12–24 months from their baseline measurement, respectively, to approximate the time intervals for case participants' baseline and follow-up assessments. In addition to this main study with a pre-post, case-control design, a supplemental study—Community Survey of current Mueller residents—was conducted between December 2016 and August 2017 to assess current Mueller residents' PA patterns within and outside Mueller and the perceptions of their neighborhood environment. A follow-up qualitative study was carried out with a subgroup of Community Survey participants to identify factors serving as barriers and facilitators to physical and social health among these Mueller community residents. Data for this qualitative study were collected *via* focus group sessions

TABLE 1 | Physical environment and population characteristics of the activity-friendly community (AFC) (Mueller community) and City of Austin (71)[a] at the time of the pilot study (2013).

	Features	City of Austin	Mueller Community
Physical Environment[b]	Population density (persons/acre)	Mean: 6.8 (SD[c]: 3.7)	14
	Land use mix	Mean: 0.45 (SD: 0.24) (range: 0–1)[d]	10,000 employees, 10,000 residents, and 366,000 square feet of retail space on the 711-acre site
	Street connectivity (intersections/100 acres)	Mean: 19.7 (SD: 11.3)	66
	Sidewalk coverage (%)	Mean: 23.7 (SD: 13.7)	100
	Parks and open space coverage (%)	Mean: 8.9 (SD: 9.6)	20 (Each household has green space within 600 feet.)
Population[e]	Hispanic or Latino (of any race)	31.4%	35.1%
	White (one race)	68.3%	71.4%
	Population under the age of 18	22.1%	21.9%
	Mean household income	$68,659	$66,923

[a] *This table was first published in the journal of World Health Design and republished here with permission (71).*
[b] *Physical environmental measures for the City of Austin were based on the authors' previous measures of 74 neighborhoods (defined as public elementary schools' attendance areas) in Austin (72). Physical environmental features of the Mueller community in this table represent the master plan at time of our pilot study (2013). As of May 2022, Mueller has about 750,000 square feet of retails space, and is projected to accommodate about 16,400 residents and 16,000 employees upon completion by the end of 2024.*
[c] *SD: Standard deviation.*
[d] *The land-use mix measure describes the evenness of land use distribution based on the square footage of residential, commercial, and office land uses (73). The value ranges from 0 (single land use) to 1 (a perfectly even mix).*
[e] *The population information was obtained from the 2010 Census and the 2005-2009 American Community Survey (74).*

between November 2018 and February 2019 with the subgroup of residents, who resided in senior living or affordable housing units, or self-identified as members of an ethnic/minority group within the Mueller community.

Measurement of PA Using Accelerometer, GPS, and Travel Log

PA level was captured through a self-report survey (conducted online *via* Qualtrics or using a paper copy) for all participants and objectively through accelerometer and GPS units for the sub-group of participants willing to join the objective measure. Surveys were distributed to all participants *via* email or during the introductory in-person meeting. The survey instrument was composed of standardized items adopted or adapted from published work to ensure both practicality and psychometric quality (**Table 2**) (75, 76, 78–84), and was designed to be completed in ∼20–30 min. In terms of PA measures, the self-reported survey was used to identify the minutes per day and days per week of PA for three intensity levels (light, moderate, and vigorous) as well as transportation and recreation walking within and outside respondents' neighborhoods. Relevant survey items were adapted and/or modified from the International Physical Activity Questionnaire (IPAQ) to measure hours and minutes of MVPA on a typical day of the week which can also be translated to weekly measures of MVPA for comparisons to PA guidelines.

For objective measures, the ActiGraph GT3X+ accelerometer was used to capture the total minutes of PA by intensity levels (light, moderate, and vigorous). Additionally, participants were asked to wear a Qstarz BT Q1000 XT GPS unit to provide the location data for all outdoor PA and the speed of movement data to help more accurately detect walking activities (85, 86). In addition, a travel log was used to record the origin and destination, start and end times, the purpose of each trip, and PA type and duration at destinations on a small paper booklet. This information provided complementary data to help confirm the trip purpose and validate the data captured from the devices (87). The combination of the accelerometer and GPS data, supplemented by the information from the travel log, allowed for accurate measures of the PA outcome variables.

Participant training manuals for objective measures helped participants follow standard protocols for the use of devices and travel logs. A field manager delivered the devices with an instruction card and contact information and personally demonstrated how and when to wear the devices and charge the GPS unit. When completed, the devices were picked up by our field manager or dropped off at a designated location. The data from the devices were downloaded immediately after the devices were returned, and those who failed to provide minimally valid data (i.e., 4 days with 10+ h of valid data per day) were asked to re-wear the devices. Respondents were offered incentives (i.e., gift cards) for participation, including the chance to win more substantial gift cards through a raffle mechanism at the end of data collection.

For each participant, accelerometer data were processed using a bout of 7+ consecutive minutes with a two-minute tolerance. The total counts of bouts were averaged over the total wear time, and more than 90 consecutive minutes of zero activity counts were considered non-wear time. Standard/accepted activity

TABLE 2 | Study variables and measurement methods.

		Variables	Measurement details	Measurement source
Outcome variables	H[a]-1A; H-1B	Change in total physical activity (PA)	Daily minutes of moderate-to-vigorous PA (MVPA)	Accelerometer: ActiGraph GT3X+ Self-reported PA: Items adapted and/or modified from the International Physical Activity Questionnaire (IPAQ) to measure hours and minutes of MVPA in a typical week
	H-1C	Change in spatial and temporal patterns for specific types of PA	Percentage of MVPA taking place within the 0.25-, 0.5-, and 1-mile street network buffers around home	Accelerometer: ActiGraph GT3X or GT3X GPS: Qstarz BT Q1000 XT Travel log
			Number of PA bouts/sessions per day	
			Percentage of total PA accounted by walking	
Mediators/ Intermediate outcomes	H-2	Change in psycho-social factors	*Attitudinal factors:* PA beliefs and attitudes, perceived barriers and facilitators, reasons for moving	Survey: Items adapted and/or modified from the "Healthy Community Survey" (75), which was adapted in part from the "Twin City Walking Study," the "Active Where Survey," and the "Neighborhood Environment Walkability Scale (NEWS)" (76–79)
			Social influence: social support, neighborhood cohesion, and perceived safety	
Independent and control variables	Personal factors		Age, sex, ethnicity, education, health status, marital status	Survey: Items adapted and/or modified from the BRFSS Questionnaire (80)
			Quality of life	Survey: Items adapted and/or modified from the "EQ-5D-5L" (81, 82) and the BRFSS
			Weight, height, body composition	Tanita Scale: TBF-400 Total Body Composition Analyzer Height measure: HM-200P Portstad Stadiometer
	Household factors		Household income, number of children	Survey: Items adapted and/or modified from the BRFSS Questionnaire (80)
	Physical environment		*Built:* Population density (persons/acre), land use mix entropy (0-1), proximity to and density of PA facilities and utilitarian destinations, street connectivity (intersection density), sidewalk completeness, transit stop density, traffic speed	GIS: proximity and buffer (0.5-mile airline, network, and sausage buffer) measures around each respondent's home, using ArcGIS version 10.6; raw GIS data for land use, density, streets, traffic, sidewalks, bike lanes, transit stops, etc. from City of Austin, ESRI, Austin Transit Authority, Capital Area Metropolitan Planning Organization, etc.
			Natural: Proximity to, coverage of, and density of parks, trails/paths, water features, and other open spaces; tree canopy (%); mean slope (%)	GIS: Proximity and buffer (0.5-mile airline, network, and sausage buffer) measures around each respondent's home, using ArcGIS version 10.6; raw GIS data from Austin Parks & Recreation Department, Digital Orthophoto Quadrangle (DOQQ) images, and Digital Elevation Model (DEM) data from US Geological Survey.

[a]*H, Hypothesis.*

count thresholds (e.g., 2,691–6,166 counts/min for moderate intensity and >6,166 counts/min for vigorous intensity based on recommendations from previous studies) (88) were used to determine the PA intensity level, and to estimate the total MVPA.

Spatial and temporal patterns of PA were captured by (a) the percentage of PA that takes place within the Mueller community or their comparison neighborhoods among the total PA, (b) the percentage of PA that is accounted for by walking, and (c) the frequency and distribution of PA episodes per day (as an indicator for the extent PA is integrated into daily routines).

One of the challenging prerequisites to obtain these measures was to detect PA types/modes. We used a machine learning approach (e.g., two-phase recognition, Tree-Structured Parzen Estimator, Random Forest) to detect target PA modes including walking, biking, driving, and sedentary behavior, and to estimate the hourly, daily, and weekly minutes of each mode within and outside each participant's neighborhood. The final training, validation, and test sets achieved an accuracy of 96.7% for the training data in detecting walking, and 77.3% for the test data in detecting walking, utilizing the data collected from the specific accelerometer and GPS devices and the travel log template that this study used. The variables generated from the machine-learning algorithms will be used with the detailed geospatial data generated from GIS, GPS, travel logs, and street

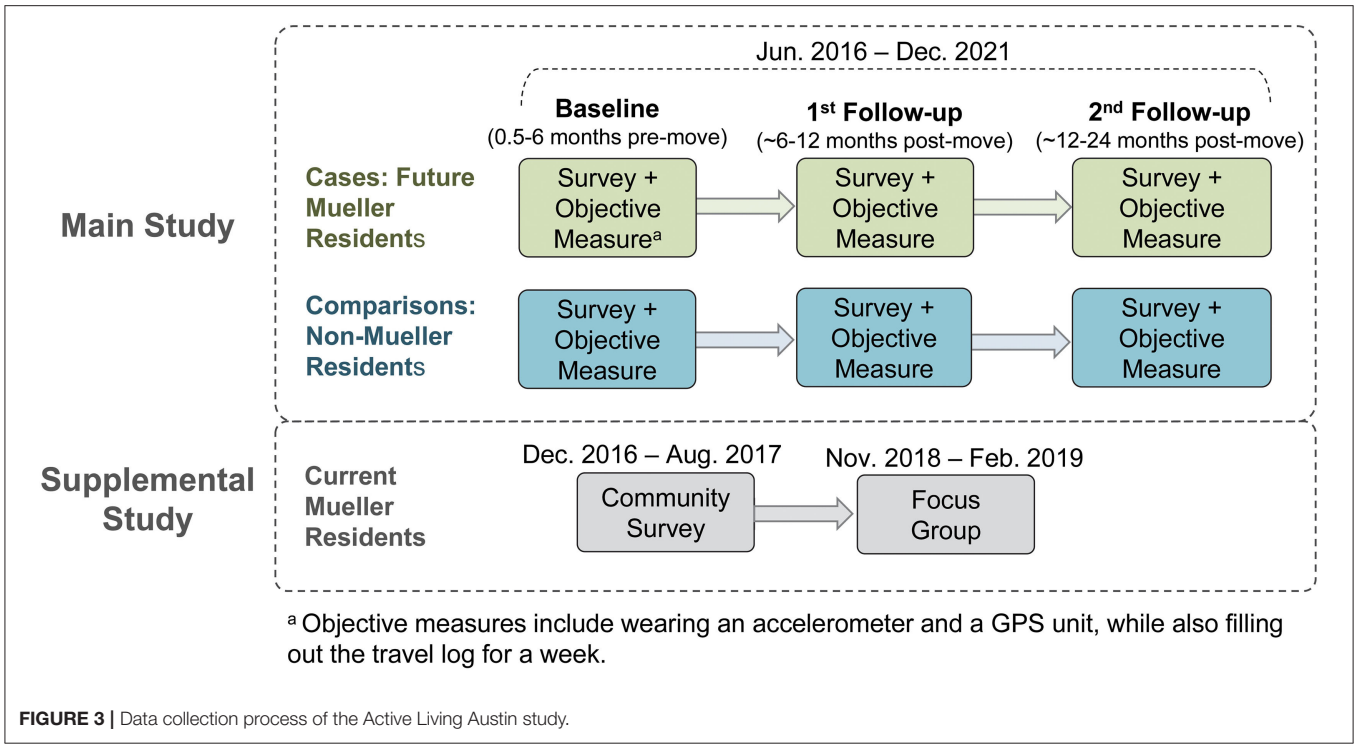

FIGURE 3 | Data collection process of the Active Living Austin study.

audits to explore the spatial and temporal patterns of PA as described above.

Measurement of Demographic and Psychosocial Factors Using Survey Items

Demographic and psychosocial factors were captured through the survey. If participants needed assistance filling out the survey, the fieldworker provided such assistance. Control variables in the survey include demographic factors such as age, sex, race, ethnicity, education, marital status, and household composition; general self-assessed health (including number and type of co-morbid conditions); and quality of life (**Table 2**). The follow-up survey also assessed intermediate psychosocial outcomes/mediators such as attitudes toward PA (e.g., self-efficacy, beliefs about PA), and social influences (e.g., social support, neighborhood cohesion, perceived safety) (**Table 2**).

Measurement of Physical Environment Using GIS and Field Audits

Analyses of objectively measured neighborhood environments included the use of GIS software, ArcGIS, as well as field audits (89). GIS measures include *proximity measures* (distance from home to the closest destination) and *buffer measures* (characteristics within 0.5-mile of three types of buffers—airline, network, and sausage buffers—around each survey respondent's home). Proximity measures include distances to both *utilitarian* (grocery stores, restaurants, retail stores, banks, post offices, education, and community facilities, religious facilities, etc.) and *recreational* (parks, trails, gyms, etc.) destinations. Buffer measures include: (a) overall *land use characteristics* (percent of different land uses, number of utilitarian and recreational destinations, residential density, land use mix/diversity); (b) *street characteristics and walkability* (street connectivity, sidewalk completeness, marked crosswalks, bike lane, traffic signals and stop signs, and transit stop); (c) *safety* (crime and crash density, posted speed); (d) *natural environment* (tree canopy coverage, greenery coverage, water coverage, mean slope); and (5) *others* (socio-demographic characteristics, affordable housings, residential appraisal value, number of jobs, and construction permits).

Measurement of Weight, Height, and Body Composition

Our trained research staff also measured participants' weight and body composition using a portable Tanita Scale (TBF-400 Total Body Composition Analyzer) and height measure, which has been tested for validity/accuracy and has been used in several studies to obtain clinical measures of body composition (90–93). Height was measured by a portable stadiometer (HM-200P Portstad) (94, 95). These measures were collected during the research staff's home visits to deliver the objective measurement devices. Measurements were taken twice, and their mean values were used for the analysis.

Analysis Plan

A standard data management protocol will be used, including detailed coding manuals and pre-processing protocols such as data cleaning, integration, reduction, and transformation, to ensure data quality and accuracy. Results of preliminary analyses

will then be applied to determine appropriate statistical models to be applied.

Analyses of data will include descriptive statistics, graphical exploratory data analytic techniques to (a) describe distributions of the data, (b) identify outliers and missing values, and (c) check for the violation of assumptions necessary for the planned statistical methods. If statistical assumptions are severely violated, variables may be transformed, or analogous non-parametric tests may be used. Further analyses will include evaluating the population representativeness of the sample because of exclusions or dropouts while checking the comparability of treatment groups and the need for covariate adjustment using bivariate analyses. Statistical software for analyses will include but is not limited to SAS (version 9.4) (96), SPSS (97), STATA (98), R (99), R packages *lme4*, *mediation,* and *SpatStat*, for exploratory analysis, visualization of spatial-temporal point patterns data, patterns and mechanisms of missing data, and sensitivity analyses to assess the robustness of the analysis methods, including addressing any missing data problems (100).

For *Hypothesis 1A*, analyses will include paired *t*-tests and difference-in-differences methods to test pre-post changes and case-comparison differences in total MVPA per week. First, *t*-tests will be conducted using the pwr.t.test function of R software and follow Cohen's method (101). Required sample sizes were calculated by assuming two-tailed paired sample *t*-test and a 0.05 significance level to achieve the power of 0.8. We referred to the effect sizes in (a) our preliminary study (75) on self-reported PA among insufficiently active residents moving to Mueller from non-AFCs (effect size: 0.95), and (b) the effect size (0.50) from another study (84) of accelerometer-measured MVPA for residents from communities with different levels of walkability. The smaller effect size (0.50) was selected to reach a conservative estimate. The target sample sizes to detect pre-post differences in total MVPA per week in Hypothesis 1A using *t* tests are *34 pairs at first follow-up* for a power of 0.8. In addition, we will also use the difference-in-differences method to test the significance of the pre-post differences between the case and comparison participants. This method will help reduce the impact of uncaptured confounding factors and isolate the treatment (i.e., moving to Mueller in this case) effect (102, 103). For *Hypothesis 1B*, analyses will include repeated-measures linear mixed models to compare PA levels at 1st and 2nd follow-up with baseline levels. This method has the advantage of allowing an unequal number of repeated measurements over time. Analyses will also include the use of the *lme4* function in R software. We will use G*Power software to compute the conservative power estimates for a repeated measure ANOVA analysis with three repeated measures and two case and control groups. Assuming a 0.05 significance level, a small effect size of Cohen's $f = 0.1$, a moderate correlation of 0.6 among repeated measures, and an attrition rate of 20% at the 2nd follow-up, the target sample sizes for the smallest group to detect changes of PA levels for Hypothesis 1B are *82 pairs at 2nd follow-up* to reach a power of 0.8.

For *Hypothesis 1C*, analyses will include machine learning, artificial intelligence, and pattern recognition techniques to characterize activities with respect to the exact type of PA (walking, running, etc.) as well as for the classification of activity spaces and purposes (e.g., exercise or utilitarian) using a combination of location (GPS), time (GPS + accelerometer), and activity intensity information (accelerometer). These classification techniques are based on the individual patterns of each study participant and are learned automatically as the participants wear the devices over the study period. These classifications of activities within specific activity spaces provide the ability to independently assess the roles that each of the built and natural environmental factors play in promoting or hindering PA around the participant's home, workplace, and other activity spaces. They also help quantify the effects of these drivers on observed changes in levels of PA for both exercise/recreational and utilitarian purposes. These high-level, per-individual activity patterns can then be integrated with the static GIS data layers that characterize aspects of the built and natural environments and for utilization within spatial-temporal data analysis techniques. Spatial-temporal patterns of specific types of PA will then be examined using the *marked space-time Poisson point pattern analysis* (104). The observed locations and times of specific PA are treated as random points from a Poisson process and the corresponding types of PA are treated as marks. For each type of PA, the random space-time point of PA is assumed to follow a Poisson process with a space-time varying intensity, which we estimate by nonparametric intensity estimation approaches in the R package *SpatStat*. This point process model will allow for describing, visualizing, and evaluating spatial-temporal patterns of PA.

For *Hypothesis 2*, analyses will include hierarchical linear mixed models to describe longitudinal repeated measurements of PA in the presence of mediator effects (105). Variables of built and natural environmental factors and latent mediator variables of psychosocial factors are incorporated into linear mixed models as fixed effects and mediation effects, respectively, to investigate the direct and indirect associations between physical environmental explanatory variables and increased PA. We will also incorporate random effects into our model to account for dependence among repeated measures. Specifically, let $PA_{i,t}$ denote the total PA levels measured on individual i at time point t, for $t = 1, 2, 3$. Let $BN_{i,t}$ denote a vector of physical environmental explanatory variables, and $PS_{i,t}$ denote a vector of psychosocial variables. Our linear mixed model consists of two model equations: $PA_{i,t} = X_{i,t}\beta_{BN} + M_{i,t}\beta_M + L_t + \varepsilon_{i,t}$, $M_{i,t} = PS_{i,t}\gamma_{PS} + BN_{i,t}\gamma_{BN} + \eta_{i,t}$, *where* $M_{i,t}$ are latent psychosocial mediators that are modeled as linear regressions with explanatory variables as measurements of psychosocial factors and built and environmental factors, $X_{i,t}$ *is* a vector of covariates for fixed effects including physical environmental factors, temporal trend, and treatment effect, and L_t is modeled as a random effect to account for dependence between repeated measurements within the same participant.

Linear mixed models deal with unbalanced repeated measures due to attrition. We will use functions in R package *lme4* for fitting, analyzing, and testing longitudinal fixed and random effects in linear mixed-effects models, and use functions in R

package *mediation* for the mediation analysis. Missing values, as needed, can be handled by following the multiple imputation approach by Schafer to improve efficiency and correct potential bias in parameter estimations (106).

DISCUSSION

Summary of Major Changes to the Original Protocol

During the process of implementing this study, some adjustments were made to the initial study protocol due to the unique yet commonly occurring challenges in natural experiment studies (107). The procedures reported above reflect the final/actual protocol that was implemented, while this section summarizes major adjustments made to the original protocol. The lessons from this process represent typical challenges in natural experiments when researchers cannot randomly assign participants to treatment. As a result, research teams should be ready and able to implement alternative strategies as needed to ensure the success of the overall project. We hope the lessons learned from implementing this study can inform future planning efforts in similar community-based natural experimental studies in community settings.

The major challenge emerged from difficulties in recruitment as we needed to identify case participants before their move from various locations that were not known to the researchers in advance and the contact information of these target participants was not directly accessible. This challenge was further complicated by the fact the baseline assessment was limited to a fleeting time window as case participants, especially apartment residents, were often identified and recruited shortly before their move. In response to these challenges, several adjustments were made to our original protocol. First, we expanded our recruitment criteria to include not only those who were insufficiently active at baseline (as originally proposed) but also those meeting the PA guidelines, to increase the sample size for the analysis. Second, the difficulty and the corresponding delay in recruitment also made it necessary to reduce the total of four waves of follow-up assessments (originally planned at ∼6, ∼12, ∼18, and ∼24 months post-move) to two waves (at about 6–12 and 12–24 months post-move).

Furthermore, we had to employ additional recruitment sources such as advertisements on local media and referrals through the social network of local residents and leasing agents at apartment complexes, for which a modest amount of cash incentive was provided. In addition, like many other studies, our recruitment and follow-up challenges were amplified by the COVID-19 pandemic, which made face-to-face recruitment and objective assessments more challenging.

We will also face a challenge in population representativeness that will need to be addressed as a potential limitation. Although the population characteristics of Mueller and other Austin neighborhoods were similar at the early stage of our research, some differences have emerged over time. More up-to-date information from the 2019 American Community Survey (108) 5-year summary data showed that compared with the City of Austin, the Mueller population has a higher percentage of White (59.0% vs. 48.3% for Mueller vs. citywide mean), non-Hispanic, or Latino (79.6% vs. 66.1%), and residents with graduate or professional degree (36.2% vs. 19.4%). In terms of the household annual income, the Mueller population has a higher percentage of both high-income households (28.8% vs. 19.0% with $150,000+) and low-income households (19.2% vs. 15.1% with <$25,000). Covariate analyses can help mitigate these differences.

Advantages of the Transdisciplinary Team

The transdisciplinary nature of our team was a major asset. We had members from urban planning, landscape architecture, architecture, public health (health behavior, health policy), exercise physiology, statistics, and computer sciences. The unique training and research experience gained from a diverse and transdisciplinary team allowed us to approach research questions that might not otherwise have been asked in a more siloed approach, and as such, this was a major strength. For example, the team engaged in the development of data collection protocols, surveys, planning for knowledge dissemination, engaging key stakeholders, and so forth, all informed collectively by the interactions of multiple disciplines, but in an integrative team approach that might not otherwise have been available. This approach also allowed us to go beyond the traditional boundaries of a field-specific approach, and to capture items that may not be common in a single field. We recommend taking multidisciplinary, interdisciplinary, and/or transdisciplinary approaches where possible, realizing these approaches are not identical (109). Given the value added in the current study and that the National Institutes of Health (NIH) (110) and others (111) have embraced this approach, we believe this was of significant value in the current study.

CONCLUSIONS

This study's *longitudinal design and inclusion of case and matched comparison* participants allow us to better specify the impact of moving to an AFC on population-level behavior changes toward more physically active lifestyles. Moving into an AFC provides a proxy test for the health effects of innovative land-use policies that facilitate the development of AFCs. Using this timely opportunity for gaining longitudinal assessments for this natural experiment is of critical importance to advancing the status of knowledge on the intersection of health and place, as it relates to promoting PA as a means to enhance healthy living/aging by reducing the risk for chronic conditions such as cancer, diabetes, and heart disease. Not only do we expect more favorable health outcomes for AFC residents, but we also expect that this research may have positive effects on the community and private development investment in AFC environmental features.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Texas A&M University Institutional Review Board. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

XZ, CL, and MO co-led the development of the Active Living Austin study protocol presented in this manuscript, with other co-authors providing assistance for their specific area of expertise. XZ led the writing of this manuscript. CL and MO oversaw the overall protocol and writing, all other co-authors helped with the writing and review. MO and ST assisted with the section about surveys. MX and JL aided with the section about objective measures of physical activity. CL, HL, and ZL helped with the description of environmental measures. TH, MX, and CL helped with the section about machine learning. EM and LS helped with the qualitative section of the study protocol. HS provided the description of the data analysis plan. All authors contributed to the article and approved the submitted version.

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Epidemiology of children's swimming competence and water safety

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Introduction: The main purpose of this study was to investigate children's swimming competence in primary schools of districts in Vojvodina, Serbia.

Methods: Included subjects were primary school students from first to eighth grade (N = 2,778; male = 1,454, female = 1,324; age = 10.73 ± 2.1 years). We used Swimming Competence Questionnaire to acquire and analyze their swimming experience, non-fatal aquatic events, and demographics. For the statistical analysis, logistic regression and hierarchical multiple regression were used to evaluate if the factors and SC and NFAE were associated. The analyses were carried out by using SPSS® software version 24.0 (SPSS, Inc., Chicago, Illinois, USA).

Results: Families with more income and education generally have children with more swimming competence, experience, knowledge, and skills related to water safety. First step in analysis revealed that gender ($\beta = 0.05$, $p < 0.01$), education level ($\beta = 0.06$, $p < 0.01$) age ($\beta = 0.171$, $p < 0.01$), and family income ($\beta = 0.04$, $p < 0.01$) were significant swimming competence (SC) predictors (R2 = 0.04). Age (OR = 1.15, $p < 0.01$) was the only significant predictor in Step 1 predicting non-fatal aquatic events (NFAE). In Step 2, variables associated with SC were swimming location ($\Delta R2 = 0.06$, $p < 0.01$), swimming experience ($\Delta R2 = 0.16$, $p < 0.01$), swimming accessibility ($\Delta R2 = 0.05$, $p < 0.01$), and learning experience ($\Delta R2 = 0.03$, $p < 0.01$) (total R2 = 0.26 to 0.47, $p < 0.01$). Only a minority of participants reported that they could not swim further than 5 meters using general stroke (37.15%).

Conclusion: National education trainers programs must be prioritized with the primary strategy of transferring knowledge to swimming and water safety. Families with lower income must be included without exceptions. This is perhaps a key factor in preventing NFAE, increasing SC, and increasing water safety.

KEYWORDS

school children, drowning, safety measures, swimming skills, aquatic events

Introduction

Regular engagement in physical activity provides numerous acute and chronic beneficial effects to adolescents (1). Swimming is characterized as a lifelong and low-impact activity, regarded as one of the most popular among children (2). Both aquatic activities participation and learning how to swim contribute to children's development of health and social and psychological welfare (3, 4). On the contrary, swimming is considered the leading activity related to drowning (5). According to the World Health Organization (WHO), aquatic events are the third leading cause of unintentional injury and death worldwide, with an estimated 236,000 annual deaths attributed to drowning (6). It is critical to preserve one's safety in and around water, and it requires a high level of awareness. Children's safety, in particular, in both open and confined waters, is essential for individuals and the community, and factors affecting the safety of children need to be identified for preventive measures to be taken.

Numerous studies indicate that drowning indeed represents a threat to children (5, 7–11). In highly developed countries, both fatal and non-fatal aquatic events (NFAE) are more frequent in public pools (12). However, there is insufficient qualitative data regarding the swimming competence (SC) of young children and adolescents. Analysis of current literature shows that existing methods for assessment of children's SC are rather limited. Often, the examination does not assess a range of skills such as swimming distance or basic aquatic survival skills. For example, previously, SC was evaluated based on their reported maximum swimming distance (13, 14) or subjective swimming skills evaluation (9, 15). Previous studies revealed that SC could be influenced by gender (13), Swimming Experience (2), Age (16), Socio-Economic Status (17), Swimming Location and Accessibility (18).

A recent study by Chan, Lee, and Hamilton (18), shows a positive correlation and prediction of demographic factors (age, sex, school grade, parent education level, and family income) with SC. Also, treading water seemed to be negatively linked with NFAE, meaning that better treading skills are correlated to fewer accidents. However, a certain gap for further investigation of these global problems is needed, especially among the European population. The primary reason for evaluating S.C. is its connection with water safety and fewer NFCA or drowning cases. In addition, a case-control study among the U.S. population found a favorable relationship between swimming lessons and lower drowning risk in young children (8). Also, best to the author's knowledge, none of the previous studies evaluated SC among the Serbian population. Therefore, this study aimed to evaluate SC and examine types of SC in Serbian children.

Abbreviations: NFAE, non-fatal aquatic events; SC, swimming competence.

Methods

Participants

All registered local primary schools in Vojvodina, Serbia, were questioned for this study. There were no specific inclusion or exclusion criteria. A total of 2,778 students from first to eighth grade participated in this study. Students incorporated in the study were 10.73 ± 2.1 years old, of which 1,324 (47.7%) were females and 1,454 (52.3%) males. For more demographic characteristics, see Table 1A.

Study design

The study was conducted using a cross-sectional design utilizing a parent-assisted self-reported questionnaire (19). In our study, questionnaire was translated to Serbian language in order for all participants/parents to understand it easily. The questionnaires were not validated in the Serbian language; it is validated only in their original form (19). The participants took around 30 min to complete the questionnaire, which consisted of swimming and demographic-related items. The study was conducted in accordance with Helsinki Declaration and obtained approval from the Ethical Committee of the University of Novi Sad, Serbia (Ref. No. 46-06-02/2020-1). All participants were instructed to complete the questionnaire honestly, and from all parents, written informed authorization to participate was obtained.

Demographic factors

Several demographic information was collected: age of children, sex, and grade. Parents reported their level of education (recorded as the highest level) and economic status (Table 1B).

Swimming competence

SC was assessed through an SC questionnaire designed by Chan et al. (19). This questionnaire is specifically designed for children to be completed with or without the help of their parents/guardians. Maximum swimming distance (in meters) was reported as distance without resting and using a general stroke. Subjects were able to do any swimming technique that they preferred.

Level of swimming experience

Swimming experience level was obtained through several questions related to swimming frequency (calculated as how

TABLE 1A Descriptive characteristics of the sample.

	N (%)	Mean (SD)	95% CI
Demographic information			
Age		10.73 (2.1)	10.64–10.81
Sex			
Female	1,324 (47.7)		
Male	1,454 (52.3)		
School grade			
Primary 1	281 (10.1)		
Primary 2	317 (11.4)		
Primary 3	342 (12.3)		
Primary 4	324 (11.7)		
Primary 5	427 (15.4)		
Primary 6	414 (14.9)		
Primary 7	372 (13.4)		
Primary 8	301 (10.8)		
Parent highest education level			
Secondary or lower	987 (26.8)		
Post–school training college	319 (8.7)		
University (undergraduate)	1,082 (29.4)		
University (postgraduate)	390 (10.6)		
Family income			
Low	201 (5.5)		
Middle	1,483 (40.3)		
High	233 (6.3)		
I don't want to declare myself	861 (23.4)		
Swimming experience			
Age to start learning swimming		5.29 (2.41)	5.20–5.38
Years of swimming		5.44 (3.01)	5.32–5.55
Frequency of swimming (times per month)		2.10 (4.65)	1.93–2.28
Duration of swimming (mins per session)		24.71 (34.135)	23.43–25.98
Winter swimming	831 (30.1)		
Swimming location			
Public swimming pools	2,225 (80.6)		
School swimming pools	49 (1.8)		
Club swimming pools	538 (19.5)		
Estate swimming pools	1,001 (36.3)		
Beaches	2,359 (85.4)		
Swimming accessibility			
Public swimming pools	2,526 (91.5)		
School swimming pools	36 (1.3)		
Club swimming pools	687 (24.9)		
Estate swimming pools	1,031 (37.3)		
Beaches	2,083 (75.4)		
Learning experience			
Parent/guardian	1,751 (63.4)		
Swimming club	691 (25.0)		
Government class	22 (0.8)		
Private coach	115 (4.2)		
School/PE teacher	11 (0.5)		
Sibling	67 (2.5)		
Friend	26 (1.0)		
Relative	36 (1.3)		
Grandparent	68 (2.5)		
Non–fatal aquatic event			
Cuts/bruises	230 (6.34)		
Out of breath	56 (1.48)		
Fatigue	205 (5.46)		
Non/fatal drowning	26 (0.88)		
Muscle cramp	75 (2.32)		
Anxiety/panic	59 (1.59)		

many times they swim in 1 month), duration (calculated in minutes per session), winter swimming participation (1 = yes and 0 = no), age of learning swimming and swimming experience (calculated in years).

Swimming location and accessibility

For swimming location and accessibility, participants declared whether they had access to swimming locations in a checklist of typical swimming sites. Responses were registered and scored as 1 = yes and 0 = no, relying on the location and access to the pool.

Learning experience

Participants conveyed their learning experience by selecting from a list of key factors/persons, where they responded if they received the instructions from them. Answers were coded 1 = received swimming instruction and 0 = did not receive swimming instruction.

Non-fatal aquatic events

To examine NFAE, participants answered by circling the questions associated with accidents or injury during some aquatic events. Answers were coded 1 = existence of NFAE and 0 = absence of NFAE.

TABLE 1B Descriptive characteristics of the sample.

Swimming competence index

Maximum swimming distance	General	Front crawl	Breaststroke	Backstroke	Butterfly
Very weak (0–4.99 m) (%)	4.30	7.10	6.40	7.10	7.70
Weak (5–12.49 m) (%)	10.55	15.10	13.00	16.30	13.55
Beginner (12.5–24.99 m) (%)	12.15	4.55	11.45	8.75	5.00
Intermediate (25–49.99 m) (%)	22.70	15.70	21.25	14.80	7.45
Good (50–99.99 m) (%)	18.65	12.70	17.40	11.10	4.30
Excellent (<100 m) (%)	19.10	14.00	16.90	13.30	5.25
Mean distance (m)	100.87	77.25	79.30	58.92	21.18

Swimming skills	Poolside kicking	Kicking with kickboard	Holding breath underwater	Floating	Treading water	Swimming underwater
Able	97.20%	91.65%	93.45%	87.00%	90.30%	83.00%
Not able	2.80%	8.35%	6.55%	13.00%	9.70%	17.00%

TABLE 2 Maximum swimming distance by sex and school grade.

		General	Front-crawl	Breaststroke	Backstroke	Butterfly
Sex	Male ($N = 1,444$; M-age = 10.71)	116.41 (99.19–136.89)	95.91 (80.43–113.11)	89.15 (75.07–105.79)	68.32 (56.76–81.05)	28.00 (22.73–33.45)
	Female ($N = 1,308$; M-age = 10.74)	84.25 (69.31–101.64)	55.20 (41.30–71.54)	67.01 (54.62–82.68)	47.07 (37.19–60.97)	12.83 (10.03–15.73)
School grade						
	Primary 1 ($N = 277$; M-age = 7.11)	18.06 (13.38–23.61)	17.66 (9.69–27.66)	15.78 (12.36–19.67)	9.31 (6.20–12.75)	3.53 (1.50–5.84)
	Primary 2 ($N = 315$; M-age = 8.07)	31.99 (22.11–46.78)	22.21 (12.59–36.72)	31.66 (20.48–50.33)	20.03 (10.50–35.33)	5.13(2.76–8.37)
	Primary 3 ($N = 341$; M-age = 9.12)	50.41 (36.34–68.26)	40.20 (27.75–54.07)	43.98 (28.92–63.51)	26.31 (18.48–35.73)	10.06 (6.53–14.11)
	Primary 4 ($N = 319$; M-age = 10.10)	66.49 (50.94–84.22)	43.55 (31.30–56.92)	53.29 (41.18–67.40)	35.30 (25.99–46.26)	13.17 (9.44–17.96)
	Primary 5 ($N = 422$; M-age = 11.13)	122.01 (94.44–154.44)	88.55 (66.08–114.58)	100.76 (73.28–131.99)	75.09 (57.03–94.77)	27.08 (18.02–37.70)
	Primary 6 ($N = 412$; M-age = 12.20)	143.75 (114.41–178.30)	107.56 (81.67–139.29)	111.15 (89.29–135.55)	79.23 (60.97–100.52)	29.02 (21.20–38.45)
	Primary 7 ($N = 366$; M-age = 18.08)	170.65 (115.01–244.59)	133.01 (83.93–196.83)	108.17 (79.64–153.47)	99.19 (64.87–150.13)	26.1 (17.95–35.84)
	Primary 8 ($N = 300$; M-age = 14.06)	172.14 (128.64–221.34)	136.14 (96.07–185.73)	140.45 (103.22–185.66)	101.54 (74.79–132.09)	46.83 (30.41–67.19)

Values are mean (95% bias-corrected and accelerated bootstrap confidence interval). Maximum swimming distance indicates the maximum swimming distance participants could swim without any assistance or rest. "General" indicates the maximum swimming by any stroke or combination of strokes. M-age, mean age of the category.

Data analysis

Firstly, descriptive statistics were calculated as means and standard deviation for the number of NFAE and SC. After checking the normality of the distribution, the data for SC data was not distributed normally; the 95% CIs of the descriptive statistics of the variables were estimated by bias-corrected and accelerated bootstrapping with a total of 1.000 resamplings (20). Then, logistic regression and hierarchical multiple regression were used to evaluate if the factors and SC

TABLE 3 Swimming skills by sex and school grade.

Swimming skills		Poolside kicking	Kicking with kickboard	Holding breath underwater	Floating	Treading water	Swimming underwater
Sex							
Male	Able	1,414 (97.58)	1,337 (92.27)	1,371 (94.62)	1,258 (86.82)	1,318 (90.96)	1,228 (84.75)
	Not able	35 (2.42)	112 (7.73)	78 (5.38)	191 (13.18)	131 (9.04)	221 (15.25)
Female	Able	1,270 (96.80)	1,194 (91.01)	1,208 (92.07)	1,144 (87.20)	1,175 (89.56)	1,063 (81.02)
	Not able	42 (3.20)	118 (8.99)	104 (7.93)	168 (12.80)	137 (10.44)	249 (18.98)
School grade							
Primary 1	Able	256 (91.76)	215 (77.06)	220 (78.85)	182 (65.23)	204 (73.12)	162 (58.06)
	Not able	23 (8.24)	64 (22.94)	59 (21.15)	97 (34.77)	75 (26.88)	117 (41.94)
Primary 2	Able	301 (95.56)	275 (87.30)	278 (88.25)	253 (80.32)	264 (83.31)	217 (68.89)
	Not able	14 (4.44)	40 (12.70)	37 (11.75)	62 (19.68)	51 (16.19)	98 (31.11)
Primary 3	Able	337 (98.54)	319 (93.27)	321 (93.86)	290 (84.80)	301 (88.01)	278 (81.29)
	Not able	5 (5.07)	23 (24.66)	21 (22.37)	52 (61.32)	41 (46.58)	64 (78.73)
Primary 4	Able	315 (98.44)	292 (91.25)	308 (96.25)	282 (88.13)	295 (92.19)	264 (82.50)
	Not able	5 (5.08)	28 (8.75)	12 (3.75)	38 (11.88)	25 (7.81)	56 (17.50)
Primary 5	Able	415 (98.11)	400 (94.56)	407 (96.22)	386 (91.25)	398 (94.09)	384 (90.78)
	Not able	8 (1.89)	23 (5.44)	16 (3.78)	37 (8.75)	25 (5.91)	39 (9.22)
Primary 6	Able	402 (97.34)	395 (95.64)	396 (95.88)	388 (93.95)	399 (96.61)	376 (91.04)
	Not able	11 (2.66)	18 (4.36)	17 (4.12)	25 (6.05)	14 (3.39)	37 (8.96)
Primary 7	Able	362 (98.10)	350 (94.85)	359 (97.29)	339 (91.87)	345 (93.50)	340 (92.14)
	Not able	7 (1.90)	19 (5.15)	10 (2.71)	30 (8.13)	24 (6.50)	29 (7.86)
Primary 8	Able	296 (98.67)	285 (95.00)	290 (96.67)	282 (94.00)	287 (95.67)	270 (90.00)
	Not able	4 (1.33)	15 (5.00)	10 (3.33)	18 (6.00)	13 (4.33)	30 (10.00)

Values are N (%).

and NFAE were associated. The analyses were carried out by using SPSS® software version 24.0 (SPSS, Inc., Chicago, Illinois, USA). Regarding the hierarchical linear multiple regression model, Demographic Factors were presented as independent variables in Step 1. Whereas, Swimming Location, Swimming Accessibility, and Learning Experience were introduced in Step 2 in separate models. For the hierarchical logistic regression model, demographic factors were placed in Step 1; Swimming Experience was introduced in Step 2; while SC, Swimming Location, Swimming Accessibility, and Learning Experience were placed in Step 3.

Results

Results from our study showed that participants could swim in general 116.41 meters for males or 84.25 meters for females (Table 2). Also, it was established that distance covered increased with the age of the participants. More than 80% of the participants were able to do every given task (e.g., kicking with a kickboard, floating, treading water, etc.) (for details, see Tables 2, 3). Similar trends with swimming distance were noticed in basic skills, where older kids were more successful and able to do given tasks. Furthermore, only a minority of participants reported that they could not swim further than 5 meters using general stroke (37.15%). Similar trends were obeyed in specific swimming techniques.

Prediction of swimming competence

In Step 1. demographic factors of gender ($\beta = 0.05, p < 0.01$), education level ($\beta = 0.06, p < 0.01$) and age ($\beta = 0.171, p < 0.01$) were significant SC predictors ($R2 = 0.04$). In Step 2, following variables were associated with SC: swimming location ($\Delta R2 = 0.06, p < 0.01$), swimming experience ($\Delta R2 = 0.16, p < 0.01$), swimming accessibility ($\Delta R2 = 0.05, p < 0.01$), and learning experience ($\Delta R2 = 0.03, p < 0.01$) (total $R2 = 0.26$ to $0.47, p < 0.01$). Result are displayed in Table 4.

Prediction of non-fatal aquatic events

NFAE estimation revealed that the demographic factor of age ($OR = 1.15, p < 0.01$) was the only significant predictor in Step 1. Further, in Step 2 and Step 3. there were no statistically significant factors. The results are displayed in Table 5.

TABLE 4 Results of hierarchical linear multiple regression models.

Dependent variable = swimming competence

Step	Independent variables	β	95% CI of B	*F*	ΔF	R^2	ΔR^2	VIF
Demographic factors								
1	Age	0.171**	20.690 to 32.551	25.378**	N/A	0.036	N/A	1.027
	Sex	−0.049**	−60.951 to −8.378		1.000			
	Parents' highest education	0.059**	8.130 to 27.842		1.048			
	Family Income	0.037	0.591 to 25.340		1.038			
Swimming experience								
2	Years of swimming	−0.054**	−11.433 to −4.441	66.038**	102.928**	0.162	0.126	1.028
	Frequency of swimming	0.304**	14.834 to 32.525					1.482
	Swimming duration	0.051*	−0.014 to 1.067					1.443
	Winter swimming	−0.044*	−60.303 to −4.562					1.294
Swimming location								
2	Public swimming pool	−0.042*	−58.707 to −13.848	19.535**	14.478**	0.060	0.025	1.049
	School swimming pool	0.025	2.361 to 125.652					1.036
	Club swimming pool	−0.139**	−165.500 to −75.154					1.052
	Estate swimming pool	0.031	−1.160 to 47.519					1.039
	Beach	0.046*	1.239 to 97.989					1.053
Swimming accessibility								
2	Public swimming pool	0.003	−29.380 to 44.213	16.989**	10.057**	0.053	0.017	1.056
	School swimming pool	−0.004	−106.842 to 68.074		1.023			
	Club swimming pool	−0.117**	−128.647 to −60.982		1.036			
	Estate swimming pool	0.044*	6.093 to 55.270		1.039			
	Beach	0.047*	3.550 to 76.367		1.062			
Learning experience								
2	Learning experience	−0.004	−5.624 to 3.648	20.194**	0.048**	0.035	0.000	1.003

Step 1 was identical throughout the three models. CI of B, 95% bias-corrected and accelerated bootstrap confidence. VIF, variance inflation factor. Swimming duration, duration of each swimming session in minutes. Learning experience, "Learn swimming from whom?". PE teacher, physical education teacher. *$p < 0.05$; **$p < 0.01$; N/A - not applicable.

Discussion

The present study aimed to explore the SC and NFAE and their interconnected factors in a sample of primary school pupils in Vojvodina, Serbia. Study results explore the current understanding of children's SC. The connections between SC and NFAE are significant given that the existing literature has predominantly concentrated on factors linked to fatal drowning (7, 21–23). Therefore, these results could help expand further knowledge of this specific topic and help contribute to future projects to address SC in the primary school population.

Results in the current study differ from the previously available data. More than 80% of the study sample were capable of doing every given task. In addition, only 35% of them reported that they could not swim the 5 m distance. On the opposite, in Fife and Goldoft (24) study, nearly 38 % of youths under 14 were declared non-swimmers, and 37% of adults had registered as very limited SC (13). In addition to these results, 37% of the Hong Kong primary school pupils were underlined as weak swimmers with a low level of SC (18). Compared to previous studies, cultural diversity should also be considered as one of the factors for the possible difference in the results. However, even the results from the present study show much higher levels of SC; the initiatives must be taken in a mission to promote swimming skills.

Present results displayed that pupils with greater SC were predominantly from higher income and/or higher education levels families. Previous research unequivocally indicates that children from families with lower economic or educational status generally show lower participation in sports and typically have lower coach-led activity levels (17, 25), which corresponds with results obtained from our sample. Similar findings were found in Chan, Lee, and Hamilton (18) study. These results indicate that special attention should be paid to enabling children's education from these families. Present results also revealed that boys had significantly better SC compared to girls. Although small, gender differences are compatible with prior investigations (13, 26). Other variables in step two also shown significant correlation with SC. Swimming location and accessibility of swimming facilities (public, school,

TABLE 5 Results of hierarchical logistic regression models.

Dependent variable = non-fatal events

Step	Variables	Odds ratio	95% CI of B	WALD	X^2	R^2	ΔR^2
Demographic factors							
1	Age	1.151**	1.109–1.195	54.651	58.469**	0.029	N/A
	Sex	1.102	0.939–1.294	1.422			
	Parents' highest education	1.027	0.956–1.103	0.535			
	Family income	1.005	0.927–1.091	0.018			
Swimming experience							
2	Years of swimming	0.997	0.963–1.031	0.040	58.568**	0.029	–
	Frequency of swimming	1.001	0.980–1.022	0.011			
	Swimming duration	1.000	0.997–1.003	0.018			
	Winter swimming	1.000	0.821–1,219	0.000			
Swimming competence							
3	General	1.000	0.999–1.000	0.213	11.433	0.034	0.005
	Breaststroke	1.000	0.999–1.000	0.427			
	Front-crawl	1.000	0.999–1.001	0.330			
	Backstroke	1.000	0.999–1.001	0.143			
	Butterfly	1.000	0.998–1.001	0.352			
	Swimming underwater	1.215	0.922–1.602	1.908			
	Floating	1.114	0.816–1.522	0.465			
	Poolside kicking	1.541	0.872–2.724	2.212			
	Kickboard kicking	1.133	0.773–1.661	0.410			
	Holding breath underwater	0.816	0.538–1.238	0.917			
	Treading water	0.905	0.628–1.303	0.289			
Swimming location							
3	Public swimming pool	1.082	0.874–1.339	0.527	64.141**	0.032	0.003
	School swimming pool	1.257	0.651–2.430	0.465			
	Club swimming pool	1.186	0.940–1.496	2.074			
	Estate swimming pool	0.943	0.796–1.117	0.465			
	Beach	1.108	0.876–1.401	0.735			
Swimming accessibility							
3	Public swimming pool	1.029	0.764–1.384	0.035	62.323**	0.031	0.002
	School swimming pool	1.264	0.597–2.678	0.375			
	Club swimming pool	1.137	0.929–1.390	1.551			
	Estate swimming pool	0.925	0.782–1.095	0.815			
	Beach	1.050	0.866–1.272	0.244			
Learning experience							
3	Learning experience	0.996	0.945–1.049	0.027	59.267**	0.030	0.001

Controls are age, gender, grade, parents' education, income and years, frequency, duration of swimming, and winter swimming. Steps 1 and 2 were identical throughout the three models. R2, Nagelkerke R-squared. 95% CI of EXP (B), 95% confidence interval of the odds ratio. Learning experience, "Learn swimming from whom?". PE teacher, physical education teacher. **$p < 0.01$; N/A - not applicable.

and club swimming pools) were correlated positively with swimming competence. Similar findings were observed in the study by Chan et al. (18), where they highlighted the importance of swimming facilities and their availability to children SC.

Although some of the factors such as years of swimming, swimming frequency and learning experience were significant predictors of children's SC (2, 24), but these factors were not significant predictors of NFAE. In previous studies, only the duration of each swimming session was found to correlate positively with NFAE (2, 24). However, in the present study, age was the only significant factor for prediction of NFAE. Similar to these findings, other studies have similar conclusions that younger children had more chances for NFAE (9, 18).

Interestingly there was no difference in risk of NFAE based on pupils' gender. For example, in the study by Chan, Lee, and Hamilton (18), males had greater SC, but there was no difference in NFAE in genders. Consequently, the gender differences should be further explored to develop an awareness of dangerous aquatic behaviors.

Another interesting finding was that none of the demographic characteristics or variables in swimming experience and SC, swimming location, swimming accessibility, or learning experience were influential predictors of NFAE. These results can partially be explained because most children usually participated/visited swimming areas such as pools supervised by lifeguards, which could influence the low rate of NFAE.

Although results from this study are promising, drowning still represents a major concern. Firstly, children from families with lower income should be included in educational and practical sessions, with special attention addressed to water safety. Secondly, national and community programs should be developed in such a way as to educate parents and coaches about the importance of water safety. We highly recommend parents/guardians teach children to swim as early as possible. The development of the infrastructure in schools, with access to the swimming pool and an increased number of public swimming pools, can significantly influence the rate of drowning and NFAE and increase SC.

We must highlight that this study had several limitations. First, the usage of questionnaires, retrospective measures, and self-report data of SC and NFAE may increase worries about social utility and response bias (19, 27). On the other hand, this questionnaire showed high correlations with the coaches' attitudes about SC children (18). Secondly, this study was conducted on a narrow population of one province in Serbia. Most of the children/parents surveyed are primarily from cities, which leaves the question of the actual situation of SC children from non-urban areas. In the end, future studies should consider selecting longitudinal studies with a mission to better understand and confirm available findings. Regardless of limitations, this study was the first to investigate swimming competence in Vojvodina and Serbia. Further, the research was conducted on considerably large sample size, and statistical methods were divided into steps to understand the results of this important topic better.

Conclusion

The results of our study indicate fundamental data on SC and NFAE. Children from wealthier families generally have more experience, knowledge, and skills related to water safety. Further, older children have higher competency, knowledge, and a lower volume of NFAE. Therefore, the education of children and parents must be a priority in the field of safety in and around water facilities or open water places. In addition, infrastructure and general accessibility of facilities such as swimming pools, landscaped beaches, and aqua parks must be prioritized by the community and governments. Furthermore, educating children in non-urban environments about water safety is one of the key long-term goals, although there are lack information on their swimming competencies. In the future, national education trainers programs must be prioritized with a primary mission to transfer knowledge and skills in swimming and water safety.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Ethical Committee of the University of Novi Sad, Serbia (Ref. No. 46-06-02/2020-1). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

AS-G, BA, NT, and JF-L were involved in study conception and design and wrote the first draft of the manuscript. MR, VŠ, NZ, AS-G, and JF-L collected the data and analyzed the data. AB, PD, and JC-G revised, edited, and approved the final manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Exploring trends of running performance during matches of professional soccer players in Montenegro: A longitudinal study

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The practical value of monitoring is that well-chosen performance indicators can help coaches identify the good and bad performance of individuals or teams. External monitoring of matches is useful in establishing the physiological requirements of the sport and assessing how a player compares to the requirements of the event in this regard. This study aimed to analyze the trend component of running performance during a game of professional soccer in Montenegro. The research included a sample of 82 professional soccer players. The first subsample included 44 professional soccer players of the club Budućnost from Podgorica, height 185.89 ± 6.29 cm, mass 81.06 ± 5.47 kg, BMI 23.47 ± 0.96 kg/m², age 28.86 ± 3.85 yrs. The second subsample included 38 professional soccer players from the Sutjeska club from Nikšić, height 181.88 ± 6.35 cm, mass 77.28 ± 6.78 kg, BMI 23.32 ± 1.08 kg/m², age 29.43 ± 5.68 yrs. The InStat kinematic system captured the outfield players by using six cameras placed around the perimeter of the field at the minimal height of 12 m. The frame frequency was 25 frames per second; data were centralized for further analysis. Statistically significant differences were noted only in the variable sprint distance in the 2017 season. The results of the current research indicate that the soccer players who compete in Montenegro are below the values achieved by those who compete in Europe.

KEYWORDS

performance analysis, external monitoring, time-motion analysis, high intensity running, soccer

Introduction

Soccer is one of the most complex sports in the world; players need technical, tactical, and physical skills to achieve successful performance and eventually win a game. The cooperative relationships between players who play different positions are critical to a team's success. For instance, the main role of midfielders is to organize the offense with proper ball control and passes, while the main duties of defenders are to win aerial duels

and tackles or to perform interceptions of the balls passed to attackers. Understanding these position-specific demands is crucial in the evaluation of players' achievements (1). Modern soccer requires a high level of endurance, speed, strength, and coordination (2). Therefore, players must have well-developed physical fitness. Given that the energy used by soccer players is mainly produced by aerobic metabolism (3, 4), it is essential that players have well-developed aerobic fitness.

Running in-game performance is a set of variables used in soccer performance analysis and is defined "as the choice and combination of variables that define an aspect of performance and help achieve sporting success" (5), in which the player's duties are passing, shooting, throwing the ball, dribbling, etc. Currently, several video-based platforms are available to track player performance indicators; some of the most commonly used platforms are InStat, Optasport, and Wyscout. Such platforms quickly and accurately provide a wide range of data on game performance indicators, enabling simultaneous analysis of physical effort, movement patterns, and technical actions of players, with and without the ball (6).

Various studies have examined these characteristics and requirements within a soccer team (7). Yi et al. (8) explored the technical requirements of different playing positions for play in the UEFA Champions League. In contrast, Modrić et al. (6) identified running performance specific to each playing position in professional soccer players. Dellal et al. (9) identified positional requirements from technical and physical aspects in the French premier league. All studies indicated high applicability of running performance in evaluating team-specific achievements and team position. It is known that running performance during the game is an essential determinant of success in professional soccer, which has been studied repeatedly, although some studies have been done with different aims (10–12). However, due to its importance, more research is required in different countries according to different levels of players and leagues. This is the first study to monitor the performance of running during the game in the first Telekom Montenegrin league. In this study, we hypothesized that examining the differences in the variables mentioned in different matches could provide a useful, practical report to coaches and trainers in Montenegro. Therefore, this study aimed to explore trends of running performance during the match in professional soccer players in Montenegro in three competitive matches of different seasons.

Materials and methods

Participants

The research included a sample of 82 professional soccer players. The first subsample included 44 professional soccer players of the soccer club Budućnost from Podgorica, height 185.89 ± 6.29 cm, mass 81.06 ± 5.47 kg, BMI 23.47 ± 0.96 kg/m^2, age 28.86 ± 3.85 yrs. The second subsample included 38 professional soccer players from the Sutjeska soccer club from Nikšić, height 181.88 ± 6.35 cm, mass 77.28 ± 6.78 kg, BMI 23.32 ± 1.08 kg/m^2, age 29.43 ± 5.68 yrs. All soccer players compete in the first Telekom Montenegrin league, the highest competitive rank in Montenegro. The study is longitudinal in nature, and testing was done in three seasons: 2014/2015, 2016/2017, and 2019/2020, where derby matches between Budućnost and Sutjeska were observed each season. The criteria for inclusion were that the first team's players had been team members for at least 6 months, that all the players went through the preparation period with the team, were without injuries in the previous 6 months, and that they played one half-season before testing. Exclusion criteria were athletes in the recovery phase from some form of acute or chronic injury and athletes who did not complete the entire preparation period. All respondents were first informed about the study and the purpose and goal of the research; the possible consequences were explained to them. Also, the procedure and the course of the testing itself were explained to the respondents. Prior to the survey, each respondent signed a consent form to participate. For this research, the consent and approval of the head coach and the club president were obtained, and testing was started. The research was in accordance with the Declaration of Helsinki (13).

Study design

InStat Kinematic System—"Currently, various video-based systems track performance indicators of soccer players (InStat, Optasport, Wyscout). Such platforms quickly and accurately provide a large range of match-related performance measures, allowing the simultaneous analysis of the physical efforts, movement patterns, and technical actions of players, both with and without the ball" (6). "The match performance indicators for each player were determined by the position-specific InStat system. The InStat tracking system was previously employed to analyze the association between running performance and game performance indicators in professional soccer players" (6). "The InStat kinematic system captured the outfield players using six cameras placed around the perimeter of the field at the minimal height of 12 m. The frame frequency was 25 frames per second; data were centralized for further analysis. InStat Autocrop allows filming matches without a cameraman. The footage covered every player on the field. There is minimum human involvement in the process; a person is only needed to set up a panoramic camera at the required height, connect it to a computer, and check the Internet connection before the start of the match. An Autocrop camera is set at a height of 8–10 meters and 23–24 meters away from the sideline. A special algorithm allows the camera to cover the entire field. The

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program analyzes every frame and centers the image depending on the players' positions, without any sudden zooming. The following parameters of running performance were selected to estimate the match performance of players: total distance covered per match and during each half (m), the average speed per match and during each half (km/h), maximal speed (km/h); the total distance covered at high-intensity (m) (speed range 19.8–25.2 km/h) per match and for each half, the total distance covered sprinting (m) (speed above 25.2 km/h) per match and for each half, and the number of sprints. The speed thresholds for each category are similar to those reported previously" (6) and have been universally accepted.

Statistical analysis

All data collected by the survey were processed using descriptive and comparative statistics. Regarding descriptive statistics, mean and standard deviation were measured for each variable. Regarding comparative statistics, a discriminant parametric procedure was used: analysis of variance with one-factor *Anova* and *Post Hoc*, which determined the differences in running performance every year separately. The statistical program for personal computers SPSS for Windows version 20.0 was used for data processing.

TABLE 1 Descriptive data of performance running.

Variables	Team	2015	2017	2020	F	Sig.
		Mean ± SD	Mean ± SD	Mean ± SD		
TD (m)	Budućnost	8.274 ± 3.87	8.041 ± 3.40	9.129 ± 2.46	0.760	0.541
	Sutjeska	9.441 ± 3.11	7.081 ± 3.12	7.019 ± 3.45		
WD (m)	Budućnost	2.776 ± 1.23	2.899 ± 1.23	3.431 ± 0.85	0.004	0.996
	Sutjeska	3.194 ± 0.99	2.995 ± 1.04	2.498 ± 1.28		
JD (m)	Budućnost	3.436 ± 1.67	3.175 ± 1.39	3.589 ± 1.15	1.168	0.422
	Sutjeska	3.841 ± 1.46	3.070 ± 1.37	2.795 ± 1.50		
RD (m)	Budućnost	1.378 ± 0.71	1.281 ± 0.72	1.395 ± 0.53	1.585	0.339
	Sutjeska	1.552 ± 0.72	1.283 ± 0.63	1.155 ± 0.64		
HSRD(m)	Budućnost	719 ± 0.44	583 ± 0.30	617 ± 0.28	5.389	0.102
	Sutjeska	794 ± 0.30	538 ± 0.23	461 ± 0.26		
SD (m)	Budućnost	92.75 ± 93.2	437 ± 0.32†	119 ± 0.09	0.401	0.010
	Sutjeska	105 ± 72.1	347 ± 0.23‡	66 ± 0.05		

†2017 vs. 2015, 2020; ‡2017 vs. 2015, 2020; TD, total distance; WD, walk distance; JD, jog distance; RD, run distance; HSRD, high speed runs distance; SD, sprint distance.

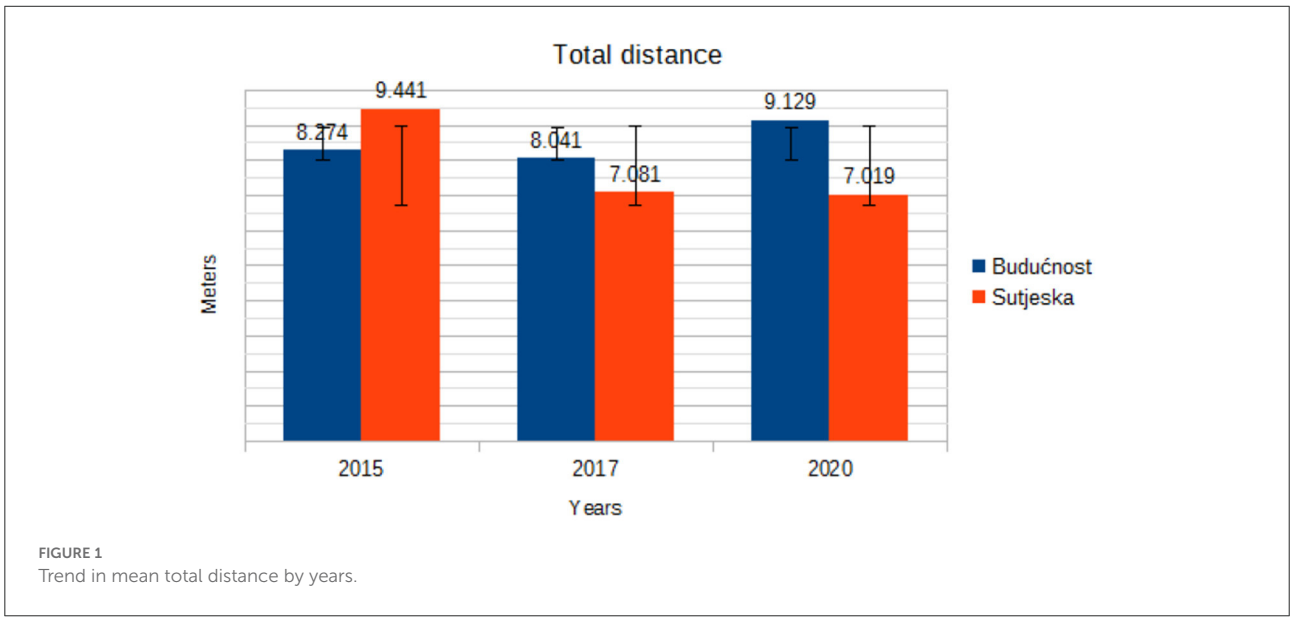

FIGURE 1
Trend in mean total distance by years.

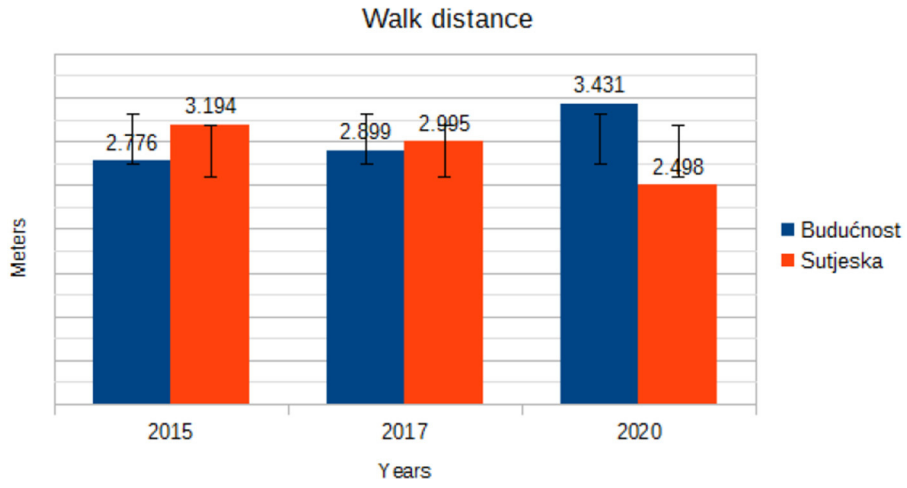

FIGURE 2
Trend in mean walk distance by years.

Results

Table 1 shows the basic central and dispersion data on running performance during in-game soccer players. Analyzing the results in Table 1, it is evident that the players of both clubs achieved identical results in running performance during the game. Analyzing the derby match from 2020, it is evident that the soccer players of Buducnost ran more (9,129 m) in relation to the players of Sutjeska (7,019 m). Comparing the derbies from 2015 and 2017, it is clear that in the previous two derbies, the players from Sutjeska ran a greater distance compared to the derby from 2020, while the players from Buducnost ran the most in the derby in 2020. Also, in the derby in 2017, the players of both teams achieved a higher number of sprints compared to the derbies in 2015 and 2020. Applying appropriate statistical procedures, it was found that there are no statistically significant differences in running performance.

Trends in running performance during the game by year are shown in the figures (Figures 1–6). Figure 1 shows the trend of the total length of running during the match. Unlike the soccer players of Buducnost, the soccer players of Sutjeska have a sharp drop in the total length of running in 2017.

Figure 2 shows the trend of walking in the game. The analysis of the graph shows that the number of meters spent walking during the game varies from year to year. The soccer players of Sutjeska reduced the trend of walking, while the soccer players of Buducnost increased the trend of walking during the game. Unlike Figure 2, which shows a walk during the game, Figure 3 shows the total jog distance of the course during the game. Inspecting Figure 3 shows that the soccer players of Buducnost have a continuous trend of jogging, while the soccer players of Sutjeska have a trend of declining jogging in all 3 years.

Figure 4 shows the downward trend in the running among Buducnost soccer players in all 3 years. The Sutjeska soccer players have seen a downward trend in all 3 years.

Figure 5 shows the high-speed running distance for the soccer players of Buducnost and Sutjeska. Looking at Figure 5, it is evident that the players of both clubs have a downward trend in the most important zone for success in top soccer with one characteristic that the players of Buducnost have a minimal increase in 2020 compared to 2017, while the players of Sutjeska have a declining trend throughout the analyzed period. In contrast, Figure 6, which provides an insight into sprint distance, shows an increase in the number of sprints at both clubs in 2017, where the players of the Buducnost made a larger number of sprints, while in 2020 there is a decline and return to identical values as in 2015.

Discussion

The practical value of such analyses is that well-chosen performance indicators can help coaches identify the good and bad performance of individuals or teams. In this regard, match analyses help identify the physiological requirements of the sport and in examining how a particular player compares to the requirements of their event. Understanding the physiological load imposed on top players in accordance with their positional role during competitive matches (activity profile, distance traveled, intensity, energy systems, and muscles involved) is necessary when developing a sport-specific training protocol. Especially with elite athletes, the most important form of training is the one that corresponds to the use of energy and biomechanics of the planned competitive effect. Therefore,

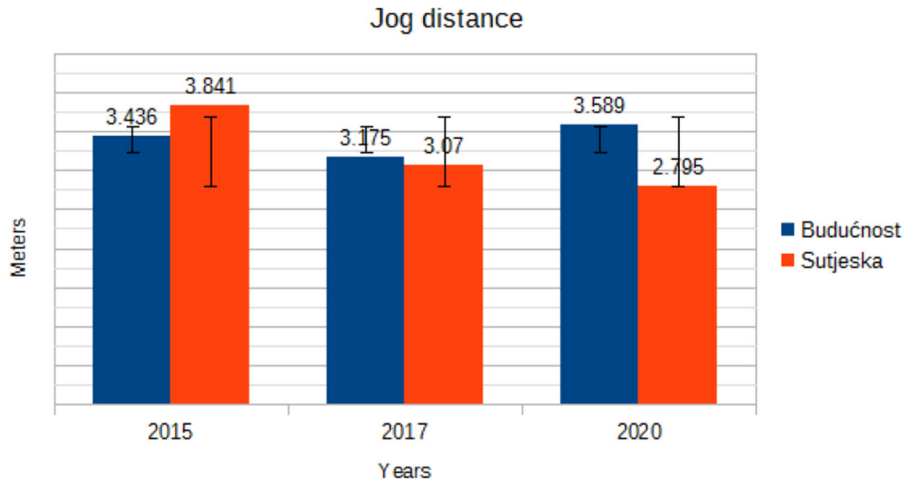

FIGURE 3
Trend in mean jog distance by years.

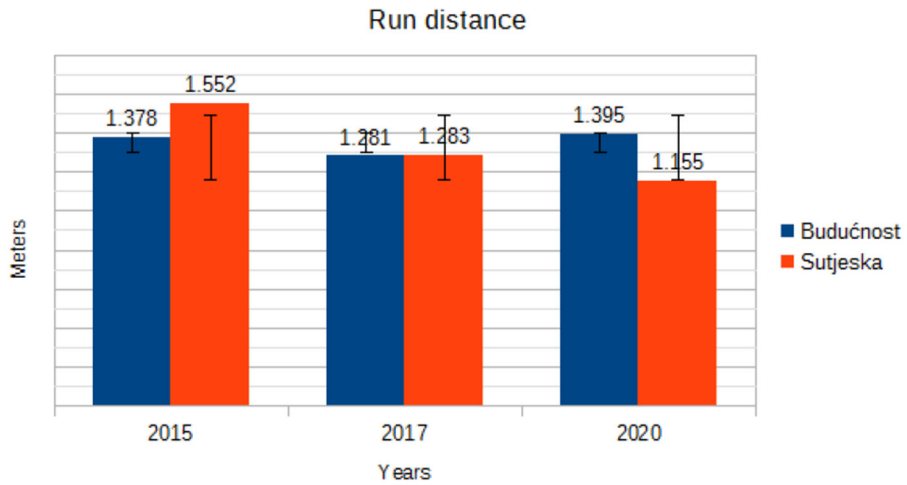

FIGURE 4
Trend in mean run distance by years.

match analyses are helpful for the development of a specific training program that mimics the physiological conditions imposed by the game. Elite sports performances in soccer are a composite of the elite characteristics of physical performance, which in turn depend on several physiological characteristics, as well as on the training and health status of the individual athlete (14).

The current study aimed to analyze trends of running performance in professional soccer players in Montenegro in three competitive matches of different seasons. During the game, soccer players perform different types of movement, ranging from resting to running at maximum speed, the intensity of which can change at any time. The distance covered during the match with elite soccer players is in the range of 10,000–12,000 m (15). The results of this study indicate that the trend component for the variable total distance is on an upward trajectory for Buducnost soccer players, ranging from 8,274 m in 2015 to 9,129 m in 2020, while for Sutjeska soccer players, there is a declining trend component of 9,441 m in 2015 to 7,019 m in 2020. Di Salvo et al. (14) recorded an average distance of 11,393 m for players competing in the Spanish Premier League in the 2003/2004 season. Osgnach et al. (16) recorded an average distance of 10,950 m for soccer players competing in the Italian Serie A in the 2007/2008 season. Comparing the stated results with the current research, it is evident that the soccer players who compete

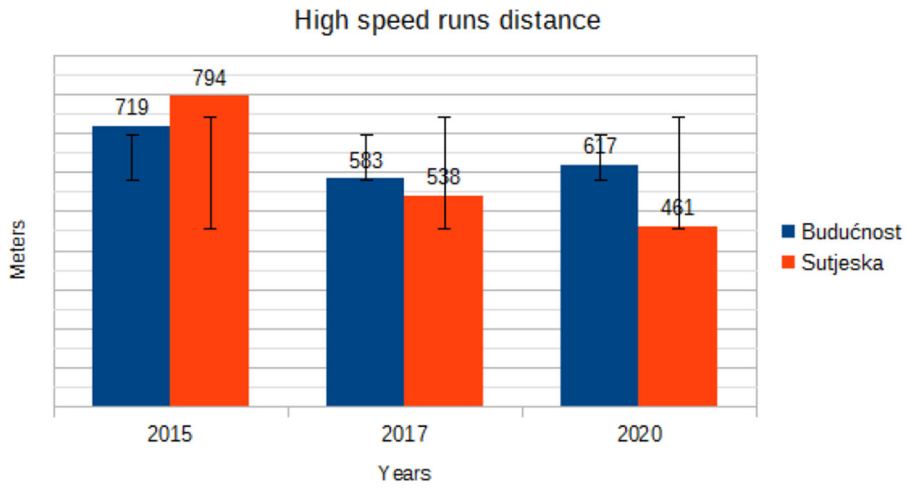

FIGURE 5
Trend in mean high speed runs distance by years.

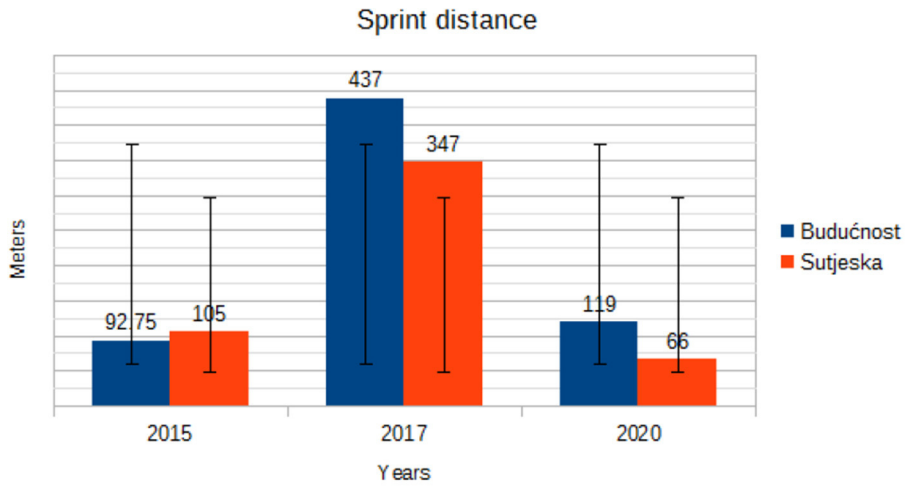

FIGURE 6
Trend in mean sprint distance by years.

in Montenegro are below the values achieved by those who compete in Europe.

In the current study, the distances covered were categorized into five levels of intensity. The trend component in the walking distance variable for Buducnost players ranges from 2,776 m in 2015 to 3,431 m in 2020, while for Sutjeska players, there is a trend component of declining walking during the game from 3,194 m in 2015 to 2,498 m in 2020. In the variables jog distance and run distance, there is a continuous trend component without large oscillations in the players of both clubs. Withers et al. (17) state that 26.3% of the total game time falls on the intensity up to 14 km/h, 64.6% on the running intensity of 14.1–19 km/h, and 18.9% on the intensity of 19.1–23> km/h. Mayhew and Wenger (18) established that a soccer player walks 46.6%, runs slowly 38%, runs quickly or sprints 11.3%, and stands without moving 2.3% of the total playing time of a game. During a match, soccer players perform different types of behavior, ranging from standing still to maximum speed runs, the intensity of which may change at any given time. However, intensity parameters are not precisely defined in these papers.

"Soccer is a non-cyclical and intermittent sport in which short-duration maximum-intensity activities, for example, sprint runs over a distance of 10–20 m, and high-intensity actions, such as counterattacks, are intertwined with activities

of low and moderate intensity (marching and jogging) and with pauses, for example, standing. Sprinting is one of the most important activities in soccer, although it merely constitutes between 1 and 12% of the mean total distance covered by a player during a match, that is, from only 0.5–3% of playing time. During a competitive game, players perform 2- to 4-s long-sprint runs every 90–180 s on average. It is assumed that players of higher ability cover longer sprinting distances with higher intensity" (19). The results of our study indicate that there is a downward trend in the most important zone for success in top soccer (high-speed runs distance), with one characteristic that the players of Buducnost have a minimal increase in 2020 compared to 2017, while Sutjeska players have a noticeable declining trend throughout the analyzed period. In contrast, an increase in the number of sprints at both clubs was recorded in 2017, while in 2020, there is a decline and return to identical values as in 2015. "The amount of high-speed running is what distinguishes top-class players from those at a lower level. Computerized time-motion analysis has demonstrated that international top-class players perform 28% more high-intensity running (2.43 vs. 1.90 km) and 58% more sprinting (650 vs. 410 m) than professional players at a lower level" (20). Furthermore, Ingebrigtsen et al. (21) "found that top teams in the Danish League covered 30–40% more high-speed running distance compared to the middle and bottom teams." In contrast, Di Salvo et al. (22) "observed that Championship players did more high-speed running and sprinting than players in the Premier League, even though the differences were small. Along the same lines, a study comparing the match performance of players in the top three competitive standards of English soccer found that players in the second (Championship) and third (League 1) categories performed more high-speed running (>19 km/h) than those in the Premier League (803, 881, and 681 m, respectively), which was also the case for sprinting (308, 360, and 248 m, respectively)" (23).

From the physiological aspect, the results of our study can be explained by the following fact: "During repetitive speed exercises, the contribution of phosphocreatine hydrolysis to the meeting of energy the demand of working muscles increases after each loading. The cool-down phase duration depends not only on the stimulation of the central nervous system but also on the rate of recovery of the autonomic nervous system functions related to the payoff of oxygen debt run up during physical exercise and on the rate of phosphocreatine resynthesis" (19).

In contrast, soccer players perform significantly less high-intensity activities when they win than when they lose or when the result is a draw. Also, if the players score a goal in the early phase of the match, they do not use the maximum of their capacities during the match. Since winning is a pleasant situation for the team, it is possible that the players have set a strategy of keeping the ball, which results in fewer sprints (24).

The limitations of this study are that only two soccer clubs from the first Telekom Montenegrin league were analyzed. Nevertheless, these two clubs are the most trophy-winning in the Montenegrin league, so they are included in the analysis. Future studies are recommended to enlarge the database. Such studies might be more suitable for detecting evolutionary trends in match-related variables.

Conclusions

The conclusion of this study provided information on performance in Montenegrin soccer, which could consequently improve the applicability of running performance in training and competitions. Based on the obtained results, the coaches will be advised in which direction the training process should go in order to increase the performance of Montenegrin elite soccer players.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval was not required for the study of human participants in accordance with the local legislation and institutional requirements. Written informed consent was obtained from the participants.

Author contributions

MJ formulated the research goals and aims, developed and designed the methodology, prepared the published work, and specifically wrote the initial draft. KG, JP, RH, and MJ prepared the published work, specifically with critical reviews, editing, and revisions. All authors commented on the draft and contributed to the final version, approved the publication of the manuscript, and agreed to be accountable for all aspects of the work.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Benefits of active life in student experiences during COVID-19 pandemic time

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The first wave of the COVID-19 pandemic has led to extreme global consequences. In this paper, changes in the basic segments of students' everyday life and their subjective perception are investigated. The research was conducted in Croatia, Serbia and Slovenia. The application of the mixed method was performed to provide breadth and depth of understanding of students' responses to lifestyle changes. The research was conducted in two phases: a quantitative, using an online survey (N = 1,053), from April 15th to April 28th 2020, and a qualitative, using semi-structured interviews (N = 30), from June 10th to July 27th 2020. Students showed similar responses to the measures, but it turned out that the response in that population was different when their gender and study program were taken into account. The results suggest that students of study programs that are not "health-related" were more sensitive to change in habits than students of "health-related" study programs, but generally changes are visible in sleep patterns (going to bed late and waking up 60 to 80 min earlier). At the same time, the time spent in front of screens increased, from M = 4.49 (SD = 2.72) hours to M= 8.27 (SD = 3.44) hours during Covid-19, not only due to the transition to e-learning, but also due to a "stay at home" measure. Furthermore, students were less physically active, there was a decrease in exercise by 20 min (SD = 86.52) and a decrease in walking (M = 54 min, SD = 103.62) per day, and what is positive is that they were able to maintain the recommended amount of physical activity. The research contributes to the understanding of social consequences of extraordinary measures in students as young, healthy and highly educated social actors, as well as deeper insight into everyday strategies they undertake to counter or adapt to the new situation.

KEYWORDS

epidemic emergency measures, the youth, eating habits, sleep habits, daily routine, studying

Introduction

Coronavirus (COVID-19) causes severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and was first reported in Wuhan, China, on December 31st 2019 (1–3). World Health Organization (WHO) declared the outbreak of the COVID-19 pandemic in March 2020. The pandemic caused a number of epidemiological, social, psychological, political and economic consequences for people around the world. Since the declaration of the pandemic on March 12th 2020 (3), until the end of this field research on July 27th 2020, 16.114.449 confirmed positive coronavirus cases have been recorded with 646.641 deaths reported by the WHO (4). As noted by Matthewman and Huppatz (5), the mortality rate from infections is largely correlated with age, and the negative physical effects of COVID-19 are most evident among the elderly population. When it comes to social impact, it is assumed that young people are most affected by "lockdowns" (5). Due to this, the focus of the research is the social impact of the COVID-19 pandemic on university students in Croatia, Slovenia and Serbia. The 2-month restrictive measures of the first pandemic wave probably had direct impact on the daily lives of most students and some adjustment was needed. In addition, a new life situation that a generation of students has never experienced before was in line with Zygmunt Bauman's "liquid life" theoretical framework, when the old balance between freedom and security was lost. The "new normal" turns life into a state of constant concern about the danger (natural and environmental disasters, random terrorist attacks, dangerous viruses that threaten people) that can happen unannounced at any time. Fear has become a name for insecurity because of the dangers that characterize our fluid modern age, with a lack of awareness of what poses a threat and our inability to determine what can and cannot be done against it (6). With fear of COVID-19, individuals are looking for some new goals to address in order to reduce excess insecurity, with personal security increasingly dominating daily plans. According to Bauman (7), the nature of *public* space and retreat into the *private* sphere could be seen, because concerned individuals are motivated by recommendations and instructions of government measures, barricade their homes and dream of the benefits of "fenced communities". "Time of fear" also corresponds to the concept of "risk age" and/or "risk society", as stated by Beck (8, 9). He mentions many aspects of the risk of global modern society, as well as the fact that new scientific discoveries and new technologies improve the quality of people's daily lives, but, on the other hand, produce and continue to create many uncertainties such as numerous health risks. These risks transcend national boundaries and do not differentiate between races, nations, social classes, social groups, gender, religion or religious affiliation (8, 9) because they become latent in the circumstances of the COVID-19 pandemic. The student generation (youth) in modern Western societies is vulnerable and enabled to reach individual maturity points fluidly and uncoordinated in time, to delay growing up and/or not be forced into certain adulthood patterns (10, 11) in postmodern society. Hence the new circumstances caused by the COVID-19 pandemic, the presence of "liquid life" in "liquid modernity" that affects rapid changes in habits and routines that have little chance of consolidating and settling and becoming a pattern, have fuelled uncertainty, insecurity and fear. This is also reflected in eating habits, sleeping habits, sports and recreational activities, which represent a significant part of the everyday life of young people (12). Individuals are the ones who have to find their own ways to deal with the anxiety and fear that is endemic to "liquid life".

Relying on the referential theoretical framework (7–9), as well as previously published papers on compatible topics (12, 13), this paper is based on the results of field research of everyday student practices in three European countries: Croatia, Serbia and Slovenia. Namely, this is part of a larger study we conducted in the first wave of the pandemic from 15th to 28th April 2020, on the population of citizens aged 18 to 82 ($N = 4{,}018$) in nine European countries (12). When processing the data, we noticed greater similarities (see Table 1) of epidemiological measures in Croatia, Slovenia and Serbia and the limitation in the implementation of study programs in isolation as well as the similarity of the epidemiological situation (number of infected/100,000 inhabitants, number of deaths/100,000 inhabitants) in comparison with the epidemiological situation and emergency measures in other European countries covered by the study. Consequently, these three societies represent the spatial framework of this research. Furthermore, although social grouping can be based on different bases (such as gender, age, region of residence, etc.), for the purposes of this research we have chosen active university education as a key feature of grouping. Hence, the demographic feature – generational affiliation – in conjunction with the participation in a certain educational sphere, prompted us to single out students for research purposes as a relatively autonomous social group. We also assumed that the mentioned generational and educational affiliation conditions similarities in the domain of lifestyles, economic dependence or independence and other features of the "transition to adulthood". In the current public health crisis, this can lead to an unequal social position of the student population, which is present in both private and public spheres of their social life, which is why we assume that the student population is socially highly affected by government measures and "lockdowns" and reduced freedom of movement. By analyzing the restrictive measures in these societies, it is obvious that the threat of pandemic spread was taken seriously in all three countries and their governments reacted quickly by introducing these measures, between 16th and 20th of March 2020. These measures included the closure of educational institutions (schools, colleges, dormitories). A new set of measures followed to ensure physical distance (2

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TABLE 1 Emergency measures in Croatia, Slovenia and Serbia in the first wave of COVID-19 (review of everyday life and university education).

Country	The first declared case of COVID-19	When did the competent authorities in your country start to apply the measures?	What are these measures in particular society?	What are the measures in the field of higher education?	When did the "easing of measures" begin?
Croatia*	25. of February 2020	19. of March 2020	Closing public life, distance limitation, ensured normal supply of food and goods;	Switching to online teaching, Eviction of students from dormitories	3. of May 2020
Slovenia*	04. of March 2020	12. of March 2020	State of emergency, locking of kindergartens, schools, colleges, playgrounds, (with the exception of) sports gyms	Switching to online teaching, Eviction of students from dormitories	6. of April 2020
Serbia*	6. of March 2020	16. of March 2020.	State of emergency; curfew 18:00-5:00 20. of March 2020 15:00-5:00	Switching to online teaching, Eviction of students from dormitories	21. of April 2020

*NIJZ -National institute of public health Slovenia; *Data of Croatia on official web site: https://www.koronavirus.hr/; *Data of Slovenia available on official Slovenian government web site: https://www.gov.si/en/topics/coronavirus-disease-covid-19/; *Data of Serbia available on official web site: https://covid19.rs/.

TABLE 2 Sample structure of respondents – survey.

Gender	Study program	*n*	%
F	SP1	182	27.3
	SP2	484	72.7
	Total	666	63.3
M	SP1	167	43.1
	SP2	220	56.7
	Total	387	36.7

n, the number of entities in the subsample; %, relative frequency.

TABLE 3 Sample structure of respondents – interview.

Gender	Study program	*n*	%
F	SP1	7	46.7
	SP2	8	53.3
	Total	15	
M	SP1	7	46.7
	SP2	8	53.3
	Total	15	

n, the number of entities in the subsample; %, relative frequency.

meters indoors, 1 meter outdoors). The mentioned measures prohibited all activities involving a large number of people in close contact and gatherings of more than 5 people. All activities that were not necessary were canceled, but many facilities and shops remained open to ensure the usual delivery of food and goods. Studying and communicating with the outside world have been moved to online platforms i.e., online teaching and social networks, while restricting movement has restricted individual freedom, that lasted until the 1st week of May 2020.

Assuming that the proclamation of the COVID-19 pandemic and the introduction of extraordinary epidemiological measures directly affected students' daily lives, the main goal was to investigate changes in daily practices, habits and routines of students in different study programs and the ways in which they responded, reacted and adapted to new circumstances.

In addition, we assumed that possible changes in differences arose as a result of the study or the so-called "high awareness of healthy lifestyle practice". As we have witnessed an acute decline in physical activity (12, 14, 15) caused by movement restrictions in the first wave of the pandemic, this could be especially true for those students who lost access to campus recreational facilities and social support for physical activity after university closures nationwide. Based on evidence of positive effects of physical activity on stressful life events (16), we assume that students of health majors (study programs) will respond more positively to sudden changes in daily practice, habits and routines than others.

In this regard, it was necessary to determine the extent to which students of study programs, which we divided into health-related study program group, SPG1 (study programs of sports and physical education, kinesiology, medicine, health) and those from other study programs – study program group, SPG2, managed to maintain their daily life habits and routines, in extraordinary social circumstances. Specific objectives included research into (possible) changes in the domain of:

- sleeping habits;
- eating habits (frequency and size of meals, consumption of fast, unhealthy or high-calorie foods; consumption of alcohol and smoking);

TABLE 4 Descriptive statistic for study program groups (SPG1 and SPG2) – male students.

Var.		Valid (*n*)	Median	Mean	Std.	Skew.	Kurt.	Shapiro–Wilk (*p*)	Range	Min.	Max.
deltaQ2a	SPG1	167	1.000	1.079	1.555	−0.218	−0.131	0.007	8.000	−3.000	5.000
deltaQ2a	SPG2	220	1.000	1.068	1.736	−0.607	1.989	<0.001	12.500	−6.500	6.000
deltaQ2b	SPG1	167	2.000	1.715	1.682	−0.252	1.949	<0.001	12.000	−4.000	8.000
deltaQ2b	SPG2	220	1.500	1.360	1.951	−0.767	3.854	<0.001	15.000	−8.000	7.000
deltaQ3	SPG1	167	−0.500	−0.687	1.488	−0.985	2.120	<0.001	9.000	−7.000	2.000
deltaQ3	SPG2	220	0.000	−0.443	1.426	−0.180	0.979	<0.001	9.000	−5.000	4.000
deltaQ4	SPG1	167	3.000	3.428	2.596	0.096	0.653	<0.001	15.000	−5.000	10.000
deltaQ4	SPG2	220	2.000	2.784	3.974	0.571	0.941	<0.001	22.000	−7.000	15.000
deltaQ10	SPG1	167	−40.000	−50.060	97.194	0.547	3.227	<0.001	680.000	−300.000	380.000
deltaQ10	SPG2	220	−40.000	−49.445	106.260	−0.707	3.653	<0.001	840.000	−600.000	240.000
deltaQ11	SPG1	167	−30.000	−39.407	96.458	−0.355	0.845	0.033	600.000	−380.000	220.000
deltaQ11	SPG2	220	0.000	−13.050	77.113	−0.585	6.207	<0.001	670.000	−370.000	300.000
deltaQ13	SPG1	167	0.000	20.868	74.278	0.974	16.214	<0.001	890.000	−420.000	470.000
deltaQ13	SPG2	220	0.000	17.373	113.356	3.951	46.686	<0.001	1,618.000	−478.000	1,140.000
deltaQ6	SPG1	167	3.000	3.428	2.406	0.078	1.752	<0.001	17.000	−6.000	11.000
deltaQ6	SPG2	219	3.000	3.486	3.177	0.332	0.837	0.003	21.000	−6.000	15.000
deltaQ7c	SPG1	167	1.000	1.743	2.098	1.095	1.869	<0.001	12.000	−3.000	9.000
deltaQ7c	SPG2	220	2.000	2.466	2.765	0.785	1.766	<0.001	19.000	−7.000	12.000
deltaQ8a	SPG1	167	0.500	0.641	1.769	−0.230	2.063	<0.001	13.000	−7.000	6.000
deltaQ8a	SPG2	220	1.000	1.175	2.795	0.631	4.478	<0.001	23.000	−9.000	14.000
Q17a	SPG1	166	3.000	3.277	1.019	−0.057	−0.213	<0.001	4.000	1.000	5.000
Q17a	SPG2	215	3.000	3.344	0.929	0.216	−0.475	<0.001	4.000	1.000	5.000
Q17c	SPG1	164	3.000	2.817	1.147	0.044	−0.834	<0.001	4.000	1.000	5.000
Q17c	SPG2	215	3.000	2.781	1.141	0.057	−0.707	<0.001	4.000	1.000	5.000
Q17d	SPG1	98	1.000	1.714	0.931	1.231	0.970	<0.001	4.000	1.000	5.000
Q17d	SPG2	160	2.000	2.025	1.154	0.795	−0.498	<0.001	4.000	1.000	5.000
Q17e	SPG1	37	3.000	2.676	1.156	0.001	−0.670	0.002	4.000	1.000	5.000
Q17e	SPG2	76	3.000	2.526	1.227	0.182	−0.852	<0.001	4.000	1.000	5.000

- awake time related to physical activity and inactivity, time spent in front of the screen as the dominant activity in a sitting position;
- new routines or routines that occurred when others were discontinued.

As habits repeat relatively automatically, with little variation, but at the same time, as habits interact with time, other people and context, and therefore are not performed in the exact same way over and over again (17), we also focused on routines as regular, less or more immutable procedures, common, prescribed, or daily, both business and personal (18). The study of daily routines as relatively fixed time patterns of consecutive activities in which one participates during a typical day (19, 20) was divided into habits (sleeping and eating), and physical activity and other routines, based on the attitude that people differ in routines, which are defined as the degree to which people are "motivated to keep everyday events in their lives in relatively unchanged and orderly patterns" (21). As we stated, for the purposes of analysis students were divided into two different study program groups: SPG1 - sports or applied kinesiology study programs, medicine; and study program group, SPG2 - other study programs such as: natural and technical sciences; humanities and social sciences; and the rest, in order to establish various everyday life circumstances, based on a particular study program. We assumed that there is a difference in the domain of life habits and lifestyles of students/members of two different groups of study programs.

Methods

Mixed (quantitative and qualitative) field research was conducted in three European countries (Croatia, Slovenia, Serbia), with the aim of observing and analyzing changes in daily life habits and routines of university students (graduate and postgraduate programs), during the first wave of emergency

TABLE 5 Descriptive statistic for study program groups (SPG1 and SPG2) – Female students.

Var.		Valid (*n*)	Median	Mean	Std.	Skew.	Kurt.	Shapiro–Wilk (*p*)	Range	Min.	Max.
deltaQ2a	SPG1	182	1.250	1.330	1.643	−0.212	0.764	0.003	10.750	−4.000	6.750
deltaQ2a	SPG2	484	1.000	1.179	1.727	−0.625	2.757	<0.001	15.500	−9.500	6.000
deltaQ2b	SPG1	182	2.000	2.059	1.883	0.093	0.734	0.034	11.500	−3.000	8.500
deltaQ2b	SPG2	484	2.000	1.774	1.708	−0.129	1.306	<0.001	12.500	−4.500	8.000
deltaQ3	SPG1	182	−1.000	−0.826	1.499	−0.332	0.426	0.001	8.500	−5.500	3.000
deltaQ3	SPG2	484	−1.000	−0.854	1.741	−0.112	1.345	<0.001	12.000	−7.000	5.000
deltaQ4	SPG1	182	3.000	3.805	3.398	0.305	0.486	<0.001	19.500	−6.000	13.500
deltaQ4	SPG2	484	3.000	2.843	3.350	−0.145	0.905	<0.001	25.000	−12.000	13.000
deltaQ10	SPG1	182	−60.000	−74.363	107.216	−0.361	0.959	<0.001	690.000	−390.000	300.000
deltaQ10	SPG2	484	−40.000	−51.217	102.987	−0.300	2.653	<0.001	840.000	−420.000	420.000
deltaQ11	SPG1	182	−30.000	−49.150	108.031	−0.192	2.482	<0.001	810.000	−360.000	450.000
deltaQ11	SPG2	484	0.000	−7.378	74.320	−0.647	4.245	<0.001	700.000	−400.000	300.000
deltaQ13	SPG1	182	0.000	26.132	77.829	1.478	8.434	<0.001	740.000	−320.000	420.000
deltaQ13	SPG2	484	0.000	16.665	65.800	−0.253	11.740	<0.001	735.000	−375.000	360.000
deltaQ6	SPG1	182	4.000	3.880	2.828	0.623	1.588	<0.001	18.000	−4.000	14.000
deltaQ6	SPG2	484	4.000	4.001	3.207	−0.058	1.704	<0.001	25.000	−11.000	14.000
deltaQ7c	SPG1	182	1.500	1.808	2.214	1.211	3.682	<0.001	17.000	−5.000	12.000
deltaQ7c	SPG2	483	2.000	2.513	3.131	0.374	2.031	<0.001	26.000	−9.000	17.000
deltaQ8a	SPG1	182	1.000	0.997	2.165	0.365	2.490	<0.001	16.000	−6.000	10.000
deltaQ8a	SPG2	483	2.000	1.848	3.204	−0.466	1.703	<0.001	25.500	−12.000	13.500
Q17a	SPG1	179	3.000	3.291	1.003	−0.272	−0.346	<0.001	4.000	1.000	5.000
Q17a	SPG2	475	3.000	3.475	1.033	−0.311	−0.306	<0.001	4.000	1.000	5.000
Q17c	SPG1	179	3.000	2.939	1.142	−0.084	−0.697	<0.001	4.000	1.000	5.000
Q17c	SPG2	476	3.000	2.981	1.228	−0.108	−0.997	<0.001	4.000	1.000	5.000
Q17d	SPG1	102	1.000	1.833	1.025	1.017	0.290	<0.001	4.000	1.000	5.000
Q17d	SPG2	342	1.000	1.874	1.096	1.031	0.067	<0.001	4.000	1.000	5.000
Q17e	SPG1	50	3.000	2.360	1.321321	0.510	−0.701	<0.001	4.000	1.000	5.000
Q17e	SPG2	188	2.000	2.436	1.333	0.447	−0.948	<0.001	4.000	1.000	5.000

epidemiological measure due to COVID-19. The use of the mixed method expanded the scope of the research by using research components of the questionnaire and semi-structured interview type, and additionally provided an explanation of the results of the quantitative method with the results of the qualitative method.

Sample

The sample consists of students from the University of Zagreb, Split, Rijeka and Osijek in Croatia, the University of Novi Sad and Belgrade in Serbia, and the Universities of Ljubljana, Maribor, Primorska, Alma Mater Europaea and the Faculty of Physiotherapy in Slovenia, who filled in an online questionnaire (12) ($N = 1053$, $n_{(Male)} = 387$, $n_{(Female)} = 666$; $M_{age(Male)} = 22.04$, $SD_{age(Male)} = 2.74$, $Min_{age(Male)} = 18$, $Max_{age(Male)} = 34$; $M_{age(Female)} = 21.80$, $SD_{age(Female)} = 2.39$, $Min_{age(Female)} = 18$, $Max_{age(Female)} = 34$).

We assumed that there are possible differences in lifestyle changes and coping strategies between students of different study programs. That is the reason why the sample was divided into two different study program groups and two gender samples (see Table 2).

The sub-sample of entities used in the qualitative research consists of students from these universities who participated in online questionnaires and who were willing to participate in semi-structured interviews (Table 3). The interview was conducted by three sociologists, who are also members of the consortium "Everyday life practices-ELP COVID-19" (12).

The sample of variables

The sample of variables of this study consists of a subset of 14 questions taken from the study (12) presented as the resulting difference (delta) between the results of variables recorded at the time of emergency epidemiological measures compared to the

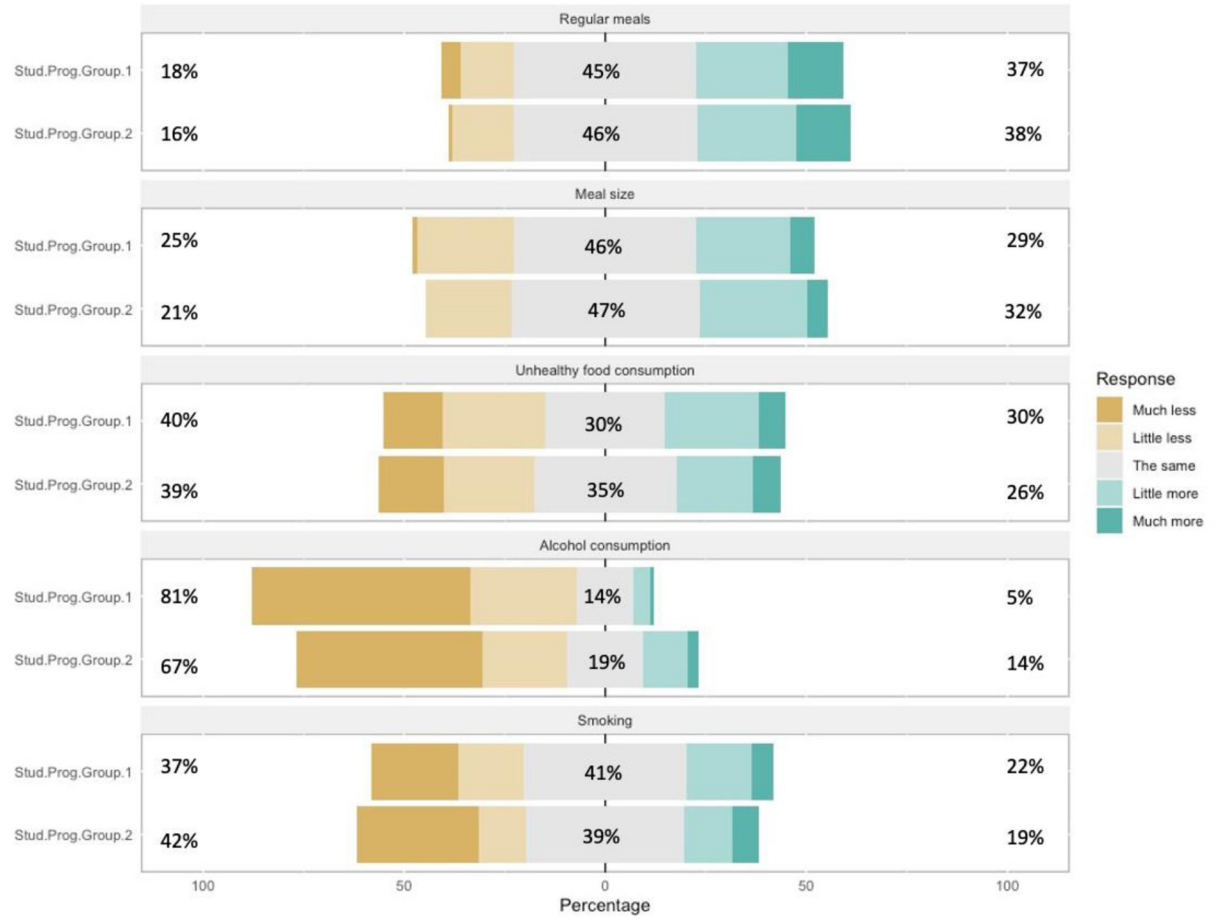

FIGURE 1
Changes in eating habits and other habits – female students.

results of variables that subjects had before the introduction of emergency epidemiological measures and 2 category variables: Study program group, (SPG1, SPG2) and gender (Female, Male).

Variables can be grouped according to the types of changes according to:

- Changes in sleeping habits: deltaQ2a (going to bed), deltaQ2b (waking up), deltaQ3 (sleeping time).
- Changes in physical activity and inactivity: deltaQ4 (inactivity time), deltaQ10 (walking for transport) and deltaQ11 (exercise/recreation), deltaQ13 (moderate or high physical activity).
- Changes in time spent in front of the screen: deltaQ6 (time in front of the screen), deltaQ7c (time on the computer), deltaQ8a (time in front of the screen for learning).
- Variables of regular meals (Q17a), consumption of unhealthy foods (Q17c), alcohol (Q17d) and smoking (Q17e), which belong to the group of variables for the analysis of eating habits (current eating habits compared to the previous usual period) are shown on Likert scales (1–5, much less, less, same, a little more, a lot more).

Questionnaire

The questionnaire was distributed in the form of an online survey in Croatian, Serbian and Slovenian in the period from 15th to 28th of April 2020. It contains a total of 24 questions with customized parts of the questionnaire (SIMPAQ – Simple Physical Activity Questionnaire) (22), which indicate data on sleep time, physical activity time (TA) and inactivity time before and during emergency epidemiological measures related to COVID-19 pandemic.

Questions and scales for assessing eating habits and together with the adapted scale for assessing changes in eating and other health habits (alcohol and smoking) were taken from EHIS

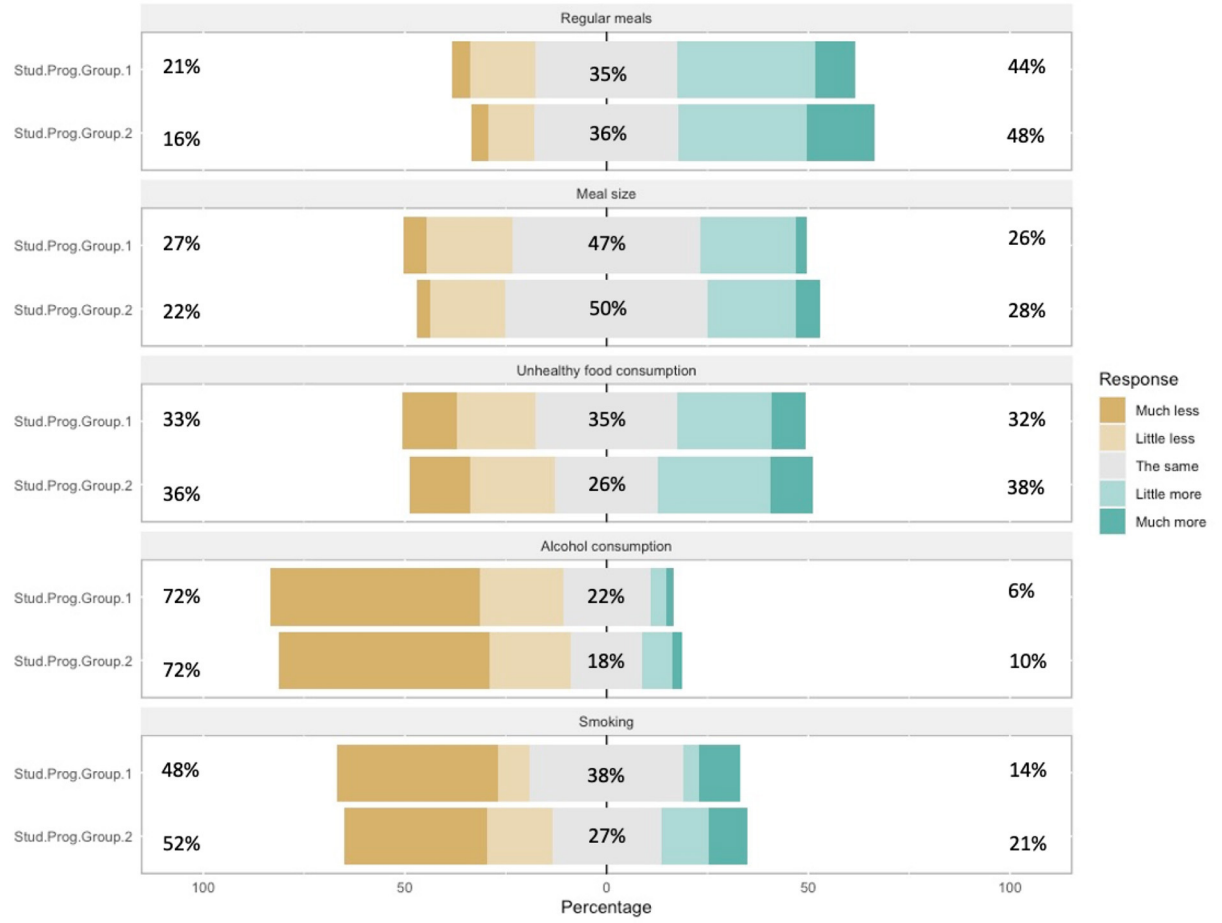

FIGURE 2
Changes in eating habits and other habits – male students.

(European Health Interview Survey, National Institute of Public Health in Slovenia [NIJZ], 2007). Survey data were collected and analyzed in accordance with the General Data Protection Regulation (GDPR).

Semi-structured interviews

Qualitative data were collected through thirty semi-structured interviews with university students from Croatia, Serbia and Slovenia (15 male and 15 female students), from June 10th to July 27th 2020. The interviews were structured around two main topics:

- changes in daily life routines and habits during anti-COVID-19 measures regarding sleep habits, eating habits, waking time related to physical activity, sedentary time and time spent in front of a screen;
- psycho-social changes due to the impact of restrictive measures against COVID-19 (personal relationships, feelings, coping with new learning regimes and perceptions of the future) that were not the subject of analysis in this paper.

The questions asked to the interviewees within the mentioned topics were aimed to indicate more deeply and specifically whether there have been any changes at all in the domains of sleep, nutrition, physical activity and time spent in front of screens. Detailed descriptions of changes in daily routines, conditioned by the establishment of isolation, and then the creation of "new routines" as the isolation lasted longer and longer created the basis for questions about the interviewees' perception of what psycho-social consequences these changes caused in their lives. Researchers did not encounter ethically questionable situations during the research. Anonymity is guaranteed to all participants, and each interviewees was given

a number and was categorized according to the type of the study programme. All interviewees agreed to participate in the research (each of them signed an agreement to participate) and were informed about all the conditions under which the data obtained during the research will be used. Interviews were recorded using a dictaphone or a smartphone app. All recordings are stored in private researchers' databases.

The average age of the interviewees was 21.86 years (SD = 2.06). The average duration of the interview was 23:37 min. The shortest interview was 8:38 and the longest was 50:53. The duration of the interview was related to the type of interviewees (dominated by moderately honest and completely honest type of interviewee), age of the interviewee, year of study, study program, but also the need and willingness of the interviewee to speak more or less openly about their personal experience of the emergency measures during the COVID-19 pandemic. Most of the interviews were conducted live (in offices or other places), and seven (6) of them were conducted by video call (MS Teams, Zoom), because the current circumstances of the daily life of the interviewees required such interviews.

Results

Descriptive parameters (Mean, Median, Mode, Standard deviation, Minimum, Maximum, Range, Skewness, Kurtosis) were calculated for all quantitative variables. The normality of the distribution was tested by the Shapiro-Wilk test and the Q-Q plot. Descriptive parameters were calculated separately for the male subsample of students and female subsample of students of both study program groups (SPG1, SPG2) (see Tables 4, 5).

Analyzing the parameters of the form of distribution, homogeneity of variance, normality of distribution of residual values, and balance of subsamples, it was found that the necessary prerequisites for using the parametric method of differences were not met so Mann Whitney *U* test was used to determine differences between two samples. The analysis was performed using the R (23) software environment for statistical computing and graphics, using the "psych" (24) and "dplyr" (25) packages.

For the empirical material collected in the interviews, qualitative analysis software was used (26) NVivo 12 for data storage, transcription for recording connections, notes and arrangements of codes and nodes. In addition, the researchers performed data analysis, imaginative research and thinking. Interviews were conducted according to an agreed protocol. The initial code tree also tracked blocks of protocol questions, as well as additions agreed between researchers from Croatia, Serbia and Slovenia. The basic nodes were: "sleeping habits", "eating habits", "physical activity", "time in front of the screen" and other (new) habits.

More detailed analysis of empirical material within nodes:

- sleeping habits (stays the same, goes to bed later, sleeps more);
- eating habits (eating habits are related to emotions (eat more, unhealthy), eat less, eat healthier, eat carefully when it comes to selection of foods, no changes in eating habits);
- physical activity (PA) leads to more sub-responses (less PA, more PA, new PA program);
- time in front of the screen (more time in front of the screen (TV, mobile phone, tablet), for work, study, information or entertainment);
- New habits/routines (new, re-established or transferred habits).

Sleeping habits

Sleeping, as one of the basic physiological functions of human beings, plays an important role in the process of learning, memory, work results and the overall quality of life of the student population (27). Research results show that sleep-related variables, such as lack of sleep, sleep habits/schedules, and the like, affect student performance and interpersonal relationships (28–30). As epidemiological measures caused by the COVID-19 pandemic significantly increased the time respondents spent at home, it was necessary to investigate their habits/sleep schedule.

Mann Whitney *U* test found that there was no statistically significant difference between the differences (deltaQ2a) in "bedtime" between the analyzed study program groups for female students (W = 046060.5, p-value = 0.358) and male (W = 18,389.5, p-value = 0.986).

The variable (deltaQ2b) - "wake-up time" showed a significant difference between study program groups in the student subsample and it was found that there is a statistically significant difference (W = 20,742.5, p-value = 0.028) but not in the female subsample (W = 47,785.5, p-value = 0.089).

The variable (deltaQ3) - "sleep time" did not show statistically significant differences between the study program groups of female students (W = 44,736.5, p-value = 0.752 nor in male students (W = 17,076.0, p-value = 0.225).

Qualitative analysis showed that more than half of the students observed changes in sleep pattern and sleep quality that were not detected as statistically significant by quantitative research, and in some cases we detected sleep disorders, as evidenced by students' responses to sleep pattern.

"I definitely prolonged my going to bed time for 3 h, so instead of going to bed at midnight, I went to bed between 2 and 3 am in the morning, because I could get up later." (Student, social sciences).

"I have problems with my sleep, I go to therapy every year and I have periods when everything is fine and I have periods when sleep is a disaster. I even took medication for it, but after those 1st months of COVID-19 it didn't matter anymore or I didn't even pay attention to what time it was, or what time of day

it was, I stayed awake until 5 in the morning, actually complete chaos." (Student, social sciences)

"No, there is basically no change because I get up at 6 am and go to bed from 10 pm to 11 pm for a year, or more than a year, and during the pandemic it was more or less the same. Nothing has changed, I slept the same." (Student, sports)

"Sleeping at 10 pm, I leave the phone much earlier, I really liked it, I could have fallen asleep earlier because I didn't look at the screen, I didn't answer some messages, I would finish something quickly, leave the phone like that and rest." (Student, sport)

Students' reactions point to a certain transformation of everyday life practices in two ways: students who talked about longer sleep said it was due to the fact that "they had nothing else to do" or the fact that their daily life at faculty is simply full of obligations. Longer sleep was *necessary* to finally get some rest. The students (most from SPG1), who reported going to bed at the same time, said they "tried to maintain a routine", meaning that in the face of epidemic measures caused by the COVID-19 pandemic, they had to make an effort to maintain more or less the same routine of their daily life.

Sedentary behavior and physical activity of students

Physical inactivity is considered to be the fourth leading risk factor for mortality in the world and is estimated to result in 3.2 million deaths each year (31). The risk of increased physical inactivity was higher with the introduction of emergency epidemiological measures to prevent the spread of COVID-19. These measures included the closure of gyms, fitness centers, the closure of parks and outdoor gyms, as well as a ban on gathering more than five people at the same time, in all three countries. At the same time, these measures directly affected freedom of movement, but also the ability to engage in physical activity (12, 14, 32–34). In this regard, this research points to the characteristics of students' physical activity during the quarantine of the first wave of the coronavirus pandemic.

Analysis of differences in the inactivity difference variable (deltaQ4) indicates a statistically significant difference in the inactivity time of female students of the analyzed study program groups (W = 50,505, p-value = 0.003), also between male students in SPG1 and SPG2 (W = 21,298.5, p-value = 0.007). The time of inactivity is significantly lower in the subsample of students in the study program group 2, as the restriction of sports activities affected members of this group less than the students of SPG1, which increased the time of inactivity (on average by almost an hour), which is a logical consequence of higher PA before SPG2.

Analysis of the variable differences in walking for transport (deltaQ10) indicates a statistically significant difference in time spent walking for transport and recreation between study program groups of female students (W = 38,512.5, p-value = 0.012) but not between male students (W = 17,998, p-value = 0.733). Walking for transport and recreation decreased in both subsamples. Female students of SPG1 group reduced (SPG1 median−60) walking time for transport and recreation more than female students of SPG2 (SPG2 median−40), while students of both groups obviously increased (SPG1 / SPG2 median = −40) walking for transport and PA, which may be the result of more time devoted to recreational walking.

The difference in time spent in sports activities (deltaQ11) between the analyzed study program groups is also statistically significant. The difference was also found in the subsample of female students (W= 32,678, p-value < 0.001) and male students (W = 14,945, p-value = 0.002).

It can be seen that, in general, SPG1 students significantly reduced the time spent in sports activities (median−30) compared to students of SPG2 study program groups (median 0). The same difference was found in the subsample of SPG1 female students (median−30) compared to SPG2 female students (median 0).

The variable (deltaQ13) – "time of moderate or vigorous physical work" does not indicate statistically significant differences between the study program groups SPG1 and SPG2 female students (W = 46,255.5, p-value = 0.290) and male (W = 19,753, p-value = 0.184).

Interviews also confirmed some results of quantitative analysis in changing time for physical activity (PA). Here are some student responses that explain the reasons for lower exercise intensity, mainly due to movement limitations, related to laziness, lack of discipline, and time required to adjust:

"A lot has changed. I am quite active, I like to walk, but when quarantine was introduced, we were all forced to be in the house and then you could not move, so we were all pretty lazy and it is certain that we all gained a little weight, including me... Simply, sometimes you don't feel like cooking, so order food delivery, and since you're so stressed out, it had a bad effect on my physical activity." (Student, humanities)

"It was a disaster, literally, although I am the type of person who prefers to be at home and I am not particularly physically active during the day, I mostly sit and study, rest or possibly go to the gym which is my only type of physical activity (...) I eat everything and anything, not taking care of myself, not training, not disciplined and it all started to annoy me." (Student, social sciences)

"Maybe the first month there was less exercise because I didn't have the riding and fitness training I normally had. Then, after a month, I replaced exercising in the gym with exercising at home, which is not the same thing." (Student, sports)

However, half of the students (15) trained regularly, and some even increased their training intensity. In the second half, there were students who were less physically active (6) and equally physically active (8). Some of them stated that

they exercise at home, through online training sessions or individually. One student (sports science) stated that after 31 days of quarantine, he became first a coach to his mother and later an online coach to friends and relatives. Several students reported lower PA levels because they were active athletes (e.g., football, horseback riding), due to an emergency measures they were forced to stop training in at least the first 2 weeks of quarantine. On the other hand, several students stated that they are more physically active than usual. Some sports students said exercise, regular sleep and healthy eating habits are linked. One student (social sciences) started training only after the introduction of emergency measures because she gained a few kilograms due to an unhealthy diet during the pandemic. Students of the Faculty of Kinesiology (KIF), Faculty of Sports and Physical Education (FSFV) and Applied Kinesiology (AK) state that they exercised regularly, which again leads to the conclusion that students of these study programs have more clearly defined health-related routines in terms of daily practices.

"I exercised at home, before I went to the gym 3 times a week (...) After the first week of quarantine I was completely crazy because I was used to going out, hiking, playing volleyball during the summer, I missed it so much, I felt captured. Then I bought the online program HIT (high intensity training)... from a kinesiologist, just to get an idea, because I know how to exercise on my own, but that's just to have an idea, as well as a little incentive, and it really came in handy (…) I'm practicing now every day." (Student, sports)

"I tried to stay physically active and every day I did whatever came to my mind, from running, Pilates, kickboxing, we even ordered a punching bag and hung it on a tree in the yard, so I always had some kind of recreation, activities; I read what I like." (Student, sports)

"I practiced regularly. Then my mom started exercising with me in the living room. When my aunt heard that my mother was training, then she also wanted to train with us, so we had to use Skype. Then my girlfriend wanted to practice with us, and so did her father, so my brother asked for the same. At one point, 5–6 of them practiced. So, I practiced and became an online coach (laughs)." (Student, sports)

Having in mind the overall results of quantitative and qualitative data, we can conclude that students were generally less physically active during the 2-month epidemiological measures. Not only did exercise as a physical activity decrease, but daily walking also decreased (not significantly in relation to gender and study program) as a result of the "*lockdown*." All students reported a decline in walking (40 to 50 min per day), with the largest decline in sports students (SPG1) and fewer in students of SPG2 group.

Such results were also expected, as the quarantined state suddenly closed entire families to apartments with limited time and space to move and exercise. On the other hand, the narrative responses of students showed that the effect of restrictive measures results in increased inactivity, less walking, while exercise increases in several students who were previously inactive and use *lockdown* to start exercise. Additionally, students with an active lifestyle and regular physical activity habits found a way to continue exercising at home, despite space constraints. This also points to the fact that emergency epidemiological measures have necessarily influenced the change in students' daily practices, but also that they have produced some new strategies that some students have implemented to stay or even become more physically active.

Screen time as students' daily habit

Time spent on screens as a passive, sedentary habit, changed the most during the study period due to the shift of reality to online mode.

Analysis of the variable time difference spent in front of the screen (deltaQ6) does not indicate a statistically significant difference between study program groups SPG1 and SPG2 subsample of female student subsample ($W = 41{,}896$, p-value $= 0.329$) and male student subsample ($W = 18{,}255$, p-value $= 0.977$).

This is expected, as the increase in time spent in front of the screen can be seen as a result of the increased need to use technical aids (computers, tablets, smartphones) to conduct online forms of study and continue education, which was significant in both groups of students.

One of the segments of the analysis, which is manifested through the analysis of the variable differences in time spent in front of computers (deltaQ7c), partially determines its impact on differences. A statistically significant difference was observed between the two study program groups of female student subsamples ($W = 36{,}448$, p-value < 0.001) and male student subsamples ($W = 15{,}392$, p-value $= 0.006$). There is a visible increase in time spent in front of computers in subsamples of male and female students of study program group 2 (SPG2 students median = 2, SPG2 students median = 2) compared to medians of subsamples of male and female students of study program group 1 (SPG1 students median = 1.5, SPG2 students median = 1).

Statistically significant differences were also observed in the analysis of the variable differences in time spent in front of the screen to meet study obligations (deltaQ8a) between study program groups of female student subsample ($W = 33{,}297.5$, p-value < 0.001) and male student subsample ($W = 15{,}963.5$, p-value $= 0.026$).

The SPG2 male student subsample increased screen time for study more than SPG1, (SPG1 median = 0.5, SPG2 median = 1), as well as female students, where time spent in front of the SPG2 screen changed significantly compared to SPG1 (SPG1 median = 1, SPG2 median = 2).

The results of the interviews confirm the obvious increase in time spent in front of screens and sedentary time, mainly as a result of increased time for learning and other study obligations.

"Yes, it only increased... records were broken, there was no other, because I was writing a master's thesis. It was 5, 6 h a day, and then the phones, but yes, there was certainly more, much more in front of the screen, a lot of sitting, it was even boring, quite boring." (Student, sports)

"The time spent on the screens, however, has increased abnormally. I was practically at the computer all day long. First because we had lectures, and then we played games and that was the only way you could hang out with someone and talk online, otherwise it would be absolutely pathetic (...) Yes, and time spent on a cell phone, I was on the phone all the time... both on the computer and on the phone together."(Student, social sciences)

"Watching movies and series has definitely increased, I know the first 10 days, it was 24 h a day (…) When I did not have any ideas for movies, then I asked someone to recommend a new movie to me. (…) Over time, it was less and less. The second month was more focused, I think there were still movies and series, but a lot less. Then the lectures started somehow, and I kept pace with them." (Student, social sciences)

In addition, the interviews confirmed that "time spent in front of screens" appears to be the dominant daily habit. All students have in common that they spend a lot of time in front of screens. However, their answers should be classified into three groups:

- passive time spent watching television/mobile phone;
- time spent in front of the screen due to online learning/studying;
- time spent on social media to access information on the COVID-19 pandemic and/or entertainment.

These responses suggest an association between physically inactive behavior and time spent in front of (different) screens, which was also confirmed in basic research (12). Increased physical inactivity is closely related to increased time spent behind screens, such as a TV, smartphone, computer, or tablet. In the primary sample, 65% of the increased time spent on screens, along with increased meals, unhealthy food consumption, and decreased exercise, was explained by an increase in body weight in 20.6% (12).

Eating habits and other habits

Reported quantitative and qualitative data indicate more inactive, sedentary behavior, more time spent on screens and situations related to different emotions (fear, loneliness). These emotions were associated with eating more of fast and unhealthy food in one third of students (female, humanities / social sciences or natural sciences), mostly at the beginning (first 2 weeks) of the introduction of emergency epidemiological measures, which resulted in weight gain. A disrupted work/study routine resulted in unstructured schedules, which could lead to boredom and/or increase time spent on screens, which in turn can lead to overeating and consequent unbalanced energy intake (35).

The analysis did not identify statistically significant differences in the variables of differences between groups SPG1 and SPG2 and subsamples of male and female students, related to eating habits and other habits (for variables regular meals (Q17a), unhealthy food consumption (Q17c), alcohol (Q17d) and smoking (Q17e).

Regular meals (Q17a) generally for SPG1 and SPG2 no statistically significant differences were observed between female student subsamples [$H_1 = 3.281$, $P = 0.070$] and male student subsamples [$H_1 = 0.208$, $P = 0.649$]. As well as regular meals and consumption of unhealthy food (Q17c) was not differ among students of different study program groups of male student subsamples [$H_1 = 0.086$, $P = 0.769$] or subsamples of female student [$H_1 = 0.243$, $P = 0.622$]. It can be interpreted that belonging to different study programs does not show an impact on eating habits.

The variable alcohol consumption (Q17d) did not show statistically significant differences between the study program groups of female student subsamples [$H_1 = 0.018$, $P = 0.894$], but a marginally statistically significant difference was observed in the male student subsample [$H_1 = 3.741$, $P = 0.053$], which speaks of reducing the amount of alcohol consumption by students, which can be explained by the decline in socializing of young people, often accompanied by alcohol consumption.

Likewise, smoking (Q17e) as a health risk behavior showed a statistically insignificant difference between the study program groups of female student subsamples [$H_1 = 0.151$, $P = 0.697$] and study program groups of male student subsamples [$H_1 = 0.427$, $P = 0.513$] (see Figures 1, 2).

Qualitative analysis shows some quantitative results regarding the question of how feeding habits have changed negatively:

"For the first 2 weeks, we just ordered food. By ordering again and again, there is e.g., lack of vegetables… Lack of some healthier foods… There are no specifically made meals such as breakfast, lunch, dinner, but it is more like, lunch is at 12 and then it is a meal for the whole day because we eat so much… And then dinner at 10 in the evening, which is completely disturbed." (Student, social sciences)

"It wasn't a big habit, but I liked to eat a much richer dinner in the evening, a little sweet during the day, so that it also accumulates there – I gained two kilos, let's say…" (Student, sports)

"I ate… I think I definitely ate more, that made me feel bad, more sweet, so much unhealthy food, but because it was some new environment, I didn't know so many products on the market, and because my boyfriend and I had a different diet,

what suits his stomach, may not suit mine. So it took me a while to figure out what I was doing for myself at home, to adjust to that environment and start, let's say, eating better. Less in the evening, because I feel like I've eaten a full meal already; I was very tired and suddenly I had a greater need for sweets. So, over the last few weeks, I've been slowly fixing that. Because I was somehow stricter, I ate more carefully." (Student, science)

It is encouraging that 2/3 of the students in the interviews stated that they did not change their eating habits or changed them in a positive way, with a healthier, more balanced diet and regular meals.

"I cooked every day to help out and then I found some recipes, meals that can be prepared a little healthier, a little less fatty, and then I found a way and food that suits me and (…) Then I started to establish a rhythm that suits me. Then, at one point, I felt really good, I got up in the morning and that day I knew I was going to eat what I like, I was going to eat something sweet, I was not going to bother about it and I was just pretty relaxed, I got out of that cramp, actually during the extraordinary measures, it helped me a lot to calm down, relax, to understand some things differently, it helped me." (Student, sports)

This new daily rhythm caused students to acquire some new habits/skills or to "strengthen" the intensity of some old behaviors. Several female students said they have started cooking healthier food, while others more sweetscakes. Although cooking is a common answer, we should classify these answers into two groups: preparing healthy meals and cooking and baking desserts. Some students began to learn foreign languages or develop their talents for drawing or photography. These answers point to the fact that the interviewed students found some strategies for *surviving* the new everyday life. One of the indicators is the redirection of *excess* free time to the acquisition of new knowledge and skills.

"I started learning Japanese more intensively. (…) Basically, this quarantine was an opportunity for me to focus a little more." (Student, sports)

"I started doing meditation and breathing exercises. Now I am more relaxed and believe in myself. That was the biggest change. Yes, this meditation relaxed me and gave me a better sleep." (Student, sports)

"(...) On the one hand, it was great to learn a little more, reading things that I am interested in…" (Student, mechanical engineering)

In addition, unhealthy habits such as alcohol consumption and smoking before and during the pandemic did not show statistically significant differences between the sexes and study programs, but a decline was observed in students representing 70.42% of the population (average = 1.92 on Likert scale) in alcohol consumption and smoking (34.98% of the student population) and slightly lower smoking was also observed during emergency measures. The results coincide with a general reduction in alcohol consumption and smoking (12) and can be explained by severe limitations in social life and accompanying social habits, drinking and smoking (especially among young people), including countries where a pandemic has broken out.

"Since there were no parties at that time, I can easily say, there was not so much alcohol, all in all, it was gloomier, more serious." (Student, sports)

In addition, most students described the time they spent with family members as a "new routine" and generally described it in a positive context.

"I think that by shutting people down, they had to look at their family members to see if everything was okay with them. And then people probably turned to themselves and their own, which is most important because they realized how important these relationships are. I've improved relationships with my family, I think, and I've had a really good relationship with them before, especially with my mom and sisters. We realized that we love our Sunday lunch when we are not limited by time, that we enjoy how much we love spending time together." (Student, sports)

"I think the only positive thing is that some people who work a lot have finally spent more time with their family and made up for it with them, so that's one of the positive things." (Student, humanities)

The results of the qualitative research show that the unforeseen social crisis, conditioned by the threat to human health, has led the respondents to reconsider their daily life priorities, rhythm of life and family life. For many of them, this is the first extreme life situation, and they were somewhat *forced* to look for new strategies to maintain the old everyday life or establish a new routine. One of the new routines was the obligation to return home (due to the closure of dormitories and the closure of state borders for foreign students) and stay all day with family members. Given most of the interlocutors' responses, this was also one of the few positive changes during quarantine.

Discussion

Taking into account the results of previously conducted quantitative research, we can highlight several negative consequences caused by the introduction of emergency measures caused by the COVID-19 pandemic, namely: poor mental health with symptoms of post-traumatic stress disorder, avoidance of other people and anger, fears, frustrations, boredom, stigmatization, lack of stocks, lack of adequate information, financial loss (36–40), as well as an increase in negative health impacts and routines such as reduced physical activity (walking, exercise), in favor of increased sedentary behavior, mainly due to the time people spend in front of screens (12, 41). More precisely, from the perspective of the results of our study, we can summarize the impact of emergency epidemiological, i.e., restrictive measures caused by the

COVID-19 pandemic in two directions. First of all, the negative consequences of the "lockdown" are related to the development of unhealthy daily habits in the student population, as follows:

- reduction of physical activity,
- increasing inactive time spent in front of the screen,
- unhealthy diet associated with overeating or "emotional overeating", especially food that provides *comfort* due to boredom,
- Interrupted scheduling and due to possible psychological factors (uncertainty, loneliness and fear) that resulted, according to the testimonials in qualitative research, weight gain of some respondents or sometimes sleep disorders.

These negative consequences should not be ignored when it comes to the health of the population, especially young people. Particular attention should be paid when similar emergencies occur with a more sensitive view of government policy when preparing measures such as closing education systems, sports and recreational programs to avoid serious impacts not only on physical but also on mental health.

The results of the research also indicate some positive outcomes of the 2-month pandemic experience, namely:

- Some students improved their lifestyle, ate healthier during the pandemic, and had more time for hobbies and the acquisition of new knowledge and skills (learning, reading, meditation, acquiring new skills);
- It is significant that students of sports and medical study programs spoke about maintaining daily routines and health habits even during a pandemic. In this regard, they rarely talked about sleep disorders, and more often about healthier eating, maintaining a routine of continuous physical activity adapted to new circumstances. These habits have a protective role against stress in challenging times because the individual can better guard against new, unpredictable, or threatening stimuli (42);
- SPG 1 students confirmed the importance of developing habits and routines that enable effective response to emergencies that threaten the routine of daily life.

Results we obtained are to some extent in line with Bauman's "liquid life", which we have used as theoretical framework of the research. As we assumed, the "old" balance between freedom and security was lost for the first time in our respondents' and interviewees' lives. The *new* epidemiological and social circumstances turned their life into a state of concern about the *invisible* danger. Nevertheless, the results indicate that SPG1 adopted a more successful strategy to fight against the mentioned *invisible danger*.Such selected answers point to the double consequences that extraordinary measures have left on the everyday life of university students, with special emphasis on sleeping habits, diet, sedentary and physical activities, and time spent in front of screens. Finally, both negative and positive consequences of the above-mentioned measures indicate individual *strategies* used by university students for confronting with unforeseen epidemiological as well as socio-psychological circumstances.

Conclusion

Taking into account the results of this field research, we can conclude that changes in daily life routines in the student population were obvious. During the *lockdown*, students spent most of their time at home and were mostly inactive. They lacked socializing, interpersonal communication, social interaction and free movement, which they mostly made up for with more time spent on social media – in front of the screen and sedentary. By summarizing the impact of the COVID-19 pandemic measures on students' daily lives, by showing changes with positive and negative impacts, we were able to explore students' social responses and their adaptation to new social circumstances. Although the negative impact is primarily related to negative health habits in the domains of physical (in)activity, time spent in front of screens and consuming unhealthy food, they positively affected partnerships and time needed for self-development of students. Students of sports study programs showed a more positive response and successful coping with the new situation compared to students of other study programs, which confirms the importance of maintaining daily routines and habits in times of extreme situations such as the COVID-19 pandemic. Finally, by researching the daily life practices of students of the three societies during emergency, extraordinary epidemiological measures, this research contributes to illuminating and understanding the social consequences of these measures on young, healthy and highly educated social actors. It also provides a deeper insight into the day-to-day *strategies* they are undertaking to counter or adapt to the "new normal". However, it should be borne in mind that the research was conducted in the middle and at the end of the first wave of the COVID-19 pandemic. At the time of writing, these societies were experiencing a third wave of pandemics. Therefore, it is important to take into account the need to continue research (transformation) of everyday practices of the student population.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Ethical Committee of the Faculty of Sport and Physical Education, University of Novi Sad, Serbia (46-11-07/2020-1). All respondents and interviewees signed written informed consent for participation.

Author contributions

SP, IM, DK, SB, and SR wrote the manuscript, performed analyses, and revised the manuscript. SP, IM, and SB collected the data. SP, IM, DK, and SR overviewed previous studies. SP, IM, and DK discussed the results. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Sports activity and changes in physical fitness of Polish children and adolescents: OSF study

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Background: Physical activity promotion programs for children and adolescents should constitute the basis of any national health policy aiming to improve physical fitness, which is a significant health indicator in children, adolescents, adults as well as elderly persons.

Methods: The study included 1,230 children and adolescents aged 8–16 years (60.1% of girls) from Poland. Five hundred and twenty-seven persons covered by the survey (42.8%) participated in physical activity promotion called "Athletics for All!" (AFA) as an experimental group and 703 peers not participating in any forms of physical extra-curricular activities as a control group. Participants were measured for basic anthropometric parameters and body mass indices were calculated: Body Mass Index (BMI) and Ponderal Index (PI). Evaluation of physical fitness was made using the OSF Test (3 × 10 m shuttle run, standing broad jump, 1 kg medicine ball overhead throw, 4-min run). Comparative analysis between the experimental and control groups was carried out using the *T*-test for independent samples. Analysis of correlations between quantitative variables was performed with Pearson's *r* coefficient.

Results: Statistically significant differences in all the tests were noted between the experimental group (AFA) and the control group in favor of the former one. Taking into account reference ranges of BMI created according to the latest Polish norms, statistically significant differences were noted between the subgroups in all physical fitness tests. As far as PI is concerned, in the AFA group significant differences were noted in all physical fitness tests between subgroups created in accordance with the aforementioned norms.

Conclusion: The findings of our study show that it is necessary to introduce physical activity promotion programs for children and adolescents. Such programs should constitute the basis of national health policy aiming at improving physical fitness among young people.

KEYWORDS

sports activity, physical activity, physical fitness, Body Mass Index (BMI), Ponderal Index (PI)

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Introduction

Increased physical activity (PA) produces numerous health-related benefits that are particularly important for children and adolescents. These include improved physical fitness and mental health, enhanced cardiovascular fitness and metabolism as well as better developed musculoskeletal system (1–4). Moreover, PA may exert a positive influence on cognitive abilities and learning outcomes (5). Increased PA also constitutes the main element of prevention of obesity and metabolic diseases (including type 2 diabetes) (2). Due to the epidemic of obesity among children worldwide, activities aimed at health promotion and taking up physical activity are extremely significant (6).

According to the latest guidelines of the World Health Organization (WHO), it is recommended that children and adolescents aged 5–17 should perform moderate-to-vigorous physical activity (MVPA) for at least 60 min every day. At the same time, they should do vigorous PA as well as muscle- and bone-strengthening exercises at least three times a week (7).

Regular PA is an indication of the acquired health competences: knowledge, skills, beliefs, attitudes and needs associated with health (8). Unfortunately, a large proportion of children and adolescents do not follow recommendations regarding PA (9). Sedentary activities, i.e., activities performed in a sitting or lying position with energy expenditure of $\leq$1.5 METs (Metabolic Equivalent of Tasks) constitute a common element of lifestyle in contemporary societies all over the world (10). Since 2020, COVID-19 pandemic has brought about changes in the functioning of many areas of economy and education (working from home and distance learning), which has led to a rise in sedentary behaviors (11). Therefore, there is an urgent need to increase PA particularly among children and adolescents. It is schools as well as external organizations that should promote PA in this group (3).

Physical fitness (PF) can be defined in a variety of ways. Most often, it is described as an ability to perform body movements vigorously, without excessive fatigue and with enough energy to cope with different life situations. Thus, this term encompasses endurance of the respiratory system and skeletal muscles, strength and power of skeletal muscles, speed, flexibility, agility, balance, reaction time and body composition (12, 13). PF level is conditioned by a number of factors. It depends on both genetic factors and regular PA (14). In the case of children and adolescents, it is particularly important to implement PA with exercises aimed at developing motor abilities that will ensure effective muscle performance in adult life (15). Blair et al. (16, 17) reported that higher levels of PF in adults reduce the risk of cardiovascular diseases and cancer significantly and delay mortality caused by any factors. In turn, lower PF levels increase such risk both in men and in women.

In the literature we can come across numerous studies on measurement and evaluation of PF in different populations and social groups (18–23). The use of different tests is a necessary form of assessing and monitoring motor ability levels (24). It is based on testing motor abilities in a simple and intelligible manner, and each test ought to be reliable and valid (25).

The development of batteries of fitness tests began in the USA after the publication of Kraus regarding the comparison of PF between American children and their European counterparts in the 1950s (26). The first European study based on American methodology was carried out in the 1960s in Belgium and the Netherlands (27). In Poland, the most common tests are Denisiuk's Physical Fitness Test, Trzesniowski's Physical Fitness Measure, International Physical Fitness Test, Eurofit and Zuchora's Index of Physical Fitness (25).

Physical fitness of children and adolescents is the main area of interest of teachers, doctors, physical therapists and parents. Different sets of tests are used to assess PF (28, 29)—teachers' area of interest is the assessment of PF levels (performance progression), medics' area of interest is the health-related aspect (recovery, rehabilitation progression), while parents' area of interest is the general wellbeing of children.

PF may be measured accurately with the use of laboratory tests; however, due to the need to employ proper measurement instruments and because of high costs and time limitations, it is still impossible to conduct such examinations on the whole population. Field tests are easy to carry out, can be performed with little equipment, they are cheap and can be used with a larger number of people and over a longer period of time (30). Three components are assessed most often: (1) anthropometric parameters, (2) physical capacity parameters, (3) motor abilities.

Anthropometric parameters that are measured most frequently include body height and mass as well as BMI or PI (31). Physical capacity parameters are usually measured using running tests due to their simplicity and accessibility. Motor abilities are assessed with the use of specially designed tests with particular components included in them.

Eurofit, FitnessGram, and Alpha-fit are the most commonly used batteries of tests (32). Monitoring PF levels in children and adolescents is significant not only because PA is crucial in maintaining health but also owing to the fact that it facilitates the selection of talented individuals for particular sports (33).

The aim of the study was to assess differences in PF of children and adolescents participating in Athletics for All program (AFA) and those not participating in any extra-curricular sports activities.

The study sought to determine whether the implementation of programs promoting PA such as AFA may improve PF of young individuals and whether it improves anthropometric parameters (BMI, PI).

Materials and methods

Participants

Since 2014, the Polish Athletic Association (PAA) has been supervising the program of physical activity promotion called "Athletics for All!" (AFA)[1], whose aim is to promote athletics as "the first choice" sport among children and adolescents. Sports activities within the program are conducted by qualified athletic coaches and instructors. The program is financed by the Ministry of Sport and Tourism, local governments and external sponsors. AFA includes over 600 training groups in Poland. Training sessions are held taking into account the age of the participants (grades 1–8 of primary school) and their level of sports advancement. The most accomplished children may continue their careers in the so-called Centers of Oriented Training (COTs). In COTs, training is more advanced; adolescents take part in sports competitions and training camps and undergo physical fitness tests regularly. In the youngest group (grades 1–4 of primary school, i.e., 6–10 years of age), 90-min training sessions are held twice a week. In grades 5–8 (10–14 years of age), 90-min sessions are held three times a week, while in COTs (13–17 years of age) 90-min sessions take place 5 times a week[2].

The study included 1,230 young individuals from Poland, i.e., 527 children and adolescents (42.8%) participating in AFA (experimental group) and 703 individuals not participating in any forms of physical extra-curricular activities (control group). Average age of the respondents (M) was 12.21 years (SD = 1.11)—the age of the study participants was calculated in decimal values taking into consideration date of birth and date of examination. Girls constituted a larger proportion of the studied population (60.1%)—Table 1.

The study was carried out in April and May 2017 according to strictly defined rules (in compliance with the Evaluation of Physical Fitness test—OSF). Prior to the study, AFA coaches had been trained in terms of the study protocol. Each participant provided a written informed consent signed by their parents or legal guardians to take part in the OSF test and have their body height and mass measured.

Anthropometric measurements

Measurements were made using properly calibrated equipment. Each measurement was made twice in the same conditions. If the difference between the first and the second measurement was 300 g or more for body mass and 5 mm or more for body height, the third measurement was performed.

Body height was measured with an accuracy of 1 mm using SECA 213 stadiometer. Each participant stood barefoot with their hips and arms perpendicular to the longitudinal axis, knees together, arms at the side and the head in the Frankfurt plane.

Body mass was measured using SECA 875 scales in accuracy class 3 (200 g). The following indices were calculated: (1) Body Mass Index (BMI)—body mass in kilograms divided by the square of body height in meters, (2) Ponderal Index (PI)—body mass in kilograms divided by the cube of body height in meters.

Evaluation of physical fitness

Evaluation of physical fitness was made using the OSF (Evaluation of Physical Fitness) test that consists of four validated tests:

- 3 × 10 m shuttle run (speed test),
- standing broad jump (power test),
- 1 kg medicine ball overhead throw (strength test),
- 4-min run (endurance test),[3]

Test performance was preceded by a 5-min warm-up. Participants were familiarized with the tasks both theoretically and practically (task performance during the warm-up).

The OSF test was carried out indoors (sports hall) or outdoors (sports field) on natural or synthetic surfaces. All the testing stations had been set up prior to the commencement of the test. Each station was supervised by two persons, i.e., an AFA coach who was responsible for making measurements and a person who recorded the results. Throughout the test, participants were wearing sports clothes (shorts, a T-shirt, sports shoes).

The results of individual fitness tests were standardized and converted into points on a scale from 1 to 100, taking into account the age and gender of the participants, with a higher number of points indicating a higher fitness level.

Statistical analysis

Statistical analysis of results was performed using SPSS 17.0 (Softonic, USA). To calculate qualitative data, two correlation coefficients based on the Chi-squared test were employed, i.e., Phi and V Kramer. For variables on ordinal scales, Kendall's Tau-b and Tau-c were applied.

Comparative analysis between the experimental and con groups was carried out using the *T*-test for independent samples.

1 Available at: https://www.lekkoatletykadlakazdego.pl/o-programie/zalozenia/o-nas (accessed July 7, 2022).

2 Available at: https://www.lekkoatletykadlakazdego.pl/dla-trenera/system-szkolenia-sportowego (accessed July 7, 2022).

3 Available at: https://www.lekkoatletykadlakazdego.pl/dla-trenera/filmy-i-kinogramy/filmy-instruktazowe (accessed July 7, 2022).

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TABLE 1 Characteristics of the studied population ($N = 1,230$).

Group	Variable	Gender	*N*	Mean	Standard deviation
Total	Age (years)	F	739	12.28	1.18
		M	491	12.11	0.99
	Body height (cm)	F	739	156.26	9.31
		M	491	157.66	10.78
	Body mass	F	739	47.92	11.31
		M	491	48.52	12.97
	BMI	F	739	19.43	3.41
		M	491	19.28	3.47
	PI	F	739	12.43	2.05
		M	491	12.23	2.04
AFA	Age (years)	F	302	12.32	0.82
		M	225	12.30	0.99
	Body height (cm)	F	302	158.02	7.89
		M	225	159.32	10.36
	Body mass	F	302	47.35	9.64
		M	225	48.03	11.19
	BMI	F	302	18.82	2.80
		M	225	18.72	2.79
	PI	F	302	11.91	1.65
		M	225	11.76	1.64
Control	Age (years)	F	437	12.24	1.37
		M	266	11.95	0.97
	Body height (cm)	F	437	155.05	10.01
		M	266	156.26	10.96
	Body mass	F	437	48.31	12.33
		M	266	48.94	14.31
	BMI	F	437	19.85	3.72
		M	266	19.75	3.91
	PI	F	437	12.80	2.22
		M	266	12.63	2.26

TABLE 2 Differences in physical fitness levels measured with the use of OSF.

Fitness test	Group	Mean	SD	Standard error	*t*	*p*-value	Difference in means	Standard error of difference in means	95% CI	
									Lower	Upper
3 × 10 m shuttle run (s)	AFA	8.32	0.61	0.03	−21.01	0.001***	−0.87	0.04	−0.95	−0.79
	Control	9.19	0.84	0.03						
Standing broad jump (m)	AFA	1.82	0.36	0.02	5.95	0.001***	0.24	0.04	0.16	0.32
	Control	1.58	0.87	0.03						
Medicine ball throw (m)	AFA	7.82	1.79	0.08	14.11	0.001***	1.38	0.10	1.19	1.58
	Control	6.44	1.58	0.06						
4-min run (m)	AFA	815.74	95.20	4.15	17.07	0.001***	98.12	5.75	86.84	109.40
	Control	717.62	103.07	3.89						

***Statistical significance p-value ≤ 0.001.

TABLE 3 Differences in body mass indices between AFA and Control groups.

	Group	*N*	Mean	SD	Difference in means	95% CI		*p*-value	Cohen's D
						Lower	Upper		
BMI	AFA	527	18.78	2.79	−1.03	−1.40	−0.67	0.001***	−0.30
	Control	703	19.81	3.79					
PI	AFA	527	11.84	1.64	−0.89	−1.11	−0.67	0.001***	−0.44
	Control	703	12.74	2.24					

***Statistical significance p-value ≤ 0.001.

TABLE 4 Correlations of physical fitness levels with age and anthropometric indices.

Fitness test	Pearson's correlation	AFA group			Control group		
		Age	BMI	PI	Age	BMI	PI
3 × 10 m shuttle run (s)	*r*	−0.273	0.115	0.241	−0.193	0.120	0.210
	p	0.001***	0.008**	0.001***	0.001***	0.001***	0.001***
Standing broad jump (m)	*r*	0.244	−0.027	−0.148	0.114	−0.030	−0.049
	p	0.001***	0.541	0.001***	0.003**	0.424	0.192
Medicine ball throw (m)	*r*	0.418	0.347	0.127	0.470	0.319	0.125
	p	0.001***	0.001***	0.004**	0.001***	0.001***	0.001***
4-min run (m)	*r*	0.28	−0.253	−0.335	0.059	−0.341	−0.358
	p	0.001***	0.001***	0.001***	0.116	0.001***	0.001***

**Statistical significance p-value ≤ 0.01.
***Statistical significance p-value ≤ 0.001.

Quantitative variables were described in terms of the parametric distribution (checked with the Shapiro-Wilk test and the Kolmogorov-Smirnov test) taking into account such descriptive characteristics as mean (M) and standard deviation (SD). One-way ANOVA was used for comparisons of equally numbered groups. If the homogeneity of variance was disturbed, the Games-Howell test was used for *post-hoc* comparisons.

Analysis of correlations between quantitative variables was performed with Pearson's *r* coefficient.

Statistical significance was set at $\alpha = 0.05$. The Bioethics Committee of Warsaw University of Life Sciences, Faculty of Human Nutrition and Consumer Sciences (Resolution No. 16/2017) approved the protocol in accordance with the Declaration of Helsinki.

Results

The AFA group included 523 participants (mean age of 12.31 years), while the control group consisted of 703 individuals (mean age of 12.14 years).

Statistically significant differences were noted between the AFA group and the control group in all the fitness tests (Table 2) and body mass indices (Table 3).

Statistically significant differences in all the tests were noted between the AFA group and the control group in favor of the former one. Taking into account BMI as a differentiating variable, a positive correlation was found in 3 × 10 m and the medicine ball throw, while a negative correlation was observed in 4-min run. Moreover, in the AFA group a positive correlation was noted between PI, 3 × 10 m and the medicine ball throw, whereas a negative correlation was found between PI and standing broad jump as well as 4-min run. In the control group, similar correlations were noted taking into consideration age (with the exception of 4-min run) and BMI. In the case of PI, a positive correlation occurred in 3 × 10 m shuttle run and the medicine ball throw, while a negative correlation was noted in 4-min run (Table 4).

Statistically significant differences were noted between girls and boys in all physical fitness tests in the AFA group and in almost all tests in the control group (with the exception of standing broad jump) (Table 5).

Taking into account reference ranges of BMI created according to the norms developed in the OLAF study (34), statistically significant differences were noted between the subgroups in all physical fitness tests. In the control group, significant differences between BMI subgroups were found in 3 × 10 m shuttle run, medicine ball throw and 4-min run (Tables 6, 6.1).

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TABLE 5 Differences in the OSF test results taking into account gender.

AFA group										
Fitness test	**Group**	**Mean**	**SD**	**Standard error**	***t***	***p*-value**	**Difference in means**	**Standard error of difference in means**	**95% CI**	
									Lower	**Upper**
3 × 10 m shuttle run (s)	F	8.46	0.57	0.03	6.46	0.001***	0.33	0.05	0.23	0.43
	M	8.13	0.60	0.04						
Standing broad jump (m)	F	1.78	0.42	0.02	−2.79	0.006**	−0.09	0.03	−0.15	−0.03
	M	1.87	0.27	0.02						
Medicine ball throw (m)	F	7.49	1.48	0.09	−4.80	0.001***	−0.78	0.16	−1.09	−0.46
	M	8.27	2.06	0.14						
4-min run (m)	F	794.94	91.81	5.28	−6.00	0.000***	−48.71	8.12	−64.65	−32.76
	M	843,65	92,68	6,18						
Control group										
Test	**Group**	**Mean**	**SD**	**Standard error**	***t***	***p*-value**	**Difference in means**	**Standard error of difference in means**	**95% CI**	
									Lower	**Upper**
3 × 10 m shuttle run (s)	F	9.33	0.84	0.04	5.96	0.001***	0.38	0.06	0.26	0.51
	M	8.95	0.79	0.05						
Standing broad jump (m)	F	1.57	1.08	0.05	−0.44	0.660	−0.03	0.07	−0.16	0.10
	M	1.60	0.25	0.02						
Medicine ball throw (m)	F	6.24	1.50	0.07	−4.43	0.001***	−0.54	0.12	−0.77	−0.30
	M	6.77	1.66	0.10						
4-min run (m)	F	694.16	92.55	4.43	−7.78	0.001***	−61.98	7.96	−77.63	−46.34
	M	756.15	107.93	6.62						

**Statistical significance p-value ≤ 0.01.
***Statistical significance p-value ≤ 0.001.

As far as PI is concerned, in the AFA group significant differences were noted in all physical fitness tests between subgroups created in accordance with the aforementioned norms (34). In the control group, however, significant differences were only observed in 3 × 10 m shuttle run and 4-min run (Table 7).

In the control group, significant differences were only observed in 3 × 10 m shuttle run and 4-min run; however, *post-hoc* tests showed the significance of differences in standing broad jump as well (Table 7.1).

Statistical significance of the variation in physical fitness concerning body mass indices, demonstrated by ANOVA analysis, was further confirmed by the Games-Howell *post-hoc* test (Table 8).

Discussion

The aim of the study was to assess differences in physical fitness of children and adolescents participating in the AFA program and those not participating in any extra-curricular sports activities.

In all the tests, significantly better results were noted in the AFA group. Similar observations were made by other researchers. In the study of Hazar children taking part in aerobic training (5 times a week for 8 weeks) obtained significantly better results in the majority of tests compared to their untrained peers (35). Also, Ara et al. revealed significant differences in most motor tests between physically active and non-active groups both among girls and boys (36).

In our study, significantly better physical fitness test results were obtained by boys from the AFA group. These findings are in line with the observations of Seccia et al., who revealed significant differences in favor of physically active boys in 4 × 10 m run and standing broad jump (37). Huang et al. (38) reported negative effects of sedentary behaviors on physical fitness levels. In that study, the authors noted significant differences in standing broad jump and 50 m run between girls and boys in favor of the latter group. Slightly different results were presented by Ortega et al., who compared physical fitness

TABLE 6 Physical fitness test results taking into account BMI.

Fitness test	BMI	*N*	Mean	SD	Standard error	95% CI		Normality of distribution tests		*p*-value
						Lower	Upper	Kolmogorov-Smirnov	Shapiro-Wilk	
AFA group										
3 × 10 m shuttle run (s)	Underweight	272	8.32	0.63	0.04	8.24	8.39	0.001	0.001	0.001***
	Norm	239	8.26	0.54	0.04	8.19	8.33	0.001	0.001	
	Overweight and obesity	16	9.15	0.51	0.13	8.88	9.42	0.115	0.257	
Standing broad jump (m)	Underweight	272	1.81	0.44	0.03	1.76	1.86	0.001	0.001	0.002**
	Norm	239	1.86	0.25	0.02	1.82	1.89	0.084	0.095	
	Overweight and obesity	16	1.53	0.18	0.04	1.43	1.62	0.149	0.736	
Medicine ball throw (m)	Underweight	272	7.24	1.61	0.09	7.05	7.43	0.004	0.001	0.001***
	Norm	239	8.45	1.77	0.11	8.22	8.67	0.200[a]	0.007	
	Overweight and obesity	16	8.44	1.76	0.44	7.49	9.38	0.200[a]	0.757	
4-min run (m)	Underweight	272	823.45	98.33	5.96	811.71	835.19	0.001	0.001	0.001***
	Norm	239	816.86	83.82	5.42	806.18	827.54	0.200[a]	0.597	
	Overweight and obesity	16	667.81	85.03	21.26	622.50	713.12	0.200[a]	0.296	
Control group										
3 × 10 m shuttle run (s)	Underweight	295	9.15	0.93	0.05	9.04	9.26	0.001	0.001	0.001***
	Norm	338	9.14	0.73	0.04	9.06	9.22	0.011	0.002	
	Overweight and obesity	70	9.58	0.85	0.10	9.38	9.78	0.200[a]	0.681	
Standing broad jump (m)	Underweight	295	1.56	0.25	0.01	1.53	1.59	0.003	0.098	0.071
	Norm	338	1.64	1.22	0.07	1.51	1.77	0.001	0.001	
	Overweight and obesity	70	1.39	0.24	0.03	1.34	1.45	0.200[a]	0.245	
Medicine ball throw (m)	Underweight	295	5.85	1.45	0.08	5.68	6.02	0.019	0.001	0.001***
	Norm	338	6.80	1.48	0.08	6.64	6.96	0.001	0.001	
	Overweight and obesity	70	7.17	1.74	0.21	6.76	7.59	0.200[a]	0.764	
4-min run (m)	Underweight	295	745.23	99.83	5.81	733.79	756.67	0.005	0.001	0.001***
	Norm	338	712.6	93.22	5.07	702.68	722.63	0.001	0.001	
	Overweight and obesity	70	625.23	105.49	12.61	600.07	650.38	0.052	0.001	

[a]Lower limit of actual significance.
**Statistical significance p-value ≤ 0.01.
***Statistical significance p-value ≤ 0.001.

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TABLE 6.1 Significance of differences in physical fitness in relation to BMI confirmed by *post-hoc* test (Games-Howell test).

Dependent variable			Difference in means	Standard error	Relevance	95% CI	
						Lower	Upper
AFA group							
3 × 10 m shuttle run (s)	Underweight	Norm	0.06	0.05	0.525	−0.07	0.18
		Overweight and obesity	−0.83*	0.13	0.000	−1.17	−0.49
	Norm	Underweight	−0.06	0.05	0.525	−0.18	0.07
		Overweight and obesity	−0.88*	0.13	0.000	−1.22	−0.55
	Overweight and obesity	Underweight	0.83*	0.13	0.000	0.49	1.17
		Norm	0.88*	0.13	0.000	0.55	1.22
Standing broad jump (m)	Underweight	Norm	−0.05	0.03	0.304	−0.12	0.03
		Overweight and obesity	0.28*	0.05	0.000	0.15	0.41
	Norm	Underweight	0.05	0.03	0.304	−0.03	0.12
		Overweight and obesity	0.33*	0.05	0.000	0.21	0.45
	Overweight and obesity	Underweight	−0.28*	0.05	0.000	−0.41	−0.15
		Norm	−0.33*	0.05	0.000	−0.45	−0.21
Medicine ball throw (m)	Underweight	Norm	−1.21*	0.15	0.000	−1.56	−0.85
		Overweight and obesity	−1.20*	0.45	0.043	−2.36	−0.04
	Norm	Underweight	1.21*	0.15	0.000	0.85	1.56
		Overweight and obesity	0.01	0.46	1.000	−1.16	1.18
	Overweight and obesity	Underweight	1.20*	0.45	0.043	0.04	2.36
		Norm	−0.01	0.46	1.000	−1.18	1.16
4-min run (m)	Underweight	Norm	6.59	8.06	0.692	−12.35	25.53
		Overweight and obesity	155.64*	22.08	0.000	99.14	212.14
	Norm	Underweight	−6.59	8.06	0.692	−25.53	12.35
		Overweight and obesity	149.05*	21.94	0.000	92.77	205.32
	Overweight and obesity	Underweight	−155.64*	22.08	0.000	−212.14	−99.14
		Norm	−149.05*	21.94	0.000	−205.32	−92.77
Control group							
3 × 10 m shuttle run (s)	Underweight	Norm	0.01	0.07	0.98	−0.15	0.17
		Overweight and obesity	−0.43*	0.12	0.00	−0.70	−0.16
	Norm	Underweight	−0.01	0.07	0.98	−0.17	0.15
		Overweight and obesity	−0.44*	0.11	0.00	−0.70	−0.18
	Overweight and obesity	Underweight	0.43*	0.12	0.00	0.16	0.70
		Norm	0.44*	0.11	0.00	0.18	0.70
Standing broad jump (m)	Underweight	Norm	−0.09	0.07	0.41	−0.25	0.07
		Overweight and obesity	0.16*	0.03	0.00	0.09	0.24
	Norm	Underweight	0.09	0.07	0.41	−0.07	0.25
		Overweight and obesity	0.25*	0.07	0.00	0.08	0.42
	Overweight and obesity	Underweight	−0.16*	0.03	0.00	−0.24	−0.09
		Norm	−0.25*	0.07	0.00	−0.42	−0.08
Medicine ball throw (m)	Underweight	Norm	−0.95*	0.12	0.00	−1.23	−0.68
		Overweight and obesity	−1.32*	0.22	0.00	−1.85	−0.79
	Norm	Underweight	0.95*	0.12	0.00	0.68	1.23
		Overweight and obesity	−0.37	0.22	0.23	−0.90	0.16
	Overweight and obesity	Underweight	1.32*	0.22	0.00	0.79	1.85
		Norm	0.37	0.22	0.23	−0.16	0.90
4-min run (m)	Underweight	Norm	32.58*	7.71	0.00	14.46	50.70
		Overweight and obesity	120.00*	13.88	0.00	86.97	153.03
	Norm	Underweight	−32.58*	7.71	0.00	−50.70	−14.46
		Overweight and obesity	87.42*	13.59	0.00	55.05	119.80
	Overweight and obesity	Underweight	−120.00*	13.88	0.00	−153.03	−86.97
		Norm	−87.42*	13.59	0.00	−119.80	−55.05

*The difference in means is significant at $\alpha \leq 0.05$.

TABLE 7 Physical fitness test results taking into account PI.

Fitness test	PI	*N*	Mean	SD	Standard error	95% CI		Normality of distribution tests		*p*-value
						Lower	Upper	Kolmogorov-Smirnov	Shapiro-Wilk	
AFA group										
3 × 10 m shuttle run (s)	Underweight (up to 10)	180	8.23	0.61	0.05	8.14	8.32	0.001	0.001	0.001***
	Norm (11 do 15)	335	8.34	0.58	0.03	8.27	8.39	0.001	0.001	
	Overweight (16 and above)	12	9.15	0.59	0.17	8.77	9.52	0.200[a]	0.677	
Standing broad jump (m)	Underweight (up to 10)	180	1.84	0.25	0.02	1.80	1.87	0.019	0.038	0.012*
	Norm (11 do 15)	335	1.82	0.41	0.02	1.78	1.87	0.001	0.001	
	Overweight (16 and above)	12	1.52	0.19	0.06	1.39	1.64	0.200[a]	0.944	
Medicine ball throw (m)	Underweight (up to 10)	180	7.55	1.82	0.14	7.28	7.81	0.008	0.001	0.021*
	Norm (11 do 15)	335	7.95	1.75	0.09	7.76	8.14	0.012	0.001	
	Overweight (16 and above)	12	8.50	1.97	0.57	7.24	9.75	0.200[a]	0.654	
4-min run (m)	Underweight (up to 10)	180	843.56	83.28	6.21	831.30	855.80	0.200[a]	0.058	0.001***
	Norm (11 do 15)	335	806.10	94.55	5.17	795.94	816.26	0.001	0.001	
	Overweight (16 and above)	12	667.50	98.27	28.37	605.06	729.94	0.200[a]	0.437	
Control group										
3 × 10 m shuttle run (s)	Underweight (up to 10)	150	8.97	0.81	0.07	8.84	9.10	0.004	0.001	0.001***
	Norm (11 do 15)	491	9.20	0.85	0.04	9.13	9.28	0.001	0.001	
	Overweight (16 and above)	62	9.60	0.72	0.09	9.42	9.78	0.200[a]	0.564	
Standing broad jump (m)	Underweight (up to 10)	150	1.62	0.26	0.02	1.58	1.66	0.200[a]	0.663	0.118
	Norm (11 do 15)	491	1.59	1.02	0.05	1.51	1.69	0.001	0.001	
	Overweight (16 and above)	62	1.37	0.20	0.03	1.32	1.42	0.200[a]	0.288	
Medicine ball throw (m)	Underweight (up to 10)	150	6.24	1.59	0.13	5.99	6.50	0.089	0.059	0.105
	Norm (11 do 15)	491	6.46	1.56	0.07	6.32	6.60	0.001	0.001	
	Overweight (16 and above)	62	6.73	1.71	0.217	6.29	7.16	0.200[a]	0.638	
4-min run (m)	Underweight (up to 10)	150	754.43	101.11	8.26	738.12	770.75	0.038	0.003	0.001***
	Norm (11 do 15)	491	718.06	99.44	4.49	709.25	726.88	0.001	0.001	
	Overweight (16 and above)	62	625.01	76.09	9.66	605.69	644.34	0.047	0.001	

[a]Lower limit of actual significance.
*Statistical significance p-value ≤ 0.05.
***Statistical significance p-value ≤ 0.001.

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TABLE 7.1 Significance of differences in physical fitness in relation to PI confirmed by *post-hoc* test (Games-Howell test).

Dependent variable			Difference in means	Standard error	Relevance	95% CI	
						Lower	Upper
AFA group							
3 × 10 m shuttle run (s)	Underweight	Norm	1.04*	0.27	0.01	0.26	1.83
		Overweight	1.08*	0.27	0.01	0.30	1.86
		Obesity	0.88*	0.27	0.03	0.10	1.65
	Norm	Underweight	−1.04*	0.27	0.01	−1.83	−0.26
		Overweight	0.03	0.07	0.96	−0.14	0.21
		Obesity	−0.17*	0.06	0.04	−0.33	−0.01
	Overweight	Underweight	−1.08*	0.27	0.01	−1.86	−0.30
		Norm	−0.03	0.07	0.96	−0.21	0.14
		Obesity	−0.20*	0.06	0.00	−0.35	−0.05
	Obesity	Underweight	−0.88*	0.27	0.03	−1.65	−0.10
		Norm	0.17*	0.06	0.04	0.01	0.33
		Overweight	0.20*	0.06	0.00	0.05	0.35
Standing broad jump	Underweight	Norm	−0.18	0.07	0.06	−0.36	0.01
(m)		Overweight	−0.22*	0.07	0.02	−0.41	−0.03
		Obesity	−0.20	0.07	0.06	−0.40	0.01
	Norm	Underweight	0.18	0.07	0.06	−0.01	0.36
		Overweight	−0.04	0.03	0.42	−0.11	0.03
		Obesity	−0.02	0.04	0.97	−0.13	0.09
	Overweight	Underweight	0.22*	0.07	0.02	0.03	0.41
		Norm	0.04	0.03	0.42	−0.03	0.11
		Obesity	0.02	0.05	0.95	−0.09	0.14
	Obesity	Underweight	0.20	0.07	0.06	−0.01	0.40
		Norm	0.02	0.04	0.97	−0.09	0.13
		Overweight	−0.02	0.05	0.95	−0.14	0.09
Medicine ball throw (m)	Underweight	Norm	−1.35*	0.41	0.02	−2.51	−0.19
		Overweight	−2.26*	0.41	0.00	−3.42	−1.10
		Obesity	−2.63*	0.40	0.00	−3.79	−1.48
	Norm	Underweight	1.35*	0.41	0.02	0.19	2.51
		Overweight	−0.91*	0.13	0.00	−1.24	−0.58
		Obesity	−1.28*	0.11	0.00	−1.58	−0.99
	Overweight	Underweight	2.26*	0.41	0.00	1.10	3.42
		Norm	0.91*	0.13	0.00	0.58	1.24
		Obesity	−0.37*	0.12	0.01	−0.68	−0.06
	Obesity	Underweight	2.63*	0.40	0.00	1.48	3.79
		Norm	1.28*	0.11	0.00	0.99	1.58
		Overweight	0.37*	0.12	0.01	0.06	0.68
4-min run (m)	Underweight	Norm	−86.77*	20.23	0.00	−143.80	−29.74
		Overweight	−75.73*	19.98	0.01	−132.32	−19.13
		Obesity	−29.72	19.75	0.46	−85.92	26.49
	Norm	Underweight	86.77*	20.23	0.00	29.74	143.80
		Overweight	11.04	8.44	0.56	−10.71	32.79
		Obesity	57.05*	7.88	0.00	36.76	77.35
	Overweight	Underweight	75.73*	19.98	0.01	19.13	132.32
		Norm	−11.04	8.44	0.56	−32.79	10.71

(Continued)

TABLE 7.1 Continued

Dependent variable			Difference in means	Standard error	Relevance	95% CI	
						Lower	Upper
		Obesity	46.01*	7.20	0.00	27.47	64.56
	Obesity	Underweight	29.72	19.75	0.46	−26.49	85.92
		Norm	−57.05*	7.88	0.00	−77.35	−36.76
		Overweight	−46.01*	7.20	0.00	−64.56	−27.47
Control group							
3 × 10 m shuttle run (s)	Underweight	Norm	−0.28*	0.05	0.00	−0.41	−0.16
		Overweight and obesity	−0.96*	0.09	0.00	−1.18	−0.74
	Norm	Underweight	0.28*	0.05	0.00	0.16	0.41
		Overweight and obesity	−0.68*	0.09	0.00	−0.89	−0.47
	Overweight and obesity	Underweight	0.96*	0.09	0.00	0.74	1.18
		Norm	0.68*	0.09	0.00	0.47	0.89
Standing broad jump (m)	Underweight	Norm	0.05	0.03	0.27	−0.03	0.13
		Overweight and obesity	0.35*	0.03	0.00	0.28	0.42
	Norm	Underweight	−0.05	0.03	0.27	−0.13	0.03
		Overweight and obesity	0.30*	0.04	0.00	0.21	0.39
	Overweight and obesity	Underweight	−0.35*	0.03	0.00	−0.42	−0.28
		Norm	−0.30*	0.04	0.00	−0.39	−0.21
Medicine ball throw (m)	Underweight	Norm	−0.11	0.12	0.62	−0.39	0.17
		Overweight and obesity	−0.06	0.24	0.96	−0.63	0.50
	Norm	Underweight	0.11	0.12	0.62	−0.17	0.39
		Overweight and obesity	0.05	0.23	0.98	−0.49	0.59
	Overweight and obesity	Underweight	0.06	0.24	0.96	−0.50	0.63
		Norm	−0.05	0.23	0.98	−0.59	0.49
4-min run (m)	Underweight	Norm	49.28*	6.72	0.00	33.48	65.07
		Overweight and obesity	171.14*	10.95	0.00	145.18	197.10
	Norm	Underweight	−49.28*	6.72	0.00	−65.07	−33.48
		Overweight and obesity	121.86*	10.11	0.00	97.81	145.92
	Overweight and obesity	Underweight	−171.14*	10.95	0.00	−197.10	−145.18
		Norm	−121.86*	10.11	0.00	−145.92	−97.81

*The difference in means is significant at $\alpha \leq 0.05$.

levels in girls and boys aged 13. They did not find any significant differences between both genders in standing broad jump and 4 × 10 m shuttle run (39). Also, Ramírez-Vélez et al. did not reveal significant differences in physical fitness tests between both genders (40).

Due to its simplicity, BMI is the most widely used anthropometric tool (41). This index is considered to be a tool for assessing overweight and obesity (42–44). BMI is recognized as a component of physical fitness associated with the health of children and adolescents in different regions of the world (45–47). In the case of anthropometric measurements in children, it is recommended that BMI should be applied together with other anthropometric indices (48). Therefore, Ponderal Index (PI) was also used in the present study (44). This index is more

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TABLE 8 Significance of differences in physical fitness in relation to body mass indices confirmed by *post-hoc* test (*multiple comparisons*).

Dependent variable			Difference in means	Standard error	Relevance	95% CI	
						Lower	Upper
Overall fitness test score	Underweight	Norm	7.516	3.719	0.108	−1.21	16.24
Total		Overweight and obesity	62.074*	6.091	0.000	47.63	76.52
	Norm	Underweight	−7.516	3.719	0.108	−16.24	1.21
		Overweight and obesity	54.558*	6.123	0.000	40.04	69.08
	Overweight and obesity	Underweight	−62.074*	6.091	0.000	−76.52	−47.63
		Norm	−54.558*	6.123	0.000	−69.08	−40.04
Overall fitness test score	Underweight	Norm	−5.252	4.448	0.465	−15.71	5.20
AFA		Overweight and obesity	73.305*	12.113	0.000	42.25	104.36
	Norm	Underweight	5.252	4.448	0.465	−5.20	15.71
		Overweight and obesity	78.558*	12.152	0.000	47.44	109.67
	Overweight and obesity	Underweight	−73.305*	12.113	0.000	−104.36	−42.25
		Norm	−78.558*	12.152	0.000	−109.67	−47.44
Overall fitness test score	Underweight	Norm	9.235	4.197	0.072	−0.63	19.10
Control		Overweight and obesity	35.925*	6.851	0.000	19.65	52.20
	Norm	Underweight	−9.235	4.197	0.072	−19.10	0.63
		Overweight and obesity	26.690*	6.692	0.000	10.77	42.61
	Overweight and obesity	Underweight	−35.925*	6.851	0.000	−52.20	−19.65
		Norm	−26.690*	6.692	0.000	−42.61	−10.77

*The difference in means is significant at $\alpha \leq 0.05$.

accurate in determining percentage values of body fat than BMI (31). According to Cossio-Bolaños et al., PI may serve as a very useful tool for analyzing physical fitness in adolescents since it is a more accurate index of differences in body mass than BMI (31, 49). Niederer et al. (50) indicate that differences in physical fitness connected with BMI values occur already in pre-school children, and these differences grow larger in older children.

The findings of the current study show that in the AFA group, BMI and PI values are significantly lower. Furthermore, statistical analysis revealed positive correlations of BMI and PI with 3 × 10 shuttle run and 1 kg medicine ball throw in both groups and negative correlations with 4-min run. Only in the AFA group was a negative correlation noted between PI and standing broad jump, which indicates that individuals with higher BMI obtained worse results in the jump test. Ceschia et al. (51) did not show any differences in physical fitness levels between both genders. At the same time, overweight and obese persons demonstrated significantly worse results in the tests of speed, endurance and lower limb strength. Body mass did not affect upper limb power. Conversely, Dumith et al. showed that individuals with normal body mass obtained better results than their counterparts with higher BMI. It was only in the medicine ball throw test that persons with higher BMI scored better (52), which is in line with our findings.

In the OSF test, 3 × 10 m shuttle run constituted the test of speed. In both groups, participants with higher values of BMI and PI had worse results. As for the test of strength (1 kg medicine ball throw), those with higher values of BMI and PI obtained better test results.

In their study, Sacchetti et al. (53) also used standing broad jump and the medicine ball throw. Similar to our findings, they found significant correlations between body mass and test results. Participants who trained regularly also achieved significantly better overall physical fitness test results.

Lower levels of physical fitness in children are associated with a higher risk of obesity as well as cardiovascular and metabolic diseases (54, 55). Well-developed motor abilities may be the factor conditioning a high level of physical fitness that is conducive to increased physical activity in children (56). What is more, physical fitness in childhood is considered to be a significant predictor of current and future health status (2).

Children who achieve early success in a given sport (not necessarily as professionals) are more likely to participate in sports activities and lead an active lifestyle later on (57). Tests that assess physical fitness may be useful in talent identification procedures among children. Also, participation in sports activities chosen based on children's motor abilities increases the likelihood of following an optimal sports career development path in the future. Last but not least, matching an individual anthropometric profile as well as physical and motor fitness of a child with sport-specific characteristics may prevent injuries and early dropout effectively (58).

In the case of gender-related physical fitness differences, Seccia et al. reported significantly better results of boys in 4 × 10 m run (speed test) and in standing broad jump (37). Ortega et al. compared physical fitness levels of girls and boys aged 13 and did not note any significant differences between both genders in standing broad jump and 4 × 10 m shuttle run (39). This regularity was confirmed by Ramírez-Vélez et al. (40). Physical fitness levels are also linked to sedentary activity. Huang et al. (38) revealed a negative influence of sedentary behaviors on physical fitness levels. They noted significant differences between genders (in favor of boys) in power and speed tests.

The findings of our study indicate that physically active children (AFA group) demonstrated higher levels of physical fitness. Numerous researchers confirm correlations between physical activity levels and motor abilities of children (59–64). However, Haga et al. show that these correlations become weaker with age (61). What is interesting, physically active children are more confident with regard to their own motor competences than less active children, which may also influence their sports performance (65).

As many studies indicate (66, 67), the implementation of programs promoting physical activity results in increased overall physical activity particularly among children and adolescents. Verstraete et al. (68) showed that the introduction of a comprehensive physical activity promotion program led to a significant increase in PA engagement.

Correlations between PA levels and PF and motor abilities were also confirmed by Larouche et al. (69). Similar observations were made by Morrison et al. (70), who found correlations between PA and PF as well as between PF and body fat in children aged 6–8.

Undoubtedly, there is a need for implementing research results that show beneficial effects of regular PA in everyday practice. The findings of our study show that it is necessary to introduce physical activity promotion programs for children and adolescents. Such programs should constitute the basis of national health policy aiming at improving physical fitness among young people.

There are some limitations of our study. The research tool used was developed for the purposes of the AFA program. It stemmed from the fact that it was necessary to select tests assessing motor abilities that are fundamental to athletics, i.e., strength, speed, endurance, and power. This work focuses on assessing physical fitness of children and adolescents with the use of the OSF test, a validated tool that has never been applied in any research before. Our findings constitute an introduction to broader analyses of research results obtained within the AFA program regarding physical fitness of children and adolescents in Poland.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the Bioethics Committee of Warsaw University of Life Sciences, Faculty of Human Nutrition and Consumer Sciences (Resolution No. 16/2017). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

JB-K implementation of research and analysis of research material preparation of publications. KZ and MS analysis of research material and preparation of publications. PL preparation of a test sheet. MW implementation of tests and verification of test material. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Changes in leisure activities of the elderly due to the COVID-19 in Korea

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Recreational activities such as physical and social activities are key components of a healthy life for the elderly. Since the outbreak of Corona 19, leisure facilities such as indoor sports facilities, religious facilities, and cultural facilities have been closed, and group activities such as volunteer activities and clubs are also being held under control. These measures are expected to bring about many changes in the leisure activities of the elderly. In this study, an empirical analysis was made on how COVID-19 caused changes in leisure activities of the elderly using national statistical data. For the data analysis, raw data of the "2019 National Leisure Activities Survey" and "2020 National Leisure Activities Survey" conducted by the Ministry of Culture, Sports and Tourism were used, and data of a total of 5,069 elderly people were analyzed. As for the analysis method, the changes in leisure activities of the elderly before and after COVID-19 in terms of participation rate were compared and analyzed. In addition, the changes in leisure activities of the elderly in terms of the type of leisure activities were examined before and after COVID-19 as well. As a result of the analysis, the participation rate in sports activities, hobbies and entertainment activities, and leisure activities increased, while the participation rates in culture and art viewing and participation activities, sports viewing activities, tourism activities, and social activities decreased. In particular, it was found that the proportion of the elderly spending leisure time centered on active and social activities decreased, and the proportion of the elderly consuming leisure time centered on passive activities increased. As a result, it was found that the leisure activities of the elderly are changing passively due to COVID-19. Leisure support policies for active leisure activities of the elderly are likely to be necessary.

KEYWORDS

COVID-19, post covid, the elderly, leisure activity, physical activity, social activity, national leisure activity survey

Introduction

First reported in Wuhan, China in December 2019, Corona virus (later referred to as Covid-19) quickly spread to neighboring countries and developed into a global epidemic (1). The aftermath of COVID-19 is not diminishing even now while vaccinations are in progress, and it is facing a prolonged phase. Unlike previous infectious diseases, which pass as a single social wave or first wave, Corona 19 is expected to act as a catalyst for social change and lead to another wave (second wave), causing a great social transformation (2). In this regard, efforts to predict and prepare for social changes in the post-corona era are required.

COVID-19 is even more lethal for people over the age of 60. The U.S. Centers for Disease Control and Prevention reports that 8 out of 10 deaths from COVID-19 are from people over the age of 65 (3). In Korea, 92.9% of COVID-19 deaths were people over the age of 60 years old, and the mortality rate of COVID-19 for the elderly over 80 years old reached 25.3%, and thus it was found that the mortality rate increased sharply with increasing age (4).

Given the high infection rate and mortality rate among the elderly, the government recommended that elderly people avoid going out as much as possible and live within their residence, and stopped operating welfare facilities for the elderly, such as senior welfare centers and senior citizens' centers. These measures have brought about significant changes in the daily lives of the elderly. Numerous studies have found that there were decreases in physical activity and increases in sedentary behavior in the elderly after the outbreak of COVID-19 (5–11), and various psychological problems including stress, anxiety, and depression (12, 13). According to the results of studies within the Korean context, the overall risk of developing depression among the elderly after the COVID-19 pandemic has doubled compared to before the pandemic; furthermore, it was reported that even for the elderly who had no history of depression, the risk of developing depression increased 2.4 times compared to before the pandemic (14). In particular, it is revealed that the decrease in social activities is a major factor that increases the risk of depression in the elderly in the pandemic era (14).

Recreational activities such as physical and social activities are very important to the elderly. Physical activity contributes to mental wellbeing (15), particularly as a protective factor against viral infections (16). Nieman and Wentz (17) reviewed the evidence for an immune response to physical activity and found that moderate exercise strengthened the immune system and reduced inflammation. Accordingly, medical researchers and institutions in each country are recommending maintaining a healthy life in the era of COVID-19 according to the rules of physical activity (18). Zhang et al. (19) also point out that participation in leisure activities is protective of decline in cognitive abilities and has diverse benefits in health conditions among the elderly.

Besides physical activity, social activity is also related to the health of older people. Social bonds affect health, and these effects last a lifetime (20). Social activity provides a stress buffering effect, and social integration promotes a positive psychological state, resulting in positive physiological responses (21). In particular, social activities of the elderly are associated with a lower mortality rate compared to other leisure activities (22). In addition, the elderly who participate in some leisure activities are likely to experience less depression based on the results of the longitudinal study (23).

These results indicate the importance of maintaining active leisure activities for the elderly during the period of COVID-19.

It is said that the happiness of the elderly is higher when they engage in active leisure activities rather than passive leisure activities (24), and those who enjoy active leisure activities such as club activities, volunteering, and travel have higher life satisfaction (25). The elderly who engage in physical and social leisure activities rather than simple recreational activities for rest have higher health-related quality of life (HRQoL) (26), and leisure satisfaction among the elderly who actively participate in outdoor activities is relatively high (27).

Meanwhile, in the midst of the COVID-19 situation, the society has been focusing on quarantine and trying to contain the spread of the infection. Leisure facilities such as indoor sports facilities, religious facilities, and cultural facilities are closed under the judgment that they are vulnerable to the spread of infectious diseases, and group activities such as volunteer activities and clubs are also controlled. These government measures have brought about many changes in the leisure activities of the elderly. According to a study observing changes in leisure life after COVID-19, the number of cases of enjoying active leisure activities decreased after COVID-19, and the number of cases of enjoying passive leisure activities increased (4). Leisure activities with a social nature, such as family meetings and religious activities, decreased (28), but online-based leisure activities increased (29, 30). In addition, there have been cases of switching to other types of leisure activities due to the limited leisure environments (9), and changes in the form of existing leisure activities (31) have been observed.

Although many studies have observed changes in leisure activities after COVID-19, most studies have focused on students and general adults, so it is difficult to obtain information on what changes have occurred in leisure activities of the elderly after COVID-19. In addition, there are limitations in generalizing the research results because previous studies analyzed a relatively small number of samples (32). Considering the importance of leisure activities in life in old age, it is believed that examining how COVID-19 has changed the leisure lives of the elderly will have great value and implications from academic and practical aspects.

Therefore, this study intends to empirically analyze the changes in leisure activities of the elderly after COVID-19 by using the raw data of the National Leisure Activities Survey in 2019 and in 2020 conducted by the Ministry of Culture, Sports and Tourism in Korea, which has a relatively large number of samples as national statistical data.

The purpose of this study is to understand the leisure behaviors of the elderly in the pandemic situation by examining the changes in the leisure activities of the elderly due to COVID-19. Ultimately, this study is expected to contribute to preparing timely leisure policies in the with- or post-Corona era.

The main research questions of this study are as follows.

Research Question 1. After the outbreak of COVID-19, what changes are there in the leisure activities of the elderly?

Research question 2. After the outbreak of COVID-19, what changes are there in the leisure patterns of the elderly?

Research method

Analysis data

The data analyzed in this study are the "2019 National Leisure Activities Survey" and "2020 National Leisure Activities Survey" announced by the Ministry of Culture, Sports and Tourism. The National Leisure Activities Survey is a state-approved statistics that "analyzes the state of the people's leisure activities, identifies changes in lifestyle and quality of life, and uses them as basic data for establishing related policies" (33, 34). The population of the 2019 National Leisure Activities Survey is 10,060 men and women aged 15 and older in 17 cities and provinces nationwide, and the population of the 2020 National Leisure Activities Survey is 10,088 men and women aged 15 and older in 17 cities and provinces nationwide. Specific information on the analyzed data is as follows.

First of all, concerning the research structure of this study, the "2019 National Leisure Activities Survey" and "2020 National Leisure Activities Survey" were conducted by Ministry of Culture, Sports and Tourism, Republic of Korea, with population aged 15 and over nationwide. The number of valid respondents was 10,060 in 2019 and 10,080 in 2020, respectively. As a survey method, a household visit interview survey in which a professional surveyor visits selected households and fills out the responses to the questionnaire was employed. All the statistics in the surveys were approved by the National Statistics Office (approval number: No. 113014) and open to the public.

With regard to the sampling design of this study, the survey population was defined as household members aged 15 years or older residing in all households in Korea at the time of the survey baseline. The sampling frame was decided based on data from the 2017 Census survey by Statistics Korea. For stratification, a total of 17 cities and provinces are stratified into large cities and rural areas which divided into dong (i.e., towns) and eup/myeon (i.e., villages) reflecting the characteristics of urban and rural areas. As a sampling method, random extraction after allocating the number of households in each province by square root proportional distribution considering the precision and appropriateness of the sample was done based on Stratified Multi-Stage Cluster Sampling.

For weight calculation, final weight was calculated as follow:

Design weight*Non-response adjustment coefficient*(1/In-household extraction rate)*Population information adjusted coefficient.

In this study, male and female elderly people in their 60s or older were selected as the study subjects among the valid respondents, and after weighting, 2,526 people in 2019 and 2,543 people in 2020 total 5,069 people. The demographic characteristics of the study subjects are shown in (Table 1).

Analysis variables

The variable used to analyze the type of leisure activity was the questionnaire "Which leisure activity did you engage in the most during the past year?" The response items consist of 88 items for 2019 and 2020, and the participants were allowed to respond to up to 5 leisure activities from 1st to 5th. In this study, all five responses were used for analysis, and they were reclassified into active leisure, passive leisure, and social leisure according to the existing literature (35) as follows.

First, active leisure refers to cultural and artistic viewing and activities, sports viewing and participation activities, tourism activities, and hobbies, excluding rest activities such as watching TV and taking a nap, or social activities such as meeting friends and social gatherings. Examples include cultural and art viewing activities such as visiting museums, theater performances, and exhibitions; cultural and artistic participation activities such as participating art activities, traditional art activities, and playing musical instruments; sports viewing activities such as direct or indirect viewing of sports events; participation activities in sports such as tennis, golf, and swimming; tourism activities such as camping, overseas traveling, and getting aboard a cruise ship; and hobbies such as life crafts gardening, and collection activity.

Second, passive leisure refers to passive activities such as listening to music, watching TV, taking a nap, listening to the radio, or doing nothing.

Last, social leisure refers to socially-oriented activities such as meeting friends, reunions/social gatherings, and club activities. In this study, other activities such as volunteer activities and religious activities were also classified as social leisure activities according to the leisure activity classification criteria of the National Leisure Activities Survey.

Analysis method

The detailed analysis method of this study is as follows. First, we looked at the changes in leisure activities of the elderly after COVID-19 in terms of participation rate. The percentages (%) that responded to the most frequently participated leisure activities were presented by grouping them into eight major categories, and the percentage difference (%p) and the rate of change were calculated to find out the change.

Next, the changes in leisure activities of the elderly after COVID-19 were examined in terms of the type of leisure activities. By dividing individual leisure activity types into active leisure-oriented type, passive leisure-oriented type, social leisure-oriented type, and leisure mixed type, the percentage

TABLE 1 Demographic characteristics of the study subjects.

Characteristics	Division	2019 ($n = 2,526$)		20202019 ($n = 2,543$)	
		Frequency	Percentage	Frequency	Percentage
Gender	Male	1,131	44.8	1,141	44.9
	Female	1,395	55.2	1,402	55.1
Education	Elementary school	948	37.5	153	6.0
	Middle school	556	22.0	740	29.1
	High school	782	31.0	563	22.1
	University	240	9.5	875	34.4
	Missing value	–	–	212	8.3
Marital status	Unmarried	26	1.0	19	0.7
	Married (with a spouse)	1,684	66.7	1,637	64.4
	Bereavement/Divorce/ETC	816	32.3	885	34.8
	Missing value	–	–	2	0.1
Monthly income	<1 million won	715	28.3	709	27.9
	Between 1 and 2 million won	568	22.5	579	22.8
	Between 2 and 3 million won	478	18.9	447	17.6
	Between 3 and 4 million won	321	12.7	336	13.2
	Between 4 and 5 million won	199	7.9	195	7.7
	Between 5 and 6 million won	131	5.2	117	4.6
	More than 6 million won	114	4.5	160	6.3
Regional scale	Large cities	967	38.3	1,060	41.7
	Medium and small cities	660	26.1	734	28.9
	Small towns and villages (e.g., Eup, Myeon areas)	899	35.6	749	29.5

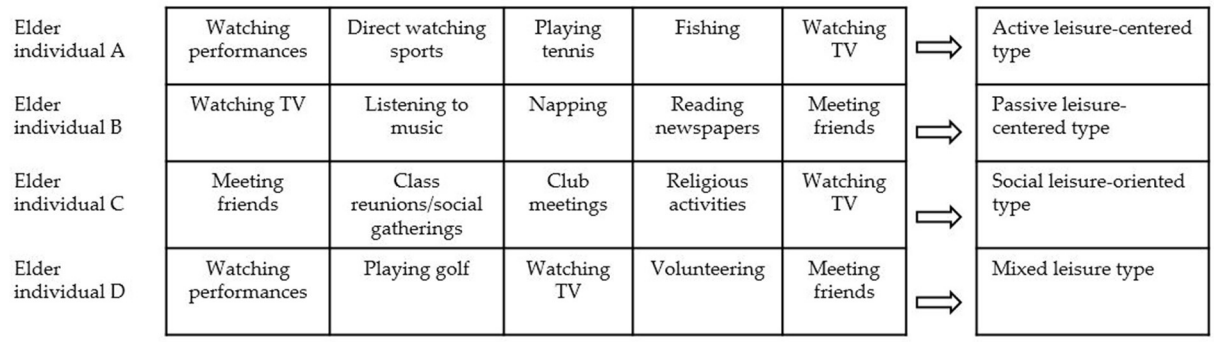

FIGURE 1
Conceptual diagram of individual leisure activity type.

(%), percentage difference (%p), and increase/decrease rate before and after COVID-19 were examined. Here, the active leisure-centered type refers to a case in which more than half of the responses to the leisure activities, in which they participated the most, were active leisure. For example, as in the case of elderly person A in Figure 1, individual leisure activities consist of watching performances, direct watching sports, playing tennis, fishing, and watching TV. The passive leisure-centered type refers to a case in which more than half of the responses to an individual's leisure activity type consisted of passive leisure. For example, as in case B in Figure 1, leisure activities consist of watching TV, listening to music, napping,

reading newspapers, and meeting friends. The social leisure-oriented type refers to a case in which more than half of the responses to the leisure activities in which they participated the most were composed of social leisure. For example, as in the case of elderly person C in Figure 1, leisure activities consist of meeting friends, class reunions/social gatherings, club meetings, religious activities, and watching TV. Lastly, the mixed leisure type refers to a case in which active, passive, and social leisure is mixed. For example, as in the case of elderly person D in Figure 1, leisure activities consist of watching performances, playing golf, watching TV, volunteering, and meeting friends. Data analysis was performed using IBM SPSS version 23.

Results

Changes in leisure activities of the elderly after COVID-19: Aspects of participation rate

The results of analyzing the changes in leisure activities of the elderly after the outbreak of COVID-19 were shown in Table 2. The participation rate of 'sports participation activities, hobbies and entertainment activities, and leisure activities' increased, and the participation rate of 'culture and art viewing/participation activities, sports viewing activities, tourism activities, and social activities' decreased.

Specifically, the participation rate of cultural and art viewing activities were 5.5% before COVID-19 and 3.6% after COVID-19, with a percentage difference of−2.0% and a change rate of−35.4%. The participation rate of cultural and artistic participation activities was 6.3% before COVID-19 and 5.1% after COVID-19, with a percentage difference of−1.2% and a change rate of−18.9%. The participation rate of sports watching activities was 13.3% before COVID-19 and 7.6% after COVID-19, with a percentage difference of−5.7% and a change rate of−42.8%. The participation rate of sports participation activities was 18.5% before Corona 19 and 23.6% after Corona 19, with a difference of 5.1% and a change rate of 27.8%. The participation rate of tourism activities was 19.5% before Corona 19 and 12.7% after Corona 19, the percentage difference was−6.8%, and the increase/decrease rate was−35.0%. The participation rate of hobby and entertainment activities was 102.7% before Corona 19 and 104.6% after Corona 19, with a difference of 1.9% and a change rate of 1.8%. The participation rate of rest activities was 221.7% before Corona 19 and 231.7% after Corona 19, with a difference of 10.0% and a change rate of 4.5%. The participation rate in social and other activities was 111.6% before COVID-19 and 102.2% after COVID-19, with a percentage difference of−9.4% and a change rate of -8.5%.

Changes in leisure activities of the elderly after COVID-19: Aspects of leisure activities

The results of analyzing the changes in leisure activities of the elderly after COVID-19 were explained in Table 3. The active leisure-centered type, with more than half of active leisure activities, showed a decrease of−4.7% from 20.6% before COVID-19 to 19.6% after COVID-19, with a difference of−1.0%p. The passive leisure-centered type, with more than half of passive leisure activities, showed an increase of 20.6%, from 36.9% before COVID-19 to 44.4% after COVID-19, and the percentage difference was 7.6%p. The social leisure-oriented type, in which more than half of the social leisure activities were performed, showed a decrease of−36.6% from 5.0% before COVID-19 to 3.2% after COVID-19, and the percentage difference was−1.8%p. The mixed leisure type, in which active, passive, and social leisure activities are mixed, showed a decrease of−12.7% from 37.5% before Corona 19 to 32.8% after Corona 19, and the percentage difference was -4.8%p.

Discussion and conclusion

The purpose of this study is to provide basic data for leisure policy in the post-corona era by empirically analyzing how the leisure life of the elderly has changed since Corona 19. The results derived from this study are discussed as follows.

Since the outbreak of COVID-19, many changes have occurred in the leisure activities of the elderly. Culture, art, sports viewing, tourism, and social activities of the elderly decreased, while sports participation, hobbies, and leisure activities increased. First of all, the most notable result of the leisure activity participation rate is that the rest activity increased. This supports the results of studies that showed that the elderly had decreased physical activity and increased sedentary behavior after the outbreak of COVID-19 (5–7, 9–11). The increase in resting activities, such as watching TV, sleeping, and listening to radio, is not desirable in terms of the health of the elderly, but it may be an unavoidable choice for the elderly who are vulnerable to the virus. Despite the increase in inactive rest activities, the fortunate thing is that sports participation increased. These results are likely to be related to an increase in home-based exercise. The popularity of home training is increasing due to the closure or limited operation of sports facilities, with 8 out of 10 people experiencing home training after the COVID-19 pandemic (36), and the average social postings related to home training in 2020 increased by 112.7% compared to before COVID-19 (37). Hobbies such as gardening, caring for companion animals, and crafts also increased, which can be interpreted as the reason for the increase in hobby activities that the elderly can do alone at home.

TABLE 2 Changes in leisure activities of the elderly after COVID-19: aspects of participation rate.

Category	Before COVID-19 A(%)	After COVID-19 B(%)	Difference	
			% Difference B-A	Change rate(%) (B-A)/A
Cultural and art viewing activities	5.5	3.6	−2.0	−35.4
Cultural and artistic participation activities	6.3	5.1	−1.2	−18.9
Sports watching activities	13.3	7.6	−5.7	−42.8
Sports participation activities	18.5	23.6	5.1	27.8
Tourism activities	19.5	12.7	−6.8	−35.0
Hobby and entertainment activities	102.7	104.6	1.9	1.8
Rest activities	221.7	231.7	10.0	4.5
Social and other activities	111.6	102.2	−9.4	−8.5

TABLE 3 Changes in leisure activities of the elderly after COVID-19: aspects of leisure activities.

Division	Before COVID-19 A (%)	After COVID-19 B (%)	Difference	
			% Difference B-A	Change rate (%) (B-A)/A
Active leisure-centered type	20.6	19.6	−1.0	−4.7
Passive leisure-centered type	36.9	44.4	7.6	20.6
Social leisure-oriented type	5.0	3.2	−1.8	−36.6
Mixed leisure type	37.5	32.8	−4.8	−12.7

On the other hand, in the case of cultural and art viewing activities, there was a decrease. Recently, as the online platform-based non-face-to-face performance culture is spreading, cultural and art viewing activities are becoming more active (38), but this study showed the opposite result. Digitalization is accelerating all over the world due to COVID-19, and this phenomenon is expected to continue even after the end of COVID-19. It seems that policy efforts are needed to ensure that the elderly can equally enjoy the benefits of digital technology without discrimination or exclusion.

There was also a decrease in social activities, and these results are in agreement with the results of previous studies that the frequency of meeting with friends and acquaintances decreased and the leisure time spent alone increased to some extent after Corona 19 (8, 39). In addition, the participation rate of the elderly in tourism activities also decreased, which is in contrast to a recent study that revealed that outdoor and natural activities of adults increased after the onset of COVID-19 (40). These results predict that the older people experience relatively greater restrictions on outdoor activities than the younger ones.

The next notable result in terms of the composition of leisure activities is that the number of elderly people who spend most of their leisure time in passive leisure after the outbreak of COVID-19 is increasing. This is a very unfortunate result considering that the leisure patterns of the elderly in Korea were becoming active and diversified before the outbreak of COVID-19 (35). This result shows the negative changes in the leisure life of the elderly due to COVID-19, and predicts the health problems of the elderly. Inactive leisure activities among the elderly can lead to decreased physical and cognitive functions, decreased muscle mass, and increased levels of inflammation. This can exacerbate chronic diseases and lead to extreme stress and depression, leading to suicide. Therefore, policy measures for the healthy leisure life of the elderly should be prepared.

Combining the above results, this study was able to identify changes in leisure activities of the elderly due to COVID-19. These changes are expected to return to the previous state after the end of COVID-19, but it is expected to continue for a considerable period of time. Based on these analysis results, the researchers intend to draw and present implications that can contribute to timely leisure policies in the post-corona era. First, online recreation services for the elderly need to be activated. At the government level, it is necessary to create an environment where the elderly can receive various recreational services at home by producing various online contents such as sports, art, music, and gardening activities. Furthermore, it is necessary to activate an *Ontact* type of recreational service that enables two-way communication between the elderly and the recreation leader. Second, digital inclusion of the elderly is necessary. First, it is necessary to conduct digital competency education

so that the elderly can use online recreation services smoothly. In addition, it is necessary to create an environment where the elderly can freely use the Internet anytime and anywhere, and it is also necessary to consider support for digital devices such as smartphones, tablets, and PCs.

This study is meaningful in that it explains the effect of COVID-19 on leisure activities of the elderly by using national statistical data with relatively high reliability of the survey and a large number of samples. It is hoped that this study will be used as a reference for those involved in the leisure industry and leisure policymakers preparing for the post-corona era.

Finally, this study suggests the following for further research. First, it is proposed to examine whether changes in leisure activities of the elderly due to COVID-19 differ according to economic status, region of residence, number of household members living together, gender, and age. Second, it is suggested that a qualitative study be conducted for in-depth discussion on changes in leisure activities of the elderly after COVID-19.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

Conceptualization, validation, investigation, data curation, and writing—original draft preparation: EK and HK. Methodology, formal analysis, and visualization: EK. Writing—review and editing: SP. Supervision and project administration: HK. All authors have read and agreed to the published version of the manuscript.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Does an active lifestyle matter? A longitudinal study of physical activity and health-related determinants in older adults

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Introduction: It is well-known that regular physical activity, and thus an active lifestyle, has positive effects on aging and general wellbeing. However, the question remains as to whether regular or increased physical activity can improve self-perception of health status and quality of life in older adults.

Methods: We conducted a longitudinal study on a group of active older adults between 2013 and 2021. At baseline, i.e., the 1st measurements (baseline), 147 participants were enrolled (mean age 68.4 ± 5.6). After 8 years, in 2021 (follow up), 52 older adults (mean age 75.9 ± 5.3 years) were measured. For the purpose of this study, we included 52 older adults participated at both time-points. For both measurements, participants reported their physical activity and sedentary behavior using the Global physical activity questionnaire (GPAQ), socio-demographic and environmental determinants, recording their self-perception in terms of overall wellbeing. Furthermore, we conducted a qualitative study using semi-structured interviews to obtain subjective data on the changes and events that may have affected physical abilities and general health over an 8-year period.

Results: At the follow up, participants reported lower physical activity and sedentary behavior compared to baseline, but still met health-enhancing physical activity (*HEPA*) standards for total self-reported physical activity (>3,000 METmin/week). In addition, they rated their overall health ($p < 0.001$), physical fitness ($p < 0.001$), psychological wellbeing ($p < 0.001$) and overall quality of life ($p < 0.001$) as better. The qualitative data confirmed that the 8-year period involved changes in physical activity. Specifically, they have continued to carry out physical work (gardening, working in the vineyards, olive groves), but previously organized physical activities were replaced by walks in nature, which probably also influenced the reduction of sedentary behavior.

Conclusion: After 8 years, as expected, participants reported a decrease in physical activity and a lower level of sedentary behavior. It appears from the interview that healthy older adults filled their days with daily tasks and found more time for walking. Individuals who were more active in the past 8 years also reported better overall health and wellbeing. Selected variables correlated with an active lifestyle and better perceptions of quality of life.

KEYWORDS

older adults, aging, physical activity, wellbeing, quality of life, leisure time

Introduction

Active engagement, absence of disease, and good physical and cognitive function are key components of successful aging (1). Various leisure activities have a positive impact on older adults' perceptions of wellbeing (2–4). It is already known that there is a positive correlation between an active life and life satisfaction (5), and physical activity in particular can have a positive impact on health and functioning of older adults (6–8). Yet, many people are much less active than recommended (9, 10). Most older adults do not engage in enough substantial physical activity (11). Usually their physical activity is represented by housework or going to the supermarket (12), but unfortunately, this is not enough to stay healthy. To maintain protection against the development of age-related functional and health impairments, planned physical activity is necessary (13).

In addition to physical activity (PA), sedentary behavior (SB) also plays an important role in healthy aging. According to the World Health Organization guidelines, the definition of SB is any waking behavior characterized by energy expenditure of 1.5 METs or less while sitting, lying, or leaning (13). But SB, or "too much sitting," is not the same as physical inactivity or "too little exercise." Individuals can meet current recommendations for physical activity but, on the other hand, spend the rest of the day heavily sedentary (14). Alternatively, they may not meet current recommendations for moderate to vigorous physical activity (MVPA) but still have very low SB. According to the Survey of Health, Aging, and Retirement in Europe, 11.8% of older adults in Slovenia are physically inactive (11).

High SB and low PA levels are independent risk factors for major chronic diseases (13, 15). According to (16), older adults are aware that any kind of physical activity is necessary for healthy aging. Self-perception of one's health reflects the ability to function in a given social and organizational situation (17). Individuals with low scores of self-perceived health status are more likely to use medical services and have lower functional independence than those with the opposite attitude toward their health (18). It is already known that leisure-time PA is associated with better self-rated health in young adults (19, 20). But what about older adult? After reviewing the literature, we did not find a longitudinal study with a data collection of physical activity and general wellbeing interval of 8 years. Therefore, a longitudinal approach to data collection would be necessary in this area of research to evaluate the importance of active lifestyle on self-awareness of health and wellbeing of older adults. Our research question was whether older adults with an active lifestyle perceive their health status and wellbeing to be better. We wanted to determine whether the influence of an active lifestyle, such as regular or increased PA and low SB, affects self-perception of individual health status and quality of life in older adults.

Methods

Participants

This study included baseline data of 52 participants from the Physical Activity and Nutrition for Great Aging (PANGeA) mass measurements in 2013. The baseline study enrolled older adults (≥60 years) from three Slovenian cities – Koper, Ljubljana and Kranj. At baseline, in Koper, we enrolled 147 older adults aged 60–79 years from the Slovenian city of Koper and its surroundings living independently. Inclusion criteria for the first leg were older adults aged between 60 and 80 living independently. Exclusion criteria for baseline measurements were as follows: the inability to walk a distance of 2 km independently and continuously; severe cognitive decline [MoCA score <10 points (after correction for age and schooling)]; acute illness or with a recent hospitalization (in the 6 months prior); having diabetes mellites or insulin therapy or being on medications other than metformin. After 8 years, in 2021, all participants from baseline measurements made in Koper were invited to take follow-up measurements. Fifty-two participants were measured again (22 men and 30 women, mean age: 75.9 ± 5.3 years). For the follow-up, we invited participants by mail and over the phone. Of the participants who were unwilling or unable to respond to the follow-up measurement, we obtain the reason for dropping out (death, unreachable, other health issues). Specific data is described in the "Results" section.

Ethical approval

The original mass measurements study, PANGeA, which was co-financed by the Cross-border Cooperation Program Slovenia – Italy 2007–2013, was conducted according to the standards set by the latest revision of the Declaration of Helsinki from 2012 to 2014. Both the baseline and follow up measurements were approved by the National Ethical Committee of the Slovenian Ministry of Health (baseline ethical approval no. 102/04/12; follow-up ethical approval no. 0120-76/2021/6) and confirmed by the ZRS Koper Scientific Council no. 0624-77/21. Moreover, the clinical trial protocol was registered on ClinicalTrials.gov, Identifier: NCT04899531. The purposes and objectives of this study were carefully explained to the participants and written informed consent was obtained from all of them.

Study protocol

The data was collected in Koper on two occasions (baseline and follow-up) at the Institute for Kinesiology

research laboratory. Participants came for measurement at a prearranged time and completed a series of tests in this order: (see below).

Measurements

The PANGeA Questionnaire consists of several different parts covering general health status, wellbeing and lifestyle (PA, nutrition and habits) of the older adult population. It includes GPAQ – Global physical activity questionnaire for self-assessment of PA, and has adapted part of the European Health Interview survey – EHIS (21) to assess eating habits (regular diet, type of diet) and indicators of quality of life.

Self-assessment of physical daily habits and general health and wellbeing

To evaluate PA habits and SB, the Global physical activity questionnaire (GPAQ) was translated into Slovene and used (22). It consists of 16 questions divided into three domains as well as a sedentary behavior section. The three domains are as follows: activity at work, travel to and from places on foot, and physical activities. Since the study mainly involved retired elderly people, we included all activities that elderly people have to do at home or around the house (e.g., gardening, working in vineyards, olive groves, etc.) within the scope of occupational activities.

Bearing in mind that quality of life has a frame of reference which is broader than aging, we used a part of EHIS (adapted into Slovenian language in 2007). Self-assessment of general health status, physical condition, psychological wellbeing and general quality of life were assessed through the Likert scale, from 1-poor to 5-excellent. Participants were asked to respond to five categories: (a) general health status, (b) physical condition, (c) psychological wellbeing, (d) general quality of life and (e) extent to which they care for their health (1- do not care at all; 2- care very little/not enough; 3- care somewhat; 4- care quite a lot, 5- care enormously). Participants also had the option of answering "do not know"; these responses were not considered in the statistical analysis of the data.

Semi-structured interviews

Additional qualitative material was collected by interviews to cover changes in the daily life of an individual that could affect physical abilities and general health over the period of 8 years. The background topic for nodes and codes was "changes in everyday life" regarding daily practices, routines in *diet, PA domains and general* wellbeing. Participants were invited to participate in the measurements by mail and then again by phone call.

Researchers did not encounter any ethically questionable situations with participants while conducting the interview. Anonymity was guaranteed to all participants, and each respondent was given a code number. All interviewees agreed to participate in the research (each of them signed a consent form) and were informed of all conditions under which data acquired through research would be used. The interviews were recorded using a smart phone application. All recordings are stored in the researchers' private databases and were used solely for transcription purposes.

Data analysis

Quantitative data from the questionnaire were reported as means (standard deviations) for continuous variables or numbers (percentages) for categorical variables. All statistical analyses were performed using Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA, USA) and SPSS Statistics version 22 (IBM, Chicago IL, USA). Comparison between the sexes and points in time (baseline and follow-up) for normally distributed outcome measures (PA and SB) were performed by means of Mixed model ANOVA, to account for between-subject (differences between women and men) and within-subject (differences between baseline and follow-up measurements) variability. G*Power (23) was used for sample size calculation and the detection of a large effect size (i.e., $f = 0.25$) for the group*time interaction of the Mixed model ANOVA (two groups, two measurements) was made ($\alpha = 0.05$, power = 0.95). Outcome measures of general health and wellbeing were not distributed normally and as such we used the Wilcoxon Signed Ranks Test to compare baseline and follow-up outcome measures. Correlation between self-assessed PA and SB and self-assessed general health and wellbeing was evaluated using Spearman's rank correlation coefficient. Statistical significance was set at $p \leq 0.05$.

For the qualitative analysis, the software NVIVO 12 was used for data storage of transcriptions, and for recording connections, annotations, and codes and nodes layout. Additionally, the data analysis, imaginative exploration, and reflection were carried out by researchers. The interviews were conducted using an agreed protocol under an initial code and set of basic info: date and time of the conducted interview. To capture a personal perspective on the significance of the changes occurring during this period between T1 and T2, we encouraged respondents to answer questions on whether anything had happened in the 8 years since the first measurement that had influenced a change in their daily routines.

We set basic nodes: "changes in daily routines," "changes in eating habits," "changes in physical activity/exercise" and "other (new) habits." A more detailed analysis of the empirical material within the nodes of changes in daily routines due to stressful life events was divided into:

a) health-related issues (illness, injuries) and
b) social issues; negative familial events (death, severe illness/injury) or positive familial events (birth of grandchildren, new relationship, etc.).

Additionally, more specifically we focused on changes of:

a) "Physical activity (PA)" resulting in more sub-entries (less PA, more PA, no changes in PA, new PA program).
b) "Eating habits": (un)healthier eating habits, eating less/more (quantity), "mindful eating," no changes in eating habits.
c) any other new habits.

TABLE 1 Description of sex and education frequencies of sample.

Variables	Baseline	
	N	(%)
Sex		
Women	30	57.7
Men	22	42.3
Education		
Short vocational upper secondary	10	19.2
Technical upper secondary	18	34.6
General upper secondary	1	1.9
Higher vocational education	9	17.3
First cycle academic education	13	25.0
Master/Doctor of science	1	1.9

Results

After 1 month of personal engagement by researchers to persuade participants to re-engage in the study, we got a final sample of 52 participants from the baseline ($n = 147$), which is a fair response rate (35%). Additionally, we obtained different reasons for non-participation in measurements: 13 participants died (information was obtained from the Central population register of the Republic of Slovenia) and an additional 82 participants were unable to participate in follow up measurements due to various reasons, of which 66 participants did not respond to the re-invitation. Eleven participants could not participate due to health problems, while 5 participants made an appointment but did not come to take the measurements. Characteristics of older adults who participated at both stages are described in Tables 1, 2. The mean age of participants who are included in this study, at the baseline was 68.4 ± 5.6 years and the majority were women (57.7 %).

There was a statistically significant difference in PA and SB between baseline and follow up measurements (see Table 3). Moreover, we found a statistically significant increase in prescribed medications ($t = -3.252$, $p = 0.002$).

Further analysis of self-reported PA (see Table 4) showed a significantly lower amount of moderate work-related PA in follow-up measurements ($F_{(1,45)} = 4.972$, $p = 0.031$). None of the participants (men or women) reported vigorous PA in their work activities.

After analyzing self-reported general health and wellbeing, we found significantly better general health ($Z = -4.705$, $p < 0.001$), physical condition ($Z = -4.603$, $p < 0.001$), psychological wellbeing ($Z = -5.489$, $p < 0.001$) and general quality of life ($Z = -5.806$, $p < 0.001$) in older adults who participated in the study (Table 5).

In baseline measurements, there was a positive correlation between total PA and concern for health ($r = 0.441$, $p = 0.045$) and between moderate PA and psychological wellbeing ($r = 0.627$, $p = 0.002$), only for men.

In follow up measurements, there was a positive correlation between walking time and general health status ($r = 0.472$, $p = 0.027$) and between vigorous PA and psychological wellbeing ($r = 0.465$, $p = 0.029$) for men. Meanwhile, in women we found a positive correlation between moderate PA and general health status ($r = 0.378$, $p = 0.047$) and between moderate PA at work and psychological wellbeing ($r = 0.466$, $p = 0.011$).

Semi-structured interviews

To help us understand the quantitative results of the questionnaire, quantitative research (in the form of semi-structured interviews) was used to explain in more detail why self-assessment improved in all five categories for both men and women (general health, physical condition, psychological wellbeing, general quality of life, and concern for health), as they rated them statistically better after the 8-year period. The only exception was the "concern for health" category, for which there was no statistically significant difference, and which was rated lower by women.

All but one of the participants taking part in the semi-structured interviews ($N = 51$) were men ($N = 22$), and interviews lasted 7.53 min on average. All interviews were recorded on a smartphone, with the personal consent of the participants, and were used for transcription and further qualitative data analysis. The main start question was "if anything had happened to interrupt or change their daily routines in the 8-year period since the first baseline measurement?

Responses were divided at the first level into those who reported no changes and those who perceived changes. Interestingly, one-third of participants [$N = 17$, men (N) = 9] reported an unchanged daily routine, which in most cases signifies the absence of a serious illness or injury. Furthermore,

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TABLE 2 Sample description on baseline and follow-up measurements.

Variables	Baseline		8-year follow-up	
	N	(%)	*N*	(%)
Marital status				
Single	3	5.7	4	7.7
Married/cohabiting	32	60.4	33	63.5
Widowed/divorced/separated	13	24.5	12	23.1
Decline to answer	4	9.4	3	5.7
Age (years)				
60–64	18	34.6	/	/
65–69	13	24.9	5	9.6
70–74	11	21.1	20	38.5
75–79	10	19.3	10	19.2
80–84	/	/	14	26.9
85–89	/	/	3	5.8
Number of members sharing the same residence				
Living alone	12	22.6	17	32.7
Living with a partner	28	52.8	27	51.9
Living with children	1	1.9	1	1.9
Living with grandchildren	2	3.8	1	1.9
Living with children and grandchildren	6	11.3	6	11.3
Declined to answer	4	7.5	0	/
Number of comorbidities	3.4	/	3.5	/
Number of prescribed medicines	1.9	/	2.9	/

TABLE 3 Self-reported physical activity and sedentary behavior (SB) at the baseline and in follow up measurements.

	Baseline		8-year follow-up		p_{time}	$p_{time*sex}$
	Men	Women	Men	Women		
GPAQ (METmin/week)	5,988 ± 3,008	4,515 ± 3,096	4,425 ± 2,821	3,437 ± 2,504	**0.029**	0.681
SB (min)	244 ± 105	272 ± 122	119 ± 51.6	147 ± 88.6	**<0.001**	0.998

GPAQ – physical activity related energy expenditure from Global Physical Activity Questionnaire (in metabolic equivalent minutes per week). Bold values indicate the statistically significant difference.

in the first phase, we examined those who reported changes [$N = 31$, men (N) = 13] within the scope of a broader range of factors associated with aging that may have influenced self-assessment of quality of life, namely:

A) Changes in health status, i.e., those that:

- observed a decrease in vitality as a natural sign of aging.
- reported illness.
- reported injuries.
- reported new routines.
- and the influence on PA/exercise habits and eating habits as the most prominent features of a healthy lifestyle.

B) Reported life events (negative or positive) that influenced changes in daily routine.

Table 6 shows health-related changes that interrupted the daily routine of another third of those questioned (17 participants). Only two women noted a decline in vitality, and thus motor skills, as a result of natural aging.

We can see in detail that the presence of diseases was given as a reason for changes in daily routine by seven participants (13.7%; men = 4), who most frequently mentioned strokes, heart attacks, cancer, and respiratory and neurological diseases. The other health factor, injuries, was reported by five participants, and another three participants reported a combination of injuries and negative psychosocial factors, with

TABLE 4 Self-reported physical activity (PA) of different levels of intensity for men and women at the baseline and in follow-up measurements.

	Baseline		8-year follow-up		p_{time}	$p_{time*sex}$
	Men	Women	Men	Women		
Moderate PA at work (time)	3,014 ± 2,670	2,315 ± 3,060	1,771 ± 1,451	1,431 ± 1,930	**0.031**	0.709
Walking time (min)	529 ± 740	680 ± 835	443.1 ± 491	607 ± 763	0.564	0.965
Vigorous PA (min)	377 ± 854	148 ± 471	228.6 ± 619	46 ± 166	0.219	0.816
Moderate PA (min)	1,657 ± 1,522	1,258 ± 1,077	1,303 ± 1,640	1,250 ± 1,301	0.463	0.481

PA, physical activity. Bold values indicate the statistically significant difference.

TABLE 5 Self-assessment of general health and wellbeing at the baseline and in follow-up measurements.

	Baseline	8-year follow-up	*p*-Value
General Health status	2.4 ± 0.6	3.5 ± 0.6	**<0.001***
Physical condition	2.4 ± 0.7	3.4 ± 0.6	**<0.001***
Psychological wellbeing	2.1 ± 0.7	3.9 ± 0.7	**<0.001***
General quality of life	2.2 ± 0.6	4.0 ± 0.5	**<0.001***
Concern for health	3.0 ± 0.5	3.1 ± 0.5	0.366

The symbol and bold values indicate the statistically significant difference.

the most frequently cited injuries being fractures (hand, ankle, hip, and spine injuries).

Interestingly, negative life events, rather than health-related factors, were the most frequently cited reason for interruption of daily routine in nine participants [men (N) = 5], with the death of a spouse (N = 3), death of a close relative (N = 4), and poor relationships (misunderstandings with relatives) being the most frequently mentioned.

When considering PA changes in habits and diet as factors of healthy lifestyles, female participants reported in two cases that changes in daily routines occurred only after COVID-19 measures were implemented.

In addition, in five cases, participants reported that PA decreased during COVID-19 due to the annulment of organized exercise that could not be replaced with individual exercise. Reduction in PA due to a natural decline in physical capacity forced three male participants to give up more intense exercise: cycling and running. The reason for reducing and abandoning more intense forms of PA was generally health problems [illness and injury = 15, men (N) = 7]. Interestingly, two women and one man reported an increase in PA due to more regular exercise on their own (as a result of the COVID-19 lockdown) and additional work in an olive grove, while one woman reported a new breathing exercise as more beneficial to her health.

The majority of those who reported changes in daily routine also indicated changes in diet [12 of 17 participants, men (N) = 5]. Most did so for health reasons; they tried to eat healthier and eat more vegetables, and some reported eating less meat. Some tried to avoid certain foods that they thought were unhealthy, such as foods high in sugar and white flour. Participants also reported using more herbs, spices, and other supplements.

In addition, positive changes related to healthy living were mentioned, whereby they began to incorporate regular exercise and a healthier diet into their lifestyle due to the onset of chronic non-communicable diseases (diabetes) and/or injuries (back pain).

Finally, positive life events must be mentioned, such as the joy of new grandchildren and great-grandchildren, which gives new meaning and significance to the lives of older people despite the interruption to their daily routines.

Discussion

The aim of our study was to evaluate the self-assessed general health status and wellbeing of active older adults over an 8-year period.

This study uses an explanatory mixed-method design (24). In the first phase, quantitative results on self-reported PA, SB and quality of life were obtained using a specially-developed questionnaire (PANGeA), aware that some of the key factors determining quality of life in old age involves considerable overlap with the constituents of positive or successful aging (e.g., maintaining independence, social participation, control over one's life, social role functioning, cognitive ability, adaptability, morale, wellbeing, and life satisfaction) (25). As such, quality of life could be defined as a broader concept, evolving from a variety of disciplinary perspectives - mainly sociological, biomedical, psychological, economic, and environmental. To better understand the possible connection between self-assessed quality of life and successful aging, additional qualitative research with semi-structured interviews was carried out with

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TABLE 6 Changes in daily routines over an 8-year period.

	Total (*N*)		Men (*N*)		Women (*N*)	
No changes to routine	17	33%	9	18%	8	16%
Changes related to COVID-19 measures	2	4%	0	0%	2	4%
Changes to routine	31	61%	13	25%	19	37%
Positive impact						
Health-related changes	2	4%	1	2%	1	2%
Positive psychosocial factors	4	8%	2	4%	2	4%
Negative impact						
Natural health decline	2	4%	0	0%	2	4%
Health-related illness	7	14%	4	8%	3	6%
Health-related injuries	5	10%	2	4%	3	6%
Injuries and neg. psychosocial factors	3	6%	0	0%	3	6%
Negative psych-social factors	9	18%	4	8%	5	10%
Total	51	100%	22	43%	29	57%

participants. Semi-structured interviews were used to capture events that may have influenced changes in older people's daily practices, particularly dietary and exercise habits, and that consequently influenced the self-assessment of quality of life.

The study showed that after 8 years, one third of the participants did not notice any changes in their lifestyle, so they continued to live active and healthy lives, the other 2/3 reported changes that were mostly negative in terms of motor decline, occurrence of injuries and diseases, and psychosocial factors and a combination of the above, consistent with a statistically significant decline in both PA and SB. This can be explained by the fact that the participants are now less physically active while engaging in less sedentary activities. Some of them pointed out that their motor skills have decreased, while PA has decreased mainly due to injuries and illnesses. At the same time, they fill their days with various household tasks, so they indicate less sedentary activities. Their PA activity consists mainly of walking and gymnastics (yoga, Pilates), but also dancing, while cycling, walking and games with bats and balls are decreasing. Most active time is spent gardening, working in the olive grove, vineyard and orchard, which was also a seasonal and geographical characteristic of the observed cohort.

In general, after 8 years, all participants still exceeded the limit of >3,000 MET/min/week (in average: men = 4,425 ± 2,821 MET; women = 3,437 ± 2,821), which classified them into the health-enhancing PA (HEPA) population, the HEPA active population. The HEPA active population includes individuals who carry out enough PA for a healthy lifestyle. According to the literature, high-intensity PA is linked to an improved sense of wellbeing and satisfaction (26), and low and moderate PA has more positive effects for the physical health and wellbeing of older people (27, 28). This is also in line with our results; participants who reported a greater amount of walking (this can be categorized as low or moderate PA) also reported a better self-assessed general health status. Moreover, older adults who met the vigorous PA and moderate-to-vigorous PA (MVPA) recommendations score higher in positive affect and lower in depressive symptoms (29). In our sample, men who were more active, specifically vigorously and moderately physically active, reported better psychological wellbeing. On the contrary, Carriedo et al. (29) concluded that the recommended 300 min/week of low PA is not enough to experience a positive mood. We can conclude that participants that were included in our study reported a better self-assessment of general health and wellbeing in comparison to baseline measurements (8 years ago). Therefore, self-selected PA and sustainable lifestyle can have an important influence on psychological benefits as we can confirm with the statement of several participants.

- Woman F164, 81 years: "Since I retired, I've been mostly concerned with nutrition because I was exhausted from work…/… Now I've my own way of eating, my own schedule… I put everything on nutrition, on health, because old age can be beautiful too…/… all these years I liked to do sports, I go to the club, and we go on trips with my colleagues."
- Man 1M220, 83 years: "I'll tell you my motto: A man must be physically active, must find time for a good book and for smart things."

However, to maximize our health, we also need to reduce the amount of time spent sitting. Sitting time is associated with a higher risk of adverse health outcomes, including cardiovascular disease, type 2 diabetes, cancer and mortality, even after adjustment for moderate-to-vigorous PA (30–34). In 2020, the WHO published, for the first time, an official document (13) describing SB and its negative impact on health. The WHO recommends that older people should sit as little as possible (13).

According to Smith et al. (35), older adults whose SB is more than 11 h per day (in comparison to those who sit 4 h or less) have higher odds of sarcopenia and it may affect their health. Moreover, older adults who are more sedentary also have a lower quality of life (36), therefore the importance of SB behavior is clear. Participants in this study reported that, on average, they spend 244–272 min per day sitting, which is 4.1–4.5 h per day. This is still low SB according to the literature (37).

In addition, most participants reported better overall health and wellbeing. This can also be explained by the positive changes mentioned in the structured interviews related to intentions for a healthier lifestyle. Although participants reported lower levels of physical activity, the changes that occurred over the 8 years led them to intend to exercise more regularly, eat healthier, and generally lead healthier lifestyles. We already know that productive activities can have a positive impact on people's perception on life, both physically and sociologically (4, 27, 38). This may also be related to the different correlations found between PA and overall health or wellbeing at baseline and after completion of the study. At baseline, we found only positive correlations between PA and concern for health or wellbeing. In addition, participants felt better after making positive changes because they made conscious efforts to improve their health, mental wellbeing, and wellbeing.

Nevertheless, in 8 years, the number of comorbidities rose from 3.4 to 3.5, and we found an increase in the use of prescribed medicaments indicating declining health status and the onset of diseases that accompany aging. Mijnarends et al. (39) reported that people with more comorbidities were more likely to have dropped out of the study between the baseline and follow-up measurements. We have also recorded 11 participants that could not participate in follow up measurements due to health problems. Moreover, we can assume that participants who did not take part in follow-up measurements could have an important role in concluding the number of obtained comorbidities. We can speculate that the 68 participants who did not respond to the re-invitation and the five participants who made an appointment but did not show up may have also developed comorbidities which can have an important impact study conclusion. Meanwhile, half ($N = 26$) reported some negative changes in daily routines, mostly due to life events, such as illness, and injury, which on the one hand affected the reported lower PA, but on the other generally showed increased commitment to a healthier diet.

Since we are dealing with only a sample of the population of active older adults, it is understandable that even those whose daily routines have changed during these 8 years estimate their general health, physical condition, psychological wellbeing, and general quality of life, better compared to their elderly peers (4). Interestingly, we found a positive response and easier adaptation to the COVID 19 measures, as most of them maintained their daily routines and replaced organized exercise with walking or online exercise. The majority emphasized the advantage of living conditions, as they live in a suburb in a house with a garden, which could also be a factor in assessing quality of life.

- Man 1M011, 73 years: "My wife and I retired to the garden so as not to be confined at home… There we spent the whole day gardening."

During the pandemic, however, they noticeably missed social contact with family, friends, and especially organized exercise, which was interrupted.

- Woman 1F089, 75 years: "… you can't go out, you can't go to town… I missed the contact with my friends, my children, they were afraid to infect us. I didn't go to town because you couldn't sit on the bench, you were afraid to drink and eat outside in the park.

The only exception is in the category "concern for health," with no statistically significant difference and a lower rating amongst women, which could be explained by the perception of the involvement of women in caring for others (caring for sick and elderly parents as well as spouses and grandchildren), which increased even more during the pandemic, where there is not enough space left to take care of their own health.

Limitations

This study was conducted on a sample of older adults who were re-invited to the follow up measurements after 8 years. However, the sample number is relatively small to draw a firm conclusion and the fact that only physically active participants were included in the study may also influence the conclusions. In addition, while the literature demonstrated the acceptable validity and reliability of the selected questionnaires, wellbeing could be better assessed using multi-trait and multi-method scales. PA was evaluated using a questionnaire, which is not as accurate as the use of instrumental measures such as accelerometers. Moreover, the evaluation of SB was made with just one question, which may have led to biased results. The limitations of using questionnaires with a relatively small number of participants were reduced by the addition of qualitative, semi-structured interviews. The narratives about the past years and the data from the questionnaires provided us with valuable information about changes, events that affected daily life, and some lifestyle factors.

Conclusions

After 8 years, participants reported lower levels of physical activity (mainly at the expense of moderately intense work

activity) which is the result of a subjectively perceived decline in motor abilities and the occurrence of injuries or diseases. They reported also on lower levels of sedentary behavior which may be subjectively conditioned by the perception of sitting time. In summary, participants who were more active during this time also reported better general health and wellbeing… In addition, the qualitative interviews indicate participants' awareness of the importance of a healthy lifestyle for healthy aging, as they include PA and care for healthy nutrition as well as maintaining social contacts in their daily lives. Therefore, we can conclude that an active life matters and an active life leads to a better perception of certain areas of life at old age. The analysis of longitudinal data provided important insights into the long-term impact of active lifestyles on the self-awareness of health and wellbeing in older adults.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by National Ethical Committee of the Slovenian Ministry of Health. The patients/participants provided their written informed consent to participate in this study.

Author contributions

KT and SP collected and analyzed the data, and wrote the manuscript. KT, SP, BŠ, and RP edited, revised the manuscript, and approved the final version of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Effects of message framing, psychological distance, and risk perception on exercise attitude in Chinese adolescents

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Objectives: Health communication campaign that promotes physical activity may aid in reducing the prevalence of childhood and adolescent obesity in China. This study examined the effects of message framing and psychological distance on the exercise attitude of Chinese adolescents, along with the interactive role of risk perception.

Methods: Participants in this study were between 10 and 19 years of age. Three experiments were conducted independently. In experiment 1, 76 participants were recruited to assess the effectiveness of message manipulation. In experiment 2, 40 participants were recruited to compare the effects of gain- and loss-framed messages on the exercise attitude. In experiment 3, 37 participants were recruited to explore the interaction between message framing (gain vs. loss), temporal distance (proximal vs. distal), and risk perception (low vs. high) on the exercise attitude. Exercise attitude and risk perception were assessed by Likert-type questionnaires.

Results: There was a significant main effect of message framing ($P < 0.05$), with the gain-framed message inducing a stronger exercise attitude than the loss-framed message. There was a significant main effect of temporal distance ($P < 0.05$), with the proximal temporal distance condition inducing a stronger exercise attitude than the distal temporal distance condition. In addition, a significant interaction ($P < 0.05$) was observed, and the perception of obesity-related risk was a crucial moderator of the message framing and temporal distance. Regardless of whether they were exposed to a gain- or loss-framed message, the proximal temporal distance condition induced a stronger exercise attitude in participants with a high risk perception ($P < 0.05$).

Conclusion: Messages promoting exercise that are framed as having a near-future gain effect and that emphasize disease risks are effective in motivating adolescents to engage in physical activity.

KEYWORDS

physical activity, obesity, temporal distance, health communication, health promotion

Introduction

Obesity is caused by an excess of energy intake over energy expenditure, which develops gradually over time and results in an excessive accumulation of body fat. Obesity leads to a wide array of health problems, including hypertension, type 2 diabetes, coronary heart disease, osteoarthritis, and stroke, and contributes significantly to morbidity and mortality (1). The Chinese government prioritizes preventing and resolving the issue of childhood obesity. In 2016, the Outline of the "Healthy China 2030" Plan (2) proposed strengthening the prevention and treatment of childhood overweight and obesity. According to the most recent Report on Chinese Residents' Chronic Diseases and Nutrition 2020, the prevalence of overweight and obesity in school-aged children aged 6–17 has reached 19% (3). Lifestyle modifications such as dietary intervention and physical activity are necessary for the effective management of obesity (1). In response to the alarming obesity trend, the National Fitness Program (2021–2025) emphasizes the promotion of physical activity for key populations and exercise interventions for childhood obesity (4). Participation in physical activity is voluntary and, thus, subject to individual's decision-making processes. Correspondingly, it is crucial to help children and adolescents shape a positive exercise attitude first.

According to the theory of reasoned action, behavioral attitude and subjective norms influence behavioral intention, and behavioral intention can directly determine the occurrence of behavior (5). The exercise attitude-behavior model has subsequently been proposed for exercise promotion (6). Theoretically, an individual's exercise attitude exerts positive influence on their exercise intention, which in turn influences their actual exercise behavior. With the continuous development and improvement of research theories pertaining to exercise attitude, more studies have been conducted on the practical applications of exercise attitude. Qiu and Zhang (7) reported a single session of cognitive learning can successfully modify implicit exercise attitude; nevertheless, its effect on physical activity is very transient, lasting only 1 day in their study. Liu and Li demonstrated that the exercise attitude of Chinese University students positively predicted exercise behavior, including duration, intensity, and frequency of exercise (8). A longitudinal study revealed that American adolescents with more positive exercise attitude engaged in 30–40% more moderate-to-vigorous physical activity at 5-year and 10-year follow-up than those with less positive exercise attitude (9). Recently, French researchers looked into the effect of eHealth (i.e., online and social media exercise and physical activity promotion) on exercise attitude and actual exercise activity during the first COVID-19 pandemic wave (10). eHealth users demonstrated significantly higher levels of exercise attitude, vigorous physical activity, and total physical activity per week compared to non-users. These findings illustrate the importance of developing health communication with evidence-based material for encouraging an exercise-friendly attitude, and its therapeutic implications are now being explored and expanded (11).

Message framing is a persuasive message that can influence an individual's decision preferences by altering the presentation of the alternative message (12). There are three types of framing effect: risky choice framing, attribute framing, and goal framing (13). The goal framing effect, which describes whether a persuasive message emphasizes the positive outcomes of performing an act or the negative outcomes of not performing the act, has gained popularity in health communication research of exercise attitude. In general, the effect associated with goal framing is both positive and diverse. Latimer et al. (14) presented gain- or loss-framed messages to sedentary, healthy participants at baseline, week 1, and week 5. At week 9, it was found that gain-framed messages led to greater participation in physical activity than loss-framed messages. Similarly, Berenbaum and Latimer-Cheung found that gain-framed messages resulted in stronger exercise attitude than loss-framed messages when presented to female University students (15). In anther study, University students who received framed mental health messages on social media had a stronger exercise attitude than those who got random health facts unrelated to physical activity (16). However, the authors did not find a significant difference between gain- and loss-framed messages in terms of exercise attitude or actual exercise behavior as measured by total MET minutes per week. This disparity in outcomes may be attributable to the heterogeneity of the focus participants investigated. For instance, Song et al. (17) demonstrated that exercise self-efficacy was negatively affected when individuals with high body image dissatisfaction viewed an image of themselves on a video game screen, indicating that overweight and obese individuals may have different psychological responses to physical activity. In addition, existing research have not explored the exercise attitude of children and adolescents in a more homogeneous manner. In light of these gaps, research of message framing should explore the framing effect on specific populations and likely include perception of disease risks as a covariate.

When constructing health communication aimed at fostering a more positive exercise attitude, it is crucial to take into account variables that mediate the presence, strength, or absence of framing effect. First, the relative persuasiveness of message framing is dependant on the psychological distance (18). Psychological distance is a cognitive separation between the self and other things, such as other people, events, or times (19). The theory posits four dimensions of psychological distance, including spatial distance, temporal distance, social distance, and hypotheticality. Research on marketing communication suggests that consumers in a pre-decisional mindset are more likely to be persuaded by psychologically distal messages, whereas those in a

TABLE 1 Framed messages (translated from Chinese).

Gain-framed message	Loss-framed message
According to the "Core information and interpretation of Chinese youth health education (2018 version)" published by the National Health Commission, if you regularly engage in scientific exercise and sports, you will burn more calories and your body will become healthier and slimmer. In addition, you will feel more comfortable during your exercise and sports and grow to appreciate it more and more. And the cardiovascular disease, fatty liver disease, and other health problems caused by obesity will gradually disappear as exercise habit is maintained. When you reduce the trouble caused by obesity, you will be more appealing to your peers.	According to the "Core information and interpretation of Chinese youth health education (2018 version)" published by the National Health Commission, if you do not engage in regular exercise and sports, you run the risk of gaining weight and your physical health will deteriorate. In addition, subsequent exercise and sports will be increasingly difficult, and you will develop an increasing aversion to it. And as a result of obesity, cardiovascular disease, fatty liver disease, and other health conditions will worsen if you do not exercise. Furthermore, social rejection from your peers will increase as a result of your obesity.

post-decisional mindset are more likely to be persuaded by psychologically proximal messages (20). To date, very few studies have been conducted on the interaction between message framing and psychological distance on exercise attitude (21) and are limited to the general population. A recent study examined the effects of a 3-month exercise promotion program on the attitude and behavior of 18- to 65-year-old adults (22). It has been observed that persons with more negative distal affective attitudes at baseline exhibited the highest proximal affective attitudes toward daily exercise. Moreover, the specific effect of temporal distance in adolescents is completely undocumented.

Second, the relative persuasiveness of message framing is also influenced by the risk perception associated with the advocated health behavior (23). Risk perception is an individual's subjective, more intuitive evaluation of risk (24). Research on health communication found that perception of junk food risk can amplify the relationship between regulatory focus and health consciousness, and message framing combined with the appropriate regulatory focus has a positive effect on consumers' intentions to avoid junk food (25). Similarly, a perception of obesity risk, may also influence one's exercise attitude, which has not previously been noted in published literature. Considering the cognitive connection between the perceived risk and behavioral responses in health decision-making, it is essential to understand the role of risk perception in shaping exercise attitude among adolescents in order to implement effective message framing.

Integrating health promotion campaigns into the school curriculum and daily life may be a promising strategy for encouraging children and adolescents to improve their health-related beliefs and behaviors. To develop tailored exercise promotion, a comprehensive understanding of the mechanisms underlying the formation of exercise attitude is urgently required. This study therefore examined the interaction between message framing, temporal distance, and risk perception on the exercise attitude of Chinese adolescents.

Experimental 1

Methods

Participants

Experiment 1 was designed to validate the framed messages employed in experiments 2 and 3. Participants had not previously participated in similar experiments. Seventy six students participated in experiment 1, with 39 participants being female. Their age was 14.5 ± 1.2 yrs (girls, 14.4 ± 1.2 yrs; boys, 14.7 ± 1.1 yrs). All participants and their legal guardians were verbally and in writing informed about the research prior to providing written informed consent to participate. This experiment was approved by the Ethical Review Board of Hunan Normal University.

Instrument

Table 1 presents the messages framed to motivate exercise. The gain-framed message emphasized the advantages of regular participation in exercise and sports, whereas the loss-framed message underlined the disadvantages of non-participation.

The effectiveness of framing manipulation was evaluated based on participants' affective reaction and information acceptance to the framed message. Affective reaction to the framed message was measured using a peer-reviewed, 7-point semantic differential scale (scale: 1, mostly negative; 7, mostly positive) (26). It was anticipated that the gain-framed message would produce stronger positive affect, whereas the loss-framed message would produce stronger negative affect.

Information acceptance of the framed message was measured using a peer-reviewed, 7-point semantic differential scale (27). Participants rated the extent to which they thought the message was relevance (1, very relevant; 7, not at all relevant), interest (1, very interesting; 7, not at all interesting), objectivity (1, very objective; 7, not at all objective), and exaggeration (1, very exaggerated; 7, not at all exaggerated). In addition, participants rated their level of agreement with the message (1, I totally agree; 7, I totally disagree). The

information acceptance score was calculated by reversing (except "exaggerated"), combining, and averaging all individual item scores. It was anticipated that the information acceptance score of both framed messages would be higher than the median score 4. Cronbach alpha of this scale was 0.81 (27).

Procedure

Participants read gain- and loss-framed messages at random. They completed the affective reaction scale after reading each message and the information acceptance scale after reading both messages.

Statistics

The deidentified data from experiments 1, 2, and 3 that supporting the conclusions of this study are available on figshare (https://doi.org/10.6084/m9.figshare.20286075.v2). Data were analyzed using the IBM SPSS Statistics (version 26.0). Data are expressed as mean ± standard deviation. A two-tailed Welch's *t*-test (28) was used to compare the affective reaction score between the gain- and loss-framed messages. A one-sample Wilcoxon signed rank test was used to compare the information acceptance score against the median score 4. A *P*-value < 0.05 indicates statistical significance.

Results

Affective reaction scores of gain- and loss-framed messages were compared. On average, gain-framed massage (6.12 ± 0.71) was perceived significantly more positive than loss-framed message (2.76 ± 1.30), $t_{(116.5)} = 19.80$, $P < 0.001$. The medium score for information acceptance was 5.4, which is significantly higher than 4, $P < 0.001$. In summary, the manipulation check confirmed that both framed messages satisfy the experimental conditions.

Experimental 2

Methods

Participants

Experiment 2 compared the framing effect on the exercise attitude. According to previous research, it was hypothesized that the gain-framed message should be more persuasive than the loss-framed message. Based on the G*POWER (version 3.1), a total of 34 participants were required to ensure a medium effect size (statistical power = 0.8, effect size = 0.25, significance level = 0.05). Forty students participated in experiment 2, with 23 participants being female. Their age and figure rating scale (29) were 14.4 ± 1.2 yrs (girls, 14.2 ± 1.2 yrs; boys, 14.7 ± 1.1 yrs) and 5.0 ± 1.0, respectively. All participants and their legal guardians were verbally and in writing informed about the research prior to providing written informed consent to participate. This experiment was approved by the Ethical Review Board of Hunan Normal University.

Instrument

The messages framed to influence exercise attitude are identical to those used in experiment 1. Exercise attitude was measured using a peer-reviewed, 7-point semantic differential scale (15). The questionnaire was constructed as "I consider routine scientific exercise to be" followed by seven adjective pairs with the following anchors: "bad–good; beneficial–harmful (reverse coded); worthless–valuable; unenjoyable–enjoyable; pleasant–unpleasant (reverse coded); interesting–boring (reverse coded); relaxing–stressful (reverse coded)". The average score of seven items reflects an individual's exercise attitude, with a higher score indicating a greater propensity for exercise participation. Cronbach alpha of this questionnaire was 0.76–0.78 (15).

Procedure

Participants chose images that resembled their own body shape based on the figure rating scale (29). Participants then read gain- and loss-framed messages at random. After reading each message, participants rated their exercise attitude and took a 5-min break between messages.

Statistics

Data were analyzed using the IBM SPSS Statistics (version 26.0). Data are expressed as mean ± standard deviation. A one-tailed Welch's *t*-test was used to compare the exercise attitude score between the gain- and loss-framed messages. A *P*-value < 0.05 indicates statistical significance.

Results

Participants scored significantly higher on the exercise attitude after reading the gain-framed message (5.78 ± 0.79) than after reading the loss-framed message (5.28 ± 1.31), $t_{(64.29)} = 2.076$, $P = 0.02$.

Experimental 3

Methods

Participants

Experiment 3 examined the effects of message framing and temporal distance on the exercise attitude of students who perceived a high risk of obesity and those who perceived a low

risk of obesity. Based on the G*POWER (version 3.1), a total of 34 participants were required to ensure a medium effect size (statistical power = 0.8, effect size = 0.25, significance level = 0.05). Thirty seven students participated in experiment 3, with 24 participants being female. Their age and figure rating scale (29) were 14.3 ± 1.7 yrs (girls, 14.3 ± 1.7 yrs; boys, 14.3 ± 1.7 yrs) and 6.5 ± 1.6, respectively. All participants and their legal guardians were verbally and in writing informed about the research prior to providing written informed consent to participate. This experiment was approved by the Ethical Review Board of Hunan Normal University.

Instrument

Risk perception was assessed with items adapted from the risk behavior diagnosis scale (5-point Likert scale: 1, strongly disagree; 5, strongly agree) (30). Each of the two dimensions of risk, severity and susceptibility, consists of three items. Severity was measured using three items, including "I consider my obesity to be severe", "I believe that the health consequences of obesity are severe", and "I believe that the consequences of obesity due to a lack of regular exercise are significant". Susceptibility was measured using three items, including "I am experiencing the risks of being obese", "I am highly susceptible to the dangers associated with obesity", and "I am likely to experience the risks associated with being overweight". The average score of six items indicates an individual's perception of obesity, with a higher score indicating a greater risk.

The message framing used in experiment 3 were identical to those used in experiment 1, with the addition of a temporal distance factor for the text material of exercise attitude. In this study, temporal distance refers to the period of time between when obese middle school students participated in physical activity and the present day. The manipulation of temporal distance is based on the research of Trope and Liberman (31), in which the proximal temporal distance is expressed as "tomorrow" and the distal temporal distance as "a year from now". The questionnaire of exercise attitude was altered as follows: "I believe that beginning tomorrow, routine scientific exercise is…" and "A year from now, I anticipate routine scientific exercise to be…".

Procedure

Before message exposure, participants' risk perception was evaluated; those with a risk perception ≥3 were considered to be high risk of obesity, while those with a risk perception < 3 were considered to be low risk of obesity. Participants chose images that resembled their own body shape based on the figure rating scale (29). Participants then randomly read four different categories of message: gain-proximal, gain-distal, gain-proximal, and loss-distal. After reading each category of message, participants completed the exercise attitude scale and took a 5-min break for each category completed.

Statistics

Data were analyzed using the IBM SPSS Statistics (version 26.0). Data are expressed as mean ± standard deviation. The interaction effect on the exercise attitude was analyzed by repeated measures analysis of variance. Two within-subjects variables are message framing (gain vs. loss) and temporal distance (proximal vs. distal) and one between-subjects factor is perceived risk (low vs. high). A customized SPSS syntax employing LSD as post hoc was constructed to decompose a significant three-way interaction into simple main effects. A P-value < 0.05 indicates statistical significance.

Results

Initially, we examined the effects of message framing and temporal distance on the exercise attitude, without differentiating the risk perception levels among the participants. There was a significant main effect of message framing on the exercise attitude, [$F_{(1, 36)} = 7.871$, $P = 0.008$]. When participants read the gain-framed message (5.00 ± 1.25), they had stronger exercise attitude than when they read the loss-framed message (4.60 ± 1.34). There was a significant main effect of temporal distance on the exercise attitude, [$F_{(1, 36)} = 13.416$], $P < 0.001$. Participants' exercise attitude was stronger in the proximal temporal distance condition (5.25 ± 0.98) than in the distal temporal distance condition (4.35 ± 1.44). The interaction between message framing and temporal distance was not significant, [$F_{(1, 36)} = 1.671$], $P = 0.204$.

Then, the between-subjects factor risk perception was added to investigate whether participants' exercise attitude differed when comparing low and high risk perception. A two-way interaction between message framing and risk perception was not significant, [$F_{(1, 35)} = 1.627$], $P = 0.211$, nor a two-way interaction between temporal distance and risk perception, [$F_{(1, 35)} = 0.829$], $P = 0.369$. However, there was a significant three-way interaction between message framing, temporal distance, and risk perception, [$F_{(1, 35)} = 4.927$], $P = 0.033$.

Subsequently, we performed a simple main effects analysis and the results are presented in Table 2. Participants with a low risk perception had stronger exercise attitude in the proximal psychological distance condition after reading the gain-framed message ($P = 0.032$). However, temporal distance had no effect on the exercise attitude of participants with a low risk perception in the reading loss-framed message ($P = 0.132$). Participants with high risk perception had stronger exercise attitude in the proximal temporal distance condition than in the distal temporal distance condition, regardless of whether they read the gain- or loss-framed message (all $P < 0.05$).

TABLE 2 Results of simple main effects.

Risk perception	Message framing	Temporal distance	Exercise attitude	*F*	*P*
Low	Gain	Proximal	5.64 ± 0.92	4.973	0.032
		Distal	4.88 ± 1.24		
	Loss	Proximal	4.99 ± 1.12	2.378	0.132
		Distal	4.38 ± 1.38		
High	Gain	Proximal	5.13 ± 0.84	5.155	0.029
		Distal	4.33 ± 1.58		
	Loss	Proximal	5.25 ± 0.97	13.193	< 0.001
		Distal	3.78 ± 1.43		

Data are expressed as mean ± standard deviation.

General discussion

Based on experimental results, the gain-framed message induced stronger exercise attitude than loss-framed message. In addition, under the proximal temporal distance condition, adolescents displayed stronger exercise attitude. Moreover, we demonstrate that the perception of obesity-related risk is a crucial moderator of the framing effect. For adolescents with a low risk perception, proximal temporal distance is more likely to induce the gain-framing effect. For adolescents with a high risk perception, homogeneity of risk perception is high, resulting in a feeling of temporal oppression. Consequently, proximal temporal distance condition induced stronger exercise attitude, regardless of whether adolescents were exposed to the gain- or loss-framed message. There are significant theoretical and practical implications for these findings.

In health communication literature, gain-framed messages are generally more effective than loss-framed message in promoting health promotion behaviors such as smoking cessation and physical activity (32), while loss-framed messages are more effective in promoting disease prevention behaviors (33). For example, Notthoff et al. (34) chose six exercises, and the advantages and disadvantages of these six exercises were presented in gain- and loss-framed messages, respectively. It was found that elderly individuals felt more motivated to engage in physical activity when gain-framed messages were paired with health promotion. Therefore, gain-framed messages are recommended for exercise behavioral interventions when designing exercise promotion campaigns (35). Based on the existing literature, we conducted a more comprehensive study on the exercise promotion strategies for obesity intervention.

We selected adolescents, a focus population for the prevention of overweight and obesity. Obesity in youth is a significant predictor of adult disease and premature mortality (36). The adolescents' exercise attitudes were significantly stronger after reading the gain-framed message than after reading the loss-framed message, corroborating previous research. In a broader context, exercise attitude is a health-related decision-making process that can be explained by the prospect theory. Prospect theory posits that in a benefit scenario, people tend to avoid risk, whereas in a loss scenario, they tend to seek risk (37). When adolescents read about the various health benefits of physical activity, they will develop positive attitudes toward physical activity. In contrast, when adolescents read that not exercising will result in a greater health burden, they may experience acute stress responses (38) and cause active avoidance behavior (39). Due to psychological stress, information that emphasizes the severe health consequences of inactivity may have an acute negative impact on their exercise attitude. In addition, the loss-framed message includes self-esteem-related language such as "social rejection from your peers will increase as a result of your obesity", which may impede exercise self-efficacy (17) and should be avoided in the future. In light of our findings, we suggest information encouraging adolescent physical activity be framed in terms of health benefits and increased self-confidence.

In health communication research, psychological distance can affect an individual's comprehension of the message framing, thereby impacting his or her decision-making behavior (40). It has been demonstrated that temporally proximal framing makes risks appear more immediate and concrete than temporally distal framing, leading to increased self-risk perceptions, intentions to engage in precautionary behavior, concern and anxiety about the hazard, and risk communication effectiveness (41). However, there is a paucity of research on the effect of psychological distance on exercise behaviors, and the interaction between message framing and temporal distance remains unknown. We found that adolescents' exercise attitudes were consistently stronger in the proximal temporal distance condition than in the distal temporal distance condition, regardless of whether the messages were gain- or loss-framed. This consistency (as opposed to temporal variation) in the near future health decision-making can be explained by the construal level theory (31). In the presence of health stress, individuals are more eager to reduce their health burdens through physical activity, i.e., they anticipate more specific, detailed changes in

their bodies as a result of physical activity in the proximal temporal distance condition. This type of cognitive preference for near future certainty has substantial implications for the creation of persuasive health promotion messages. The messages should emphasize the definitive, key, and immediate health outcomes of regular exercise participation. Consequently, the target population, such as obese adolescents, would view the desired health outcome as more attainable, and their decision status mindsets would assist them in decisively committing to near-future behavior modification.

Compared to everyday decisions, health decisions in response to risk perception are infrequent but of the utmost significance. Individual health attitudes and behaviors are influenced by the degree to which individuals perceive a threat to their health (42). When an individual is exposed to health information that is relevant to their current health concerns, their self-health awareness of disease threats increases, and this cognitive consciousness and acceptance motivates self-care behaviors. In addition, it has been suggested that proximal threat (in terms of temporal distance) may be more effective at motivating pro-health behavior (43). We observed this perception-attitude link, in which a high risk perception led to a stronger exercise attitude in the proximal temporal distance condition, regardless of whether the message was framed in terms of gain or loss. Personal risk perception is also concerned with the health belief (44). When individuals perceive health risks, a strong health belief incentivizes them to accept persuasion, adopt health advice, and avoid the consequences of unhealthy behavior. Prior research on health communication focused on matching the message's framing characteristics with the recipient's health goals. The three-way interaction observed in this study is crucial for advancing our knowledge of the factors that influence adolescents' health behavior. Practitioners of health promotion should create information that is easily understood by adolescents regarding disease risks, thereby increasing adolescents' certainty regarding their existing health conditions.

In addition to these new findings, this study has several limitations that warrant further investigation. First, previous research has shown that message framing, whether framed in terms of gain or loss, positively affects exercise motivation compared to no framing (16). Similar to other research in this field (27, 34), this study did not include a neutral message, so we cannot compare the effect size of the framing effect to that of the no-framing condition. This however should understate the obtained results. Second, this research focused solely on the effects of message framing in the written text category. No comparative cross-sectional analysis of message framing in the audio, image, and video categories was conducted. There is a need for scientific evidence regarding personalized delivery formats for different age groups and sexes in order to optimize the framing effect. Third, there are other moderators and mediators of health message framing besides risk perception. Future research could additionally examine the interactive role of prior exercise experience (45), emotions, self-efficacy, and self-esteem (46), which are expected to serve as mediators between exercise attitude and physical activity.

In conclusion, we found independent effects of message framing and temporal distance on the exercise attitude of Chinese adolescents. In addition, we found that risk perception played an important role in the high-risk group of obesity, suggesting that constructing a message with a proximal temporal distance frame could result in a stronger exercise attitude among the overweight and obese adolescents. These findings contribute theoretically to the existing literature on message framing and provide healthcare practitioners with recommendations for designing youth-tailored messages. Youth health behaviors persist into adulthood, and policymakers in China and around the world should continue to raise public awareness of the growing public health and economic burden of physical inactivity. Tailoring the frame to target populations may be one of the most cost-effective ways to induce behavioral changes for the prevention and treatment of childhood and adolescent obesity.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: The data that support the findings of this study are openly available in figshare at https://doi.org/10.6084/m9.figshare.20286075.v2.

Ethics statement

This experiment was approved by the Ethical Review Board of Hunan Normal University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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SLOfit Lifelong: A model for leveraging citizen science to promote and maintain physical fitness and physical literacy across the lifespan

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SLOfit Lifelong is a public health initiative which was created to upgrade a well-established, national physical fitness surveillance system for Slovenian schoolchildren that has been collecting annual fitness and health data for over three decades. The ultimate objective of creating SLOfit Lifelong was to build a modern societal infrastructure with the capacity and ability to detect future causal associations between childhood physical fitness trends and future health outcomes based on the lifelong surveillance of one's own fitness status. By instilling citizens with an ambition to test, understand, and follow-up their own physical fitness and health status (including related health risk factors), this initiative provides the technical support and expert feedback needed to engender greater individual control over understanding (and thus modulating), one's own physical fitness status as they progress into older adulthood. This perspective paper details the extensive approach taken to devise appropriate fitness test batteries for adults and older adults which can also relate to the student version of the original SLOfit test database, including establishing criterion health risk zones and a public approach to establish this national, citizen-driven health feedback framework. Through its sophisticated online web applications, social media, print media, and outreach workshops, SLOfit Lifelong provides the expert support for public health engagement by fostering positive lifelong physical literacy experiences an individual can enjoy across their aging journey.

KEYWORDS

aging, exercise monitoring, participatory research, policy making, population health, surveillance

Introduction

Cardiovascular diseases (CVD) have become the leading cause of global mortality in the 21st century primarily due to lifestyle changes, including increased physical inactivity (1, 2). Recent estimates find the direct health care costs of physical inactivity in Europe reach upwards of 11.7 billion euros per year, with an additional 3.8 billion being lost to poor productivity (3). Although CVD events occur more frequently during, or after, the fifth decade of life, there is strong evidence that the precursors of CVD originate in childhood and adolescence (4, 5) and can be tracked into adulthood (6). Amongst the most important modifiable CVD risk factors is physical fitness. Being physically fit means being able to carry out daily tasks with vigor and alertness (7). Physical fitness refers to a full range of physical qualities, including cardio-respiratory fitness, muscular strength, speed of movement, agility, coordination, flexibility, and body composition. Having higher childhood fitness provides lower risk of developing CVD later in life and lower risk of premature death (8). Increased physical fitness in childhood is associated with positive CVD risk factors (9), improved mental health (10), and quality of life (11, 12).

With aging, negative physiological and physical changes can occur, including sarcopenia (13), progressive muscle mass loss (14), and declines in muscular strength (15, 16), cardiovascular function (17), flexibility (18), and balance (19). These can cause functional declines that prevent older people from performing basic tasks (20–22), affecting mortality rates (23), increasing fall risk, and leading to higher incidence of hospitalization (24). Physical fitness is clearly an important health marker across the lifespan (25). The American Heart Association recommends checking fitness as part of general check-ups (26). Therefore, monitoring physical fitness across the life course is critical not only to prevent chronic disease, but also to maintain functional capacity, identify weaknesses, and addressing them early enough to possibly reverse declines *via* lifestyle interventions.

The purpose of this paper is to communicate how SLOfit Lifelong was developed, the health data it conveys, and how this initiative collaborates with individuals to provide quality testing and expert feedback for adults of all ages who wish to better understand their body and its functional capacity across their lifetime.

Ethics, setting context and population

Ethics statement

Any data collected within the context of SLOfit Lifelong was approved by the Slovenian National Medical Ethics Committee (ID: 0120-468/2021/3), following the Declaration of Helsinki. Participants provided written, informed consent prior to data collection.

Setting context and population

The original SLOfit infrastructure program (herein differentiated as: SLOfit Students) monitors child fitness through their entire schooling period (27). This includes roughly $N = 13{,}000$ graduates per year who are potential SLOfit Lifelong cohort members. SLOfit Lifelong is designed to be capable of housing their fitness data from childhood to adulthood, thus "slotting" in existing SLOfit members as they age, in parallel to recruiting new participants.

In Slovenia, the physical fitness of children and adolescents is monitored by a program originally entitled "Sports Educational Card", implemented in 1982 on a sample of Slovenian schools. After 5 years of refinement and pilot testing, the program was introduced to all Slovenian primary and secondary school curricula in all Slovenian schools (28). "SLOfit Students" is one of the oldest and largest child and youth fitness databases in the world, holding information on more than 40 birth cohorts who have been followed for ∼13 years. Exact measurement protocols are published in the Sports Educational Card manual (29), a compulsory tool for every PE teacher freely available on the SLOfit website (www.slofit.org/ucitelj/administracija). Testing is administered by PE teachers trained from the Faculty of Sport, University of Ljubljana, which is the only institution in Slovenia educating PE teachers in a 5-year specialist program. All schools follow identical testing protocols and use standardized equipment. Results are entered into the "My SLOfit app" where data is first checked with smart algorithms, analyzed, and made available to all registered users, i.e., parents/guardians control access (doctors, coaches, the children themselves).

Beginning in 2016, SLOfit researchers developed and launched a free-for-use, online application system called "My SLOfit" (27). Amongst other features, this application allows users to store their personal data long after their schooling period has ended. The My SLOfit app supports 24-h movement behavior data collection and lifestyle habits (e.g., physical activity, sleep, sedentary time), in addition to direct fitness testing data. SLOfit Lifelong now has the potential to house novel data on young people graduating secondary education (18–19 y) and continue as long as they wish.

Key programmatic elements

Medical screening

We developed a medical screening protocol to mitigate health-risks associated with fitness testing for adults with specific/underlying clinical concerns. SLOfit Lifelong test

TABLE 1 Fitness test battery components for each age group included in the SLOfit Lifelong community health program.

		SLOfit young adults (18–34 y)	SLOfit adults (35–64 y)	SLOfit seniors (65+ y)
Fitness test component	**Test**			
Health screening tests	- Arterial blood pressure at rest	x	x	x
	- Oxygen saturation	x	x	x
	- Resting heart rate	x	x	x
	- Health screening questionnaire	x	x	x
	- Health history questionnaire	x	x	x
Anthropometry	- Body height	x	x	x
	- Body weight	x	x	x
	- Waist circumference	x	x	
Health-related physical fitness measures	- 600-m run	x		
	- 6-min walk test		x	x
	- 2-min step test			x
	- Sit-ups	x		
	- Stand and reach	x		
	- Chair sit and reach test			x
	- Back scratch test			x
	- Bent arm-hang	x		
	- Hand grip test	x		
	- Partial curl-up test		x	
	- Sit and reach		x	
	- 30-s chair stand			x
Skill-related physical fitness	- 20-s arm plate tapping	x	x	
	- Standing long jump	x		
	- Polygon backwards obstacle course	x		
	- 60-m run	x		
	- Standing vertical jump		x	
	- 30-s arm curl			x
	- Timed "up and go" test			x
	- Figure 8 run		x	

All adults between the ages of 19 and 35 can complete the Sports Educational Chart (i.e., SLOfit Student protocol) or older adults can choose one of the SLOfit Adult tests if the head tester determines that the participant is low risk and free of any major health issues. Participants completing the Sports Educational Chart can thus directly compare their results to those completed during their schooling period. At any point a specific test can be omitted or added to each fitness battery upon request. Alternatively, participants can complete a SLOfit Adults protocol and two fitness tests from Sports Educational Chart if they desire, to compare their results from primary or secondary school for a specific test.

batteries include preliminary medical screenings performed at rest, before exercise, for: (1) arterial blood pressure (2) blood oxygen saturation (3) heart rate, (4) medical history questionnaire (5) short health screening questionnaire. Adults visit a center of their choice (e.g., local gymnasium or school) and a fitness tester administers the assessment. The "head of testing" is an exercise expert with (at minimum) a bachelor's degree in kinesiology, physical education, physical training, physiotherapy, or medicine. Health screening questionnaire is an adapted PAR-Q form [American College of Sports Medicine (30)]. Next, participants complete anthropometry measurements, including a brief consultation with the head of fitness testing on their fitness status and potential health risks. Generally, adults between 19 and 64 y who are deemed low-risk can complete SLOfit Adult testing onsite.

Participants completed a warm-up to a prepared video based on age and fitness level of the individual. After warm-up, participants begin the motor tasks. Although testing order is not strictly specified in SLOfit Students or SLOfit Seniors (except that the cardiorespiratory endurance test should be performed last), for SLOfit Adults tests do follow a specific order, namely: vertical jump (leg power), Figure-8 run (agility), handgrip (arm strength), arm plate tapping (coordination), sit and reach (flexibility),

partial curl-up (core strength), and a 6-min walk (cardio-respiratory endurance).

Fitness tests battery identification and selection process

A working group was assembled (N = 14–16 senior and junior researchers) at Faculty of Sport, Ljubljana to identify, pilot test and define appropriate fitness tests for adults. Discussions were then held with experts from target end-users, e.g., fitness industry, sports clubs, national public health institute, patients, academia, and educators familiar with SLOfit. The entire test battery development occurred over ∼36 months, divided into 5 steps. First, the work group reached consensus on which fitness components needed monitoring. Seven components were prioritized: body composition/adiposity, cardiorespiratory endurance, muscular strength, power, coordination, agility, and flexibility. Second, it was decided to split adult test batteries to encompass advancing age and variable fitness levels. Three distinct batteries were decided for: (a) Young Adults (19–34 y), Adults (35–64 y), and Seniors (65+ y). The group then cross-referenced whether any existing published test batteries fit the specific needs of SLOfit Lifelong and found that none matched the existing SLOfit Student version well enough in terms of breadth or scope of fitness tests included. Thus, step 4 was finding the range of appropriate tests and conducting pilot measurements to assess testing feasibility (e.g., measurement duration, positive participant feedback). In the final step 5, three fitness testing batteries were defined: (a) *SLOfit Young Adults* (19–34 y) (29); (b) *SLOfit Adults* (35–64 y) and (c) *SLOfit Senior* (65+ y) (31). When identifying optimal fitness tests for adults, we searched for test with acceptable reliability and validity, while maintaining feasibility inherent to large scale filed testing. A key prerequisite was also that the components of fitness measured by the adult program should align with SLOfit Students so future comparisons could be extrapolated.

Pilot testing

SLOfit Lifelong testing was piloted on each adult group to confirm whether the selected tests were appropriate and determine the best test order for successfully completing all sections with positive vigor. All in-person testing took place at the Faculty of Sport or Faculty of Education, University of Ljubljana, Slovenia, following national guidelines for COVID-19 safety protection.

The test batteries were first piloted on university students (26.04.2021–12.05.2021). Next, Young Adults (N = 471) and Adults (N = 527) were sampled between May 2021 and June 2022, including ∼20 measurement days at the University. Seniors (N = 152) were pilot tested last, from 31.03.2022 to 21.06.2022. On 21.04.2022, measurements were performed at the Coronary Club of Ljubljana with participants having diagnosed cardiovascular disease (s). After this first stage, some tests were modified or improved slightly. Due to problems with feasibility (e.g., long duration and difficulties with standardization of the protocol), with the Sorenson test and T-test prompted replacement with "partial curl-up" and "Figure 8 run", respectively (Table 1). Statistical or other pilot test details are available upon request to the corresponding author.

Determination of criterion references—healthy fitness zones

We performed literature searches for studies published (from 1.1.1980) that investigated the ability of a specific test to predict mortality or morbidity (i.e., metabolic, cardiovascular, and bone disease or cancer) to identify cut-off values related to health risk for each test included. The search was built around two areas: (1) the specific test and (2) health-related outcomes. There were criterion-referenced standards for BMI, waist circumference, and handgrip strength. The standards for BMI and waist circumference did not vary across age groups, but handgrip strength did differ for those >65 y compared to prior age groups.

Since literature reviews failed to identify criterion-referenced standards for most tests, step 2 searched for dose-response relationships between a given fitness component and premature mortality across the life course. Two analyses on male youth found that 20% of people with the lowest cardiorespiratory fitness (32) and 10% of individuals with the lowest strength (33) were at the highest risk for premature death, with a gradual reduction in risk is seen across 3 next deciles. After the 4th decile, no clinically relevant additional benefits were observed. Similar results were found for the lowest 10% of youth with the lowest cardiorespiratory fitness (34) and strength in adolescence, and increased risk for all-cause disability 30 years after. Based on these, the 10th and 40th centile values were selected as cut-off points related to "unhealthy" and "less than optimal" fitness, respectively, for 6MWT, sit-ups, vertical jump, and all performance-related tests. Based on the evidence, three zones were specified: healthy fitness, needs improvement and health risk zone (Figure 1).

These procedures were repeated for the elderly, based on fitness components included in the SLOfit Senior fitness test battery. The search identified three studies which defined criterion-based standards for Senior fitness tests. We opted to primarily use a large, European-based study (35). For missing cut-off values, we relied largely on European normative data from Portugal (36). These normative data are available for all tests except the 2-min step test. Hence, for this test we used normative data from the

FIGURE 1
SLOfit Lifelong health risk feedback report example. The free-of-charge My SLOfit app provides all registered users with official SLOfit reports that specify healthy fitness outcomes, centiles, and participant histories. SLOfit reports help facilitate better and more concise communication between the individual and other important stakeholders, e.g., family, teachers, medical professionals, coaches. Health risk assessments are given based on available scientific evidence for that test. There are also some recommendations for physical fitness status available through the My SLOfit app– for example, explaining how one reaches or maintains a healthy level of physical fitness. The green zone means that the data is within this healthy, low-risk range. The yellow zone means that some improvements should be made to this test item. The red zone means significant improvement is necessary to prevent current (or future) health risks to the individual's overall health and wellbeing.

U.S. (37). Finally, since Sardinha et al. (35) did not include "Chair Sit and Reach" or "Back Scratch" tests, we relied on criterion-referenced values in Chilean older adults reported by Merellano-Navarro et al. (38).

Determination of normative references—population centiles

All pilot data collected from adults 19–64 years old were used to construct centile norms for each test item included in the SLOfit Adult test battery. Centile curves were obtained using the Lambda Mu Sigma (LMS) method separately for each gender following methods described elsewhere (39, 40). To note: pilot sampling was not nationally-representative, so statisticians used BMI data from a representative sample to calculate sample weights. In test items identical to those used in SLOfit Students (27), centiles curves for Adults were simply shifted downward or upwards to transition smoothly from childhood into adulthood. There is currently not enough data to confidently construct norms for SLOfit Seniors (65+ years).

Individualized healthy feedback reports

After each measurement, participants enter their results into the application and receive immediate feedback on their physical fitness levels and health risks. Feedback can be interpreted as a relative change from different time-points, or by centile value compared to peers. BMI and fitness data in the My SLOfit application are presented according to health risk based on existing scientific evidence (outlined above, see Figure 1).

My SLOfit infrastructure expansion

SLOfit system in supported by two web sites at URL *moj.slofit.org* and *www.slofit.org* (Slovenian and English), available to all web users offering program information for different user groups (children, parents, adults, teachers, physicians etc.). The My SLOfit website (URL: moj.slofit.org) is a secure web application running a DNN (formerly DotNetNuke) platform. All personal data are longitudinally saved in SQL database. Access to the data is initially granted only to the administrator of SLOfit testing providers (schools, sports clubs, health, or fitness centers etc.). If the participants of SLOfit fitness testing are registered users of MySLOfit, they can also access (their own) fitness data, complete questionnaires, and create reports, e.g., report of fitness testing (Figure 1). Registered users can share their own data with other people (e.g., physician, trainer) simply by entering their email address into the system which then sends an invitation for registration to that person. For all registered users the system is free of charge.

Maximizing recruitment and retention

SLOfit Lifelong has a robust recruitment strategy in partnership with mainstream media, social media, and partner ambassadors who are well-known Slovenians (e.g., Olympic athletes, media personalities, comedians). In this way, SLOfit is building an online and real-world community. The free online My SLOfit app is customizable for use on different screen sizes (PCs, laptops, smartphones, tablets, etc.). The SLOfit website with the application is educational platform to increase physical and health literacy of children, adolescents, adults, and seniors. My SLOfit app allows individuals of all ages to (1) manage their chronic health conditions by regularly monitoring physical performance (2) encourage individuals to partake in regular exercise, (3) share their movement history with their doctor and (4) maintain a healthy lifestyle by following SLOfit expert advice based on their individual results.

Citizen science engagement

SLOfit Lifelong encourages individuals to use data for their own exercise planning and to optimize the quality and quantity of their habitual movement behavior. Given the limited possibilities of communication between schools, physicians, municipalities, and parents it was increasingly important for us to establish holistic communication channels for the individual, their households, schools, and community environment. Since 2017/18, SLOfit registered users are already able to access information support through the SLOfit website (www.slofit.org) and free web application My SLOfit (moj.slofit.org), which provides free diagnostic tools, SLOfit reports expert advice in their native language (www.slofit.org/slofit-nasvet), and social media (Facebook, Instagram, YouTube) where citizens can engage directly with fitness, education and health professionals.

Discussion

SLOfit Lifelong is a national physical fitness surveillance program that enables tracking fitness and movement behavior across the lifespan.

Individual perspective

SLOfit Lifelong provides educational content *via* SLOfit reports and its social media presence (web magazine, Facebook, Instagram, YouTube). Each outlet provides unique tools and tips on how to increase one's health, fitness, and physical literacy. Health literacy is an important determinant of overall health, encouraging individuals to meet the demands of a modern society (41, 42) in a proactive manner. Those with greater health literacy have better health outcomes, healthcare services less frequently, with shorter hospitalization periods and increased medical adherence, motivation, and self-confidence (42, 43). The SLOfit App is specifically designed to assist individuals to understand their own health status and impart knowledge translation when one falls into a health risk zone.

Clinical perspective

From a clinical perspective, SLOfit Lifelong conveys the message "from fitness diagnostics to health changes" by: (a) informing SLOfit participants about possible weaknesses in their fitness routine, and the importance of regular exercise (b) bond SLOfit participants to competent physical fitness activity providers (c) provide 2-way communication between patients

and health care providers (d) enable health care professionals to monitor patient fitness to design appropriate, personalized physical activity programs.

Public health perspective

SLOfit Lifelong provides a scientific backbone for creating/maintaining population-based policies related to improving physical fitness and activity. In future, causal relationships between children and adolescents' physical performance and future health outcomes can be inferred. Understanding to what extent physical fitness in childhood is a predictor of future disease will improve preventive interventions to increase physical fitness across the lifespan. With these program upgrades, SLOfit Lifelong will allow for detailed secular trends analyses in Slovenian subpopulations at the municipal, regional, and country level.

Research perspective

From a research perspective, SLOfit Lifelong will develop a longitudinal cohort infrastructure using the Community-Based Participatory Research (CBPR) approach, one which involves direct participant engagement in which they can be affected by the research questions being addressed. Already, the SLOfit database includes about 8 million sets of measurements of over 1 million children. By enlarging SLOfit to include adulthood fitness surveillance, it is building a unique research platform for future studies to assess the predictive validity of health-related fitness.

SLOfit Lifelong future vision

SLOfit Lifelong will continue as a participatory research platform by adding modules for sharing real world data such as smartwatches, fitness trackers, mobile phones, etc. It will be conceivable to link data from family members, enabling custom analyses, and providing evidence for at-risk, family-based interventions. The SLOfit team is closely following artificial intelligence technology that may allow the collection and analysis of large amounts of data on individual's movement behaviors (e.g., movement through geographical location, use of public transport), which could further improve the predictive models and enhance people's lifelong physical fitness.

Conclusions

SLOfit Lifelong has developed unique physical fitness test batteries for adults which are physiologically comparable to those conducted in all Slovenian schools annually. By encasing the SLOfit Lifelong initiative within the existing SLOfit framework, web platform and infrastructure, researchers now have the capacity to store lifelong health and fitness data, including calculating health risk assessments, based on fitness data supplied by the citizen. Everyday people can follow their own fitness and health status, with expert feedback, to increase their physical literacy and fortify a sense of personal responsibility toward their own health outcomes.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statement

The studies involving human participants were reviewed and approved by Slovenian National Medical Ethics Committee (ID: 0120-468/2021/3). The patients/participants provided their written informed consent to participate in this study.

Author contributions

GJ: project administration, conceptualization, investigation, resources, writing- original draft, and writing- review and editing, writing- approving final submission. SM and VSe: writing- original draft, writing- review and editing, and writing- approving final submission. MS: conceptualization, writing- original draft, writing- review and editing, and writing- approving final submission. BL: conceptualization, investigation, resource, writing- original draft, writing- review and editing, and writing- approving final submission. MK: writing- review and editing and writing- approving final submission. TO: writing- original draft, investigation, resource, writing- review and editing, and writing- approving final submission. JK, KM, PG, VSt, and VH: investigation, resource, and writing- approving final submission. RB: investigation, resource, writing- review and editing, and writing- approving final submission. NM: investigation and writing- approving final submission. GS: conceptualization, investigation, resource, writing- review and editing, and writing- approving final submission. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Adherence to Mediterranean diet among Lithuanian and Croatian students during COVID-19 pandemic and its health behavior correlates

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Maintaining healthy behavior, especially in times of crisis like the COVID-19 pandemic, is particularly important for staying healthy. Nutrition is an everyday behavior and along with other health-related behaviors is associated with many health outcomes. The aim of this study was to assess and compare adherence to the Mediterranean diet (MedDiet) and particular food choices among the Mediterranean and non-Mediterranean populations of university students and identify its lifestyle correlates at the outburst of the COVID-19 pandemic. In total, self-reported data on health-related behavior and sociodemographic characteristics were collected from 1,388 study participants, 66.4% were Lithuanians, and 33.6% were Croatians. Results revealed that vegetables, olive oil, fruits, nuts, legumes, and fish were remarkably underconsumed among university students in the Mediterranean and non-Mediterranean countries during the COVID-19 pandemic, and the composite diet is similar between countries. The higher adherence to MedDiet is associated with physical activity ($\beta = 0.15$) and non-smoking ($\beta = 0.08$). In times of crisis, public health entities should provide knowledge, skills, and tools for healthy nutrition specifying them by age and subpopulation. Interventions at the university should be implemented to build infrastructure and provide an access to health behavior-friendly environments.

KEYWORDS

Mediterranean diet, physical activity, smoking, university students, health-related behaviors

Introduction

The beneficial effect of the Mediterranean diet (MedDiet) on health has been empirically confirmed by many cross-sectional, longitudinal, and experimental studies. Reviews and empirical studies report the benefits of MedDiet in preventing numerous chronic conditions, preterm mortality, and age-related cognitive dysfunction (1–3). Traditionally, MedDiet is related to traditional areas of olive cultivation in the

Mediterranean region and is characterized by a high intake of plant and unprocessed foods (1). By contrast, the westernized diet, characterized by a high intake of refined grains, processed meats, animal fats, and high intake of sugar, is related to the increased prevalence of non-communicable diseases, by adversely affecting both gut microbiota and the immune system (4). Meanwhile, a recent study report that poor dietary habits are responsible for more deaths than any other risks globally, including tobacco smoking (5).

The nutritional and health value of separate items in MedDiet are well established. For instance, unsaturated fats (fish, almonds, olive oil) improves blood cholesterol levels, ease inflammation, and stabilize heart rhythms (6). Additionally, fruits and vegetables high in fibers, antioxidants, and minerals prevent the development of some forms of malignancies and degenerative diseases (5). Moreover, intake of foods high in protein (chicken meat, eggs, almonds, Greek yogurt) is related to muscle gain and lower blood pressure (5). The regular consumption of nuts protects cognitive function from deterioration in adults of different ages (7). Here, to note, in recent years, the synergistic effects of the components and the overall combination of healthy foods are in the research loop as it provides a complex perspective on nutrition.

Apart from the benefits of MedDiet to individual and public health, its sustainability is also an issue. For instance, animal products (dairy, egg, meat, and fish) contribute to more than half of the impact on greenhouse gases (GHG) emissions and energy requirements. Meat products are the strongest contributors to GHG emissions and freshwater and dairy products to energy use (8). Meanwhile, plant foods even when processed, in comparison with animal-based foods, have lower GHG emissions and freshwater use (1), which preserve both human and environmental health. Besides its eco-friendly and health effect, MedDiet is also relatively affordable.

In addition to the abovementioned benefits, the MedDiet, being rich in antioxidants, having anti-inflammatory, and potential antimicrobial and immunomodulatory effect is a promising dietary approach to attenuate the severity of COVID-19 infection (9). There were already many arguments in the previous studies that adherence to MedDiet in Mediterranean countries has declined with every generation due to westernization and globalization processes (10). The call for the implementation of MedDiet is also sound globally, across non-Mediterranean and Mediterranean regions (11). However, still in general, the adherence in Mediterranean countries to MedDiet was higher than in other regions (12), especially among older populations (13).

The COVID-19 pandemic brought changes in peoples' lifestyles. Studies conducted during the pandemic found that dietary behaviors have changed, both individually and globally. Younger people (<30 years old) and more educated populations reported higher adherence to the MedDiet compared to the older population and those having lower education after the pandemic started (9). During confinement from shelter-in-place restrictions, people reported lower consumption of sugar-sweetened/carbonated beverages and alcohol. The pandemic limited options for eating out. Meanwhile, the frequency of cooking at home during the confinement was related to greater adherence to the MedDiet (14). Still, results vary in different populations. During COVID-19, the nutrient and caloric intakes decreased in Canadian university students (15). University studies become a new era of a person's living with many lifestyle changes as well. The transition from high school to university can be challenging as might be associated with the development of new health-related habits, and attitudes toward health behavior.

The combination of a healthy diet with physical activity makes the MedDiet a sustainable lifestyle model (16) that can be easily adopted by all population groups of various cultures with country-specific variations (17). However, along with the deteriorating diet, during the confinement, physical activity also decreased (18) across different age groups (15, 19, 20) and sedentary behavior increased (15).

This study is aimed to assess and compare adherence to MedDiet and particular food choice among the Mediterranean and non-Mediterranean populations of university students and identify its lifestyle correlates at the outburst of the COVID-19 pandemic.

Based on the previous research on MedDiet, its adherence across the Mediterranean and non-Mediterranean regions, and health behavior change during the COVID-19 pandemic in this study is hypothesized that students in Lithuania and Croatia have similar MedDiet adherence and the higher adherence is related to higher physical activity, non- or moderate consumption of alcohol, and non-smoking.

Materials and methods

Study design and procedure

This study is a part of a bigger study. Study participants in this cross-sectional study were enrolled using snowball sampling—a non-probability, convenience sample gathered in Lithuania and Croatia. Several researchers in both countries formed their initial samples selected from available participants (personal and professional contacts: university students, college students, members of youth organizations, representatives of professional societies, followers, and groups in social networks). Then, these participants were asked to enroll more participants in the study and share the survey's internet link with their friends, and colleagues–potential participants aged 18–36-year-old. An online questionnaire was shared through popular social networks and emails within the period October 2020 to May

2021. The study procedure took ∼15 min. For this particular research, data only from university students were extracted.

Participants

In total for both countries, data were collected from 1,388 study participants, 924 (66.4%) were Lithuanians and 467 (34.6%) were Croatians. Most of each national sample consisted of female participants, 62.0 and 63.6%, among Lithuanians and Croatians, respectively. Informed consent was provided along with the study questionnaire. All participants were informed about the goals of the study, the anonymity of their participation, and the option to stop participation at any time of their filling out the study questionnaire. Respondents agreed to participate in the study by submitting their filled online questionnaire. The study was conducted following the Declaration of Helsinki, and the protocol was approved by the Lithuanian Sports University Ethics Committee (No. SMTEK-50).

Measurements

Dietary pattern

Adherence to a dietary pattern was evaluated using the Mediterranean Diet Adherence Screener (MEDAS) (21), which was previously validated in adult populations in the other Mediterranean and non-Mediterranean counties (21, 22), and used in the Lithuanian (23, 24) and Croatian (14) samples of young adults. The 14 items in the MEDAS scale are included. Two of them represent nutrition habits such as the use of olive oil and the preference for white vs. red meat. The other 12 items cover the frequency or amount of consumption of both healthy (olive oil, vegetables and fruits, fish, nuts, and dishes with homemade sauce) and unhealthy (animal fat, commercial pastries, sugar-sweetened beverages) food items. Following the thresholds distinguishing predefined goals for the health-related consumption of specific food items (25), each item was scored as 0 (does not meet the healthy eating criteria) or 1 (meets the healthy eating criteria). The total score was calculated by summing all item scores. The total score on the MEDAS scale for some calculations was categorized into three categories: $\leq$7 indicated low adherence, 8–9 indicated medium adherence, and $\geq$10 indicated high adherence to the Mediterranean diet (21).

Physical activity

International Physical Activity Questionnaire (IPAQ) short form (26) was used to evaluate physical activity. However, considering the WHO definition of health-enhancing physical activity for this study only summed minutes spent in moderate and vigorous physical activity (MVPA) per week were used. The threshold of 300 min, following the WHO's latest recommendations for adult PA, was used to distinguish participants into those meeting health-related physical activity requirements (MVPA for $\geq$300 min/week) and those not meeting health-related physical activity requirements ($<$300 min/week) (27).

Alcohol consumption

Alcohol use was evaluated by asking two questions. One identified if a participant drinks alcohol in general: "Do you drink any alcohol at all?" with answers "Yes" and "No." Another question identified the frequency of risky drinking per drinking occasion "How often do you have six or more drinks on one occasion?". Those who identified that they drink that much at least monthly were categorized as heavy drinkers based on the World Health Organization's Alcohol Use Disorders Identification Test (AUDIT), interpretation of item 3 (28). Those who identified that they do not drink at all or drink less than is recognized as heavy drinking were categorized in a group of non- and moderate drinkers.

Smoking

Smoking was evaluated by asking participants if they smoke at all with the given answers "Yes" or "No." Based on the 2014 Surgeon General's Report (29) that there is no safe amount of tobacco use, two categories of smoking were created: smokers and non-smokers.

Covariates

Place of residence was indicated by respondents designating themselves as living in a city or a region. Cohabitation was identified by asking "Whom do you live together with?" by choosing between answers "Alone," "With partner," "With parents," and "With roommates." Further, this indicator was binarized as "Alone" and "Not alone." Financial status was evaluated by participants denoting their financial status as lower, the same, or higher than average in their country by answering the question "How would you evaluate your (or your family's) financial situation?". Education was evaluated by asking to indicate the highest achieved degree at the moment of the survey with answers 1–"High school," 2–"Vocational," 3–"Higher non-university degree," and 4–"Higher university degree." For age, the number of full years was the indicator. Gender was also considered a covariate. Participants had to choose between two categories of their biological gender–men (1) or women (2). Participants also had to indicate their nationality as an open question.

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Statistical analysis

Data were analyzed using SPSS 28.0 software (SPSS Inc., Chicago, IL, USA). Descriptive statistics for determining the means, standard deviations, and frequency distributions of variables used in the study. The chi-square test was employed to identify relationships between nominal and categorical study variables. The prediction of adherence to the Mediterranean diet was identified using hierarchical linear regression analysis. Skewness and Kurtosis of standardized residuals in the regression analysis were in the range between −1 and 1. Student *t* criteria were used for the comparison of the mean difference. Statistical significance was set at a $p < 0.05$.

STROBE Statement—checklist guidelines were followed in organizing this paper.

Results

In Table 1, results show that distribution between genders is similar between nationalities. Lithuanians and Croatians are of similar age as well. Most students indicate the average financial status and mostly live in a city in both countries similarly. More Lithuanian students live alone or with a partner, instead, Croatian students more often live with parents.

The comparison of adherence to MedDiet between Lithuanian and Croatian students (Table 1) did not indicate any statistical differences. In both countries, more than half of students reported poor adherence. Around 4 out of 10 reported average adherence. Only a small percent (1.4% of Lithuanians and 1.9% of Croatians) complied with MedDiet's recommendations. Lithuanian students were more physically active during the COVID-19 pandemic as there were almost one-third of sufficiently physically active Lithuanians and <20% of Croatian students. One out of five students smokes in both countries, and there is no difference between them. However, among Croatians, risky drinking is more prevalent among students than among Lithuanians.

Comparison between nationalities across food items presented in Table 2 revealed inconsistent results. A little bit more than half of the young adults living in Croatia–part of the Mediterranean region, are meeting the recommendation to include olive oil as the main fat in their diet in contrast with one-third of Lithuanians. However, only around a quarter of young Croatians meet the recommended daily amount of olive oil, but still more than Lithuanians (13.1%). More Croatians than Lithuanians consume wine, however, only around 1.9% of Croatians and 0.4% of Lithuanians meet the suggested amount of 7 glasses a week (one glass per day). Almost a quarter of Lithuanians consume a sufficient amount of nuts per week, which is significantly less than eat their peers in Croatia (31.8%). White meat over red is preferred among the majority of university students in both countries; however, there is still a significant difference of 5% in favor of Croatia. The consumption of four out of 14 items in the Mediterranean diet items list does not differ between countries in the Mediterranean region and Lithuania. In particular, in both countries, less than one-third of students consume the recommended 3 fruits a day, without any significant difference. Legumes are underconsumed in both countries, and only 12% of young adults in Lithuania vs. 14% in Croatia include them in their menu. As well, there is no difference in fish and seafood consumption; however, only about one out of ten students consumes a sufficient amount of fish and seafood. Moreover, Lithuanians outperform Croatians in several food items in the list of the Mediterranean diet. In particular, more than half of Lithuanians and Croatians meet the criteria of recommended daily amount of vegetables,

TABLE 1 Sociodemographic and health-behavior characteristics of the study sample.

Study variable	Lithuanians % or mean (SD)	Croatians % or mean (SD)
Gender		
Male	38.0	36.4
Female	62.0	63.6
Financial status		
Lower than the national average	8.4	5.2
The same as the national average	62.5	64.1
Better than the national average	29.2	30.7
Cohabitation		
Alone	18.6***	8.6
With a partner/spouse	25.2***	9.6
With parents	36.7	64.2***
With roommates	19.5	17.6
Place of living		
City	71.7	75.4
Region	28.4	24.6
Age	21.08 (2.55)	20.84 (2.12)
Adherence to MD		
Mean score	5.16 (1.91)	5.16 (1.94)
Poor	59.7	58.6
Average	39.0	39.4
Healthy	1.4	1.9
Physical activity		
Not sufficient	68.3	82.2***
Sufficient	31.7	17.8
Alcohol consumption		
Risky	11.1	21.9***
Moderate or none	88.9	78.1
Smoking		
Smoke	21.1	20.3
Do not smoke	78.9	79.7

*Significance χ^2 when *** $p < 0.001$.

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TABLE 2 The consumption of different food items among Lithuanians and Croatians university students.

Nutrition item meeting recommendations	Lithuanians (%); χ^2	Croatians (%); χ^2
Olive oil as main culinary fat (yes)	33.5	52.7***
Amount of olive oil/day (≥4 tbsp)	13.1	25.3***
Servings of vegetable/day (≥2 servings)	59.9***	49.9
Fruits units/day (≥3)	27.9	31.5
Servings of red meat, hamburger, meat products/day (<1)	56.9*	51.9
Servings of butter, margarine, cream/day (<1)	40.1***	31.6
Sweet or carbonated beverages/day (<1)	55.0*	49.7
Glasses of wine/wk (≥7 glasses)	0.4	1.9**
Servings of legumes/week (≥3)	12.1	14.3
Servings of fish or shellfish/wk (≥3)	10.2	7.5
Commercial sweets or pastries, times/wk (<3)	76.8***	54.7
Servings of nuts/week (≥3)	26.1	31.8**
White meat instead of red or processed meat (yes)	76.0	80.9*
Homemade vegetables, pasta, rice and other food/wk (≥2)	87.1	84.3

*Significance χ^2 when * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

with significant favor to Lithuanians. A little bit more than half of both countries' students refuse consumption of red and processed meat on their menu with a slightly significant difference between countries in favor of Lithuanians. There is a difference in consumption of animal fat, more students in Lithuania (40.1%) than in Croatia (31.6%) skip animal fat from their menu. About a half of university students limit their sugary drinks in both countries, by 5% more often in Lithuania. Lithuanians also resist the temptation of pastries more often than Croatians as 76% of Lithuanians vs. 56% of Croatians meet the recommendation to avoid pastries. Most Lithuanians and Croatians (>80%) eat homemade food daily with a slight advantage of 3% among Lithuanians (Table 2).

Results of multiple regression analyses show (Table 3) that among sociodemographic indicators in the first model, being women, older age is associated with higher adherence to the MedDiet. Neither financial status nor cohabitation, place of residence, or nationality predicted better adherence to MD. Among health-related behavior indicators, meeting physical activity recommendations and non-smoking is related to higher students' adherence to MedDiet.

TABLE 3 Prediction of Mediterranean diet from sociodemographic, health behavior variables in Lithuanian and Croatian university students.

Variable	Standardized beta	
	Model 1	Model 2
Gender (female)	0.076**	0.113***
Age	0.097**	0.099**
Financial status	0.048	0.052
Cohabitation (not alone)	−0.054	−0.054
Place of residence (region)	−0.026	−0.029
Nationality (CRO)	−0.014	0.023
PA (Sufficiently active)		0.150***
Alcohol intake (non and moderate drinkers)		0.039
Smoking (non-smokers)		0.081**
ΔR	0.017***	0.045***

LT, Lithuanians; CRO, Croatians; *Significance χ^2 when ** $p < 0.01$; *** $p < 0.001$.

Discussion

This study sought to assess and compare adherence to MedDiet at the beginning of the COVID-19 pandemic between Lithuanian and Croatian university students and to identify the links of adherence to MedDiet to other health behaviors and sociodemographics within the Mediterranean and non-Mediterranean populations.

The results indicated that in terms of the composite score of the MEDAS scale no statistical difference was indicated. More than half of university students have poor eating habits in both countries, despite the traditional peculiarities in nutrition. Around 40% have average adherence and only 1.4 and 1.9%, in Lithuania and Croatia, respectively, have good adherence to MedDiet. A systematic literature review revealed that Mediterranean populations have been showing moderate adherence to MedDiet in the past 10 years (30). Regardless of the expansion of Mediterranean traditions of nutrition around the globe, in Lithuania, the deterioration is observed moving from adolescence to adulthood and from pre-pandemic to pandemic

situations. Previous studies in Lithuania revealed that there is around 14% of adolescents are meeting the criteria of healthy nutrition (31). The number is reduced by half among young adults when only 7% of those meeting recommendations on the MEDAS scale were observed in the pre-pandemic study (23). Similarly, in Croatia, the comparative study indicated that the percentage of good adherence to MedDiet is lower among older age groups of youth and is about 13% among students (measured with the KIDMED scale) (32). So, the results of this study show an even worse reduction. This led to the premise that the COVID-19 pandemic in short term might have deteriorated the eating habits of youth in Lithuania and Croatia. However, there is a different opinion in the scientific literature, which states that young people during confinement had more free time to cook homemade meals and thus, comply with healthy eating standards. For instance, a study in Spain found that adherence to the MedDiet increased significantly by 0.8 points during the confinement. However, this increase refers to the first 3 weeks of confinement (33) when people focused on their household chores to use their free time, as going out was restricted, and studies and work online were not then well-established. Although some studies point out that people increased their cooking frequency during the confinement, which was associated with an increase in vegetables, legumes, and fish, as well as seafood consumption (14), other studies also noticed a higher frequency of snaking and by 50% increased demand for confectionery products (34), which might deprive the benefits of the homemade food. Other studies found that during the COVID-19 pandemic the quality of students' diet was poorer. In particular, they consumed lower amounts of grains, fruits, vegetables, dairy, and nuts (15).

The review of other studies on adherence to MedDiet during the COVID-19 pandemic indicated that most people have not changed their eating patterns; however, there were more of those who increased than decreased their adherence. Most studies found that people increased their consumption of vegetables, fruits, nuts, olive oil, and dairy products compared with the previous studies (35). One other comparative study across 16 Mediterranean and non-Mediterranean countries found higher adherence in countries identifying that there are 4.58% in Lithuania and 10.1% in Croatia of those with high adherence to MedDiet during the confinement. However, the mean scores in the Lithuanian sample in that study and the current study were very similar like 5.16 in this study and 5.13 in Molina-Montes et al. study (36) at the moment of confinement. However, their study included all adults with no age limit, so probably, the higher frequency of high adherence could be explained by the older age of their participants as most of the participants were 51 years of age or older and only <40% of their study sample were in the same age group as our sample. Another study in Croatia also confirms that high adherence to MedDiet is particularly low among younger participants compared to the older ones (37). Younger generations in the Mediterranean area are more prone to the "westernization" process, which also affects their food habits toward palatability and sensory perception–driven food, and have increasingly similar patterns of food availability (mainly non-Mediterranean food groups) among the Mediterranean and non-Mediterranean areas (38), while older generations stick with their traditional meals and food preferences (39). Lithuania has the smallest group of people with high adherence to MedDiet among 16 countries in the Southern Mediterranean region, Balkan Mediterranean region, and non-Mediterranean region (European countries). The highest percentage of high adherence was among Mediterranean countries, especially in Portugal (27%) and Spain (23%) (36). The Molina-Montes and colleagues' survey was administered at the beginning of the first confinement, meanwhile, ours is already in the Autumn 2020–Winter 2021 period.

In this study, university students in both countries mostly comply with the recommendation to choose white meat over red one (76 and 81% in Lithuania and Croatia, respectively) and eating at homemade dishes with sofrito (88 and 84% in Lithuania and Croatia, respectively). Fewer Lithuanians than Croatians consume commercial pastries. Some authors point out that the demand for confectionery products and butter also increased in more than 50% of the population during the confinement in another Mediterranean country–Spain (34). Underconsumption of olive oil, although lower among Lithuanians, is observed in both countries as only 13 and 25% of Lithuanians and Croatians, respectively, meet the recommendation for the amount of olive oil per day. For instance, among Lebanese students, there was observed a relatively high spread of usage of olive oil in cooking (86.3%), and 50.3% of them consume a recommended amount of olive oil per day (40). Underconsumption of fruits, nuts, fish, and legumes is also spread in both countries as less than one-third of young adults meet the recommended amounts. Another study revealed that although 30% of students showed high adherence to the MedDiet, only 42% of the participants had a high consumption of vegetables, which are lower than in our study, and 85% a low consumption of energy drinks, which is higher than in our study. The consumption of fruits and vegetables in that study was also related to higher psychological adjustment and health perception (41). Given the benefits that fruits and vegetables have on cognitive function, while nuts and olive oil have an impact on cardiovascular health and mortality (1), the future health of students raises concerns. Moreover, switching diet toward the plant-based is contributing not only to health but also to a healthy environment, which in turn again contributes to individual and public health. Empirical evidence confirms that MedDiet is a part of a sustainable environment (8). Some authors based on empirical research suggest that poor nutrition literacy leads to the consumption of more food associated with the Western diet (fried food, sugar-sweetened beverages, red meat, and processed food), while good nutrition

literacy is associated with Mediterranean diets (vegetables, olive oil, and nuts) (42). Policies making MedDiet more animal-based diets less affordable are encouraged.

Moreover, the results of this study show that healthier nutrition for students is also related to other health behaviors, in particular, higher physical activity and non-smoking. Seems like some students just have a healthy person profile, where health-related behaviors are clustered. Other studies similarly confirm that smokers have lower adherence to MedDiet (43–45). Better adherence to MedDiet was related to higher physical activity among Lithuanian adolescents (24) and adults (23) in previous studies. Specifically, those who consume more olive oil, vegetables, fruits, legumes, fish, and nuts are more physically active (23). Similarly, adherence to MedDiet was lower in current smokers and in those who spent more time watching TV and higher in those who were more physically active, among the elderly in Spain (46).

Further, better adherence to MedDiet is related to the female gender and students' older age. The age's links to better MedDiet were discussed above. Also, older students' age means more advanced education, which in turn might affect health-related behavior. Meanwhile, gender-related links to MedDiet are inconsistent in other studies. Similarly, in Maltese adults being women, non-smoker, and having older age was associated with higher adherence to the Mediterranean diet (44). Men were less likely to show good adherence among Croatians in one of the previous studies (37). These results might suggest the premise that older age, especially for women means more time spent cooking and eating at home, which is related to higher adherence (34). Another study found that women pay more attention to nutrition quality than males, perceive fewer barriers to food price when it comes to choosing food, and have a higher perception of the benefits of diet quality (47). So, women probably have a more conscious approach to what they eat than males, while in a country like Lithuania the food choice in favor of MedDiet still must be made consciously compared with Mediterranean countries where availability of MedDiet is higher and have long traditions.

Limitations

Some limitations should also be acknowledged. Selection bias was possible due to the snowball sampling, e.g., people who had a poor diet encouraged their friends (who also had a poor diet) to join the study. However, some other abovementioned studies in similar populations also present results that do not dramatically differ from this study's results. Another limitation is the cross-sectional nature of the study. We were not able to compare the switch in diet from pre- to pandemic. Instead, we examined nutrition habits when the acute phase of the pandemic was over, in Autumn 2020–Winter 2021, and expectedly dietary patterns became more or less stable in the new reality.

Conclusions

Vegetables, olive oil, fruits, nuts, legumes, and fish were remarkably underconsumed among students in Lithuania and Croatia during the COVID-19 pandemic. Mediterranean students in Croatia prefer and consume more olive oil, nuts, drink wine, and choose white meat over red more often than non-Mediterranean Lithuanian students, while Lithuanians consume vegetables more often. Also, non-healthy Western diet-related foods were more common among Croatian students. However, the composite score of diet, which is more important for health as it considers compensatory effects of single food items, is similar between both countries. Campaigns like fruits instead of sweets or fish instead of red meat should be incorporated into organizational (like universities or companies) health-enhancing strategies and the availability of healthy foods provided. Along, availability of unhealthy foods should be restricted. Health policy restricting unhealthy food availability should encourage food providers at any level to present more healthy foods for the market in general and to the university campus in particular. In times of crisis, or social isolation and not only then but public health entities should also provide knowledge, skills, and tools for healthy nutrition specifying them by subpopulations and including the university student population. Health organizations, scientists, food companies, and IT specialists could collaborate to create smart tools to enhance healthy nutrition among students who are usually the main users of innovative technologies. Healthy nutrition, among other health behaviors, should be also emphasized in university studies. Interventions at the university should be implemented to build infrastructure and provide an access to health behavior-friendly environments.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The study was approved by the Institutional Ethics Committee of Lithuanian Sports University (protocol code no. SMTEK-50, 29/09/2020). The patients/participants provided their written informed consent to participate in this study.

Author contributions

BM and DN: conceptualization. BM and AE: methodology. BM: software, formal analysis, data curation, and funding acquisition. IK and DN: validation and writing—review and editing. IT and DN: investigation. GB: resources. BM and GB: writing—original draft preparation. IT: visualization. AE:

supervision. All authors have read and agreed with the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Physical activity before and during the COVID-19 pandemic in Vojvodina, Serbia

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Background: The physical activity (PA) of the youth and adult population underwent changes during the last 2 years due to the coronavirus (COVID-19) pandemic, and all for the purpose of maintaining the health of the population. The purpose of this study was to estimate the levels of PA in the youth population and the adult population (young and old) during the COVID-19 pandemic in the territory of Vojvodina, Serbia, and to determine the differences between them, as well as to compare these results with the results before the pandemic.

Methods: A total of 1,117 subjects (age 36.27 ± 15.08 years) from the territory of Vojvodina, Serbia, participated in the study. Subjects were recruited and assigned to one of the three groups according to their age: youth group (N = 395; age 18–24 years), young adults group (N = 347; from 25 to 44 years), and old adults group (N = 375; age 45–65 years). All participants in this study completed the International Physical Activity Questionnaire Short-Form between July and November 2021, during the fourth wave of the COVID-19 pandemic in Vojvodina, Serbia. The Kruskal–Wallis test and Dunn multiple comparison *post-hoc* method were used for statistical analyses.

Results: The youth showed the highest result in total weekly energy expenditure (3,893.72 ± 2,010.01 MET-min/week) compared to young adults (2,528.20 ± 1,804.11 MET-min/week) and old adults (2,369.07 ± 2,084.95 MET-min/week) during the COVID-19 pandemic in Vojvodina, Serbia. In addition, adults (young and old) spent more time sitting than youth during the same period. Furthermore, the youth achieved greater results in levels of PA during the COVID-19 pandemic compared to the situation before the COVID-19 pandemic. However, adult populations achieved lower results during the COVID-19 pandemic than before the COVID-19 pandemic.

Conclusion: During the COVID-19 pandemic, the youth from Vojovida, Serbia, achieved greater results in PA levels than the adult populations. Based on that, we recommend that it is necessary to take steps toward increasing PA in the adult population, especially old adults.

KEYWORDS

coronavirus disease, the activity of the adult population, IPAQ-SF, physical activity, public health

Introduction

The respiratory syndrome coronavirus disease 2019 (COVID-19) was first detected in Wuhan, Hubei Province, China, in December 2019, and the spread of the virus continued beyond the borders of China. Older adults were at the highest risk of infection from the coronavirus (1, 2), but youth and young adults were also endangered (3). Due to the danger to public health of international importance, the World Health Organization declared a pandemic on 11 March 2020 (4). The first case of COVID-19 in the Republic of Serbia was registered on 6 March 2020, and increased very rapidly. The Government of the Republic of Serbia declared a pandemic on 20 March 2020, when a state of emergency and a curfew were introduced. Furthermore, 17 European countries also declared the pandemic, and thus they started the fight against the virus with the introduction of restrictive measures (5). The strategies applied by the states at the beginning of the pandemic differed, from a very liberal approach to the introduction of extremely restrictive measures, all with the aim of preserving the health of the population. Therefore, quarantine combined with other restrictive measures can reduce transmission of the virus (6) but increase physical inactivity (PI) (7–9).

According to the data of the World Health Report (10), the PI represents a global problem from childhood to old age before the pandemic. A detailed statistical analysis shows that 31.1% of the adult population is physically inactive worldwide. Furthermore, during the COVID-19 pandemic, the PI increased further, which is confirmed by previous reports (11–14). The study (11) reported that during the COVID-19 pandemic in nine European countries (Bosnia and Herzegovina, Croatia, Greece, Kosovo*, Italy, Slovakia, Slovenia, Spain, and Serbia), the PI and screen time in the adult population increased. Furthermore, in Croatia (12) and Spain (13, 14), during the COVID-19 pandemic (from January to April 2020), the PI increased in adolescents. In Canada and Brazil, the COVID-19 pandemic (between April and May 2020) negatively affected physical activity (PA) in young adults (15) and old adults (16). In Qatar, Hermassi et al. (17) reported that the COVID-19 pandemic reduced vigorous-intensity PA from 663 ± 320 metabolic equivalents (MET-min/week) to 323 ± 187 MET-min/week in young adults. Accordingly, it can be observed that the adult population before the COVID-19 pandemic (10) and during the COVID-19 pandemic (11, 15–17) is physically inactive. This is concerning because PI is one of the leading modifiable risk factors for global mortality (18). In Vojvodina, Serbia, the leading causes of mortality in the population are cardiovascular diseases (CVDs) (56.8%) and cancer (19.7%) (19). Therefore, it is important that the population of Vojvodina, Serbia, be physically active because the PA effectively protects from cardiovascular diseases and cancer (20), and thus mortality of the population. To the authors' knowledge, no studies were found that assessment and analyzed of PA population with the majority of CVD cases in Europe (21) has never been investigated. Also, no study assessed the PA in the population 2 years after the declared COVID-19 pandemic; these gaps are addressed in this study. Therefore, the evaluation of the PA in the population, as well as the recommendations for improving PA, is important because excessive mortality and death are related to diseases that are often caused by a decrease in PA. Based on these findings, the purpose of this study was to estimate the levels of PA in both the youth population and the adult population (young and old) during the COVID-19 pandemic in the territory of Vojvodina, Serbia, and to determine the differences between them, as well as to compare these results with the results before the pandemic.

Materials and methods

Data collection

All participants completed the online questionnaire during the COVID-19 pandemic (fourth wave) in the territory of Vojvodina, Republic of Serbia, between 8 July 2021 and 3 November 2021. This questionnaire consisted of two sets of questions. One set consisted of questions about sociodemographic factors, and the other set included questions from the International Physical Activity Questionnaire Short-Form (IPAQ-SF). Several studies argue that IPAQ-SF has high reliability and validity for measuring PA in the adult population (22–24). Therefore, the authors (25, 26) applied this questionnaire to measure PA in the youth and adult population before the pandemic and during the COVID-19 pandemic (27–30). The other questionnaires for measuring PA during the COVID-19 pandemic were also applied, such as the Godin Leisure Questionnaire (15) and the Spanish short version of the Minnesota Leisure-Time Physical Activity Questionnaire (30). Based on the results, it can be concluded that IPAQ-SF should not be the only questionnaire for measuring PA during the COVID-19 pandemic, but it is the most applicable of all the questionnaires. In addition, the evaluation of PA and the results obtained can be compared with similar studies performed in our country and other countries during the COVID-19 pandemic. The IPAQ-SF was taken from the official website of the International Physical Activity Questionnaire (31) and was translated into the Serbian language by two independent experts who were familiar with this type of questionnaire. The accuracy of the questionnaire was checked, and certain differences in translation were removed. The online questionnaire was made in electronic form (Google questionnaire). To survey a sample of respondents as large as possible, one version of the questionnaire was made in electronic form (Google questionnaire) and was shared *via* e-mail, Viber™, and WhatsApp™. Each participant completed the questionnaire only once, and responses were anonymous and confidential according to Google's privacy policy.

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TABLE 1 Sociodemographic characteristics of all participants according to age categories.

Group		Youth	Young adults	Old adults
n		395	347	375
Years (Mean ± SD)		19.89 ± 1.44	35.83 ± 5.67	53.95 ± 7.04
Male *n* (%)		261 (66.1%)	142 (40.9%)	155 (41.3%)
Female *n* (%)		134 (33.9%)	205 (59.1%)	220 (58.7%)
Environment	Village (%)	13.2	10.4	17
	Small town (%)	47.1	41.2	43.5
	Big city (%)	39.7	48.4	48.4
	Elementary (%)	62.8	0.3	2.9
Education	High school (%)	37.2	29.4	47.2
	Faculty (%)	0	70.3	49.9

Subjects

All 1, 117 participants (male: $N = 558$; age 33.53 ± 15.43 years and female: $N = 559$: age 39.01 ± 14.21 years) from the territory of Vojvodina, Republic of Serbia, during the COVID-19 pandemic (fourth wave) participated in the study. Inclusion criteria were as follows: (i) individuals living in the territory of Vojvodina, Serbia; (ii) age ≥ 18 years; and (iii) all individuals who voluntarily agreed to participate in the study. Considering that the territory of the Vojvodina is a multi-ethnic environment, there were no restrictions on nationality. Furthermore, there were no restrictions on gender, occupation, or socioeconomic level of the participants. They were no specific exclusion criteria. The study included all participants who met the inclusion criteria and divided them into three age groups. According to Celis-Morales et al. (32), age classifications were divided into three categories: youth (from 15 to 24 years), young adults (from 25 to 44 years), and old adults (from 45 to 65 years). Table 1 shows the sociodemographic characteristics of all participants. All participants signed an informed consent (which was at the beginning of the questionnaire) form to participate in the study. The Ethics Committee of the Faculty of Sport and Physical Education, the University of Novi Sad, approved the study (No-47-10-09/2021-1). All procedures were conducted according to the Declaration of Helsinki.

During this period (the fourth wave of the COVID-19 pandemic), the Government of the Republic of Serbia introduced preventive measures, including teaching at the faculties organized in the combination methods (direct teaching or e-learning at home); training centers were opened, but with special restrictions (athletes were obliged to wear protective masks and respect the 2-m physical distance in all enclosed spaces); vaccination of the population was underway; mandatory covid passes were introduced; a limit of 500 people indoors was introduced; employees in companies were working at home; and elderly citizens of Serbia were allowed to move at certain hours, with the recommendation to be vaccinated (33).

The online questionnaire

The online questionnaire was made in electronic form (Google questionnaire) and consisted of 2 sets of questions, where the first set included four questions about sociodemographic factors, such as "Gender," "Years," "Education," and "Environment in which people live." The other set of questions was taken from IPAQ-SF and records the activity of four intensity levels: vigorous-intensity PA (VPA: doing heavy lifting, performing intense aerobic exercises, and using a bike or treadmill); moderate-intensity PA (MPA: carrying light loads and cycling at a regular pace, and working out in the yard); and walking time (W), as well as the average time spent sitting (ST) on a weekday, including sitting at work, in the last 7 days. Also, this questionnaire provides information on PA level as energy expenditure in MET-min/week.

The authors of this study calculated the weekly PA levels (VPA, MPA, and W) expressed in MET-min/week. For each type of PA, MET-min/week coefficients were calculated through Microsoft Excel spreadsheet automatic scoring of the IPAQ-SF, according to Cheng (34) with the following results: 3.3 for W, 4.0 for MPA, and 8.0 for VPA. Also, we estimated the total weekly energy expenditure (Total PA), which is the sum of W, MPA, and VPA in MET-min/week (34).

Statistical analyses

The minimum sample size was calculated using Minitab Statistical Software Version 18 by using the results obtained from a similar study. The total sample size of the study was calculated to be at least 987 participants; a significant difference ($p = 0.05$) for the type I error was set at 5% and the power of the study was set at 80%. The total number of individuals who participated in this study was 1,117. The other statistical analysis was performed with the SPSS statistical program version 20 (SPSS Inc., Chicago, IL, USA). The results are presented as mean ± standard deviation (SD). The Kolmogorov–Smirnov test was used to determine normality distribution for all variables across the age. The Kruskal–Walis test was used to compare the results across all three groups for each level of PA. In addition, Dunn *post-hoc* test was used to determine which pairs of variables showed significant differences. The statistical significance was set at $p \leq 0.001$.

TABLE 2 Descriptive statistics of youth, young adults, and old adults in levels of PA during the COVID-19 pandemic.

	Group	Mean rank	Chi-square	*p*
VPA (MET-min/week)	Youth	713.37	151.39	0.000*
	Young adults	503.90		
	Old adults	447.38		
MPA (MET-min/week)	Youth	633.00	32.70	0.000*
	Young adults	513.32		
	Old adults	523.32		
W (MET-min/week)	Youth	618.60	25.07	0.000*
	Young adults	551.25		
	Old adults	503.39		
Total PA (MET-min/week)	Youth	708.77	136.15	0.000*
	Young adults	503.34		
	Old adults	452.75		
ST (h)	Youth	456.87	60.54	0.000*
	Young adults	604.27		
	Old adults	619.42		

VPA, vigorous-intensity PA; MPA, moderate-intensity PA; W, walking time; Total PA, Total weekly energy expenditure of PA; ST, sitting time.

TABLE 3 Results of Kruskal–Wallis test in levels of PA for youth and adult population during the COVID-19 pandemic.

Variables	Units	Youth (Mean ± SD)	Young adults (Mean ± SD)	Old adults (Mean ± SD)
VPA	Days per week	3.31 ± 1.98	1.90 ± 1.82	1.58 ± 1.89
	Min per week	66.37 ± 27.80	48.89 ± 32.57	55.66 ± 34.25
MPA	Days per week	3.52 ± 2.01	2.65 ± 2.00	2.89 ± 2.24
	Min per week	61.28 ± 29.76	50.10 ± 30.98	52.39 ± 30.57
W	Days per week	6.01 ± 1.65	5.27 ± 2.06	4.87 ± 2.15
	Min per week	59.82 ± 31.17	55.20 ± 29.94	54.34 ± 28.55
Total PA	Days per week	6.38 ± 1.47	4.93 ± 3.55	4.91 ± 2.64
ST	Hours per week	3.51 ± 1.95	4.93 ± 3.55	4.91 ± 2.64

VPA, vigorous-intensity PA; MPA, moderate-intensity PA; W, walking time; Total PA, Total weekly energy expenditure of PA; ST, sitting time; * statistically significant differences between the groups ($p \leq 0.001$).

Results

All 1,117 participants (males, $N = 558$: age 33.53 ± 15.43 years and females, $N = 559$: age 39.01 ± 14.21 years) were classified into three groups according to their age. Table 1 presents the sociodemographic characteristics of all participants according to their age during the COVID-19 pandemic in Vojvodina, Serbia.

Table 2 shows the descriptive statistics of youth, young, and old adults in VPA (days per week and min per week), MPA (days per week and min per week), W (days per week and min per week), Total PA (days per week), and ST (hours per week) during the COVID-19 pandemic in Vojvodina, Serbia.

In Table 3, the results of the Kruskal–Wallis test show a significant difference ($p \leq 0.001$) at all the levels of PA between the groups.

The levels of PA between the groups during the COVID-19 pandemic are presented in Figure 1.

The youth participants spend more time in VPA than young and old adults (1,836.52 ± 1,592.43 MET-min/week vs. 900.22 ± 1,126.54 MET-min/week vs. 781.81 ± 1,251.96 MET-min/week) during the COVID-19 pandemic ($p \leq 0.001$). Furthermore, youth participants achieved statistically significantly greater ($p \leq 0.001$) results in MPA (890.48 ± 801.62 MET-min/week) than young adults (609.19 ± 637.79 MET-min/week) and old adults (673.26 ± 760.70 MET-min/week) during the COVID-19 pandemic in Vojvodina, Serbia. In addition, the youth

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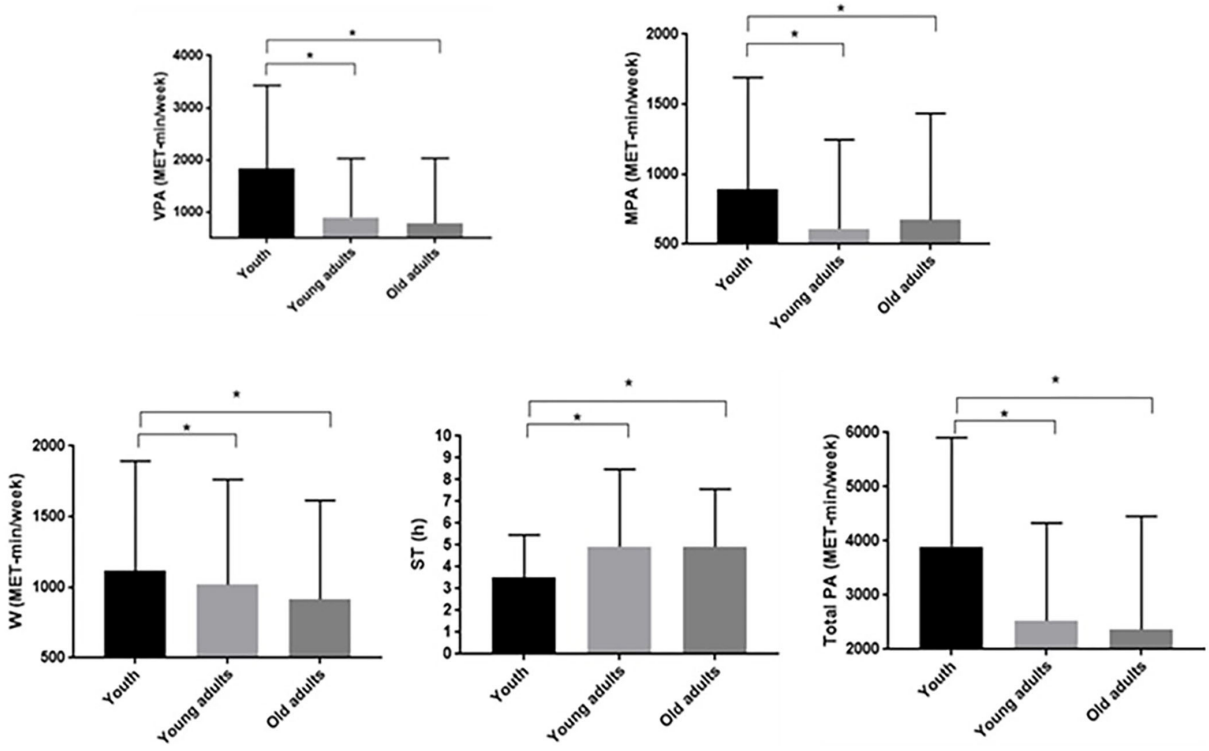

FIGURE 1
The levels of PA between the groups during the COVID-19 pandemic. VPA, vigorous-intensity PA; MPA, moderate-intensity PA; W, walking time; ST, sitting time; Total PA, Total weekly energy expenditure of PA; *statistically significant differences between the groups ($p \leq 0.001$).

TABLE 4 Physical activity before and during the COVID-19 pandemic in Vojvodina, Serbia.

Variables	Units	Youth		Young adults		Old adults	
		Before pandemic	During pandemic	Before pandemic	Duringc pandemic	Before pandemic	During pandemic
VPA	Days per week	2*	3.31	2*	1.90	1.85*	1.58
MPA	Days per week	2.5*	3.52	2.7*	2.67	3*	2.89
W	Days per week	5.7*	6.01	5*	5.27	4.85*	4.87
ST	Hours per week	from 5 to 8*	3.51	2.5*	4.93	from 2 to 5*	4.91

VPA, vigorous-intensity PA; MPA, moderate-intensity PA; W, walking time; Total PA, Total weekly energy expenditure of PA; ST, sitting time; *Results before pandemic according to Eurobarometer 2020 (35).

participants reported the highest result in W during the COVID-19 pandemic in Vojvodina, Serbia (1,116.48 ± 776.97 MET-min/week) compared to the young adults (1,018.55 ± 743.64 MET-min/week) and old adults (913.79 ± 701.20 MET-min/week).

The old adults during the COVID-19 pandemic in Vojvodina, Serbia, spent more time sitting (4.91 ± 2.65 h) compared to the youth (3.51 ± 1.95 h). In addition, young adults (4.93 ± 3.55 h) spent more time sitting than the youth (3.51 ± 1.95 h).

The results presented in Figure 1 also show statistically significant differences ($p < 0.001$) between groups in Total PA (MET-min/week). Participants from the youth group achieved greater results (3,893.72 ± 2,010.01 MET-min/weeks) compared to other groups (young adults: 2,528.20 ± 1,804.11 MET-min/week and old adults: 2,434.48 ± 2,077.83) during the COVID-19 pandemic in Vojvodina, Serbia.

Table 4 shows the differences in the levels of PA before the COVID-19 pandemic (35) and during the COVID-19 pandemic in Vojvodina, Serbia. The youth population achieved

greater results in the levels of PA during the COVID-19 pandemic compared to the situation before the COVID-19 pandemic. However, adult populations (young and old) achieved lower results during the COVID-19 pandemic than before the COVID-19 pandemic.

Discussion

The present study examined the levels of PA in both the youth population and the adult population (young and old) during the COVID-19 pandemic in the territory of Vojvodina, Serbia, and determined the differences between them. In addition, the results obtained before the pandemic and during the pandemic were compared. The major findings were that the youth population accomplished a greater result in Total PA (3,893.72 MET-min/week) in comparison to young adults (2,528.20 MET-min/week) and old adults (2,369.07 MET-min/week) during the COVID-19 pandemic in the territory of Vojvodina, Serbia. In addition, old adults spent more time sitting (4.91 ± 2.65 h) compared to youth (3.51 ± 1.95 h) and young adults (4.93 ± 3.55 h). Furthermore, the youth population achieved higher results in the levels of PA during the COVID-19 pandemic compared to the situation before the COVID-19 pandemic, but the adult population achieved lower results than before the COVID-19 pandemic. The youth population during the COVID-19 pandemic in Vojvodina, Serbia, achieved a greater result in Total PA (3,893.72 ± 2,010.01 MET-min/week) compared to young adults (2,528.20 ± 1,804.11 MET-min/week) and old adults (2,434.48 ± 2,077.83 MET-min/week). Magueri et al. (28) classified PA based on weekly MET achieved, where the low active group had less than 600 MET-min/week, the moderately active group had from 600 to 3,000 MET-min/week, and the physically active group achieved more than 3,000 MET-min/week. Our youth participants achieved more than 3,000 MET-min/week, which classified them as a physically active group, despite the peak of the fourth wave of the COVID-19 pandemic in Vojvodina, Serbia. However, in Italy, during the COVID-19 pandemic (from 1 April to 30 April 2020), the youth population achieved only 1,852 MET-min/week in Total PA (28). It is also important to note that the youth included in this study were students at the Faculty of Sport and Physical Education. Students in our sample were athletes previously, and hence they were expected to have higher levels of PA when compared to the general population (14). Also, they attended practical lectures at the faculty meeting during this research, which can also influence their PA levels. Additionally, it is assumed that restrictive measures (e.g., closing the schools and public places, and people could move only for essential activities) restricted the movement of the youth population, while in this study, it was not the case. In Vojvodina, Serbia, during this period of the COVID-19 pandemic, the number of infections rapidly increased from 74 (2 July 2021) to 6,948 (27 October 2021) (33). Therefore, the Government of the Republic of Serbia introduced restrictive measures (the school was organized by using combined methods, exercisers were using a protective mask, 2-m physical distance was maintained in all enclosed spaces, vaccination of the population was underway, mandatory COVID passes, and up to 500 people were allowed in indoors) but did not influence the movement of youth from Vojvodina, Serbia. When comparing results between the youth and adult populations at the levels of PA, we can observe that the youth population achieved higher results in VPA, MPA, and W than in young and old adults during the COVID-19 pandemic in Vojvodina, Serbia. Similar results were obtained in Italy during the COVID-19 pandemic, where youth and young adults reported higher levels of PA compared to old adults (27). Furthermore, Hallal et al. (36) demonstrated that young people were more physically active than old people before the COVID-19 pandemic. The differences between the youth, young adults, and old adult populations in the levels of PA before the COVID-19 pandemic were mostly due to the aging process (37). Additionally, the differences between youth and adult populations (young and old) in the levels of PA during the COVID-19 pandemic are also assumed to be a consequence of aging, but not the COVID-19 pandemic. During the fourth wave of the COVID-19 pandemic in Vojvodina, Serbia, the restrictive measures that were in force allowed all participants to exercise, but did not restrict their movement.

When interpreting the results according to Eurobarometer 2020 (35), the youth population before the COVID-19 pandemic achieved lower results in VPA compared to the youth population during the COVID-19 pandemic (2 days per week vs. 3.31 days per week). Furthermore, the youth population from Vojvodina, Serbia, during 2019 (before the pandemic) engaged in MPA for only 2.5 days per week (35), while the youth population from this study engaged in MPA for 3.52 days per week. Based on the average number of days in VPA and MPA, it can be concluded that the youth population spent more time in vigorous and moderate activities during the COVID-19 pandemic than before. However, it is important to note that youth from Eurobarometer (35) and youth from this study are from Vojvodina, Serbia, but with different occupations. The youth from our study are students from the Faculty of Sport and Physical Education, and they are commonly more active than other youth populations (14).

According to Eurobarometer 2020 (35), the young adults before the COVID-19 pandemic spent a longer time in vigorous and moderate PA than during the COVID-19 pandemic. In addition, young adults before the pandemic spent a shorter time sitting (2.5 h) when compared to young adults during the COVID-19 pandemic (4.93 h). Sedentary behavior is a characteristic of people in certain sociodemographic groups like citizens who stayed for longer in education, office staff, managers, and people who live in towns (35). Results from

this study (see detailed Table 1) showed that 70.3% of young adults finished faculty and 48.4% lived in big cities, which indicates that they are employed as office workers and that sedentary behavior is characteristic of them. Also, further information about restrictive measures that were in force in 2021 in Serbia (AP Vojvodina), as well as excessive screen-based activities during the COVID-19 pandemic (38), confirmed these findings.

The old adults during the COVID-19 pandemic in Vojvodina, Serbia, accomplished lower results in VPA, MPA, and W compared to old adults before the pandemic in Vojvodina (35). It is well-known that PA can contribute to the physical and psychological well-being of old people (39–41). However, our results showed that the COVID-19 pandemic had a negative impact on PA, and thus on the health of old adults of Vojvodina, Serbia.

The strength of this study is a large sample of participants, and we used IPAQ-SF as the most useful questionnaire for estimating PA in youth and adults during the COVID-19 pandemic (42). Therefore, obtained results can be compared with the results of our study and other studies. There are a few limitations to this study. First, the PA levels were estimated for different ages, excluding the variables, such as gender, education level, and the environment in which the participants live. However, these variables could be taken into account in future studies. Second, no cookie-based protection was used to exclude the possibility of duplicates. Third, Lee et al. (24) note a low correlation with objective measures in the IPAQ-SF. Future research should continue to monitor the PA of the population after the pandemic, in order to prevent a pandemic of a sedentary lifestyle. Authors (43) have reported that PI is the fourth leading cause of mortality worldwide, and 31.1% of the adult population is physically inactive (36).

Conclusion

In conclusion, the present study showed very large changes in all levels of PA after 2 years of the declared COVID-19 pandemic in the youth and adult population of Vojvodina, Serbia. However, COVID-19 infection has a greater influence on young adults and old adults than on the youth population. Therefore, our article is extremely important because this is the first study to analyze the levels of PA in the population of Vojvodina, Serbia. Also, this is the first study to analyze the levels of PA 2 years after the declaration of the COVID-19 pandemic, while previous studies (44–46) analyzed the levels of PA at the beginning of the COVID-19 pandemic. COVID-19 infection has a greater influence on adults than on the youth population of Vojvodina, Serbia. These findings provided clear evidence that adults from Vojvodina, Serbia, should be more aware of PA during the COVID-19 pandemic because of the big risk associated with low PA. This is important because the Serbian population leads to the number of CVDs in Europe (21). The occurrence of CVD is highly correlated to PI. Therefore, PI must not become a habit of the population of the territory of Vojvodina, Serbia. Furthermore, it is necessary to take steps toward increasing PA in the adult population, especially old adults from Vojvodina, Serbia. We propose several recommendations and practical implications to increase the PA of old adults, as they constitute one of the most endangered populations from the territory of Vojvodina during the COVID-19 pandemic:

- To increase public awareness about the importance and benefits of the PA through educational interventions.
- To promote PA that can be performed outside (using outdoor fitness gyms, riding bicycles, walking in nature, and getting involved in gardening).

To conclude, the mentioned recommendations can be extended to the general public, if the restrictive measures in the country allow them. The general public should be informed about the benefits of PA, and we should not allow PI (reduced PA due to the COVID-19 pandemic) to become a habit of the population.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee Faculty of Sport and Physical Education University of Novi Sad (No-47-10-09/2021/1). The patients/participants provided their written informed consent to participate in this study.

Author contributions

JO and MJ wrote the manuscript, revised the manuscript, overviewed previous studies, and discussed the results. NR and DC performed the analysis. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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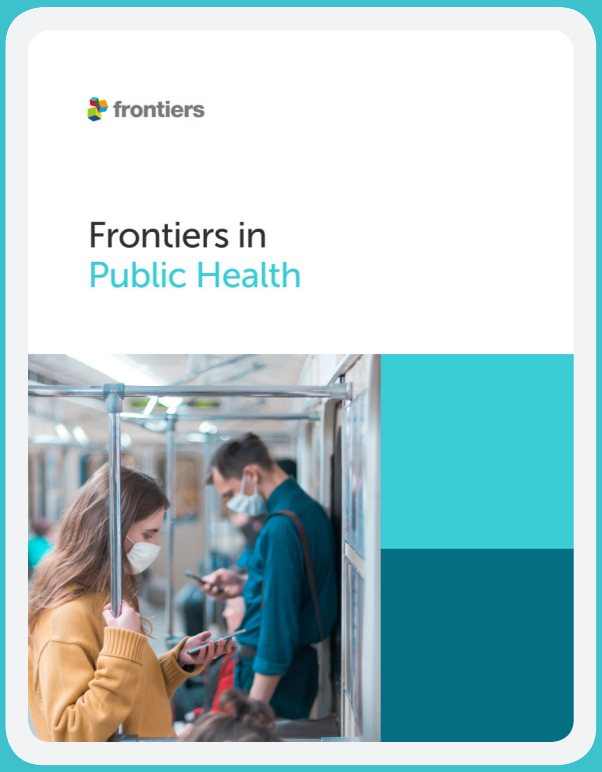

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