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Effects of physical activity on psychological well-being

Edited by
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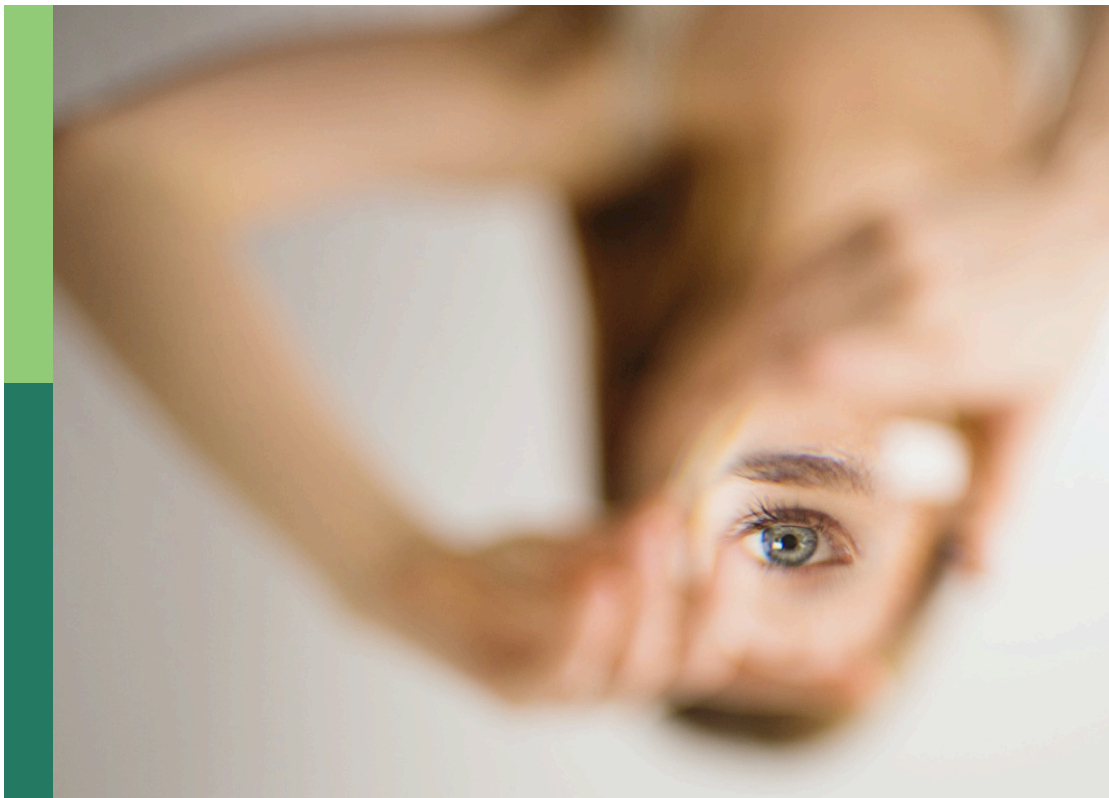

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Effects of physical activity on psychological well-being

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Editorial: Effects of physical activity on psychological well-being

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Editorial on the Research Topic
Effects of physical activity on psychological well-being

The effects of regular physical activity on overall health are well documented in the literature. Sabe et al. (2022) conducted a comprehensive scientometric analysis to evaluate topics and trends published in the Web of Science Core Collection between 1905 and 2021. The authors found an exponential annual growth rate of 6.8% since 1989 and identified seven major trends in physical activity research: cardiovascular disease, somatic disorders, cognitive decline/dementia, mental illness, sports performance, health and eating disorders, and the pandemic COVID-19. The preventive role of a physically active lifestyle is well established, and several strategies aim to get and keep the general population active to achieve better physical and mental health and a higher quality of life. In addition, the role of physical activity in public health is emphasized, and it is important to involve kinesiologists and sports professionals as stakeholders in the decision-making process, which affects the general population. Non-adherence to physical activity recommendations is an important risk factor for several somatic diseases as well as mental health problems, mental illness (Firth et al., 2020), and brain and cognitive function (Erickson et al., 2019). Regular exercise can improve social relationships, identity, sense of belonging (Stevens et al., 2021), self-confidence, self-efficacy, and body image (Kouhi et al., 2011; Abarca-Sos et al., 2015; Hao et al., 2022), which are psychological predictors of overall wellbeing. Psychological wellbeing is associated with a lower risk of disease and mortality and can be improved through relatively low-cost interventions (Boehm et al., 2012; Trudel-Fitzgerald et al., 2019). Factors known to influence mental and physical health include age, gender, chronic disease, amount and type of physical activity, environmental factors, and adaptation to emotional and physical stressors (Meyer et al., 2014; Gallagher et al., 2015).

Physical activity causes certain physiological and biochemical changes in the brain and body, as well as some changes in the perception and experience of the environment and one's own body, which contribute to improved psychological functioning. Despite these findings, the psychological benefits of regular physical activity and the psychological predictors that may influence regular physical activity are less clear. As a result, studies examining the relationship between physical activity and psychological health have become increasingly important in recent years (Ruegsegger and Booth, 2018; Kandola et al., 2019).

In this Research Topic, we address the effects of physical activity and exercise interventions on general and mental health and disease-related outcomes. In addition, we examine the relationships between physical activity/functional skills and mortality, cognition, and disease burden. This Research Topic forms a multidisciplinary perspective, covering the fields of kinesiology, medicine, psychology, and physical therapy. The articles in the Research Topic present a multidisciplinary approach to the relationships between different forms of physical

activity (type, intensity, frequency, and competitive/recreational) and psychological wellbeing, and aim to provide answers on how to maximize the potential positive effects of physical activity on psychological functioning in people with different characteristics.

Physical activity, regular sleep, fasting, and autophagy can be good ways to achieve wellbeing and longevity. However, to achieve healthy longevity and wellbeing, a combination of all four methods is required, rather than using only one (Min et al.). In addition, the aging process leads to various changes [functional abilities, fitness level, physical activity, and body mass index (BMI)], which in turn lead to changes in quality of life. It has been proven that, in the domain of physical activity, there is a correlation with the quality of life of older women (Đošić et al.). A research protocol on cognitive training combined with physical exercise in relation to cognitive functions, physical performance, and indicators of frailty in patients with hemodialysis has been discussed in detail by Bogataj et al..

Mladenović et al. noted that the COVID-19 pandemic has certain effects on people's mental health, and these effects have not yet been fully studied. When completing the Serbian version of the Multidimensional Emotion Questionnaire (MEQ), negative differences were found in terms of engagement by gender and sport, but not for the scale of regulation of positive emotions. It has also been shown that participation in sports can contribute to the improvement of emotional state, especially in situations such as during the COVID-19 pandemic. Another study (Živković et al.) found possible changes in life satisfaction of students participating in recreational sports, explained by the pandemic. Extraversion had significant predictive power for subjective experience of life satisfaction, whereas neuroticism and psychoticism did not. However, Marinkovic et al. showed that a neuromuscular exercise program can significantly improve the quality of life of young and healthy people following COVID-19 infection.

Several studies included the younger population and studied how exercise and physical activity affect their mental health. Carton et al. found that older adolescents derived greater positive affective benefits from membership in sports clubs compared to younger adolescents. Older adolescents may also use the affective benefits of sports club membership to gain advantages for the first steps in their adult lives, such as attending university or entering the workforce. Physical activity is one of the most important ways to maintain health, while life satisfaction is an indicator of students' mental health. After completing questionnaires (Exercise Adherence Questionnaire, Core Self-evaluation Scale, Positive Affect and Negative Affect Scale, and Satisfaction with Life Scale), it was found that there was a strong relationship between physical activity and life satisfaction among university students. In addition, relationships were found between physical activity, basic self-evaluation, positive emotions, and life satisfaction (Liu F. et al.). Šalaj and Masnjak found a weak relationship between children's motor skills and their social-emotional skills. Preschool children with high or low motor dispositions did not differ in terms of the occurrence of social and emotional difficulties. On the contrary, physical activity was found to have a large impact on final math grades. For boys, muscle endurance, aerobic capacity, and upper body strength were the most common predictors of final math grade, while for girls it was coordination (Sember et al.). Zovko et al. showed that mothers' moderate-to-vigorous physical activity was related to children's moderate-to-vigorous physical activity, whereas fathers' time spent in sedentary activities was related to boys' sedentary behavior but not to girls'. Grandparents' physical activity was not a significant predictor of children's physical activity, whereas grandfathers' sedentary behavior was a significant predictor of children's sedentary behavior. Zhang et al. found that physical literacy (PL) is an integral part of physical education and physical activity. The authors' study found that there was a positive relationship between cardiovascular fitness and PL. Self-confidence and physical competence have been shown to be more positively related to aspects of physical fitness (PF) in Chinese university students. Therefore, the use of PL has been shown to be a good tool to improve PF.

Unfortunately, mental health is becoming an increasing problem in the younger population, especially post-pandemic. Yu et al. found that students with myopia or other forms of impairment were more likely to suffer from anxiety. Myopia, irrational eating habits, and injuries related to physical activities were also factors leading to anxiety and stress. Risk factors for depression included low parental education, irrational eating habits, male gender, and low levels of physical activity.

Two studies dealt with professional athletes. Stanković et al. found that professional judoka were characterized by low levels of aggression, especially low expression of indirect and physical aggression. The personality traits honesty and openness to experience were also high, while emotionality and extraversion were lower. Moderate general self-efficacy was also a characteristic of professional judoka. Members of team sports, on the other hand, were characterized by increased aggression, pronounced emotionality and extraversion traits, and less pronounced honesty and openness to new experiences traits as well as general self-efficacy. Another study on athletes (Copec et al.) supports the current literature and suggests that the construct of stress attitude plays a unique role in explaining individual differences in cognitive stress ratings across general personality dimensions.

Liu X. et al. concluded that Tai Chi and Qigong exercises have a positive effect on reducing depression and anxiety and lowering cortisol levels in adolescents. However, the effects on mood, stress, and self-esteem were found to be very small. Therefore, it may be stated that Qigong is a good therapeutic tool for improving the psychological state of adolescents. Similarly, Yang et al. found in their systematic review that traditional Chinese fitness exercises can improve both negative moods and sleep disorders. On the contrary, Hammer et al. found that negative consequences occur with high-intensity interval training. However, these effects can be reduced if the intensity is maintained at approximately 80% maximum heart rate, with positive enjoyment reactions associated with interval training.

Conclusion

The current Research Topic contributes to the existing literature by providing information on the relationships between physical activity and psychological function and wellbeing. Studies have shown that physical activity contributes to a healthy life expectancy and quality of life, as well as cognitive function in various populations. The positive psychological effects of physical activity and exercise include increased life satisfaction, positive emotions, self-appraisal, self-efficacy, self-confidence, and physical competence, as well as improved socio-emotional skills in children. Higher levels of physical activity are also associated with lower cortisol levels, lower negative

mood, fewer symptoms of depression and anxiety, and fewer sleep disturbances; physical activity may be considered a protective factor for lower stress levels and stress attitudes, depression, poor eating habits, and exercise habits. In conclusion, it was found that there are some additional positive predictors of these positive effects related to physical activity, such as personality traits (extraversion, openness), parents' physical activity level, moderate intensity of physical activity, and level of physical education. However, it is important to point out that this is not only due to participation in sports or physical activity itself, but also to how these are conducted and organized.

The work published in this Research Topic raises important questions for future investigations, including (1) the role of the sport environment as a mediator of these positive effects, (2) the potential differential effects of recreational and competitive physical activity on psychological wellbeing, (3) additional investigation of the therapeutic role of physical activity participation in different patient populations or in individuals with specific impairments in terms of psychological wellbeing and quality of life, and (4) investigation of the differential effects of physical activity on wellbeing in different age groups.

Author contributions

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

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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ORIGINAL RESEARCH
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Are Family Physical Activity Habits Passed on to Their Children?

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Studies of the familial association of physical activity (PA) and sedentary behavior (SB) have increased in recent years. However, there is a lack of studies that have objectively examined the correlates between parents, grandparents, and childrens' PA. Therefore, the purpose of this study was to measure PA using accelerometers to determine the extent to which PA and SB correlate among parents, grandparents, and children. A sample of 169 children between 11 and 14 years (77 boys and 97 girls), 225 parents (98 males and 127 females), and 52 grandparents (16 males and 36 females) were recruited for the current study. Accelerometers RM42 (UKK Terveyspalvelut Oy, Tampere, Finland) were used to determine PA levels of children, parents, and grandparents. Epoch length was 6 s. Mothers' moderate-to-vigorous PA (MVPA) was associated with children's MVPA ($p < 0.05$). After adjusting for age, BMI (child), and educational status, the results remain the same. Results of linear regression analyses for boys' sedentary time showed that fathers' sedentary time was significantly associated with boys ($p < 0.01$), but not with girls. The association of grandmothers' and grandfathers' MVPA activity with that of children showed that grandparents' MVPA, when adjusted for age, BMI, and educational status, was not a significant predictor ($p > 0.05$) of children's MVPA (total sample). In contrast, grandfathers' sedentary behavior was a significant predictor ($\beta = 0.269$; $p < 0.05$) of children's sedentary behavior (total sample). The results of the current study suggest that parental involvement in PA, particularly by mothers, is important for children's PA and, accordingly, healthy outcomes.

Keywords: accelerometry, monitoring, MVPA, physical activity, sedentary behavior

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INTRODUCTION

Routines created in early childhood can strongly influence children's health. According to current guidelines (Tremblay et al., 2016; World Health Organization, 2020), which provide evidence-based recommendations for a healthy day (24 h), a combination of sleep, sedentary behaviors, light, moderate, and vigorous physical activity (PA) is essential for a healthy life.

Several studies showed a strong association between PA and a cardiometabolic risk profile in childhood (Andersen et al., 2006; Wittmeier et al., 2008; Steele et al., 2009; Ekelund et al., 2011) and later in adulthood (Kallio et al., 2021). Studies looking at factors that influence participation in PA in childhood have been the focus of scientific research for some time. There is a wide range of factors that have been investigated, including age, gender, socio-demographics, lifestyle and parental and peer influences as the most studied correlates (Craggs et al., 2011; Padulo et al., 2019).

There is strong evidence that parents' sociodemographic characteristics are associated with children's health (Dow and Rehkopf, 2010; Serbin et al., 2014). Parents serve as role models for their children and have a major influence on their PA (Birch and Davison, 2001; Jago et al., 2010; Lee et al., 2018). They encourage their children or instrumentally support their PA by taking them to events where they can be physically active (Gustafson and Rhodes, 2006).

Researchers have found that higher levels of parental education in the family environment are more relevant factors for more frequent PA in children and adolescents (Yang et al., 1996; Jiménez-Pavón et al., 2012; Vella et al., 2014). A review article that examined associations between PA in children and parents found conflicting results (Gustafson and Rhodes, 2006), most likely due to different methods of monitoring PA and the more frequent use of subjective rather than objective methods to determine PA (Gustafson and Rhodes, 2006; Jago et al., 2010). Most studies have used subjective methods to determine PA, particularly questionnaires, which are less reliable than objective methods. Studies using objective methods to determine PA most commonly use accelerometers for this purpose (Troiano et al., 2014), which provide an objective determination of an individual's PA based on objectively measured accelerations and using algorithms. Previous studies that have dealt with the determination of the PA of families based on accelerometers showed mixed results, especially considering gender (Hennessy et al., 2010; Fuemmeler et al., 2011; Garriguet et al., 2017; Song et al., 2017). Hennessy et al. (2010) found that parenting style and some parenting practices were related to children's PA. One study found a relationship only between PA levels of parents and boys, but not girls (Dozier et al., 2020). In addition, a longitudinal study showed that parents' PA was not related to children's PA (Anderssen et al., 2006). The reasons for these results could vary, from covariates included in the analysis to a number of days participants were observed.

Studies of parent-child correlates of PA using accelerometers have increased in recent years. However, to the authors' knowledge, no single study has examined objectively measured grandparent-child PA correlates. Considering that grandparents are often involved in children's lives through education and PA in some settings, it would be interesting to determine their influence on children's PA behaviors alongside that of parents. Therefore, the aim of this study was to investigate family-child PA associations using accelerometry.

MATERIALS AND METHODS

Subjects

A sample of 174 children aged between 11 and 14 years of age (77 boys and 97 girls) and their families (225 parents and 52 grandparents) were recruited for the current study. The descriptive characteristics of the participants are presented in **Table 1**.

The participants were primary school children from nine primary schools from urban and rural areas of Republic of Slovenia and their parents. The collection of participants was led by school coordinators who presented the research at parent meetings and collected signed consent forms from participants (for minor participants, they were signed by the parents). Due to the nature of the study, which requires consent from all family members, a voluntary response sample was used (Murairwa, 2015). The sample used for the analysis was designed based on the families of school-age children by including children between 11 and 14 years old and their parents. Siblings of the children who were no more than four years younger or older than them and their grandparents were also invited if they had regular contact with the child, i.e. at least twice a week.

Participants who were healthy and whose health was not affected by PA were included. The additional inclusion criterion for adults was that they were able to perform a 6-min walk test and run or walk the 600 m. Permission was obtained from the Faculty of Sport in Ljubljana in accordance with the Declaration of Helsinki (No: 6:2020-274). Data in present study were obtained within the project EUPASMOS No. 590662-EPP-1-2017-1-PT-SPO-SCP under the Erasmus+ Programme of European Union.

Procedures

The measurements were performed in autumn 2018 (October to November). They took place at two time points, one week apart. At the first time point, the accelerometers were distributed to the participants and familiarized them with their use. The accelerometers were worn for a full week. Participants were instructed to wear the accelerometers continuously throughout the whole day (24-h) for consecutive seven days, except when bathing or swimming. At the second time point, participants returned the accelerometers.

The height and weight of the subjects were measured using an electronic scale and an anthropometer (Kern and Sohn GmbH, Balingen, Germany). PA was measured with an RM42 accelerometer (UKK RM42, UKK Terveyspalvelut Oy, Tampere, Finland), which is a triaxial accelerometer (data on duration and intensity of activity were recorded), and the data were later processed using the MAD approach (mean amplitude deviation). MAD values have been validated as indicators of energy expenditure during locomotion (Sievänen et al., 2014; Vähä-Ypyä et al., 2015a). Epoch length was 6 s and results are based on 1 min exponential moving average of epochwise MET-values. As recommended, the MAD values can be converted to metabolic equivalents ($MET = 3.5$ mL/kg/min oxygen consumption) for each epoch (Sievänen and Kujala, 2017).

The accelerometer was worn on an elastic band on the right side of the hip during the day and on the non-dominant arm at night for whole week. Several studies have shown high reliability of these devices based on coarse acceleration signals (89.2%) (Sievänen et al., 2014; Vähä-Ypyä et al., 2015b; Hukkanen et al., 2018).

Child-specific cut-points (Aittasalo et al., 2015) and adult cut-points (Vähä-Ypyä et al., 2015a) were used to categorize physical activity in minutes spent in the outcome categories of interest, namely sedentary (<1.5 METs) and moderate to vigorous PA (MVPA) (>3 METs). Because accelerometry data were collected continuously during the 24-h circadian cycle, several parameters describing patients' daily PA, SB, standing, and sleep profiles were assessed but excluded for regression analysis (Vähä-Ypyä et al.,

TABLE 1 | Demographic characteristics of included participants.

	Children $n = 174$		Parents $n = 225$		Grandparents $n = 52$	
	Boys $n = 77$	Girls $n = 97$	Male $n = 98$	Female $n = 127$	Male $n = 16$	Female $n = 36$
age (years)	12.3 ± 1.2	12.5 ± 1.5	44.5 ± 4.9	43.0 ± 6.0	68.2 ± 6.3	66.2 ± 6.6
height (cm)	160.3 ± 10.9	160.4 ± 8.5	178.8 ± 7.4	168.1 ± 11.5	175.7 ± 6.3	161.3 ± 5.6
weight (kg)	50.1 ± 12.6	50.4 ± 10.3	83.8 ± 14.0	67.4 ± 12.5	86.9 ± 16.6	70.8 ± 10.5
BMI (kg/m^2)	19.5 ± 3.1	19.0 ± 3.1	26.2 ± 3.5	23.9 ± 4.2	28.2 ± 5.7	27.2 ± 4.9

n, number of subjects; BMI, body mass index.

2018). In addition, light METs (1.5–3 METs) were not included in the analyses.

Statistical Analysis

A preliminary analysis of the data revealed that the PA variables were heavily skewed. Logarithmic transformations were therefore performed to normalize the data. Linear regression models were developed to assess the effects of parental PA on children PA. The analysis began with the following cross-sectional estimates:

$$\ln\left(MVPA\ child_i\right) = \beta_0 + \beta_1 \ln\left(MVPA\ parent_i\right) + \varepsilon_i \quad (1)$$

$$\ln\left(SB\ child_i\right) = \beta_0 + \beta_1 \ln\left(SB\ parent_i\right) + \varepsilon_i \quad (2)$$

where $\ln\left(MVPA\ child_i\right)$ denotes the logarithm of the child's moderate and vigorous PA time, $\ln\left(MVPA\ parent_i\right)$ represents the logarithm of the parent's moderate and vigorous PA time, $\ln\left(SB\ child_i\right)$ is the logarithm of the child's sitting and laying time, while $\ln\left(SB\ parent_i\right)$ represents the logarithm of the parent's sitting and laying time. In addition, adjusted models were estimated including covariates and potential confounders that could influence the relationships between the parent's and the child's PA, namely the child's age and BMI, as well as the parent's education level. Both unadjusted and adjusted models were estimated separately for boys and girls. Finally, the study estimated additional models to assess the relationship between grandparent's and grandchild's PA. Unfortunately, these models could not be estimated separately for boys and girls due to small sample size. All presented statistical analyses were conducted in Stata Statistical Software 2017: Release 15 (StataCorp LLC, Texas, US).

RESULTS

Table 2 shows the mean ± SD for minutes per day of light and MVPA, and the mean counts for SB and standing activities.

Results of the linear regression analyses represent the association of mothers' and fathers' PA with children's PA, adjusted for age, BMI (child), and educational status (**Table 3**).

It was found that mothers' MVPA was significantly associated with children's MVPA ($p < 0.05$). The situation was the same after adjusting for age, BMI (child) and educational status (Model 2), only mothers' MVPA was a significant predictor of children's MVPA. Although mothers' and girls' PA were associated, the model explained only 10.1 % of the common variance. The situation was better for boys: after adjusting for age, BMI (child) and educational status, the model explained 18.1 %.

The results of linear regression analyses for SB (both models) showed that parents' SB was not significantly associated with neither boys nor with girls' SB ($p > 0.05$). In addition, girls' SB was associated with an increase in children's age ($p < 0.01$).

Linear regression analyses for the association of grandmothers' and grandfathers' MVPA activity with that of children (Model 1) showed that grandmothers' and grandfathers' MVPA was a significant predictor (**Table 4**) of children's MVPA (total sample). However, after adjusting for age, BMI, and educational status, both grandparents' MVPA was not a significant predictor ($p > 0.05$) of children's MVPA (total sample). In contrast, grandfathers' SB was a significant predictor ($\beta = 0.269$; $p < 0.05$) of children's SB (total sample), in a Model 2 that explained 35.8 % of the variance. It was also found that age was a significant predictor of the relationship between grandmothers and children (-0.075; $p < 0.01$).

DISCUSSION

The current study is important and unique because it contributes to the literature examining family-child associations in measuring PA with objective measures such as accelerometers. The main findings include the following: (i) mothers' MVPA is significantly associated with children's MVPA ($p < 0.05$); (ii) when adjusting for age, BMI (child) and educational status, only mother's MVPA showed as significant predictor of child's MVPA (10.1% of common variance for girls, $p < 0.05$; 18.1% of common variance for boys, $p < 0.05$) (iii) parental SB is not significantly associated with child's SB; (iv) grandparents' MVPA is a significant predictor of children's MVPA ($p < 0.05$); (v) only grandfathers' SB is a significant predictor ($\beta = 0.269$; $p < 0.05$) of children's SB, explaining 35.8 % of the common variance.

It was found that overall MVPA and SB were significantly associated between family members and children. However, the multivariate regression models showed that only mothers' MVPA was a significant predictor of children's MVPA, regardless of

TABLE 2 | Means and standard deviations for minutes per day of PA and SB.

	Children		Parents		Grandparents	
	Boys	Girls	Male	Female	Male	Female
SB (min·d^{1})	498.8 ± 72.2	504.3 ± 75.3	531.8 ± 105.0	497.8 ± 106.6	520.0 ± 149.2	489.8 ± 131.2
Standing (min·d^{1})	63.0 ± 36.7	78.5 ± 41.9	125.4 ± 61.1	142.1 ± 59.2	91.4 ± 31.4	130.2 ± 46.6
Light PA (min·d^{1})	221.2 ± 40.6	222.9 ± 45.2	258.4 ± 77.1	270.9 ± 82.4	215.2 ± 88.8	266.7 ± 72.9
MVPA (min·d^{1})	108.8 ± 38.5	78.5 ± 24.6	60.8 ± 54.1	47.7 ± 21.9	64.7 ± 38.4	44.5 ± 32.2

PA, physical activity; SB, sedentary behavior.

TABLE 3 | Linear regression analysis for variables predicting children's activity level.

	MVPA		Sedentary behavior	
	B	R^2	B	R^2
Boys				
Model 1				
Father	0.234	0.058	0.186	0.065
Mother	0.284**	0.114	0.048	0.004
Girls				
Model 1				
Father	0.149	0.032	0.138	0.039
Mother	0.166*	0.067	0.031	0.002
Boys				
Model 2				
Father	0.229	0.135	0.167	0.13
Mother	0.315**	0.181	0.044	0.197
Girls				
Model 2				
Father	0.161	0.054	0.158	0.273
Mother	0.178*	0.101	0.063	0.232

MVPA, moderate-to-vigorous physical activity.
***p < 0.01; *p < 0.05.*
Model 1: Unadjusted.
Model 2: Adjusted for age, BMI and education.

TABLE 4 | Linear regression analysis for variables predicting children's activity level.

	MVPA		Sedentary behavior	
	B	R^2	B	R^2
Total sample				
Model 1				
Grandfather	0.304*	0.189	0.278*	0.221
Grandmother	0.176*	0.083	0.021	0.001
Total sample				
Model 2				
Grandfather	0.182	0.415	0.269*	0.358
Grandmother	0.148	0.318	0.045	0.164

MVPA, moderate-to-vigorous physical activity.
**p < 0.05.*
Model 1: Unadjusted.
Model 2: Adjusted for age, BMI and education.

gender. The opposite results were obtained for the association with SB, which showed that fathers' and grandfathers' SB was a significant predictor of children's SB. The present results on family members' and children's PA patterns confirm the influence of parents' PA on children's PA and add important new insights into the grandparent-child relationship.

Previous findings on the PA levels association between parents and children showed different results, ranging from large correlations (Moore et al., 1991; Ruiz et al., 2011) to small (Ziviani et al., 2008; Østbye et al., 2013) or no significant correlations (Heitzler et al., 2010; Hennessy et al., 2010; Jago et al., 2010; Patnode et al., 2010; Dowda et al., 2011). In addition, a recent meta-analysis showed that parent-child PA correlates were greater with objective measurement than with self-reported questionnaires (Yao and Rhodes, 2015), resulting in more objective and reliable results of PA.

Moreover, studies have reported differences between boys and girls in both PA behaviors and influences on PA (Jago et al., 2010; Craggs et al., 2011; Fuemmeler et al., 2011; Cooper et al., 2015; Telford et al., 2016). Our findings are in line with a recent study that showed that maternal support had a significant influence on children's PA (Forthofer et al., 2016). However, this relationship changes from early childhood to adolescence, with fathers having the dominant influence on PA during preschool age, which changes later in life when mother takeover the dominance in PA (Abbott et al., 2016).

Although mothers' and girls' PA were associated, the model explained only 10.1 % of the variance. The situation was better for boys, when adjusted for age, the model explained 18.1 %. Although the current results did not find gender differences in PA, some studies have shown that boys are more active than girls at young adolescent age (Trost et al., 2002; Riddoch et al., 2004; Sember et al., 2020). A most recent study found a relationship among 8–12-year-old children only between PA levels of parents and boys, but not among girls (Dozier et al., 2020). However, in contrast to the aforementioned studies, a longitudinal study showed that PA of parents was not related to PA of children (Anderssen et al., 2006). In light of these findings, there is a need to understand how PA influences operate as children transit to adolescence. Therefore, it is clear that more longitudinal designs

examining sex-specific parental influences on young children's PA are warranted.

Talking about the associations between parents and children regarding SB, some studies found higher rates of SB in children when parents that reported higher rates of screen time for their children (Mcguire et al., 2002; Kourlaba et al., 2009; Lee et al., 2010; Hoyos Cillero and Jago, 2011). However, when accelerometers were used to measure SB, no associations between parents' screen time and time spent in SB was found (King et al., 2011).

Currently, there is insufficient understanding of the pathways through which grandparents exert their influence on children's health and development outcomes (Sadruddin et al., 2019). This is the first study to investigate family-children relationships of objectively measured PA behaviors involving grandparents who live near their grandchildren and are involved in family daily activities/chores. However, after adjusting for age, BMI, and educational status, both grandparents' MVPA was not a significant predictor of children's MVPA. Possible reasons for the results regarding PA include several factors related to the costs, presence of grandchildren in the home, and cultural considerations (Kicklighter et al., 2007). In other societies, grandparents have a much greater influence on the family's daily routine than in ours. However, interestingly, grandfathers' SB was found to be a significant predictor of children's SB, explaining 35.8% of the variance. Unfortunately, it is difficult to compare our results with other studies because there are no studies that have investigated the association of grandparents' and children's PA. However, some studies have found negative associations between grandparent involvement and children's healthy eating habits (Pearce et al., 2010; Roberts and Pettigrew, 2010). In addition, one study found no relationship between grandparent involvement and children's PA behaviors (Pulgarón et al., 2013). Therefore, there is a need for future research on grandparent and child health.

CONSIDERATIONS

The present study is the first to examine correlations between PA and SB in children, their parents and grandparents. Major strength of present study is the extension of previous findings regarding parental influence on PA and SB regarding the influence of grandparents on children's PA and SB. Based on the published literature, separate analysis of parental's PA and SB is significantly adding to the knowledge regarding parental influence on children's PA and SB. Previous findings concerning MVPA between parents, family members, and children suggest that MVPA is related, which should be used to promote and increase MVPA in children and their parents. There is a need for future studies to confirm our findings, as well as to expand this body of literature by examining the PA correlates of parents, family members, and their children. In addition, there is a need to conduct a longitudinal study examining the family PA correlates to determine how PA and SB change over the years.

To our knowledge, this is the first study examining objectively measured PA and SB of three-generation family. Nevertheless, some considerations and potential limitations have been acknowledged. First, the sample size for grandparents was small and diverse by gender (grandfathers $n = 16$; grandmothers $n = 36$), having a potential impact on the family correlates of PA and SB. In addition, a methodological limitations regarding the use of accelerometers should be mentioned: (i) although validated for measuring PA and SB, the present study did not not capture certain types of activities, such as light PA and very high PA; (ii) daily PA minutes (means and standard deviations) were very high, which may be a consequence of "cherry-picking," where only the most active families decided to participate in the study; (iii) as in all PA studies, participants were aware that they were being monitored, which might have resulted in the changes of their habitual PA patterns; (iv) high measurement and equipment costs limited the availability of accelerometers and did not allow the measurement of PA of all included participants during the same week which means that the PA patterns could be affected by other factors such as different weather conditions; (v) MVPA and SB were measured for only one week, so the results cannot be interpreted as behavioral PA; (vi) biomechanical and physical factors could affect the results as increased mass give lower acceleration and the increased and/or different height of participants produces longer or shorter pendulum, resulting in potentially different measures od PA and SB; (vii) external factors could influence PA and SB: family problems, friendship problems, dietary habits and changes of environment/school, socioeconomic status, which have not been controlled for; (viii) this study was conducted in October to November, so the conclusions cannot be interpreted for a longer period of time, as previous studies have shown that older adults change their PA depending on the season (Padulo et al., 2018).

CONCLUSION

The results of the current study suggest that parental involvement in PA, especially mothers, is significantly important for children's PA and, accordingly, their health outcomes. The discrepancy between mothers' and fathers' influence on the child PA is an interesting starting point for planning interventions that would encourage fathers to take on a greater role as promoters of PA. In addition, mothers' PA should be further encouraged and increased in order to increase PA in children. On the contrary, there is a need for additional support for grandfathers, considering that their sedentary behavior was a significant predictor of children's behavior. The present study is important because it makes a significant contribution to the study of family correlates in accelerometer-derived measures of physical activity.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

This study involved human participants. It was reviewed and approved by Ethics Committee of the Faculty of Sport, University of Ljubljana and was in accordance with the Declaration of Helsinki (No: 6:2020-274). Written informed consent to

participate in this study was provided by the participants or parents/legal guardian for children involved in this study.

AUTHOR CONTRIBUTIONS

VZ, SD, VS, and GJ conceptualized the study design and recruited subjects into the study. GJ conducted the research. VS and VZ analyzed and interpreted the data. VZ drafted the manuscript. VS, SD, and GJ reviewed the manuscript. All authors have read and approved the final version of the manuscript.

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Corrigendum: Are Family Physical Activity Habits Passed on to Their Children?

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Keywords: accelerometry, monitoring, MVPA, physical activity, sedentary behavior

A Corrigendum on

Are Family Physical Activity Habits Passed on to Their Children?
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In the original article, there was an error in the **Abstract** as published. "Epoch was set to 1 s" should have been "Epoch length was 6 s." A correction has been made to the **Abstract** as below:

Studies of the familial association of physical activity (PA) and sedentary behavior (SB) have increased in recent years. However, there is a lack of studies that have objectively examined the correlates between parents, grandparents, and childrens' PA. Therefore, the purpose of this study was to measure PA using accelerometers to determine the extent to which PA and SB correlate among parents, grandparents, and children. A sample of 169 children between 11 and 14 years (77 boys and 97 girls), 225 parents (98 males and 127 females), and 52 grandparents (16 males and 36 females) were recruited for the current study. Accelerometers RM42 (UKK Terveyspalvelut Oy, Tampere, Finland) were used to determine PA levels of children, parents, and grandparents. Epoch length was 6 s. Mothers' moderate-to-vigorous PA (MVPA) was associated with children's MVPA ($p < 0.05$). After adjusting for age, BMI (child), and educational status, the results remain the same. Results of linear regression analyses for boys' sedentary time showed that fathers' sedentary time was significantly associated with boys ($p < 0.01$), but not with girls. The association of grandmothers' and grandfathers' MVPA activity with that of children showed that grandparents' MVPA, when adjusted for age, BMI, and educational status, was not a significant predictor ($p > 0.05$) of children's MVPA (total sample). In contrast, grandfathers' sedentary behavior was a significant predictor ($\beta = 0.269$; $p < 0.05$) of children's sedentary behavior (total sample). The results of the current study suggest that parental involvement in PA, particularly by mothers, is important for children's PA and, accordingly, healthy outcomes.

In the original article, there was an error in **Materials and Methods**, **Procedures**, Paragraph 2. "Signals were recorded using 1-s epoch." should have been "Epoch length was 6 s and results are based on 1 min exponential moving average of epochwise MET-values." A correction has been made to **Materials and Methods**, **Procedures**, Paragraph 2 as below:

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The height and weight of the subjects were measured using an electronic scale and an anthropometer (Kern and Sohn GmbH, Balingen, Germany). PA was measured with an RM42 accelerometer (UKK RM42, UKK Terveyspalvelut Oy, Tampere, Finland), which is a triaxial accelerometer (data on duration and intensity of activity were recorded), and the data were later processed using the MAD approach (mean amplitude deviation). MAD values have been validated as indicators of energy expenditure during locomotion (Sievänen et al., 2014; Vähä-Ypyä et al., 2015a). Epoch length was 6 s and results are based on 1 min exponential moving average of epochwise MET-values. As recommended, the MAD values can be converted to metabolic equivalents ($MET = 3.5$ mL/kg/min oxygen consumption) for each epoch (Sievänen and Kujala, 2017).

In the original article, there was an error in **Materials and Methods**, **Procedures**, Paragraph 3. The second part of sentence 2 "compared to the double-labeled water method, which is considered the gold standard for determining physical activity according to objective criteria (Sirard and Pate, 2001)" was incorrect. The corrected **Materials and Methods**, **Procedures**, Paragraph 3 appears below:

The accelerometer was worn on an elastic band on the right side of the hip during the day and on the non-dominant arm at night for whole week. Several studies have shown high reliability of these devices based on coarse acceleration signals (89.2%) (Sievänen et al., 2014; Vähä-Ypyä et al., 2015b; Hukkanen et al., 2018).

In the original article there was also an error in **Materials and Methods**, **Procedures**, Paragraph 4. Vähä-Ypyä et al. (2018) and Aittasalo et al. (2015) were not cited in the article. Trost et al. (2002) was incorrectly cited in the article. The citations have now been amended in **Materials and Methods**, **Procedures**, Paragraph 4 below:

Child-specific cut-points (Aittasalo et al., 2015) and adult cut-points (Vähä-Ypyä et al., 2015a) were used to categorize physical activity in minutes spent in the outcome categories of interest, namely sedentary (<1.5 METs) and moderate to vigorous PA (MVPA) (>3 METs). Because accelerometry data were collected continuously during the 24-h circadian cycle, several parameters describing patients' daily PA, SB, standing, and sleep profiles were assessed but excluded for regression analysis (Vähä-Ypyä et al., 2018). In addition, light METs (1.5–3 METs) were not included in the analyses.

Deleted References

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The authors apologize for this error and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

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BRIEF RESEARCH REPORT
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Sport-Related Affective Benefits for Teenagers Are Getting Greater as They Approach Adulthood: A Large-Scale French Investigation

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The present investigation examined how sports club membership is related to adolescents' daily negative and positive affects as they age. Robust prior results demonstrated that sports club membership is positively related to positive affect and negatively related to negative affect. However, surprisingly, no prior studies examined whether these benefits are consistently present throughout the teenage years or there are certain critical periods when teenagers can affectively profit more from being members of a sports club. The present cross-sectional investigation examined these questions on a comprehensive sample of French adolescents ($N = 17{,}337$, female = 7,604, aged between 10 and 18, $M_{age} = 12.45$ years, $SD_{age} = 1.94$ years). Besides the expected affective benefits of a sports club membership, there was no interaction between age and negative affect. However, late adolescents reported greater daily positive affective benefits of sports club membership than early adolescents. These results suggest that late adolescents can use the extra affective benefits of sports club membership to gain advantages for the first steps of their adult life, such as coping with career start or transition to higher education. These results can provide guidelines for future studies to prioritize late adolescents with heightened positive sport-related affective benefits. It can also be useful information to promote sport among late adolescents.

Keywords: adolescents, positive affect, sports club membership, positive psychology, broaden-and-build, physical activity

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INTRODUCTION

In the past 20 years, robust results suggest that regular participation in physical activity and sport has a beneficial effect on physical and mental health at all ages and for a broad variety of people (Biddle and Mutrie, 2001; Haworth and Lewis, 2005; Eime et al., 2013; Gisladottir et al., 2013b). For example, Gisladottir et al. (2013b) examining more than 10,000 14-16-year-old adolescents found that practicing sports in a club is associated with a better body image ($d = 0.6$), a better physical ($d = 1.06$) and mental condition ($d = 0.76$).

These positive effects appear to be rather large. Adolescence is no exception, physical activity has a great impact on mental health in this critical and vulnerable period (Janssen and Leblanc, 2010; Ahn and Fedewa, 2011; Biddle and Asare, 2011; Rodriguez-Ayllon et al., 2019). More precisely, several authors (Richman and Shaffer, 2000; Brettschneider, 2001; Liu et al., 2015) found that doing sports is associated with a more positive self-concept and increased self-esteem, both of which are reliable indicators of mental health. Bang et al. (2020) demonstrated that belonging to sports clubs predicted positive self-esteem and also improved school engagement. Prior work reported that sport activities increased feelings of physical competence, satisfaction with physical appearance, and resulted in positive body image, which can lead to an increase in overall self-esteem (Findlay and Bowker, 2009; Zamani Sani et al., 2016; Gomez-Baya et al., 2019). Biddle et al. (2019) demonstrated that physical activity tends to decrease symptoms of depression which is among the most common mental disorders in this age group (Saxena et al., 2013). Physical activity benefited the social aspects of mental health as adolescents could develop positive social relationships through their collective practice (see Eime et al., 2013). The lack of physical activity during adolescence is correlated with poor mental health (Hume et al., 2011; Gunnel et al., 2016). All in all, it appears that physical activity and sport have a positive impact on mental health and this is especially true regarding hedonic wellbeing (maximizing positive emotions and minimizing negative ones, Diener, 2000). Indeed, sports practices allow adolescents to experience positive emotions in various ways. The broaden-and-build theoretical framework (Fredrickson, 2001) posits that positive emotions have various beneficial effects on psychological functioning and we suppose that it can provide an explanation why and how adolescents can gradually benefit from sports club membership. According to this theory, positive emotions increase physical, personal, and social resources that mobilize and unleash their potentials. Positive affects can trigger broad, curious, and optimistic thought patterns as well as spontaneous and energetic behaviors. Positive emotions accumulate over time in ways that incrementally build people's enduring resources.

In the light of the abundance of scientific studies, it is surprising that we have very little accumulated scientific knowledge about (1) the developmental aspects of these benefits, and (2) how physical activity or sports club influences daily negative and positive affects along adolescence. The present paper aims to fill this gap among adolescents aged between 10 and 18 and explore the potential affective benefits of belonging to a sports club throughout adolescence.

During and after physical activities, people experience various affective benefits that can contribute to their wellbeing. One of these is related to physical feeling states that capture sensory experiences (e.g., arousal). These experiences are distinct from the general positive/negative affects that might appear as the benefit of physical activities (Dunton et al., 2014). These two aspects have not the same duration, level of intensity and even the underlying cognitive processes are different. In the present study, instead of the sensory experiences, we will focus on core affects (Russell, 1980; Russell and Barrett, 1999); the most elementary, consciously accessible emotions and we will distinguish them based on their positive or negative valence. In the present case, positive affects included states, such as joy, enthusiasm, pride, and full-of-energy, while negative affects included anxiety, fear, sadness, shame, and guilt (Van Geel and De Mey, 2003). Our main goal was not assessing affects during or right after physical activities, but we aimed to explore these affective states in a more general way, focusing on adolescents' feelings in the few days before the assessment.

There is a consensus in the literature that sports and exercise elevate positive and reduce negative affects among not only adults, but adolescents as well (see, for example, Buckworth et al., 2013). In a recent meta-analysis, Bourke et al. (2021) demonstrated positive associations between physical activity, feeling energized, positive emotions, and vitality among children and adolescents. Their participation in sports club can also increase their social abilities (Sabiston et al., 2016; Vella et al., 2017). Being a member of a sports club has a positive influence on the adolescents' self-esteem (Brettschneider, 2001) and social competence (Howie et al., 2010). These benefits are important during the emotionally challenging times of adolescence. Considering the dynamics of emotions in this critical period of development, it appears that positive affects decline and negative affects increase throughout adolescence (Weinstein et al., 2007; Forbes et al., 2010; Frost et al., 2015; Martin-Krumm et al., 2017). Adolescents clearly benefit affectively from physical activities (Kühnhausen et al., 2013; Cushing et al., 2018), yet it is still unclear exactly in which part of this period they can benefit the most.

The Present Research

The present work focuses on an under-investigated topic at the intersection of developmental, positive, and sport psychology. The results will be interpreted in the positive psychological theoretical framework broaden-and-build. Namely, how sports club membership can be related to increased positive and reduced negative affects throughout adolescence. Contrasting to prior studies, the present work is particular in its relatively large sample of adolescents of various ages (ranged between 10 and 18).

Based on (1) the systematic review of Liao et al. (2015), physical activity and sports club participation (Miller and Hoffman, 2009) improve daily positive affective states; (2) robust prior findings show that adolescents experience more negative and less positive affects over time (Weinstein et al., 2007; Forbes et al., 2010; Frost et al., 2015; Martin-Krumm et al., 2017); and (3) the fact that adolescents affectively benefit from physical activities (e.g., Buckworth et al., 2013), we expect that in the later parts of adolescents will experience more affective benefits from sports club membership than the earlier parts of adolescents.

MATERIALS AND METHODS

Procedure and Participants

This study was conducted in accordance with the Declaration of Helsinki and with the approval of the National Ethics Committee Board (n°00012476–2021-28-05-109). Participants for this study were recruited through the project of the "*French physical and mental health inventory*" program. Besides the ethical permission, the data gathering, and its further use were approved by the National Commission on Informatics and Liberty (RF 1232206). As the respondents were minors, written and signed informed consent was obtained from their parents. Respondents of the survey were informed about the content of the investigation, and they were requested to indicate their intention for participation (provide assent).

The dataset was part of an extensive, multi-year data gathering (between 2008 and 2019). For the present paper, we only focus on the data of adolescents who reported their sports club membership status. The sample consisted of 17,337 adolescents (7,604 girls, 43.86%). Most of them (12,895, 74.39%) reported that they belong to a sports club and approximately one quarter of the participants did not belong to any sports club. The age range was 10–18 years among both the members of the sports club ($M = 12.45$ years, $SD = 1.94$) and those who are not members ($M = 12.45$ years, $SD = 1.95$), and their mean age was almost identical ($M_{all} = 12.45$ years, $SD_{all} = 1.94$ years). The sample was uneven regarding year groups.[1]

Measures

Positive and Negative Affects

Among other measurements (height, body mass, and physical fitness level), participants were requested to describe how much they experienced a set of positive and negative emotions in the past 3 or 4 days. The survey was completed 30 min after a physical fitness test. Seven adjectives described negative affects: *angry, sad, anxious, ashamed, guilty, annoyed*, and *worried*; five described positive ones: *joyful, enthusiastic, proud, full-of-energy*, and *happy*. Responses were provided on a five-point Likert scale ranging from 1 (not at all) to 5 (very much).[2]

Sports Club Participation

Before the assessment of physical fitness level and after the measurements of height and weight, the participants responded to the following question: "Are you a member of a sports club?" Respondents could answer this question with a simple "yes" or "no." If the answer was "yes," they could report the sport they practiced the most often.

[1]Eleven-year-old teens were overrepresented (39.92%), while the 17 years old were underrepresented (2.50%), while the other age groups were the following: 10 years old 4.44%, 12 year old 21.43%, 13 year old 9.81%, 14 years old 7.10%, 15 years old 7.77%, 16 years old 4.19%, and 17 years old 2.82%.

[2]Our items are very similar to other well-established instruments, such as the Multiple Affect Adjective Check List (Zuckerman and Lubin, 1965), the Profile of Mood States (McNair et al., 1971), and the PANAS (Watson and Clark, 1988).

RESULTS

Analytic Strategy

We examined the effect of sports club participation and its interaction with age (as a continuous variable) on the positive and negative affects in separate models. For this purpose, OLS regressions were conducted with using R [as well as for plotting the figure (ggplot2)]. The data met the assumption of independent errors (Negative Durbin-Watson value = 1.76 and Positive Durbin-Watson value = 1.90). The histogram of standardized residuals showed that in both the positive and negative affect models, the data included approximately normally distributed errors. It was also the case regarding the normal P–P plots of standardized residuals. In the positive affect plot, points at the two extremes of age were not completely on the line, but close. Finally, both the positive and negative scatterplots of standardized residuals indicated that the data met the assumptions of homogeneity of variance and linearity.

Psychometric Properties of the Affect Measures

We supposed that the 12 items belong to two factors. Based on an exploratory factor analysis, conducted in R with varimax method as the two factors were almost independent ($r = 0.15$), indicating two sharply separate factors (positive loadings ranged between 0.45 and 0.72; negative loadings range between 0.66 and 0.85, with the largest cross-loading of 0.13), a confirmatory factor analysis was conducted (in R, lavaan) with two first-ordered factors, with robust maximum likelihood estimator.

Main Results

Negative Affect

Adolescents who did not belong to any sports clubs experienced more negative affects then their peers belonging to a sports club, $\beta = -0.09$, $t(17{,}337) = -4.33$, 95%CI (−0.13; −0.04), $p < 0.001$, $d = 0.09$. However, the interaction between age and sports club participation was not significant ($p = 0.503$), $R^2 = 0.003$ see **Figure 1A**.

Positive Affect

Those respondents who indicated their sports club participation, experienced more positive affects in the few days before the assessment than their peers, $\beta = 0.20$, 95%CI (0.16; 0.24), $t(17{,}337) = 9.83$, $p < 0.001$, $d = 0.20$. Age also had a negative main effect on positive affect, $\beta = -0.52$, 95%CI (−0.60; −0.45), $t(17{,}337) = -13.66$, $p < 0.001$, $d = 0.52$. Examination of the interaction revealed that the sports club membership was associated with higher levels of positive affect among late adolescents than early adolescents (compared to those who do not belong to any sports clubs), $\beta = 0.18$, $t(17{,}337) = 3.95$, 95%CI (0.09; 0.26), $p < 0.001$, $d = 0.18$, $R^2 = 0.029$, see **Figure 1B**. With using Fisher's r-to-z comparison, we found that the negative relationship between age and positive affect was stronger ($z = 4.89$, $p < 0.001$) among students who do not belong to sports

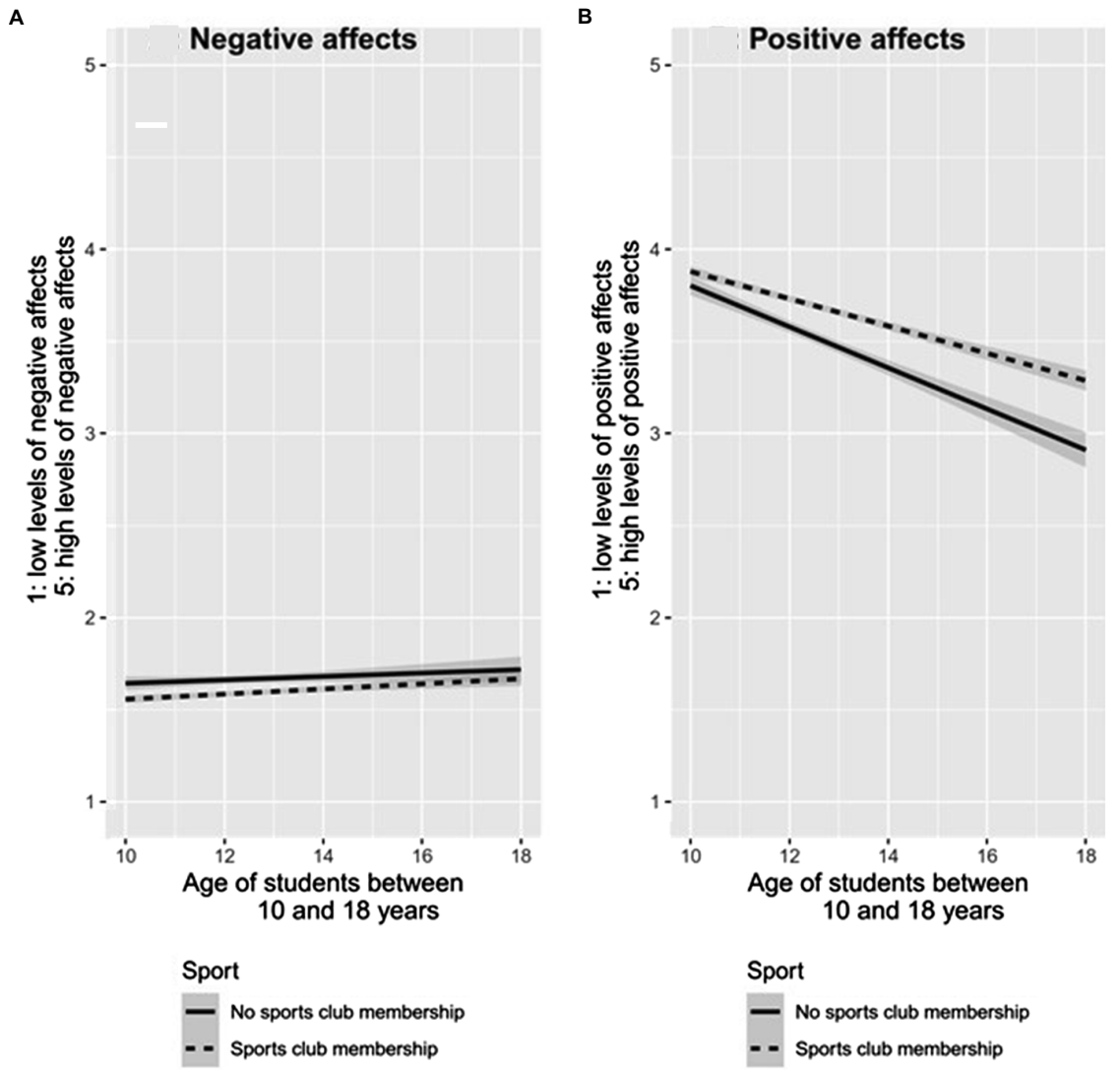

FIGURE 1 | Negative and positive affects along sports club membership and age of adolescents. The left panel **(A)** depicts negative affect-related results, and it indicates a significant main effect of the sports club membership. The right panel **(B)** depicts the main effect of the sports club membership on positive affects, as well as its interaction with the age of the students showing that late adolescents experience more positive emotions than early adolescents if they belong to a sports club (compared to the lack of membership).

clubs ($\beta = 0.52$, $t = -13.40$, $p < 0.001$) compared to their peers who belong to sports clubs ($\beta = -0.35$, $t = -15.52$, $p < 0.001$).

DISCUSSION

Being a member of a sports club during adolescence has tremendous benefits as it is associated with enhanced social competence, a better health profile, and with more positive emotions and less negative ones (Brettschneider, 2001; Howie et al., 2010; Eime et al., 2013; Gisladottir et al., 2013a). Considering these solid prior results, our main goal was to examine a missing piece in the relevant literature at what age can adolescents benefit the most emotionally from sports club membership? Potential affective benefits for late adolescents—that the present results suggest—can be especially relevant, as many career and life decisions must be made in this period. In the following, we aim to provide some explanations for this effect, discuss some nuances, highlight some limitations, and propose some questions for future studies focusing on this topic.

The positive emotional balance deriving from practicing sports can be interpreted in the light of the broaden-and-build theory of Fredrickson (1998, 2001). More precisely, according to this theory, positive emotions can accumulate and build enduring resources over time. They can also create a spiral leading to an increased likelihood of experiencing further positive emotions in the future. For example, when adolescents are experiencing positive emotions, they become more resilient

in coping with potentially emerging negative feelings. Therefore, it is possible that the affective benefits deriving from sports club membership can not only serve as a source of positive emotions, but also as an antidote to negative emotions.

The framework of the broaden-and-build theory can be connected to prior sport-related results. For example, adolescents engaged in a sports club progressively develop a positive physical self-image as the result of their satisfying body-related experiences, progress in motor control, and sport-related successes (Bowker, 2006; Gomez-Baya et al., 2019). The increased physical self-image can be also linked to physical competence and can also become a key component of global self-esteem (Marsh, 1986; Sonstroem, 1997; Fox, 2000; Richman and Shaffer, 2000; Bowker, 2006; Chen et al., 2012). To put it simply, such a potential chain reaction of physical activities makes adolescents feel good about themselves. It is possible that broad-scale positive effects do not happen overnight and require years of practice. Until now, we only discussed individual characteristics and aspects; however, adolescents are fundamentally social, and these sports club-related benefits can have an effect on their functioning in their social groups, as well.

The explanation of the broaden-and-build theory can be extended to the social aspects of physical activity, such as the sports club context. Within sports clubs, among various experiences, positive affects can be socially shared and can reinforce the bonds between club members (Rimé, 2009). In a recent study, Brown and Fredrickson (2021) put emphasis on co-experiencing positive emotions. Compared to emotions experienced individually, such collective experiences can lead to greater longevity and magnitude of the positive affects. Besides these immediate effects, teens can gradually develop a network of friends in a sports club that can prevent them from feeling lonely. Findlay and Coplan (2008) suggested that sports club participation may play a unique protective role for shy individuals who have difficulties initiating contact with peers. The social context of the sports clubs might not only increase the sense of belonging (Baumeister and Leary, 1995), but also it can serve as a "training ground" for developing social competencies (e.g., Bedard et al., 2020). Moreover, it appears that along with other competencies, social skills acquired in the sports clubs can help teens find their ways adaptively in their future lives (Fraser-Thomas and Côté, 2009; Strachan and Davies, 2015). The social benefits of a sports club membership can contribute to the recursive processes deriving from the broaden-and-build theory of Fredrickson (1998, 2001). Similarly, to the above-mentioned intra-individual benefits, social benefits also require time that can explain why late adolescents benefit most from sports club membership.

Normally, the adolescents' life becomes more complicated over the teenage years. For example, Britni et al. (2021) found that prevalence of behavioral problems and internalizing disorders, such as anxiety or depression, emerge more frequently in the later years of adolescence. Slobodskaya (2021) found that over the years, adolescents become more aware of their environmental demands. In the later part of adolescence, teens might need more resources to cope with these progressively increasing difficulties. Sports clubs can provide opportunities to build both relevant and useful resources. However, it seems reasonable that utilizing the benefits of the sports club (e.g., positive self-esteem, belonging, and social support) requires time, and when the perceived difficulties peak in late adolescence they should be available.

One of the surprising findings was not observing an interaction of age and sports club membership regarding the negative affects. Based on the prior literature (Sabiston et al., 2016; Doré et al., 2019) and based on the broaden-and-build theory, one could expect that over the years of adolescence, teens belonging to sports clubs will report less and less daily negative affects compared to their non-sportive peers. Further research is needed to explore the potential reasons. One of the potential explanations might be that sports club membership can reduce the feelings of sadness, anxiety, or worries during adolescence equally. The beneficial effect of sports club membership can be hardly accumulated over the years as academic and social challenges increase in parallel with the passing years and sport activities can only maintain their affective benefits without any visible accumulation.

Limitations

This study has some limitations. First, regarding information on sports club practice, we only know whether the adolescents practiced in a sports club or not. No further information was collected on the number of training sessions per week, the level of practice in competition, and the number of years of practice. However, if they belonged to multiple clubs simultaneously, they were requested to indicate the one they spent the most time practicing with. All this information should be incorporated in future studies. In addition, the distribution between year groups was uneven and it was not controlled for in the analysis. Second, regarding every single student, affects were surveyed 30 min after a physical fitness assessment that could have possibly—although homogeneously—influence the retrieval and evaluation of respondents' affects regarding the previous few days. Although our affect measure showed consistent factor structure and great internal consistency. We have to mention that the temporal stability of the positive and negative factors of the affect measure has not been investigated yet. Future work might either use a more commonly utilized measure or it is also possible to validate this measure. It is also possible that future studies might try to use ecological momentary assessment (Trull and Ebner-Priemer, 2013) if they are interested in short term and less pervasive benefits. The relatively low explained variances of the regression models can also be considered as a limitation of this study.

CONCLUSION

In sum, it appears that in the light of the present and prior results, the "Build-and-Broaden Theory" of Fredrickson can

provide some hints about the reasons why sports club membership contributes to more positive affects in late adolescence than early adolescence. This theory describes the form of positive emotions as to broaden awareness and their function as to build resources. To confirm these results, further studies with longitudinal and experimental methods are required that could appropriately measure the accumulation of potential affective benefits over time. This is not the only limitation of the present work. Alternatively, the use of other more recognized tools measures should also demonstrate the present results. It would be useful to consider the teens' level of advancement in their sports club. It is also possible that certain sports have more, and others have less intra-individual and inter-individual affective benefits. Future studies could not only distinguish between these effects, but they can also examine teens' different trajectories of development and the impact of sports club memberships on the affective landscape of various students. In sum, it appears that the present study only found a reasonable interaction effect; however, further studies are required to explain these preliminary results in detail.

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 Institutional Review Board of 00012476–2021-28-05-109. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

CA, AB, AC, JC, HO, and GO contributed to the study design, literature review, data gathering, manuscript writing, data analyses, and interpretation. 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.

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Emotional Reactivity and Emotion Regulation Among Young Adults During COVID-19 Lockdown: The Moderating Role of Gender and Engagement in Sports

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The effects of the COVID-19 pandemic on mental health have not been fully inspected among the young adults' population. The objectives of the present study were: (1) to examine differences in emotional reactivity and emotion regulation between, both gender and sports engagement level during the first 2 weeks of the lockdown; and (2) to examine the possible impact of emotion regulation on emotional reactivity, and possible significant roles of gender and sports engagement level as moderators. This cross-sectional study included 315 Serbian young adults (aged 18–26 years old) during COVID-19 lockdown. Respondents answered socio-demographic questions and the Serbian version of the Multidimensional Emotion Questionnaire (MEQ). The results of confirmatory factor analysis indicated good fit for both positive and negative reactivity scales (SRMR = 0.037; CFI = 0.984, RMSEA = 0.046, and SRMR = 0.055; CFI = 0.964, RMSEA = 0.064, respectively). Gender differences were found in both positive (p = 0.039; d = 0.28) and negative emotional reactivity scales ($p < 0.001$; d = 0.60), with females reported lower and higher values, respectively. Professional athletes presented higher scores in positive reactivity scale in comparison to non-athletes ($p < 0.001$; d = 0.78) and recreational athletes (p = 0.034; d = 0.34) during 2 weeks of COVID-19 lockdown. Conversely, professional athletes scored lower in negative emotional reactivity scale in comparison to non-athletes ($p < 0.001$; d = 0.85) and recreational athletes (p = 0.006; d = 0.42). Both gender and sports engagement level differences were found for negative, but not for positive emotion regulation scale. Furthermore, results showed that engagement in sports level plays a significant role as moderator in relationship between negative regulation and negative reactivity, where professional athletes presented significant interaction effect and predicted lower

negative reactivity scores compared to non-athletes and recreational athletes. However, gender does not moderate the influence of emotion regulation on emotional reactivity either positive or negative. Engagement in sports as a lifestyle may contribute to better emotional harmony especially in the crisis situation as COVID-19 lockdown.

Keywords: emotion regulation, emotional reactivity, COVID-19, lockdown, gender differences, physical activity, sport

INTRODUCTION

The COVID-19 pandemic as a global health crisis has affected not only general health but also everyday life (Restubog et al., 2020). Despite the belief that they could not potentially develop serious symptoms of the disease, young adults in Serbia were aware of the seriousness of the public health situation. The importance of physical distancing has been enlarged by the influence of national health experts and government officials through television broadcasting. Thus, information about a potential epidemiological catastrophe could influence the development of protective patterns, which may result in increased physical distancing and self-isolation (Cvetković et al., 2020). Disease outbreaks not only negatively affect daily activities but can also cause acute and long-term negative effects on overall well-being (Holmes et al., 2020). Although, it is well known that engagement in sport or physical activity has many benefits on psychological well-being, imposed social distancing measures led to significant decrease in physical activity levels (Blazevic et al., 2021). Therefore, the consequences are not only economical and physical but can also affect mental health (Restubog et al., 2020). The negative psychological consequences that people encounter the most are anxiety (Hyland et al., 2020), psychological distress and depression, and reduced quality of life (Šakan et al., 2020). These emotional responses are adaptive following a crisis, as long as the ability to live a balanced life remains intact (Panayiotou et al., 2021). However, some evidence suggests that the COVID-19 pandemic has a negative impact on the overall quality of life (Solomou and Constantinidou, 2020). Recently, Zovko and Budler (2021) emphasized that moderate physical activity is one of the best stress management methods and recommended that all healthy individuals should practice moderate-intensity exercise of all types during pandemic crisis. Emotion regulation is an important factor that could influence the extent of the negative impact of a pandemic on overall well-being and involves the conscious or unconscious efforts to influence the experience, expression, duration, and magnitude of emotions (Gross, 2002, 2015). However, although different constructs, emotion regulation cannot be separated from emotional reactivity. Emotional reactivity refers to the processes that determine the nature and strength of an individual's unaltered emotional response (Gross, 2002). According to Klonsky et al. (2019), emotional reactivity consists of sensitivity, intensity, and persistence of the emotional response. Sensitivity refers to the magnitude of stimulus required to induce an emotional response, and determine how frequently an emotional response is triggered. Intensity refers to the magnitude of the emotional response when it occurs. Persistence refers to how long the emotional response lasts before recovery to baseline. Moreover, Tracy et al. (2014) argue that increased reactivity could be explained in terms of decreased regulation, and vice versa. Recently, Klonsky et al. (2019) developed the Multidimensional Emotion Questionnaire (MEQ), a single inventory to assess both emotional reactivity and emotion regulation. However, it remains unclear whether MEQ could potentially differentiate emotional reactivity and emotion regulation regarding gender. Some studies emphasize that there are differences in the emotional reactivity and emotion regulation between females and males (Gross and John, 2003; Mackiewicz et al., 2006; Nitschke et al., 2006; McRae et al., 2008; Domes et al., 2010; Gardener et al., 2013; Zimmermann and Iwanski, 2014; Costa et al., 2020), while others failed to support this statement (Gross, 2002, 2015; Domes et al., 2010; Lane et al., 2011). A possible explanation for such diversity in emotional responding could be a function of two dissociable processes: emotional reactivity and emotion regulation (McRae et al., 2008). If so, gender or engagement in sport differences in emotional responding could arise either from differences of actual emotional reactivity, or from differences in how those emotions are regulated, or either both. Based on previous statements, gender differences in emotion regulation and emotional reactivity requires further explanation. On the other hand, several studies confirmed that athletes have higher dispositional hope (Curry et al., 1997), optimism (Nicholls et al., 2008), perseverance (Laborde et al., 2014, 2016), resilience (Padesky and Mooney, 2012), and adaptive emotion regulation strategies (Lane et al., 2009, 2011; Laborde et al., 2014; Doorley and Kashdan, 2021). Furthermore, it has been reported that professional athletes had better mental health status than non-athletes (Şenışık et al., 2021) and showed lower negative emotional state values than expected average (Leguizamo et al., 2021) during COVID-19 lockdown. It should be noted, there were no previous studies to confirm if MEQ could differentiate emotion regulation and emotional reactivity based on engagement in sports (non-athletes, recreational athletes, and professional athletes). On this account, there is a gap in the literature in which different approaches could allow potential contribution to further explain emotion regulation and emotional reactivity and their interaction. Moreover, the interaction between emotion regulation and emotional reactivity could be moderated by both gender and engagement in sports. To our best knowledge, there were no previous studies that assessed such moderating role of both gender and engagement in sports during COVID-19 lockdown. Therefore, the objectives of the present study were: (1) to examine differences in emotional reactivity and emotion regulation between both gender and engagement in sports during the first 2 weeks

of the lockdown; and (2) to examine the possible interaction between emotion regulation on emotional reactivity, and whether there is the significant role of both gender and engagement in sports as moderators.

MATERIALS AND METHODS

Study Design and Procedures

This cross-sectional study was conducted 2 weeks after the lockdown imposed by the Republic of Serbia Government on March 15, 2020. The present study included young adults and employed a self-reported questionnaire assessing emotional reactivity and emotion regulation during COVID-19 lockdown. The questionnaire was adapted in Google forms, and the link was disseminated to the targeted population. To avoid duplications, respondents could provide only one response per Google account. The completion of the questionnaire was not limited by time. To ensure the complete honesty of the self-reported emotional reactivity and emotion regulation, respondents were informed that their answers would remain anonymous, and the results would be used only for research purposes. Participants who did not respond received an email reminder with a personalized link to the respective survey. The emails were sent at random time points throughout the day. Incompletely administered responses with ambiguous outcomes were not included in the further analysis. 315 responses out of 317 met the inclusion criteria for further analysis. The questionnaire was preceded by sociodemographic questions. Therefore, it was possible to examine differences and relationships between different categories (gender and engagement in sports). The procedures in this study were conducted according to the Declaration of Helsinki as a statement of ethical principle for research involving human subjects.

Participants

The sample was comprised of a total of 315 respondents, ranging from 18 to 26 years of age, from which 240 (76.2%) were females, and 75 (23.8%) were males. We should note, since this research was part of a more extensive research and data collection, the exact age of the respondents was not collected. The respondents had the option to choose which age range they belong to (18–26, 27–33, 34–39, 40–49, 50–65). Furthermore, respondents reported their engagement in sports, from which 65 (20.6%) were non-athletes, 159 (50.5%) were recreational athletes, and 91 (28.9%) were professional athletes. Within the e-mail of the attached questionnaire, the respondents were fully acquainted with the research procedure and informed that they could withdraw from the study at any time.

Measures

Multidimensional emotion questionnaire (MEQ). The MEQ (Klonsky et al., 2019) was used in the present study. The MEQ assesses five positive (happy, excited, enthusiastic, proud, and inspired) and five negative emotions (sad, afraid, angry, ashamed, and anxious). This questionnaire is composed of four types of emotional scales: (1) 10 discrete emotions, (2) three subcomponents of emotional reactivity (frequency, intensity, and persistence), (3) superordinate dimensions of emotional reactivity (positive and negative), and (4) regulation. Discrete emotions are not further presented in this study. However, relevant items for discrete emotions were used to form composite scores included in the further analysis. Subcomponents of emotional reactivity were calculated for positive frequency, positive intensity, positive persistence, negative frequency, negative intensity, and negative persistence by summing scores for the specific items. For example, the negative persistence subscale is formed by summing the persistence scores for sad, afraid, angry, ashamed, and anxious. Superordinate positive and negative emotionality scales, frequency, intensity, and persistence scores for positive emotions were summed to form an overall positive emotional reactivity score, and frequency, intensity, and persistence scores for negative emotions are summed to form an overall negative emotional reactivity score. Emotion regulation scores were calculated for positive emotion regulation and negative emotion regulation by summing scores for the specific items.

Statements were evaluated using a four-point Likert scale. The response options for each question were as follows: (1) How Often (about once each month, about once each week, about once each day, about 2–3 times each day, more than 3 times each day), (2) How Intense (very low, low, moderate, high, very high), (3) How Long-Lasting (less than 1 min, 1–10 min, 11–60 min, 1–4 h, longer than 4 h), and (4) How Easy to Regulate (very easy, easy, moderate, difficult, and very difficult).

For the purposes of this research, the Serbian version of the previously described inventory was created and employed. Therefore, it was necessary to evaluate the fit of the model for overall negative and positive emotion scales. The results of confirmatory factor analysis indicated good fit for both positive and negative reactivity scales (SRMR = 0.037; CFI = 0.984, RMSEA = 0.046, and SRMR = 0.055; CFI = 0.964, RMSEA = 0.064, respectively). This result is consistent with one provided in the original inventory (Klonsky et al., 2019). Internal consistency in this study for all scales and subscales proved to be good (median = 0.85; range 0.76–0.92).

Data Analysis

All data analyses were carried out using IBM SPSS Statistics (Version 23.0). Descriptive statistics were computed for all sociodemographic and study variables. Means, medians, standard deviations, frequencies, percentages, and Pearson's bivariate correlations where appropriate were computed to describe both categorical and continuous variables for the total sample. Confirmatory factor analysis (CFA) was performed to evaluate the fit for the Serbian version of MEQ items indexing both overall positive and negative emotions scales. Independent samples *t*-test was performed to assess the differences between gender (female vs. male) in continuous variables, and One-way ANOVA with Bonferroni *post hoc* analysis for the differences between groups of different levels of engagement in sports (non-athletes, recreational athletes, and professional athletes) during COVID-19 lockdown. Cohen's *d* analyses were performed to evaluate the effect size. According to Cohen's guidelines (Cohen, 1992), effect

size was interpreted as small (d = 0.2), medium (d = 0.5), and large (d = 0.8). A multiple moderation model was performed to examine if the relationship between emotion regulation and overall emotional reactivity was moderated by both gender and engagement in sports. The moderation effect was estimated using SPSS macro PROCESS (Model 2) for moderation based analysis (Hayes, 2017). Emotion regulation was used as the independent variable and overall emotional reactivity as the dependent variable. A bootstrapping procedure was used (with 10,000 resamples) in moderation based analysis. Significance was set at the 0.05 level.

RESULTS

Demographic characteristics of the sample are presented in **Table 1**.

Gender-associated variation showed significant differences among groups in negative frequency, intensity, and persistence subscales, as well as overall negative emotional reactivity and negative emotion regulation scales (see **Table 2**), with females presenting higher scores compared to males. Conversely, males presented significantly higher scores in positive frequency, intensity, and overall positive emotional reactivity. Small to moderate effects regarding gender were present in both positive and negative emotion regulation and emotional reactivity scales.

Variation associated with the engagement in sports showed significant differences among groups in negative emotion regulation and emotional reactivity (overall positive and negative) (see **Table 3**). Recreational athletes (Group 2) and professional athletes (Group 3) presented lower scores compared to non-athletes (Group 1) in both overall negative emotion regulation (Group 1 vs. Group 2, d = 0.41; Group 1 vs. Group 3, d = 0.82) and negative emotional reactivity scales (Group 1 vs. Group 2, d = 0.34; Group 1 vs. Group 3, d = 0.80) The professional athletes also presented lower scores compared to recreational athletes in both overall negative emotion regulation (Group 2 vs. Group 3, d = 0.36) and negative emotional reactivity scales (Group 2 vs. Group 3, d = 0.42). Furthermore, recreational athletes and professional athletes presented higher scores on the overall positive emotional reactivity scale compared to non-athletes (Group 1 vs. Group 2, d = 0.45; Group 1 vs. Group 3, d = 0.78). The professional athletes also presented higher scores in the overall positive emotional reactivity scale compared to recreational athletes (Group 2 vs. Group 3, d = 0.34). Interestingly, non-athletes presented higher scores of positive emotion regulation compared to recreational and professional athletes but non-significant.

We computed internal consistencies, intercorrelations, means, and standard deviations for the emotional reactivity subscales (see **Table 4**). Internal consistency for the emotional reactivity subscales ranged from good to very good, with a low of 0.76 for negative persistence and a high of 0.88 for positive regulation. Internal consistencies for both overall positive and negative scales were excellent (0.92 and 0.90). Intercorrelations for positive reactivity scales (median = 0.73; range 0.55–0.86) and among negative reactivity scales (median = 0.70; range 0.55–0.87) were positive and from medium to large magnitude. Mean scores are also reported in **Table 4**. However, it is important to note that means for different types of reactivity subscales are not comparable because the scales had different labels to reflect subscale content.

Emotion regulation, gender, and engagement in sports were used to predict emotional reactivity. Data were checked for outliers and assumptions of regression, and no violations were found. The PROCESS macro (Hayes, 2017) was used to center

TABLE 1 | Summary of demographic data (frequencies and percent).

	n (%)
Gender	
Men	75 (23.8)
Women	240 (76.2)
Engagement in sports	
Non-athletes	65 (20.6)
Recreational athletes	159 (50.5)
Professional athletes	91 (28.9)
PA during COVID-19 lockdown	
Non-athletes	
No PA	44 (67.7)
2–3 times per week	13 (20)
Once per day	8 (12.3)
Recreational athletes	
No PA	32 (20.1)
2–3 times per week	81 (50.9)
Once per day	46 (28.9)
Professional athletes	
No PA	16 (17.6)
2–3 times per week	41 (45.1)
Once per day	34 (37.4)
Living status during COVID-19 lockdown	
Single	20 (6.3)
With partner	6 (1.9)
With family members	289 (91.7)

TABLE 2 | Gender differences in positive and negative emotional reactivity and emotional regulation scales, Independent Samples Test.

	Male (n = 75)	Female (n = 240)	P (2-tailed)	Cohen's d
Positive frequency	16.16 ± 4.19	14.53 ± 4.30	0.004	0.38
Positive intensity	17.25 ± 4.11	15.78 ± 4.56	0.013	0.33
Positive persistence	14.37 ± 4.96	14.22 ± 4.64	0.840	0.03
Overall positive	47.76 ± 11.51	44.53 ± 11.87	0.037	0.27
Positive regulation	9.4 ± 4.61	8.99 ± 3.58	0.484	0.11
	Male (n = 75)	**Female (n = 240)**	**P (2-tailed)**	**Cohen's d**
Negative frequency	9.45 ± 3.39	11.49 ± 4.27	<0.001	0.50
Negative intensity	11.61 ± 3.56	13.23 ± 4.41	0.002	0.38
Negative persistence	10.09 ± 3.37	12.38 ± 3.96	<0.001	0.60
Overall negative	31.16 ± 8.63	37.09 ± 10.96	<0.001	0.57
Negative regulation	10.85 ± 4.09	13.90 ± 4.83	<0.001	0.65

TABLE 3 | Differences in positive and negative emotional reactivity and positive and negative emotion regulation between three levels of engagement in sport.

	Non-athletes (n = 69) Group 1 Mean ± SD	Recreational athletes (n = 159) Group 2 Mean ± SD	Professional athletes (n = 91) Group 3 Mean ± SD	F	*Post-hoc*
OP	40.06 ± 12.26	45.26 ± 11.29	49.10 ± 11.162	11.80**	1 < 2** 1 < 3** 2 < 3*
ON	39.94 ± 11.80	36.11 ± 10.77	31.88 ± 8.48	11.68**	1 > 2* 1 > 3** 2 > 3**
PR	9.28 ± 3.86	9.01 ± 3.73	9.09 ± 4.08	0.11	1 > 2 1 > 3 2 < 3
NR	15.23 ± 4.58	13.25 ± 4.90	11.57 ± 4.33	11.66**	1 > 2* 1 > 3** 2 > 3*

*OP, Overall Positive; ON, Overall Negative; PR, Positive Regulation; NR, Negative regulation; * and ** indicates statistical significance at alpha levels of 0.05 and 0.01, respectively.*

TABLE 4 | MEQ Emotional Reactivity and Emotional Regulation scales (intercorrelations, descriptive statistics, and coefficient alpha).

Scale	PF	PI	PP	NF	NI	NP	PR	NR	OP	ON	Mean (*SD*)	Alpha
PF	–	0.73	0.55	−0.25	−0.25	−0.30	−0.20	−0.35	0.86	−0.31	14.92 (4.33)	0.81
PI		–	0.67	−0.41	−0.15	−0.21	-0.09^{NS}	−0.28	0.91	−0.30	16.13 (4.49)	0.85
PP			–	−0.41	−0.29	0.03^{NS}	−0.13*	−0.21	0.85	−0.26	14.25 (4.71)	0.85
NF				–	0.70	0.55	0.15*	0.54	−0.41	0.87	11.01 (4.17)	0.79
NI					–	0.64	0.21	0.59	−0.26	0.90	12.84 (4.27)	0.78
NP						–	0.16	0.60	−0.18	0.83	11.83 (3.94)	0.76
PR							–	0.36	−0.16	0.20	9.09 (3.85)	0.88
NR								–	−0.32	0.67	13.17 (4.83)	0.86
OP									–	−0.33	45.40 (11.85)	0.92
ON										–	35.68 (10.74)	0.90

PF, Positive Frequency; PI, Positive Intensity; PP, Positive Persistence; NF, Negative Frequency; NI, Negative Intensity; NP, Negative Persistence; PR, Positive Regulation; NR, Negative Regulation; OP, Overall Positive; ON, Overall Negative.
*All correlations are statistically significant at alpha level of 0.01, except where * indicates significant correlations at alpha level of 0.05 and ^{NS} indicates non-significant correlations.*

variables, and analyze the interaction between emotion regulation and emotional reactivity.

The overall model of association between positive emotion regulation and overall positive emotional reactivity moderated by gender, and engagement in sports was significant, [$F_{(7,307)} = 5.11$, $p < 0.001$, $R^2 = 0.10$]. Test of the highest unconditional order interactions showed that the moderation of the effect of positive regulation by both gender (see **Figure 1**) and engagement in sports (see **Figure 1**) was not significant [$F_{(1,307)} = 2.94$, $p = 0.088$; $F_{(2,\ 307)} = 0.41$, $p = 0.661$], and uniquely accounts for 0.9 and 0.2% of the variance, respectively. However, it is apparent both from the estimate of positive regulation and gender interaction and conditional effect, that the effect of positive regulation on overall positive reactivity is in opposite direction larger for females than males. For female recreational athletes, there was a significant decrease in overall positive emotional reactivity score when emotion regulation score increased by one unit $b = -0.68$, $t = -2.55$, $p = 0.011$. Interestingly, female athletes showed the largest decrease in positive emotional reactivity scores when positive regulation scores are increased by one unit, $b = -0.88$, $t = -2.47$, $p = 0.014$.

The overall model of association between negative emotion regulation and overall negative emotional reactivity moderated by gender, and engagement in sports was significant, [$F_{(7,307)} = 38.04$, $p < 0.001$, $R^2 = 0.46$]. Test of the highest unconditional order interactions showed that the moderation of the effect of negative emotion regulation by engagement in sports was significant [$F_{(2,307)} = 3.07$, $p = 0.048$], and uniquely accounts for 1.1% of the variance. Conversely, moderating effect of gender was not significant [$F_{(2,307)} = 0.0006$, $p = 0.980$] (see **Figure 1**). Furthermore, it is apparent both from the estimate of negative regulation and engagement in sports interaction and conditional effect, that the effect of negative regulation on overall negative emotional reactivity is somewhat larger for non-athletes in comparison with recreational athletes and professional athletes. For female non-athletes and recreational athletes, there was a significant increase in overall negative emotional reactivity score when negative emotion regulation score is increased by one unit, $b = 1.81$, $t = 8.27$, $p < 0.01$ and $b = 1.41$, $t = 10.52$, $p < 0.01$, respectively. Female professional athletes showed the lowest increase in overall negative emotional reactivity scores when negative regulation scores increase by one unit, $b = 1.06$,

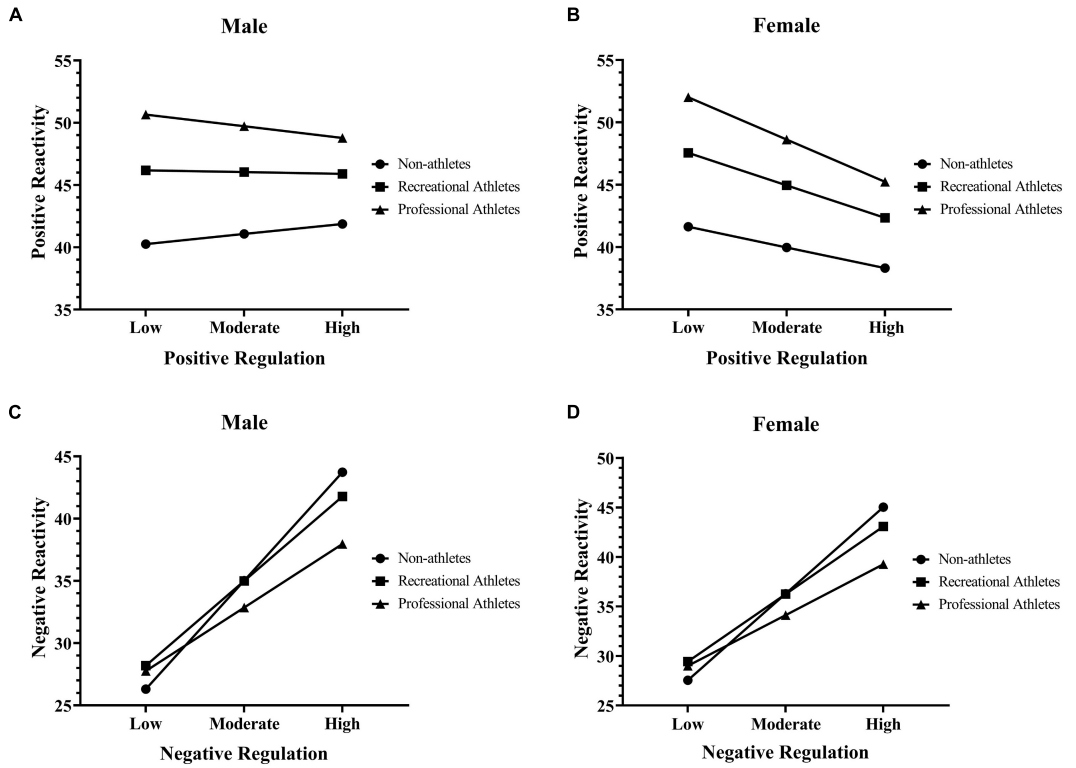

FIGURE 1 | The association between positive emotional regulation and emotional reactivity moderated by gender and engagement in sports **(A,B)**. The association between negative emotional regulation and emotional reactivity moderated by gender and engagement in sports **(C,D)**.

$t = 4.80$, $p < 0.01$ (see **Figure 1**). For male non-athletes and recreational athletes, there was a significant increase in overall negative emotional reactivity scores when negative emotion regulation scores increase by one unit $b = 1.80$, $t = 5.63$, $p < 0.01$ and $b = 1.41$, $t = 5.328$, $p < 0.01$, respectively. Male professional athletes showed the lowest increase in overall negative emotional scores when negative regulation scores are increased by one unit, $b = 1.06$, $t = 4.14$, $p < 0.01$ (see **Figure 1**).

DISCUSSION

The aim of this study was to evaluate the level of emotion regulation and emotional reactivity considering gender, engagement in sports level (non-athletes, recreational athletes, and professional athletes) in a sample of Serbian young adults during COVID-19 lockdown, and to inspect the moderating role of both gender and engagement in sports in the association between emotion regulation and emotional reactivity. Females presented lower values in positive frequency, positive intensity, and overall positive reactivity scores. Conversely, females presented higher values in negative frequency, negative intensity, negative persistence, and overall negative scores. Individuals who were classified as athletes presented lower scores in both negative emotion regulation and emotional reactivity scores, and higher scores in positive emotional reactivity subscale compared to individuals classified as non-athletes and recreational athletes. However, there were no differences between groups in positive emotion regulation scores. Moreover, lower levels of positive emotion regulation (higher scores) were negatively associated with overall positive emotional reactivity subscale, meaning that individuals with lower positive emotion regulation capabilities experience lower positive emotional reactivity. However, this association was not significantly moderated by both gender and engagement in sports level. Conversely, lower levels of negative emotion regulation (higher scores) were positively associated with overall negative emotional reactivity, meaning that individuals with lower negative emotion regulation capabilities experience higher negative emotional reactivity. This association was moderated by engagement in sports level, but not by gender.

Present study found significant differences across gender (see **Table 2**). Possible explanation for eventual differences could be that females are more likely to expect negative events regarding COVID-19 lockdown. These gender differences in emotion regulation strategies may be present due to the fact that females tend to express their emotions more than males (Gross and John, 2003), and this period of social isolation might have been an obstacle to this expressivity (Costa et al., 2020). Furthermore, previous studies have shown that anticipation of negative stimuli evokes emotional responses which are related to increased amygdala activity in females (Mackiewicz et al., 2006; Nitschke et al., 2006; McRae et al., 2008; Gardener et al., 2013). Domes et al. (2010) argue that women might attempt to downregulate their emotions as soon as the negative stimuli

appeared. Altogether, findings from above mentioned studies suggest that women have greater early emotional reactivity to negative stimuli, thus supporting a female negativity bias. However, initially enhanced emotional response in females could influence these attempts to be less effective in overall emotion regulation. These findings are consistent with the results of our study. Zimmermann and Iwanski (2014) argue that females report more social support seeking and dysfunctional rumination and males report more suppression, avoidance, and passivity. Apparently, physical distancing during COVID-19 lockdown could potentially have a greater negative impact on females, therefore present results are not surprising. However, we should be fully aware that making generalized statements, could potentially mask the real picture. For example, when we explore the moderating influence of gender on negative emotional reactivity, it is obvious that the conditional effects of the focal predictor at values of the moderator are very similar for female and male athletes in the present study (females: b = 1.06; males = b = 1.06). Similar trend could be seen across non-athletes (females: b = 1.81; males = b = 1.80) and recreational athletes (females: b = 1.41; males = b = 1.41). It seems that gender does not have a significant moderating effect in predicting the overall negative emotional reactivity. We argue that the research on gender differences in behavioral and neural responding to emotional stimuli is inconsistent, and it is not possible to draw a unanimous conclusion regarding this matter. One reason for the observed inconsistencies might be the fact that most studies could not differentiate between emotional reactivity and emotion regulation (Domes et al., 2010). We can support previous statement with the findings in our study. Although, the positive regulation scale demonstrated incremental prediction of a measure of emotion dysregulation beyond the MEQ's overall positive and negative emotional reactivity scales, negative regulation scale did not entirely. The negative regulation scale does indeed relate to emotion dysregulation, however, it correlated 0.69 with the negative reactivity scale, suggesting certain difficulty in distinguishing these constructs. These findings are consistent with the results of a recent study (Klonsky et al., 2019). Moreover, emotional responding has been conceptualized as interaction between emotional reactivity and emotion regulation, including reappraisal and suppression (Gross, 2002, 2015). It is possible that gender differences might be related to enhanced emotional reactivity and reduced emotion regulation regarding reappraisal. However, our study could not support these findings. As previously stated, although there were significant differences between males and females in our study (see **Table 2**), there was no interaction effect between negative emotional reactivity and emotion regulation moderated by gender (see **Figure 1**). It seems, that interaction effect among same entities (male vs. female non-athletes; male vs. female recreational athletes; male vs. female athletes) is not present based on the results of our study. Our results are consistent with the findings of a study conducted by Lane et al. (2011). These authors examined if there are any differences in emotion regulation between female and male athletes, and there were no significant findings to support that statement.

However, engagement in sport levels could have a valuable moderating effect. We argue that it is important that engagement in sports should be perceived as an important area for studying emotion, particularly as emotion regulation influence the daily life of athletes beyond training and competition. It is proposed that practitioners and researchers can identify moderating factors that could influence emotion regulation (Lane et al., 2011). Results of the present study showed that negative emotion regulation can predict negative emotional reactivity, and the moderating effect of engagement in sports is rather significant. This is very important in the context of physical distancing and self-isolation during pandemic outbreak like COVID-19. Zimmermann and Iwanski (2014) argue that the intensity and quality of the reported emotions are associated with the use of specific emotion regulation strategies, where the differential preferences of emotion regulation might be an indicator of emotion-specific activation and functionality of emotion regulation strategies. There are a few possible explanations why athletes scored better on both overall positive and negative reactivity subscales, and negative emotion regulation subscale. Athletes potentially have higher dispositional hope than non-athletes, which could impact overall performance (Curry et al., 1997). Moreover, participants involved in sports could be more optimistic (Nicholls et al., 2008), and athletes may develop perseverance in order to adjust to a specific environment (Guillén and Laborde, 2014; Laborde et al., 2016). Nonetheless, it seems possible that sport could develop resilience (Padesky and Mooney, 2012), and may provide the specific environment to develop this trait, because sport commonly confronts the athlete with unpleasant events. Costa et al. (2020) argued that athletes could potentially have more adaptive emotion regulation strategies to overcome negative emotions during COVID-19 lockdown. These regulatory strategies such as reappraisal and acceptance are explored less frequently among athletes in favor of studies focused on sport-specific coping and the effects of regulatory strategies on athletic performance (Lane et al., 2009, 2011; Laborde et al., 2014; Doorley and Kashdan, 2021). Athletes also have ability to improve and maintain savoring. Doorley and Kashdan (2021) argue that athletes and coaches are mainly focused on overcoming negative emotions in response to negative events than upregulating positive one. Authors emphasize that interventions like enhancing character strengths, gratitude, savoring, and compassion not only enhance positive emotions, but facilitate healthy responses to stress. However, the effectiveness of various emotion regulation strategies related to both positive and negative events in daily life, could be sport or non-sport related. Therefore, this matter should be explored in more detail.

There are several important study limitations and future directions. Although, the results of the present study showed that there is significant moderation role of engagement in sports, but the overall effect is rather small, therefore this issue should be investigated more thoroughly.

Being engaged in physical activity and regular exercise during COVID-19 lockdown may have attenuated the differences amongst individuals of different level of engagement in sports (non-athletes, recreational athletes, and professional athletes). It is hypothesized that regular physical activity and exercise have been related to numerous mental benefits, including improved mental well-being (Mandolesi et al., 2018; Frontini et al., 2021;

Sokić et al., 2021). The results from the demographic data in our study indicate that professional athletes were engaged in more frequent PA and exercise (see **Table 1**). However, these results cannot provide credible evidence, because the self-reported measures of physical activity in presented form is highly speculative and unreliable. Therefore, this variable was not included in the further analysis. Moreover, the present study did not examine the discrepancy between optimal emotion regulation and emotional reactivity relative to COVID-19 lockdown conditions. Therefore, we were not able to find cause-and-effect about the influence of lockdown on emotion regulation and emotional reactivity. Future studies should explore changes in optimal emotion regulation and emotional reactivity and individual's coping strategies to upregulate and down-regulate emotions during COVID-19 lockdown. For example, if current emotional intensity is lower than optimal, than it should be upp-regulated, possibly by using strategies like reappraisal to decrease negative and increase positive emotions (Gross, 2002). Therefore, it is possible to examine whether the interaction between emotion regulation and emotional reactivity is moderated by engagement in sports and gender or related to the individual's ability to overcome negative emotions regardless of engagement in sports and gender.

Finally, we should point out that the most of our respondents were surrounded with their family members (91.7%) during COVID-19 lockdown. Holmes et al. (2020) argue that physical isolation could cause unpleasant emotions which could be associated with altered stress, anxiety, and depression. However, the physical isolation could be compensated by altering positive family interactions, and therefore generating resilience to diminish the stressful circumstances (Holmes et al., 2020). This is important to note, because it is possible that emotion regulation strategies in conditions of self-isolation could be different, and more dependent on one's own ability to regulate emotions. Therefore, interaction between emotion regulation and emotional reactivity moderated by engagement in sports level during pandemic outbreak, could not entirely be explained based on data provided in the present study. Van Bavel et al. (2020) argue that term "social distancing" should be replaced with "physical distancing" because social interaction could be maintained even when individuals are physically separated. This statement should be highly considered before drawing any decisive conclusions.

CONCLUSION

In order to explore interaction between emotion regulation and emotional reactivity it was necessary to examine are there any differences regarding gender and engagement in sports, or any possible moderating effect of both gender and engagement in sports. Based on findings in the present study we were able to support that female individuals tend to present higher scores in both negative emotion regulation and emotional reactivity subscales. Moreover, it seems that professional athletes have a greater capability to regulate negative emotions than non-athletes and recreational athletes. Furthermore, results of our study proved that engagement in sports has a significant, yet small moderating effect, where professional athletes presented significant interaction effect and predicted lower negative reactivity scores compared to non-athletes and recreational athletes. However, based on our findings, gender does not moderate the relationship between either positive or negative emotion regulation on emotional reactivity, therefore this matter should be explored in more detail. We emphasize that engagement in sports as a lifestyle can contribute to better emotional harmony especially in the crisis situation as COVID-19 lockdown. The present study may contribute to improve mental health by stressing the importance of engagement in sports during COVID-19. However, more research on this matter is required. Future studies should explore daily changes in optimal emotional reactivity and emotion regulation and individual's coping strategies to upp-regulate and down-regulate emotions during COVID-19 lockdown.

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. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

MM was the leader of the research group that conducted the study and organized the database. MM, NS, DS, MŽ, DA, GT, and VM contributed to the conception and design of the study. MM, NS, and DS performed the statistical analysis and wrote the first draft of the manuscript. MŽ, DA, GT, and VM reviewed and edited the first draft. All authors contributed to the article and approved the submitted version.

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The Influence of Chinese College Students' Physical Exercise on Life Satisfaction: The Chain Mediation Effect of Core Self-evaluation and Positive Emotion

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Physical exercise is an important way for college students to maintain their physical health, and life satisfaction is one of the important indicators of college students' mental health. Therefore, this study aims to explore the relationship between physical exercise and life satisfaction of college students. Additionally, we also seek to demonstrate the chain mediating effects of core self-evaluation and positive emotion on this relationship. A total of 794 Chinese college students, 324 men and 470 women, participated in the study. The participants were 17–25 years old (M = 19.96 ± 1.54). They completed the Exercise Adherence Questionnaire, Core Self-evaluation Scale, Positive Affect and Negative Affect Scale, and Satisfaction with Life Scale. Results showed a strong positive relationship between physical exercise and life satisfaction and verified the mediating effect of core self-evaluation and positive emotion on this relationship. The results also confirmed the chain mediating model between physical exercise, core self-evaluation, positive emotion, and life satisfaction. It enlightens us that we should pay more attention to the organic combination of students' physical activities and mental health education.

Keywords: physical exercise, core self-evaluation, positive emotion, life satisfaction, college students

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INTRODUCTION

As the backbone of social development, college students' physical and mental health is very important. In health studies, life satisfaction is an individual's perception and evaluation of his or her overall life quality (Dew and Huebner, 1994), which is an important indicator to predict individual health level. Generally, individuals' comprehensive health increases with the level of satisfaction that have toward their current life state (Chapman et al., 2019). Physical exercise is one of the main ways for college students to maintain their physical and mental health. It refers to the physical activities with certain intensity, frequency, and time that individuals carry out in their spare time for the main purpose of health (Song, 2001). Many studies have shown that physical exercise has a positive protective effect on the level of individual cardiopulmonary level, muscle tissue, and brain cognition, and has a good therapeutic effect on metabolic diseases (Sarmento et al., 2017; Leal et al., 2018; Hernandez et al., 2019;

Borges et al., 2020). So does physical exercise affect life satisfaction? Although few studies have directly examined the relationship between physical exercise and life satisfaction, a number of studies have examined the positive effects of physical exercise on mental health. For example, moderate physical exercise can promote the improvement of individual psychological regulation ability, reduce the level of depression and anxiety, and can significantly improve the individual's quality of life (Kvam et al., 2016; Frederiksen et al., 2021; Nguyen et al., 2021). When individuals are physically healthy, emotionally sound and have a high quality of life, they may also be more satisfied with their current life. In other words, physical activity may be an important factor in life satisfaction. Does physical activity affect life satisfaction through other factors?

We hypothesized that core self-evaluation may be an important mediator variable. Core self-evaluation is an integrated personality trait that includes self-esteem, control point, neuroticism, and general self-efficacy and constitutes a basic self-evaluation (Judge and Bono, 2001). For one thing, physical exercise may have an impact on core self-evaluation. A previous study conducted a self-report questionnaire survey on 326 adolescents and found that cultivating an active lifestyle through physical exercise promotes self-esteem more than reducing bad habits (Pazzaglia et al., 2020). Self-esteem is expressed by individuals through attitudes, language, and behaviors and through subjective evaluation of their own abilities, values, and meanings. Through physical exercise, college students can not only improve their physical fitness and enhance their satisfaction with their body self-image, but also gain friendship and gain recognition from others in the process of physical exercise, and then improve their self-esteem. And self-esteem is an important part of core self-evaluation, so physical exercise can also improve the level of core self-evaluation of college students (Ma and Liu, 2015). For another, core self-evaluation can have an impact on life satisfaction. For example, in a study of 319 students aged 17 to 21, the results showed that emotional intelligence and core self-evaluation explained 34% of the difference in life satisfaction, indicating that when adolescents' core self-evaluation increased, their life satisfaction also increased (Esin et al., 2016). Other researchers verified that core self-evaluation is an important predictor of life satisfaction and further revealed its internal mechanism (Zhou and Xuan, 2015). In conclusion, both physical exercise and core self-evaluation can affect life satisfaction, while physical exercise can predict core self-evaluation. Therefore, core self-evaluation may play an important intermediary role between physical exercise and life satisfaction.

We hypothesized that positive emotion might be another important mediator. Positive emotion is short-term experiences that can cause changes in people's thoughts, actions, and psychological reactions (Fredrickson and Branigan, 2005). Research on physical exercise and positive emotion shows that physical exercise not only helps improve individual muscle stiffness and promote metabolism but also can effectively relieve individual stress and increase individual positive emotional performance (Brett et al., 2016; Aguirre-Loaiza et al., 2019). In terms of the relationship between positive emotion and life satisfaction, researchers found that positive emotion had a significant predictive effect on life satisfaction, and school students with higher positive emotional experiences also experienced higher life satisfaction (Datu and King, 2016). Emotions are an indispensable part of an individual's daily life experience. College students who often express positive emotional experiences will develop positive and optimistic attitudes. Even if they encounter negative life events, they are more likely to adopt positive coping methods to deal with problems, enhance the acceptability of negative events, and thus improve the level of life satisfaction (Jiang et al., 2021). It means that physical exercise can improve an individual's life satisfaction by promoting the expression of positive emotion. Therefore, positive emotion may also be an important mediator between physical exercise and life satisfaction.

Although the above analysis shows that core self-evaluation and positive emotion may mediate the relationship between college students' physical exercise and life satisfaction, this study holds that they do not simply play an independent mediating role but may also have a chain mediation effect. In the definition of core self-evaluation proposed by Judge, general self-efficacy is an important part of core self-evaluation. General self-efficacy consists of four aspects, namely, performance achievement, alternative experience, verbal persuasion, and physiological state (Bandura, 1977). In a study looking at what parents can do to promote healthy development in their children, it was found that when parents help children develop higher levels of general self-efficacy, children will show more positive emotion. Individuals' general self-efficacy is an important cognitive resource. Individuals with low self-efficacy tend to overestimate the difficulty of the problem when completing tasks, which leads to anxiety and a higher level of psychological pressure and negative emotion. In contrast, when individuals with high self-efficacy face pressure due to highly challenging events, a high level of self-efficacy can stimulate their self-motivation to overcome difficulties, effectively help them relieve the negative impact caused by stress, and increase their positive and optimistic emotions. Fu and Tremayne found a significant relationship between healthy behaviors, self-efficacy, and positive emotion. The stronger the sense of self-efficacy, the more healthy behaviors and the more significant positive emotion expressed (Fu and Tremayne, 2021). Students with high self-efficacy generally exhibit more healthy behaviors, which is conducive to developing healthy living habits, promotes improvements in life quality, and thus is more conducive to positive emotional experiences (Hascher and Hagenauer, 2016). Therefore, we speculate that core self-assessment can influence life satisfaction through positive emotion.

In summary, this study constructed a chain mediation model between physical exercise and life satisfaction, in order to explore the relationship between physical exercise and life satisfaction and its internal mechanism. Thus, we hypothesized that as:

> *Hypothesis 1*: Physical exercise would be positively associated with core self-evaluation, positive emotion, and life satisfaction.

Hypothesis 2: In the influence mechanism of college students' physical exercise on life satisfaction, the core self-evaluation and positive emotion play a mediating role, respectively, and there is a chain mediating effect from core self-evaluation to positive emotion.

MATERIALS AND METHODS

Participants and Procedures

Participants were undergraduate college students recruited from two colleges and universities (one key and one regular) in western China. We adopted a cluster random sampling method and selected 16 classes (two classes in each grade of two universities) to conduct a questionnaire survey. A total of 860 questionnaires were collected, and 794 valid questionnaires were left after excluding those that were not answered seriously or not standardized. Among them, 429 students are from key universities, with 130, 108, 101, and 90 students from first grade to senior grade, 140 boys, and 289 girls. The other students are from regular universities, with 105, 102, 82, and 76 students from first grade to senior grade, 184 boys, and 181 girls. All the students were aged from 17 to 25 years old ($M = 19.96 \pm 1.54$).

This study was approved by the Research Ethics Committee of Chinese Southwest University. Prior to the study, we contacted the administrators of the participating schools, obtained permission for the questionnaire test and the informed consent of the students themselves. All students participated in the survey voluntarily.

Measures

Physical Exercise

Physical exercise was measured by the Exercise Adherence Questionnaire (Wang et al., 2016). This scale contains 14 items. It measures amateur physical exercise in three dimensions, including effort input (for example, "Regardless of whether I like physical exercise, I will do my best to complete it every time."), emotional experience (for example, "I feel refreshed physically and mentally after exercise."), and behavioral habits (for example, "I have been exercising regularly for at least 6 months."). The scale measures the individual's actual exercise behavior and subjective experience after exercise and has good reliability and validity. Each item was rated on a 5-point scale (1 = totally disagree and 5 = totally agree), with higher scores indicating more adequate physical exercise. In this study, Cronbach's α was 0.95 for the total scale and ranged from 0.87 to 0.91 for the subscales.

Core Self-Evaluation

Core self-evaluation was measured by the Core Self-evaluation Scale (Judge and Bono, 2001). The scale has good reliability and validity under the Chinese cultural background (Gu and Wen, 2014). The Core Self-evaluation Scale includes 10 items covering four personality traits: self-esteem, control points, neuroticism, and general self-efficacy. A 4-point scale was used for scoring (completely disagree = 1 and completely agree = 4). The Cronbach's α coefficient in this study was 0.85.

Positive Emotion

Positive emotion was measured by the positive affect and negative affect scale (PANAS) compiled by Watson (Watson et al., 1988). This scale contains a 10-item subscale of positive emotion and a 10-item subscale of negative emotion. Each item was rated on a 5-point scale (1 = none of the time and 5 = most of the time), with higher scores indicating more positive emotional experiences. The PANAS has been shown to have high reliability and validity in the Chinese school environment (Guo and Gan, 2010). The Cronbach's α coefficient in this study was 0.90.

Life Satisfaction

Life satisfaction was measured by the Satisfaction with Life Scale compiled (Diener et al., 1985). Individuals evaluate their overall life satisfaction. This scale contains 5 items measured using a 7-point rating scale from 1 (completely nonconformance) to 7 (completely conforming), with higher scores indicating higher life satisfaction. This scale is suitable for use with adolescents in the Chinese school environment, and the reliability of the whole scale is excellent (Xiong and Xu, 2009). The Cronbach's α coefficient in this study was 0.85.

Analytic Strategy

The study used SPSS 22.0 and the Process plug-in to analyze the data and used Process model 6 to test the chain mediation model. For the significance test of the regression coefficient, the bootstrapping method with 5,000 repeated samples was selected to obtain a robust standard error and a 95% deviation-corrected confidence interval (CI). When the CI does not contain zero, the effect is significant.

At the beginning of the data analysis, we used Harman's single-factor test to explore whether there may be common method biases in this study. The results showed that there were seven factors with eigenvalues greater than 1; among these, the largest factor explained 32.26% of the variance, less than the critical range of 40%. Therefore, we believe that the possibility of common method biases in this study is relatively small.

RESULTS

Descriptive Statistics and Analysis of the Correlations Between Variables

Descriptive statistics and correlation analysis were conducted for each variable. As shown in **Table 1**, there was a significant positive correlation between physical exercise, core self-evaluation, positive emotion, and life satisfaction.

TABLE 1 | Descriptive statistics and interrelations among all observed variables.

Variables	*M*	SD	1	2	3	4
1 Physical exercise	49.78	11.66	–			
2 Core self-evaluation	33.49	6.20	0.25***	–		
3 Positive emotion	33.04	6.60	0.54***	0.41***	–	
4 Life satisfaction	22.27	5.47	0.35***	0.39***	0.54***	–

***$p < 0.001$.

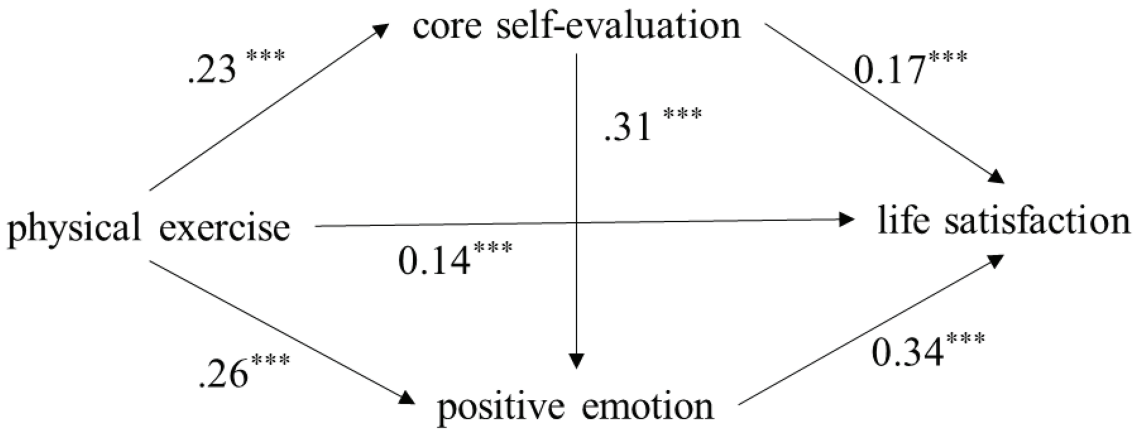

FIGURE 1 | Model of the mediator role of core self-evaluation and positive emotion in the relationship between physical exercise and life satisfaction. *** $p < 0.001$, Significant regression coefficient.

Testing the Mediating Effects of Core Self-Evaluation and Positive Emotion

Taking physical exercise as the independent variable, life satisfaction as the dependent variable, and core self-evaluation and positive emotion as the mediating variables, the chain mediation effect test yielded the results shown in **Figure 1** and **Tables 2, 3**.

The results show that, firstly, there are significant positive correlations between physical exercise, core self-evaluation, positive emotions, and life satisfaction, which supports Hypothesis 1. Secondly, physical exercise has a significant indirect effect on life satisfaction through core self-evaluation ($\beta = 0.039$, 95% CI = [0.01, 0.04]), that is, core self-evaluation has a significant mediating effect on the relationship between physical exercise and life satisfaction. Thirdly, physical exercise has a significant indirect effect on life satisfaction through positive emotions ($\beta = 0.084$, 95% CI = [0.06, 0.12]), that is, positive emotions have a significant mediating effect on the relationship between physical exercise and life satisfaction. Finally, the indirect effect of physical exercise on life satisfaction through core self-evaluation and positive emotion was significant ($\beta = 0.024$, 95% CI = [0.01, 0.02]). In other words, core self-evaluation can affect positive emotion. At the same time, the chain mediation path from physical exercise to core self-evaluation, then to positive emotion, and finally to life satisfaction is significant, supporting Hypothesis 2. These results indicate that core self-evaluation and positive emotion play a continuous mediating role in the relationship between physical exercise and life satisfaction. The total mediating effect accounted for 51.58% of the total effect; that is, 51.58% of the effect of physical exercise on college students' life satisfaction through the two variables of core self-evaluation and positive emotion.

DISCUSSION

As expected, physical exercise, core self-evaluation, positive emotion, and life satisfaction had significant positive relationships with each other. In addition, we found that core self-evaluation and positive emotion played a mediating role in the relationship between physical exercise and life satisfaction, and the chain mediation effect was significant.

First of all, from the relationship between physical exercise and core self-evaluation, physical exercise can significantly positively predict core self-evaluation. Although no studies have directly examined the relationship between physical exercise and core self-evaluation, existing studies have shown that physical exercise can significantly increase an individual's self-esteem or self-awareness (Mcauley et al., 1997; Wong et al., 2021). In the process of physical exercise, the individual's body will become stronger, which will improve the individual's positive body self-image. At the same time, individuals can make friends with the same interests, which also provides them with peer support and promotes the improvement of self-esteem. Therefore, core self-evaluation, as a comprehensive reflection of self-esteem and

TABLE 2 | The chain mediation model from physical exercise to life satisfaction.

Variable	b				c				d			
	β	SE	*t*	95%CI	*β*	SE	*t*	95%CI	*β*	SE	*t*	95%CI
a	0.23	0.02	7.03***	[0.09, 0.17]	0.26	0.02	15.68***	[0.23, 0.30]	0.14	0.02	2.75**	[0.01, 0.08]
b					0.31	0.03	10.18***	[0.25, 0.38]	0.17	0.03	6.07***	[0.12, 0.23]
c									0.34	0.03	11.28***	[0.28, 0.40]
R^2			0.16				0.37				0.33	
F			36.18***				118.01***				78.46***	

****p* < 0.001.
a, physical exercise; b, core self-evaluation; c, positive emotion; and d, life satisfaction, the same below.

TABLE 3 | Standardized indirect effects from physical exercise to life satisfaction.

Model	*β* (standardized indirect effect)	SE	95%CI	Relative mediating effect
Total indirect effect	0.147	0.013	0.10, 0.16	51.58%
a-b-d	0.039	0.006	0.01, 0.04	13.68%
a-c-d	0.084	0.013	0.06, 0.12	29.47%
a-b-c-d	0.024	0.003	0.01, 0.02	8.42%

self-awareness, will also be positively affected by physical exercise. Secondly, physical exercise significantly positively predicted positive emotion was also consistent with prior research (Greenwood, 2019). Physical exercise can promote the body to secrete dopamine, which is closely related to pleasure, thus increasing the individual's positive emotional experience. Additionally, consistent with prior research, physical exercise was positively associated with life satisfaction (Moreno-murcia et al., 2017; Reigal et al., 2019). From the function of physical exercise, moderate physical exercise can enhance the physical quality of students, while maintaining good physical health is the desire of most people. Therefore, it is understandable that moderate physical exercise can improve college students' life satisfaction. In conclusion, the results of this study demonstrate the positive promoting effect of physical exercise on mental health, and also support Hypothesis 1.

As for Hypothesis 2, physical exercise can directly affect life satisfaction and can also affect life satisfaction through the mediation of core self-evaluation and positive emotion. From the perspective of core self-evaluation, physical exercise can improve core self-evaluation. Individuals with higher core self-evaluation have stronger psychological adjustment ability, are more likely to use positive coping strategies, and have higher life satisfaction (Zhao and Shi, 2018). Therefore, core self-evaluation can play an important role in the bridge between physical and mental health, which is consistent with the existing findings (Xiang et al., 2019). From the perspective of positive emotion, physical exercise can also promote the production of individual positive emotion. When individuals experience more positive emotion, the proportion of negative emotions is significantly reduced, which helps individuals form positive and optimistic attitudes, have a greater sense of hope, and show higher life satisfaction (Ligeza et al., 2019; Bo et al., 2020). The results also showed that the mediation path of positive emotion has the greatest influence on the total mediation effect, indicating that the influence of physical exercise on life satisfaction is largely played by positive emotion. Moreover, we also found that core self-evaluation and positive emotions play a chain mediating role in the impact of physical exercise on college students' life satisfaction. In other words, core self-evaluation affects life satisfaction by influencing positive emotion. Although there are relatively few studies that directly examine the relationship between core self-evaluation and positive emotions, many studies have found that the improvement of core self-evaluation will improve the level of self-esteem, enhance

the experience of positive emotions, and adopt a more positive way to face difficulties and challenges, thus improving subjective wellbeing and work efficiency (Kim et al., 2016; Ding and Lin, 2020; Firouznia et al., 2021). This study directly proves that the improvement of core self-evaluation can enhance individuals' positive emotional experience, and further proves the importance of core self-evaluation in individuals' positive mental health.

In general, through physical exercise, individuals can improve their physical quality, gain friendship, enhance self-confidence, and thus improve their core self-evaluation. Meanwhile, in this process, individuals can enhance their positive emotional experience and ultimately improve their life satisfaction. This enlightens us, physical health and mental health are closely linked, we should encourage students to take an active part in physical exercise activities, cultivate a strong physique, promote healthy body, also need to guide students to establish positive self-evaluation, cultivate a positive, optimistic attitude toward life, and try to sports activities and the organic integration of mental health education.

LIMITATIONS AND FUTURE DIRECTIONS

This study also has some deficiencies. First, due to the limitation of objective factors, such as time and research funds, this study adopted a cross-sectional study design. Although existing studies have provided a solid foundation for this study, the results of this study can be enriched and expanded through further follow-up and empirical studies. Second, the subjects of this study were all college students without distinction. In future research, we can further explore the impact of physical exercise on life satisfaction of people of different ages. Third, physical exercise in this study was self-reported by participants through questionnaires. In the future, we can further explore the influence of frequency, time, and form of physical exercise on life satisfaction.

CONCLUSION

In conclusion, this study investigates how college students' physical exercise influences life satisfaction. Specifically, we found that physical exercise significantly positively predicted life satisfaction and verified the mediating role of core self-evaluation and positive emotions in this relationship. The results also confirmed a chain mediation model between physical exercise, core self-evaluation, positive emotions, and life satisfaction.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusion 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 Research Ethics Committee of Southwest University. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

On the basis of reading related literature, FL raised the questions of this research and was responsible for making research plans, collecting data, and writing articles during the whole research process. ZZ made a great contribution to the data collection and analysis of the research and the revision of the paper. BJ was mainly responsible for the supervision and guidance of the whole research process and provided the necessary financial and personnel assistance. All authors contributed to the article and approved the submitted version.

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The Effects of Tai Chi and Qigong Exercise on Psychological Status in Adolescents: A Systematic Review and Meta-Analysis

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Background: The purpose of this study was to systematically review the effectiveness of Tai Chi and Qigong exercise on adolescents' symptoms of depression and anxiety, and psychological status based on clinical evidences, and to calculate the pooled results using meta-analysis.

Methods: A systematic search using seven English and three Chinese databases was initiated to identify randomized controlled trials (RCT) and non-randomized comparison studies (NRS) assessing the effect of Tai Chi and Qigong exercise on psychological status among adolescents. Standardized mean differences (SMD) and their 95% confidence intervals (CI) were used to determine the pooled effect of the intervention. Study quality was evaluated using a Checklist to Evaluate a Report of a Non-pharmacological Trial (CLEAR-NPT) designed for non-pharmacological trials.

Results: Four RCTs and six NRS were identified, including 1,244 adolescents. The results suggested a potential beneficial effect of Tai chi and Qigong exercise on reducing anxiety (SMD = 0.386, 95 CI% [0.233, 0.538]) and depression (SMD = 1.937 [95 CI%, 1.392–2.546]) symptoms, and reducing cortisol level (SMD = 0.621 [95 CI%, 0.18–1.062]) in adolescents. Conversely, non-significant effects were found for stress, mood, and self-esteem.

Conclusions: The findings of this review suggest Qigong appears to be an effective therapeutic modality to improve psychological well-being in adolescents. Hope future studies will have rigorously designed, well-controlled randomized trials with large sample sizes in order to confirm these findings.

Keywords: mind-body exercise, psychological well-being, mental, adolescents, review

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BACKGROUND

The *Mental Health* topic launched by the World Health Organization declared that depression is one of the leading causes of disability, affecting ∼264 million people worldwide (WHO, 2019). Around one in five children and adolescents in the world suffer from mental health problems, and the onset of nearly half of psychological disorders occurs before the age of 14 (WHO, 2019). Mental

health problems in adolescents have been found to contribute to various types of maladaptive behavior, including poor academic performance, violent behavior, teenage pregnancy, drug abuse, self-harm, and even suicide (Das et al., 2016; Dray et al., 2017). Adolescence is a crucial period in which immediate actions should be employed to prevent the impacts of such problem behaviors from persisting into adulthood. Given the public health burden imposed by mental health disorders in adolescents, it is imperious to identify and implement effective interventions.

Currently, many studies have suggested that physical exercise, as an alternative and complimentary therapy, has a positive effect on psychological health (Tsang et al., 2008; Chen et al., 2012; Li et al., 2015; Epps et al., 2019; Garnaes et al., 2019). Qigong exercise is an easily adaptable form of mind-body integrative exercise whose basic components include thoughts concentration, relaxation, meditation, breathing regulation, body posture, and gentle movement (Tsang et al., 2002). Qigong practitioners can experience mood stabilization and mitigation of stress response as Qigong exercise helps decrease physiological arousal and promote relaxation (Wang et al., 2014a). Previous reviews have reported the effectiveness of Tai Chi and Qigong exercise on psycho-physical health among both clinical and non-clinical populations (Cheng, 2015; Webster et al., 2016; Zou et al., 2018; Chang et al., 2019). Additionally, findings of studies supported the beneficial effect of Tai Chi and Qigong exercise on improving physical health (e.g., immune function, cardiovascular health, hypertension) (Qin, 2012; Yu and Chen, 2012; Zhang et al., 2014; Liang, 2018), psychological problems (e.g., anxiety, depression, stress) (Tsai et al., 2003; Lee et al., 2004; Caldwell et al., 2009; Nedeljkovic et al., 2012; Chan et al., 2013; Chang and Wei, 2013), and cognitive function (e.g., executive function) (Tang et al., 2011; Ladawan et al., 2017; Liang, 2018).

Previous systematic reviews examining the effects of Tai Chi and Qigong exercise on psychological status mainly focused on adults and older adults, in particular, with both healthy condition and chronic diseases (e.g., diabetes, depression, cancer) (Lee et al., 2007; Wang et al., 2009; Liu et al., 2015; Sharma and Haider, 2015; Guo et al., 2018; Tong et al., 2018). There has been emerging evidence showing the effectiveness of Tai Chi or Qigong exercise on affecting psychological status in adolescents. For instance, the effect of Tai Chi and Qigong exercise on adolescents' depression, anxiety, stress, and self-esteem have been investigated (Lee et al., 2009, 2013; Terjestam et al., 2010; Sousa et al., 2012; Bao, 2013; Chang et al., 2013; Bao and Jin, 2015; Bao and Niu, 2018; Zhang et al., 2018). However, the findings were not conclusive due to inconsistent findings. Some studies favored the positive effect of Tai Chi and Qigong exercise on reducing stress of adolescents (Terjestam et al., 2010; Zhang et al., 2018), while others yielded no significant results (Lee et al., 2013). Currently, there is a scarcity of systematic reviews and meta-analysis summarizing the effect of Tai Chi and Qigong exercise as intervention on adolescents' psychological status. The purpose of this study was to systematically review the effectiveness of Tai Chi and Qigong exercise on adolescents' psychological status based on clinical evidences, and to calculate the pooled results using meta-analysis.

METHODS

This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline (Moher et al., 2009).

Search Strategy

Two reviewers independently searched the literature using the following English and Chinese databases: Medline (*via* PubMed), EMbase (*via* Ovid), PsychINFO (*via* Ovid), Eric (*via* EBSCOhost), SPORTDiscus (*via* EBSCOhost), CINAHL (*via* EBSCOhost), the Cochrane Central Register of Controlled Trials (CENTRAL), the Chinese National Knowledge Infrastructure (CNKI), Wanfang, and the Chinese Scientific Journal (VIP). The searches were conducted from inception through April 2020. The search terms used in this study was based a previous related meta-analysis (Liu et al., 2020): *Qigong, Qi Gong, Ch'i Kung, Qi-gong, Chi Kung, Chi Chung, Qi Chung, Qi-training, Chi Gong, Qigong Massage, Tai Ji, Tai-ji, Tai Chi, Tai Ji Quan, Taiji, Taijiquan, T'ai Chi, Tai Chi Chuan, Tai Chi Chih, Tai Chi Qigong, Baduanjin, Depression, Anxiety, Psychological well-being, Mental, Stress, Mood, Adolescent, Youth, Student, Teenager, Child, Children, Childhood*. Chinese translations of these terms were used in Chinese databases. A complete record of search strings is provided in the **Supplementary Material**. A manual search of reference lists of all included studies and relevant reviews was conducted to further identify relevant studies.

Inclusion and Exclusion Criteria

Types of Studies

Studies had to be either randomized controlled trials (RCTs) or non-randomized comparison studies (NRS). A study was defined as RCT if the participants were allocated to experimental and control groups randomly; a study was defined as NRS if the allocation of participants was conducted through a systematic sequence without randomization. Studies that did not involve any comparison group or did not report any comparison results between groups were excluded. Meta-analysis, reviews, commentaries, protocols, dissertations, narrative studies, observational or qualitative studies were excluded.

Types of Participants

Studies focusing on adolescents with mean age between 12 and 18 years old were included. Given the focus of this review was on general psychological status, rather than on psychopathological symptoms, this review excluded studies on patients diagnosed with major psychiatric disorders (e.g., depression, anxiety, schizophrenia). Studies in patients with chronic illnesses (e.g., asthma, heart disease) were excluded.

Types of Intervention

Studies had to use any type of Tai Chi or Qigong as an intervention with comparison such as waitlist control group or other forms of exercise group (e.g., normal P.E classes). Studies integrating Tai Chi or Qigong exercise with other forms of intervention or simply using other forms of intervention such as mindfulness-based training, yoga, and meditation were excluded.

Types of Outcome Measures

Studies had to measure the effect of Tai Chi or Qigong on various indicators of psychological status, such as perceived well-being (e.g., self-concept, self-esteem) and psychological distress (e.g., anxiety, depression, stress). Additionally, studies measured physiological indicators, such as cortisol level, which reflect the hormone changes in relation to perceived stress were also included as objective outcomes of psychological status.

Study Selection and Data Extraction

Two reviewers screened the studies based on the titles, abstracts, and full texts, independently. Discrepancies between the two reviewers (XL, RL) were discussed until consensus was reached. A third reviewer (XC) made the final decision after group discussion if consensus could not be reached. The consistency of abstracts and full-texts screening between the two reviewers was measured using Kappa value proposed by Orwin and Vevea (2009). Two reviewers used a data extraction form to extract relevant characteristics independently, including publication date, study design, location, characteristics of participants (i.e., mean age, gender, sample size), protocol of intervention and comparison group, relevant outcome measures, and main results.

Quality Assessment

Because of non-pharmaceutical intervention used in included studies, it is difficult to employ a double-blind design. Therefore, a Checklist to Evaluate a Report of a Non-pharmacological Trial (CLEAR-NPT) (Boutron et al., 2005) was used instead of some popular traditional checklist, such as Cochrane Collaboration's assessment tool (Higgins et al., 2008), to evaluate the methodological quality of each non-pharmaceutical study in a more reasonable way. It assessed the quality based on the following criteria: adequacy of randomization, allocation concealment, the availability of intervention details, the appropriateness of care providers' experiences, the adherence of participants, blinding of participants and care providers, blinding of outcome assessors, parallelity of study design, and outcome analysis methods. Since there are difficulties in executing blinding of participants and care providers in non-pharmacological studies, further assessment criteria serve as alternative evaluation regarding the risk of performance bias if there is no blinding or inadequate blinding. A full description of CLEAR-NPT was provided in the **Supplementary Material**. Some of the included studies did not provide adequate information necessary for the evaluation of each criteria. The reviewers attempted to contact the authors to obtain relevant information. If the information was inaccessible after three attempts of email inquiry, the corresponding criteria was ranked as "unclear."

Data Analysis

Comprehensive Meta Analysis (CMA) Version 2 was used to perform the meta-analysis. The *intervention* effect size in each study was presented by the standardized mean differences (SMD) with 95% confidence intervals (CI). Use of SMD allows for the comparisons across included studies where they used different psychometric instruments to measure the same outcome (Deek et al., 2008; Orwin and Vevea, 2009). The included studies were anticipated to be heterogeneous because of the different characteristics of intervention and control types. To account for the potential heterogeneity, a random-effects model was used throughout data synthesis. I^2 statistic was used to assess heterogeneity. Studies with an I^2 statistic of >75% were considered to have a high degree of heterogeneity; studies with an I^2 statistic of 50–75% were considered to have a moderate degree of heterogeneity; and studies with an I^2 statistic of <50% were considered to have a low degree of heterogeneity. Subgroup analysis on primary outcomes based on intervention types (Tai Chi vs. Qigong) was conducted where necessary. Sensitivity analyses were conducted by examining the influence of omitting a single study, respectively, on the overall pooled effect if necessary. It was unnecessary to use funnel plots to assess publication bias because each meta-analysis only included small number of studies.

Patient and Public Involvement

No patient involved.

RESULTS

Search Results

A total of 2,720 potentially relevant articles were initially screened in the databases. According to inclusion and exclusion criteria, full-texts of 44 articles were assessed for eligibility after removing duplicates, and titles and abstracts screening. Thirty-four studies were further excluded due to the following reasons after full-texts screening: (1) conference proceedings, (2) no psychological outcomes of interest, (3) no original data (4) intervention other than Qigong or Tai Chi, (5) observational studies, (6) narrative or case studies, (7) sample inappropriate, (8) one-group pre-post design. No additional studies were identified from the reference lists of included articles or relevant reviews. The kappa value for screening consistency was 0.93 for abstracts screening, and 0.87 for full-texts screening. Ten studies were finally included in the systematic review and potential meta-analysis (**Figure 1**).

Description of Included Studies

Table 1 describes the characteristics of all included studies. The 10 studies were published between year 2009 and year 2018. Three studies identified from Chinese databases were published in Chinese and seven identified from English databases were published in English. The majority ($n = 7$) of the included articles were conducted in mainland of China, Hongkong SAR and Taiwan; the remaining three were conducted in Portugal, Sweden and Korea. Six studies were NRS and four were RCTs. All included studies ($n = 10$) targeted physical healthy adolescents. Instruments used to measure each relevant outcome were also summarized in **Table 1**.

Table 2 shows the characteristics of each included study. Sample sizes ranged from 16 to 312, with a total of 1,244 participants. This included 776 in Tai Chi or Qigong group and 468 in control group. The mean age ranged from 11.75 to 18.4 years old. Several types of Qigong exercise were used, including laughing Qigong, xianggong, baduanjin, and turo

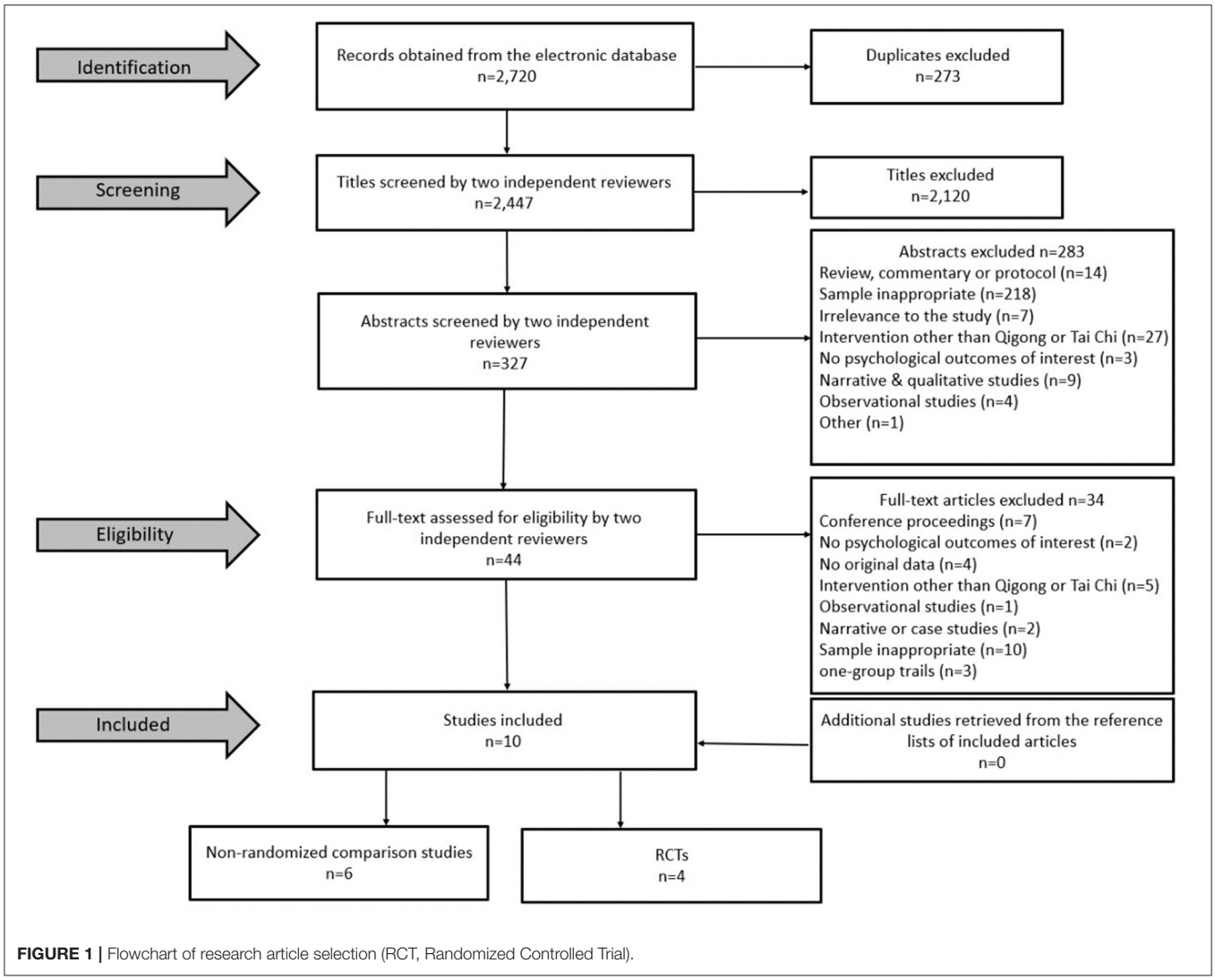

FIGURE 1 | Flowchart of research article selection (RCT, Randomized Controlled Trial).

qi training. It also used several types of Tai Chi, including Chen-style, mindfulness-based tai chi chuan, and simplified Tai Chi of 24 type. Duration of interventions varied, ranging from 7 weeks to 1 year, with each session lasting for 25–90 min. The frequency ranged from one to seven sessions per week. The control group included waitlist, normal PE classes, China's 8th edition broadcasting gymnastics, placebo group with similar movements.

Study Quality Assessment

Table 3 presents the methodological quality of all included studies. The generation of random allocation was only adequately conducted in one study (Lee et al., 2009). Although four studies were RCTs (Lee et al., 2009; Chang et al., 2013; Bao and Jin, 2015; Zhang et al., 2018), only two of them performed allocation concealment (Lee et al., 2009; Zhang et al., 2018). Five of the included studies reported the details of administration of intervention (Terjestam et al., 2010; Chang et al., 2013; Lee et al., 2013; Bao and Jin, 2015; Zhang et al., 2018). Three studies clarified the care providers' experience or skills (Lee et al., 2009, 2013; Chang et al., 2013). Dropout rate calculation was available in one study (Terjestam et al., 2010). Only one study successfully blinded the outcome assessors and participants (Zhang et al., 2018), and the blindness of care providers was conducted in four studies (Chang et al., 2013; Lee et al., 2013; Bao and Jin, 2015; Zhang et al., 2018). Two studies implemented parallel design between intervention and comparison group (Lee et al., 2013; Zhang et al., 2018). Five studies analyzed main outcomes according to the intention-to-treat principle (Lee et al., 2009, 2013; Sousa et al., 2012; Chang et al., 2013; Chen and Zheng, 2018).

Primary Outcomes

Anxiety

Four studies examined the effect of Tai Chi or Qigong exercise on anxiety (Lee et al., 2009; Bao, 2013; Bao and Jin, 2015; Bao and Niu, 2018). One study used a three-arm design with two Tai Chi groups of different intensity compared to a waitlist control group

TABLE 1 | Summary of studies included.

Criteria		Number of studies	References
Date of publication	2009–2010	2	Lee et al., 2009; Terjestam et al., 2010
	2011–2018	8	Sousa et al., 2012; Bao, 2013; Chang et al., 2013; Lee et al., 2013; Bao and Jin, 2015; Bao and Niu, 2018; Chen and Zheng, 2018; Zhang et al., 2018
Language of study	Chinese	3	Bao, 2013; Bao and Niu, 2018; Chen and Zheng, 2018
	English	7	Lee et al., 2009, 2013; Terjestam et al., 2010; Sousa et al., 2012; Chang et al., 2013; Bao and Jin, 2015; Zhang et al., 2018
Study location	China (Mainland, Hongkong, Taiwan)	7	Bao, 2013; Chang et al., 2013; Lee et al., 2013; Bao and Jin, 2015; Bao and Niu, 2018; Chen and Zheng, 2018; Zhang et al., 2018
	Others (Portugal, Sweden, Korea)	3	Lee et al., 2009; Terjestam et al., 2010; Sousa et al., 2012
Study design	RCT	4	Lee et al., 2009; Chang et al., 2013; Bao and Jin, 2015; Zhang et al., 2018
	NRS	6	Terjestam et al., 2010; Sousa et al., 2012; Bao, 2013; Lee et al., 2013; Bao and Niu, 2018; Chen and Zheng, 2018
Participants	Physical healthy adolescent	10	Lee et al., 2009, 2013; Terjestam et al., 2010; Sousa et al., 2012; Bao, 2013; Chang et al., 2013; Bao and Jin, 2015; Bao and Niu, 2018; Chen and Zheng, 2018; Zhang et al., 2018
Outcome	Anxiety (PHCSCS, SCL-90-R, MSSMHS, STAI scale)	4	Lee et al., 2009; Bao, 2013; Bao and Jin, 2015; Bao and Niu, 2018
	Depression (PHQ-9, SCL-90-R, MSSMHS)	3	Lee et al., 2009; Bao and Niu, 2018; Zhang et al., 2018
	Stress (PSS-10, General stress test, CPSS)	3	Terjestam et al., 2010; Lee et al., 2013; Zhang et al., 2018
	Salivary cortisol	2	Sousa et al., 2012; Chang et al., 2013
	Mood (FS scale, POMS)	2	Chang et al., 2013; Chen and Zheng, 2018
	Self-esteem (RSE, Self-image test)	2	Terjestam et al., 2010; Chang et al., 2013

RCT, Randomized Controlled Trial; NRS, Non-randomized comparison studies; PHCSCS, Piers–Harris Children's Self-Concept Scale; SCL-90-R, Self-reported Checklist of 90 items (Physical or Psychological symptom); MSSMHS, Middle School Students' Mental Health Scale; STAI, State Trait Anxiety Inventory; PHQ-9, Nine-item patient health questionnaire depression scale; PSS-10, Perceived Stress Scale 10-item; CPSS, Chinese version of the Perceived Stress Scale; FS, Face Scale; POMS, Profile of Mood States; RSE, Self-Esteem Scale.

(Bao, 2013). These two comparisons were, therefore, conducted separately in meta-analyses. Participants assigned to a Tai Chi or Qigong exercise group perceived less level of anxiety than did those in the control group (SMD = 0.386, 95% CI [0.233, 0.538]). Heterogeneity among studies was high ($I^2 = 90.965\%$).

The subgroup analysis based on the intervention type showed that, compared with adolescents who practicing Tai Chi (SMD = 0.294, 95% CI [0.139, 0.449]), those engaging in Qigong exercise perceived greater improvement in anxiety (SMD = 3.158, 95% CI [2.307, 4.010]) (**Figure 2A**). The difference between groups was statistically significant ($p < 0.001$).

Depression

Three studies examined the effect of Tai Chi or Qigong exercise on depressive symptoms (Lee et al., 2009; Bao and Niu, 2018; Zhang et al., 2018). Their pooled results confirmed the significant effect of Tai Chi and Qigong on reducing depression among adolescents (SMD = 1.937, 95 CI% [1.329, 2.546]). Heterogeneity among studies was high ($I^2 = 95.767\%$).

The subgroup analysis based on the intervention type showed that, compared with adolescents who practicing Tai Chi (SMD = 0.645, 95% CI [−0.207, 1.497]), those engaging in Qigong exercise perceived greater improvement in depression (SMD = 3.284, 95% CI [2.414, 4.154]) (**Figure 2B**). The difference between groups was statistically significant ($p < 0.001$).

Stress

Three studies measured self-perceived stress as the primary outcome (Terjestam et al., 2010; Lee et al., 2013; Zhang et al., 2018). Their pooled results showed that Tai Chi and Qigong had an insignificant effect on stress compared to various controls (SMD = 0.317, 95 CI% [−0.008, 0.642]), with substantial degree of heterogeneity ($I^2 = 54.622\%$).

The subgroup analysis based on the intervention type showed that both Tai Chi and Qigong exercise could not significantly reduce stress. The difference between groups was not significant ($p = 0.110$) (**Figure 2C**).

Two studies compared the effect of Qigong vs. waitlist condition on changes of cortisol level, which is the biomarker reflecting the stress response (Sousa et al., 2012; Chang et al., 2013). Their pooled results showed that Qigong exercise significantly reduced the cortisol level compared to waitlist controls (SMD = 0.621, 95 CI% [0.180, 1.062]), with a high degree of homogeneity ($I^2 = 0\%$) (**Figure 3A**).

Other Psychological Outcomes

Two studies examined the effect of Qigong vs. waitlist on mood (Chang et al., 2013; Chen and Zheng, 2018). Chen and Zheng (2018) reported the findings on boys and girls, separately, of which the results were combined and analyzed as a unit for meta-analysis. The pooled results of these two studies did not detect the significant difference between Qigong exercise and waitlist

TABLE 2 | Characteristics of included study ($n = 10$).

References	Study design and location	Study participants	Sample size (pre/post)	Intervention (frequency)	Control	Duration	Relevant outcome (measurements)	Result
Lee et al. (2009)	RCT, Republic of Korea	Adolescent (mean age: 13.3 ± 0.1)	EG: 21/21 CG: 27/27	Qigong (Turo Qi training, 40 min/session, twice each week)	Placebo with similar Qigong movement	2 months	(1) Depression & Anxiety (SCL-90-R)	(1) Depression: $p = 0.06$ (2) Anxiety: $p = 0.06$
Terjestam et al. (2010)	NRS, Sweden	Adolescent (mean age: 13.15)	EG: 85/53 CG: 71/66	Qigong (25 min/session, twice a week)	Wait list	8 weeks	(1) Well-being at school scale (WBS) (2) Psychologic distress scale (3) Self-image test (4) General stress test	(1) $p < 0.05$ (2) $p < 0.05$ (3) $p = 0.078$ (4) $p < 0.05$
Sousa et al. (2012)	NRS, Portugal	Adolescent (mean age: 11.75 ± 0.55)	EG: 8/8 CG: 8/8	Qigong (every day during 7 weeks, including doing at home on weekend for 30 min from parents)	Wait list	7 weeks	(1) Anxiety Depression and Stress (EADS-C) (2) Salivary Cortisol	(1) $p = 0.291$ (2) $p = 0.606$
Bao (2013)	NRS, China	Adolescent	EG1: 103/103 EG2: 92/92 CG: 57/57	EG1: Tai Chi (24-form, 60 min/session, five times per week) EG2: Tai Chi (24-form, 30 min/session, five times per week)	Wait list	1 year	(1) Anxiety (STAI)	(1) EG1: $p = 0.004$ EG2: $p = 0.003$
Chang et al. (2013)	RCT, Taiwan	Adolescent (7th grade students)	EG: 34/34 CG: 33/33	Qigong (60 min/session, once a week)	Wait list	8 weeks	(1) Self-esteem (RSE) (2) Humor (CHS) (3) Mood (FS) (4) Salivary Cortisol	(1) $p = 0.74$ (2) $p = 0.01$ (3) $p = 0.04$ (4) $p = 0.058$
Lee et al. (2013)	NRS, Hongkong, China	Adolescent (mean age: 13.4; 11–16)	EG: 32/32 CG: 37/37	Tai Chi (Chen-style, 80 min/session, once per week)	Wait list	10 weeks	(1) Stress (PSS-10)	(1) $p = 0.726$
Bao and Jin (2015)	RCT, China	Adolescent (mean age: 14.4±0.66)	EG: 80/73 CG: 80/69	Tai Chi (60 min/session, five times per week) including the summer and winter holidays	Broadcasting gymnastics	1 year	(1) Self-concept (PHCSCS)	(1) Self-concept: $p < 0.001$ (2) Anxiety: $p < 0.01$
Bao and Jin (2015)	NRS, China	Adolescent (mean age: 12.55 ± 0.729)	EG: 239/239 CG: 73/73	Tai Chi (24-form, 30 min/session, five times per week)	Wait list	1 year	(1) Mental health (MSSMHS)	(1) Depression: $p = 0.000$ (2) Anxiety: $p = 0.000$
Chen and Zheng (2018)	NRS, China	Adolescent (middle school students)	EG (Boys): 25/25 EG (Girls): 25/25 CG (Boys): 25/25 CG (Girls): 25/25	Qigong (Baduanjin, 60 min/session, three times per week)	Wait list	4 months	(1) Mood (POMS)	(1) Boys: $p =$ NS Girls: $p =$ NS
Zhang et al. (2018)	RCT, China	University student (mean age: 18.4 ± 2.01)	EG: 32/32 CG: 32/30	Tai Chi (24-form, 90 min/session, twice a week)	Normal PE classes	8 weeks	(1) Depression (PHQ-9) (2) Mindful Attention and Awareness (MAAS) (3) Stress (CPSS)	(1) $p < 0.001$ (2) $p < 0.001$ (3) $p < 0.001$

RCT, Randomized Controlled Trial; NRS, Non-randomized comparison studies; EG, Experiment Group; CG, Control Group; PE, Physical Education; SCL-90-R, Self-reported Checklist of 90 items (Physical or Psychological symptom); WBS, Well-being at school; EADS-C, Anxiety Scale, Depression and Stress for Children; STAI, State Trait Anxiety Inventory; RSE, Self-Esteem Scale; CHS, Chinese Humor Scale; FS, Face Scale; PSS-10, Perceived Stress Scale 10-item; PHCSCS, Piers–Harris Children's Self-Concept Scale; MSSMHS, Middle School Students' Mental Health Scale; POMS, Profile of Mood States; PHQ-9, Nine-item patient health questionnaire depression scale; MAAS, Mindful Attention and Awareness Scale; CPSS, Chinese version of the Perceived Stress Scale; NS, Not Significant.

TABLE 3 | Critical appraisal of included studies ($n = 10$).

Criterion	Study reference									
	Lee et al. (2009)	**Terjestam et al. (2010)**	**Sousa et al. (2012)**	**Bao (2013)**	**Chang et al. (2013)**	**Lee et al. (2013)**	**Bao and Jin (2015)**	**Bao and Niu (2018)**	**Chen and Zheng (2018)**	**Zhang et al. (2018)**
1. Was the generation of allocation adequate?	Y	N	N	N	N	N	U	N	N	Y
2. Was the treatment allocation concealed?	Y	N	N	N	N	N	U	N	N	U
3. Were details of the intervention administered to each group made available?	U	Y	U	N	Y	Y	Y	N	N	Y
4. Were care providers' experience or skills in each arm appropriate?	U	U	U	U	Y	Y	U	N	N	Y
5. Was participant (i.e., patients) adherence assessed quantitatively?	U	N	U	N	N	Y	U	U	U	U
6. Were participants adequately blinded?	U	N	N	N	N	N	N	N	N	Y
6.1 If Participants were not adequately blinded:										
6.1.1 Were other treatments and care (i.e. co-interventions) the same in each randomized group?	U	N/A	N/A	N/A	N/A	N/A	U	N/A	N/A	_
6.1.2 Were withdrawals and lost-to-follow-up the same in each randomized group?	Y	N	Y	U	Y	Y	Y	U	U	_
7. Were care providers for the participants adequately blinded?	N	U	N	N	Y	Y	Y	N	N	Y
7.1 If care providers were not adequately blinded:										
7.1.1 Were other treatments and care (i.e., co-interventions) the same in each randomized group?	Y	N/A	N/A	N/A	_	_	U	N/A	N/A	_
7.1.2 Were withdrawals and lost-to-follow-up the same in each randomized group?	Y	U	Y	U	_	_	Y	U	U	_
8. Were outcome assessors adequately blinded to assess the primary outcomes?	N	U	N/A	U	N	N	N	U	U	Y
8.1 If outcome assessors were not adequately blinded, were specific methods used to avoid ascertainment bias?	U	U	_	U	N	N	N	U	U	_
9. Was the follow-up schedule the same in each group? (parallel design)	N	N/A	N/A	N/A	N	Y	N/A	N/A	N	Y
10. Were the main outcomes analyzed according to the intention-to-treat principle?	Y	N	Y	N	Y	Y	N	N/A	Y	N

N, Not reported; N/A, Not applicable; Y, Yes.

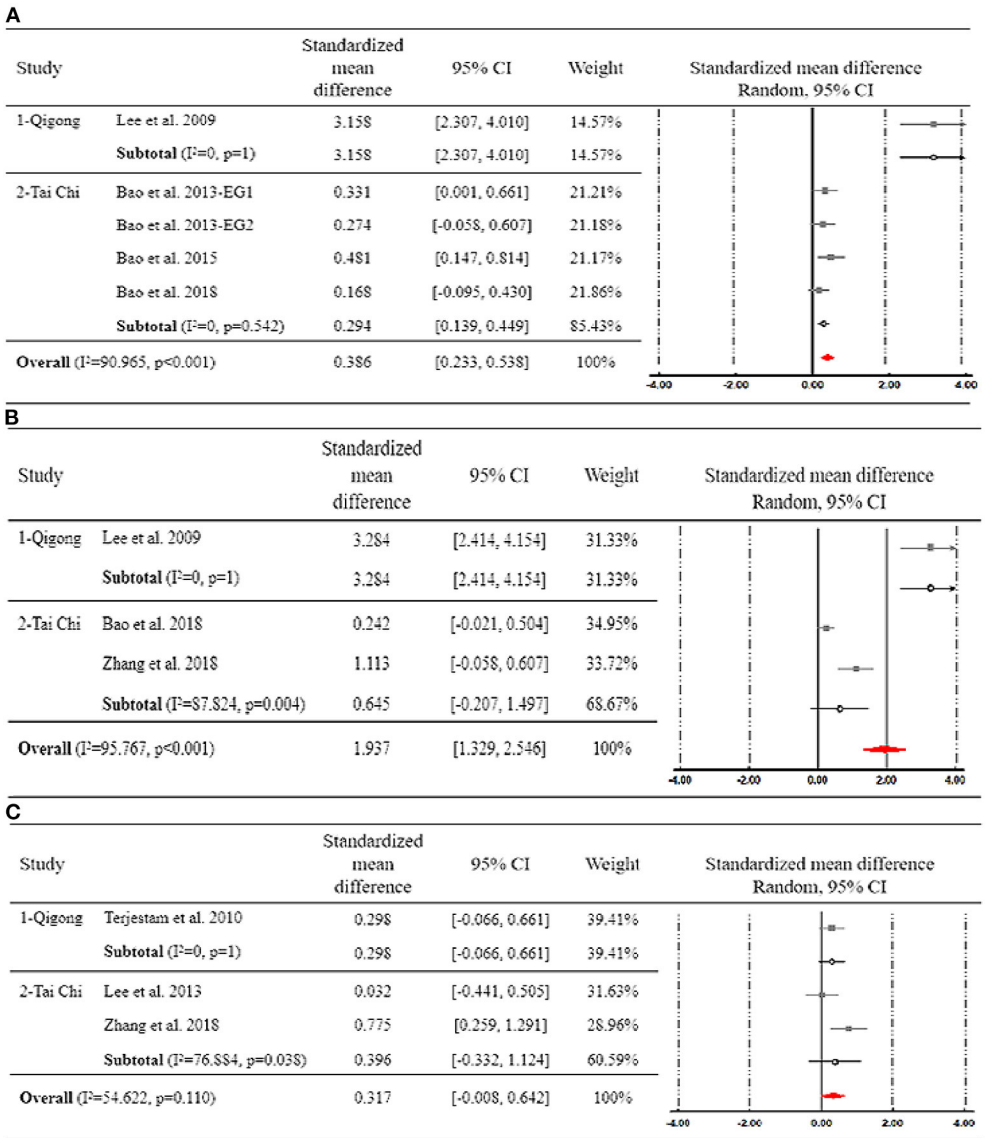

FIGURE 2 | Forest plot for subgroup analysis regarding the effect of Tai Chi and Qigong on **(A)** anxiety, **(B)** depression, and **(C)** stress.

(SMD = 0.104, 95 CI% [−0.245, 0.452]), with a low degree of heterogeneity ($I^2 = 22.555\%$) (**Figure 3B**).

Two studies examined the effect of Qigong exercise vs. waitlist on improving self-esteem (Terjestam et al., 2010; Chang et al., 2013). Their pooled results did not show a significant effect of Qigong on enhancing self-esteem (SMD = −0.059, 95 CI% [−0.348, 0.230]), with a high degree of homogeneity ($I^2 = 0\%$) (**Figure 3C**).

Some related outcomes were only studied once. For example, Terjestam et al. (2010) suggested that Qigong exercise did not result in significant improvement in psychological distress (SMD = 0.317, 95 CI% [−0.047, 0.681]). Significant enhancement in self-concept was found after 1-year Tai Chi intervention in Bao and Jin (2015), with overall effect size of (SMD = 0.499, 95 CI% [0.165, 0.834]). Additionally, Bao and Niu (2018) focused on the effect of Tai Chi on middle school students' general mental health which included a wide range of dimensions, such as emotional instability and psychological imbalance. Significant improvement in general mental health was also reported with overall effect size of (SMD = −0.377, 95 CI% [−0.641, −0.114]).

DISCUSSION

This systematic review and meta-analysis summarizes the effect of Tai Chi and Qigong exercise on improving adolescents' psychological health outcomes. Evidence accrued from RCTs and non-randomized controlled trials indicates Tai Chi and Qigong exercise – both short and long-term – appears to have potential mental health benefits in improving psychological symptoms

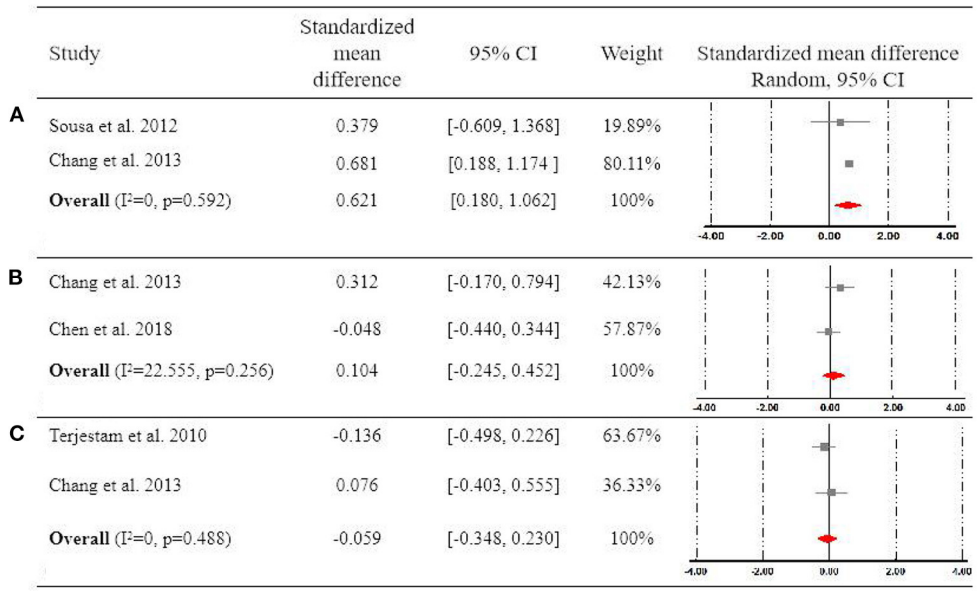

FIGURE 3 | Forest plot for meta-analysis regarding the effect of Qigong on **(A)** saliva cortisol level, **(B)** mood, and **(C)** self-esteem.

(i.e., depression, anxiety), biomarkers of stress response (i.e., cortisol level), and psychological well-being (i.e., self-concept). The findings in adolescents are partially consistent with previous reviews in various populations (Wang et al., 2010, 2013a, 2014b; Yin and Dishman, 2014; Liu et al., 2015; Sharma and Haider, 2015; Tong et al., 2018).

Anxiety and depression have been extensively focused on in previous epidemiological studies examining the association between exercise and mental health. Congruent with previous systematic reviews of other exercise interventions, such as aerobic exercise (Lees and Hopkins, 2013), yoga (Cramer et al., 2013; Gong et al., 2015; Hendriks et al., 2017), physical activity (Penedoa and Dahna, 2005; Lubans et al., 2016), this review suggested the beneficial effect of Tai Chi and Qigong exercise on reducing anxiety and depression. According to the result of subgroup analysis to compare the difference between Tai chi and Qigong exercise in terms of the effect on psychological symptoms, adolescents practicing Qigong exercise perceived greater improvement in anxiety and depression. It is probably because Qigong focus more on "inside" energy flow while Tai Chi focuses on "outside" defending and attacking intention while practicing (Liu et al., 2015). Specifically, the practice of Qigong focuses on the individual's mind, breath, and inner feeling. Liu et al. (2015) systematically reviewed the effect of Qigong and Tai Chi, respectively, on anxiety and depressive symptoms. Consistent with our results, they found that simply Qigong exercise demonstrated a significant effect on lessening the severity of depressive symptoms. Different findings revealed that Tai Chi and Qigong exercise have the same effect on anxiety and depression symptoms (Jahnke et al., 2010). Wang et al. (2013b) evaluated the effectiveness of Qigong vs. four types of control group on depressive and anxiety symptoms in individuals with anxiety and depression disorders. They found that Qigong was beneficial on depressive symptoms when compared to waiting-list controls or treatment as usual, group newspaper reading, and walking or conventional exercise, and was comparable to that of cognitive-behavioral therapy. However, the beneficial effect of Qigong exercise on anxiety symptoms were not supported by available evidence (Dickerson and Kemeny, 2004). Honestly, the results of this review should be interpreted and generalized cautiously due to the limited number of included studies and the potential heterogeneity across studies. Although the effectiveness of Qigong exercise on anxiety and depression seems to be more prominent, the findings are not conclusive because the studies that were meta-analyzed for anxiety and depression lacked methodological homogeneity in terms variation of Qigong intervention, control group, and outcome measurements. Unfortunately, the comparison of Tai Chi and Qigong exercise to different types of control group was not feasible in this study. Additionally, the meta-analysis was conducted based on various instruments, including both specialized scales measuring anxiety and depression (e.g., State Trait Anxiety Inventory; Nine-item patient health questionnaire depression scale) and integrated scales (e.g., Middle School Students' Mental Health Scale) with subsets of psychological outcomes. These methodological heterogeneities may account for the impact of excluding those studies with high heterogeneity on altering the pooled results and effect sizes on depression symptoms and stress.

Additionally, cortisol has been one of the most frequently studied biomarkers manifesting physiological responses toward social and psychological stress (Dickerson and Kemeny, 2004; Gunnar and Herrera, 2015; Adam et al., 2017). The pooled results of one RCT (Chang et al., 2013) and one NRS (Lee et al., 2009)

revealed a favorable effect of Qigong on reducing cortisol level, which reinforces the beneficial effects of Qigong exercise on stress reduction. The findings are in accordance with previous evidence on physical activity in relation to cortisol level among young healthy persons (Alghadir et al., 2015; Hötting et al., 2016). Although the variation between the included studies with regard to experimental design (i.e., RCT vs. NRS) may produce inherent bias of the pooled data, the results suggest that Qigong has the potential to relieve psychological stress by regulating cortisol level. Previous studies mainly focused on identifying dose-response effect of exercise and physical activity for self-perceived psychological outcomes (Tsang et al., 2008; Wang et al., 2009; Roswiyani et al., 2019). Similarly, the included studies rarely used objective measures of psychological outcomes, restricting the possibility to conduct further meta-analysis on these variables. Future studies are encouraged to included objective measures of biomarkers related to stress response and anxiety, such as norepinephrine, epinephrine, blood pressure, and heart rate, to form a more comprehensive understanding of the effect of Qigong on various aspects of psychological health and well-being in adolescents. Little is known regarding the underlying mechanism relating to the beneficial effect of Qigong exercise on psychological health. Possible assumptions claimed that the improvement of psychological status resulted from Qigong practice is probably mediated by the physiological process (e.g., hormone regulation, changes of brain-derived neurotrophic factors) (Litscher et al., 2001). Therefore, measures of relevant biomarkers may help investigate the potential mechanism as well as the reciprocal association between psychological and physiological variables.

Insufficient evidence is provided to confirm the beneficial effect of Qigong on other psychological variables, including mood state and self-esteem. These results may partially contradict with previous systematic review (Wang et al., 2010), which provided reliable evidence supporting the effect of Tai Chi on enhanced mood, but not on self-esteem, among community-dwelling healthy participants and in patients with chronic conditions. Target population may account for the inconsistent findings. Previous RCTs found consistent results that Baduanjin and tai chi exercise did not significantly improve mood and self-esteem, among college students (Li et al., 2015; Zheng et al., 2015). The variation in intervention duration ranging from several weeks to months may explain the inconsistent findings in these variables. For example, considering self-esteem as a relatively stable personal characteristic, it is probably that short-term exposure to intervention is not adequate to produce satisfactory change.

This review appears to support the therapeutic effect of Tai Chi and Qigong exercise on psychological health outcomes in a specified population – adolescents, which has the advantage of acquiring outcomes in particular to this target group compared to various populations involved in previous reviews (Wang et al., 2014b). Due to the limited number of studies, meta-analysis of each indicator only includes two to three trials, resulting in difficulty for data consolidation or synthesis results. The lack of number of studies is aligned with previous meta-analyses in adults in this field (Wang et al., 2013a,b, 2014a). Despite that a growing body of studies examined the psychological effects of Qigong or Tai Chi in recent years, only few of them focused on adolescents specifically. The lack of number of studies and overall unsatisfactory methodological quality prohibit to draw conclusive findings. Additionally, the included studies examined the impact of Tai Chi and Qigong on adolescents' psychological health outcomes, with psychological health outcomes measured primarily in terms of the absence of manifested psychological symptoms and problems, such as depression and anxiety symptoms. This could also be affirmed by the number of trials that are included in meta-analysis, where anxiety and depression were the most frequently measured among all the psychological outcomes. However, relatively few studies have focused on the positive attributes of mental health (Shek, 2007). This is in accordance with less quantitative data for self-esteem and quality of life that can be meta-analyzed. Different from normal adult population, adolescents' psychological well-being has close relation to academic master, peer relationship, and attachment with parents. Future studies with identifying population-based and context-based indicators reflecting the positive aspects of psychological well-being are strongly needed in this population. Additionally, the type of exercise other than Tai Chi or Qigong employed in comparison group was limited. As a result, it is impossible to compare results across studies to recognize whether Qigong exercise, with the emphasis on the movement of the body driven by thoughts and breath, provides equal or superior psychological benefits compared to other types of exercise. Next, the studies included in this review exhibit a variety of Tai Chi or Qigong styles, and frequency, intensity, and duration of intervention. Specifically, the frequency ranges from one to seven sessions per week, and the length of intervention ranges from 7 weeks to 1 year. Few studies examined whether different protocol of Tai Chi or Qigong exercise affected the psychological outcomes. Only one study compared different intensity of Qigong exercise (30 min per session vs. 60 min per session), but they failed to find any significant difference. Further studies with the comparison of different attributes of Tai Chi and Qigong exercise are encouraged to identify the optimized intervention protocol that maximize the dose-response effects and the adherence rate among participants. Finally, moderate to high heterogeneity was found for the overall effects of Qigong and Tai Chi on anxiety, depression, and stress. High variation in instruments to measure outcomes and difference in methodological rigor between RCTs and NRS of included studies may account for the potential sources of heterogeneity. Additionally, publication bias may also contribute to the methodological concern of the included studies as most of them were mainly conducted in China. Well-controlled randomized trials with rigorous study design, larger sample size, and the availability of other types of exercise (e.g., aerobic exercise) as comparison group are called on for future studies to provide complementary evidence in this field.

CONCLUSION

The findings of this systematic review only provide preliminary evidence that Qigong exercise may be potentially beneficial for adolescents' psychological well-being, including reduced

anxiety and depressive symptoms, and decreased cortisol level. However, the outcomes should be interpreted cautiously due to limited number of studies and methodological weakness. Future studies that are rigorous, prospective, well-controlled randomized trials with appropriate comparison groups, and with validated outcome measure are now needed to draw conclusive findings to understand the effects of Tai Chi and Qigong exercise on psychological well-being. Furthermore, objective measure of anxiety and stress response as well as the consideration of more positive aspects of psychological health outcomes in particular to this population may provide more reliable evidence and inspiration in this field.

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.

AUTHOR CONTRIBUTIONS

XL: conceptualization, formal analysis, and writing—original draft. RL: formal analysis and writing—review and editing. JC and FL: screening and formal analysis. LS, XC, and DZ: writing—review and editing. 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/fpsyg.2021.746975/full#supplementary-material

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REVIEW
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The Association Between Regular Physical Exercise, Sleep Patterns, Fasting, and Autophagy for Healthy Longevity and Well-Being: A Narrative Review

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This narrative review of the literature assessed whether regular physical exercise and sleep patterns, fasting and autophagy, altogether can be an adequate strategy for achieving healthy longevity and well-being within different stage of life. There are a large number of studies dealing with well-being and healthy longevity; however, few of them have given us a specific formula for how to live long and healthy. Despite all the advances that have been made to create adequate physical exercise programs, sleep patterns or nutritional protocols, the relation between different types of fasting, nutritional supplementation as well as regular physical exercise and sleep patterns have not yet been satisfactorily resolved to cause the best effects of autophagy and, therefore, well-being and healthy longevity. In this way, future studies should clarify more efficiently the relationship between these variables to understand the association between regular physical exercise, sleep patterns, fasting and autophagy for healthy longevity and well-being.

Keywords: exercise, sleep, fasting, autophagy, health, longevity, well-being

INTRODUCTION

The twentieth century is characterized as the century of world population growth and it is considered one of the most significant achievements of civilization, while the twenty-first century is characterized as the century of aging. The global average life expectancy was extended by 5.5 years in the period from 2000 to 2016 (Vukovic, 2021), which is the largest increase since the 60s of the twentieth century. According to United Nations projections, the number of people over the age of 60 will more than double by 2050, from the current 840 million to over 2 billion people (Vukovic, 2021).

There are a large number of studies dealing with healthy longevity and well-being; however, few of them have given us a specific formula for how to live long and healthy. Yet there is one man

who has brought us closer to our goal, and that is Yoshinori Ohsumi, a 2016 Nobel Prize-winning researcher in Physiology or Medicine for his initial interpretation of the mechanisms of autophagy (Antunes et al., 2018). Although the contributions of this great scientist are very well-known in the field of science, the global public, unfortunately, is not adequately acquainted with his conclusions and recommendations, as well as the outputs of a large number of studies that followed his work. For this reason, this narrative study aimed to point out that an adequate physical activity, sleep patterns, fasting, and autophagy may be highly correlated with to healthy longevity and well-being.

According to Antunes et al. (2018), autophagy is "an evolutionarily conserved lysosomal catabolic process by which cells degrade and recycle intracellular endogenous (damaged organelles, misfolded or mutant proteins and macromolecules) and exogenous (viruses and bacteria) components to maintain cellular homeostasis." Therefore, autophagy has, lately, been used in solving various health problems, including one of the greatest enemies of longevity such as cancer (Galluzzi et al., 2015; Amaravadi et al., 2016), and one of the global epidemic and the most blatantly visible yet neglected public health problem nowadays such as obesity (Lavallard et al., 2012), as well as infections and inflammatory diseases (Cadwell, 2016), neurodegeneration (Menzies et al., 2017), metabolic and cardiovascular diseases (Bravo-San Pedro et al., 2017), et cetera. Thus, it is not wrong to assume that autophagy represents well-trodden path in lifespan extension and well-being, as well as it is the primary mechanism that can help removing damaged organelles, such as mitochondria, which may have a direct impact on aging (Yen and Klionsky, 2008). On the other hand, it is very important to emphasize that regular physical activity, sleep patterns and proper nutrition are also important factors in achieving healthy longevity and well-being. So, the main goal of this study is to offer basic knowledge of association between regular physical exercise, sleep patterns, fasting and autophagy in the process of achieving healthy longevity and well-being through narrative review of scientific literature.

PHYSICAL EXERCISE

It is well-known that physical exercise, defined as "planned, structured and repetitive physical activity, has been an important force to alter physiological characteristics of human being during the process of evolution" (cited in Andreotti et al., 2020). On the other hand, physical exercise is well-connected to the aging process. This is reflected in by molecular and cellular changes over a longer period of time and it can lead to the deterioration of physiological parameters important to keeping a human body alive and healthy (cited in Andreotti et al., 2020). So, aging is "a physiological process characterized by a progressive decline of biological functions and an increase in destructive processes in cells and organs, while physical activity and exercise positively affects the expression of skeletal muscle markers involved in longevity pathways" (Mancini et al., 2019). Therefore, it is very important to understand the role of physical exercise in the process of achieving healthy longevity within different stage of life from childhood to old-age.

It is generally known that physical exercise is a natural activity during childhood, but it is very important to emphasize that habits are acquired then, but also improve certain physical abilities and characteristics. Special attention needs to be paid from adolescence onwards. Namely, physical exercise can have beneficial effects on the ability to pay attention and cognitive function in adolescents that are the findings of a study conducted by Vanhelst et al. (2016) and de Greeff et al. (2018). Also, during adolescence, certain cases of depression can occur, and physical exercise has been shown to be an effective factor in reducing the symptoms of depression, both in adolescents and young people, it was found in the studies that were conducted by Balchin et al. (2016), Sadeghi et al. (2016), Radovic et al. (2017), and Bailey et al. (2018). Physical exercise is also useful for the working population, but it is the most useful for the elderly population, who are constantly recommended regular physical exercise. However, few of older people follow the recommendations, especially moderate to vigorous physical exercise; even, some believe that physical exercise could be potentially harmful (Franco et al., 2015). According to Hupin et al. (2015), moderate physical activity can reduce mortality risk up to 22%, so it is not surprising that Cotman and Berchtold (2007) have concluded that "among the various interventions that affect aging, physical exercise seems to be the main ally in the prevention of aging-related diseases" and, therefore, the main ally of healthy longevity and well-being.

In summary, regular physical exercise increases skeletal muscle fat oxidation and anti-oxidative potential, stimulates musculoskeletal metabolic adaptations, and results in beneficial improvements in the cardiovascular system (Andreotti et al., 2020). Also, regular physical exercise improves quality of sleep and increases brain-derived neurotrophic factor production, and can decrease neuronal death and improve cognitive performance (Mancini et al., 2019). Regular physical exercise can also cause many other effects that can affect positive aging and health; however, the molecular effects of exercise training on regulation of autophagy and processes involved in longevity promotion are not completely explained by the scientific society, and there is no general agreement on this issue (Andreotti et al., 2020).

SLEEP PATTERNS

In regular conditions, people spend about one-third of their life either sleeping or attempting to do so. The key significance of sleeping time is enabling enough time for recovery functions of the organism which is crucial for effects in human health, well-being, longevity, and optimal daytime functioning (Sorathia and Ghori, 2016; Bertozzi et al., 2017). This fact confirmed that enough quality sleep is necessary to help each person maintain other activities in their daily routine. Therefore, it's clear that human health and well-being are associated with regular sleep patterns as an essential factor for 24 h of human functioning and help to the maintenance of homeostatic needs (Tufik et al., 2009). On another side, some estimations highlighted that every third person globally has sleep-related problems (Roth,

2007). These problems with sleep disorders can be caused by different factors, such as physical or medical, psychiatric, aging, genetics, medications, lifestyle, and socio-demographic factors (smoking, exercise, education, age, gender, et cetera). Further, sleep disorders can increase the number of cardiovascular (Basnet et al., 2016) and metabolic diseases (Karthikeyan et al., 2019), which are frequently causes of human diseases and mortality.

Researchers put a lot of effort to reveal contextual factors which are associated with managing sleep-related problems, intending to impact on physical, mental, social, and emotional health and well-being of people. Some conclusions revealed the negative effect of physical load at the job and intensive physical exercise on insomnia (Dubinina et al., 2021). Further, the importance of quality of sleep in a psychological context showed that depression is associated with sleep problems (Basnet et al., 2016). Also, conscientiousness, as a personal trait, can be an essential moderator in the protection of individuals of poor sleep (Williams and Moroz, 2009). On the contrary, human dispositional optimism contributes to a lower risk of chronic insomnia (Weitzer et al., 2021), and regular sleep has significant importance to cognitive health and higher level dopaminergic activity (Yang et al., 2014). Further, Eisenberger and Cole (2012) revealed the importance of social relationships in the same context.

Contemporary managing sleep-related problems require a deep approach through an interdisciplinary and holistic approach. That is a reason why many researchers point out that improvement in managing sleep problems contributes to a higher quality of life, well-being, and longevity in a population (Basnet et al., 2016).

FASTING

Fasting is "characterized by the complete deprivation of food but not water, with intervening periods of normal food intake" (Mattson et al., 2017). It has been known since ancient times, and it has remained in modern religions as a significant activity in religious rites. Although ancient religious knowledge was not based on adequate scientific facts, it is still interesting to mention it, mostly because it turned out to be correct, and the main question is how ancient people came to such valid knowledge. However, the goal of this study is not to deal with knowledge of ancient people and their methods in reaching it, but to determine contemporary knowledge and methods that would improve the health status of contemporary people and prolong their lives. Therefore, in the description of current knowledge of fasting, it is important to highlight that, according to the suggestions of Mattson et al. (2017), it has been found that fasting can "improve cardiometabolic health, reduce cancer incidence, reduce the rate of tumor growth, regenerate organs by increasing stem cell production, and increase lifespan," which significantly leads to the conclusion that it has a significant impact on improving human health status and longevity. In addition, there is scientific evidence, presented to the scientific community by Antoni et al. (2017) and Tinsley and Horne (2018), which has suggested that "fasting decreases body weight, insulin levels, blood pressure, inflammation, and appetite, and that it improves insulin sensitivity and lipid profiles," which in many ways can also improve a human health status and longevity.

The previous paragraph described how fasting can improve a human health status and longevity in the general sense of the words. However, further analysis of this issue opens up new scientific questions that should be answered and offered to potential readers of this manuscript. Namely, it is important to emphasize that fasting is not in itself starvation but it represents a way of life that requires a certain sacrifice. For that reason, not all people are ready to approach it in the same way, so there are different types of fasting, each tailored to the individual in order to improve its health status and longevity. On the one hand, there are still religious priests, who fast in accordance with their centuries-old rules and maintain their health status at an adequate level, which leads to their longevity. On the other hand, there are a large number of people who are not able to organize their diet in accordance with the needs of their body. The modern lifestyle has led to the fact that their daily meals are not prepared in an adequate way, but "fast food" is taken. Meals are extensive and contain many non-nutritious ingredients, and are ingested both during the day and overnight, without any plan. Accordingly, the modern world has encountered a problem that is reflected in obesity. Namely, obesity is a serious problem, as it is associated with poorer mental health outcomes and reduced quality of life [NCD Risk Factor Collaboration (NCD-RisC), 2019]. Obesity is also linked to leading causes of death worldwide, including diabetes, heart disease, stroke and some cancers [NCD Risk Factor Collaboration (NCD-RisC), 2017]. For this reason, there are a large number of governmental and non-governmental organizations that show interest in the use of fasting for the treatment of obesity as it has been proven to be significantly correlated with the improvement of health status and longevity. However, there is no a general formula that can be suitable for each individual and different types of fasting have been defined over time. Next to the most recognized continuous energy restriction, it is interesting to present some alternative dietary weight loss strategies. Rynders et al. (2019) have created a strategy that "involves restricting energy intake to certain periods of the day or prolonging the fasting interval between meals (i.e., intermittent energy restriction)". The strategy in question includes intermittent fasting and time-restricted feeding. Intermittent fasting is reflected to >60% energy restriction on 2–3 days per week, or on alternate days, and it covers "a broad class of interventions that alternate periods of eating and extended fasting, where it is associated with substantial weight loss in short periods of time, during around 8–12 weeks (Rynders et al., 2019)." According to the same authors, intermittent fasting interventions include "periodic 24-h fasts, intermittent energy restriction (e.g., the 5:2 diet), and time-restricted feeding that includes Ramadan fasting." On the other hand, time-restricted feeding is "limiting the daily period of food intake to 8–10 h or less on most days of the week (Rynders et al., 2019)." Mattson et al. (2017) have created another strategy based on the duration. The strategy in question includes intermittent fasting and periodic fasting. According to mentioned authors, intermittent fasting suggests alternate day fasting (≥16 h) or 48 h

of fasting/week, while periodic fasting suggests a minimum of 3 days of fasting every 2 or more weeks. Further analysis of the literature would lead to a number of other strategies, but the authors of this manuscript believe that the presented strategies are sufficient for each of the potential readers to choose one for themselves.

In summary, all the mentioned types of fasting in the previous paragraph have proven to be useful when it comes to improving human health status in many ways and, therefore, longevity. To make this claim more convincing, it is necessary, first of all, to refer to the research of Ravussin et al. (2019) who discovered that "time-restricted feeding has shown to facilitate weight loss through the meal-timing interventions by decreasing appetite rather than by increasing energy expenditure, where time-restricted feeding showed lowered values of ghrelin and leptin." Also, the following three studies (Harvie et al., 2011; Gnanou et al., 2015; Panizza et al., 2019) confirm the assumptions that "intermittent energy restriction, combined by the specific diet have shown to generate a loss of body weight and fat mass," while two more studies emphasized that "Ramadan fasting produced a weight loss through an increased energy expenditure (Lessan and Ali, 2019) and metabolic benefits (Fernando et al., 2019)." However, it is not enough to conclude this chapter only with recommendations related to limiting food intake, but it is important to note the part of the day in which food is consumed. Namely, it is a well-known fact that achieving an adequate muscle mass is a key factor for attaining a good body image, so Argiles et al. (2016) claim that "muscle is increasingly being recognized as a key tissue for the maintenance of an adequate health status." The authors of this manuscript invite readers to pay special attention to proper nutrition during the period of food intake. They suggest there are a number of studies that recommend taking protein immediately after exercise, especially whey protein, which "acutely stimulates significant increases in post-exercise muscle protein synthesis (Atherton and Smith, 2012)." As proteins are widely used for active and sedentary people as a product for muscle growth, in addition to fasting, it is very important to use a diet rich in protein to lose weight and low in carbohydrates.

AUTOPHAGY

Although the introductory part of this manuscript significantly deals with autophagy, it is still necessary to deal with another part of this topic, in order for potential readers to get a complete picture of this issue. Namely, it is very important to point out the conclusions of Thevelein et al. (2000) who emphasize that "aging cells gradually accumulate various deleterious changes, resulting in a decline in cellular function and eventually leading to cell death and disease." Also, the same group of authors points out that "the accumulation of damaged macromolecules and organelles is one of the most persistent changes in aging cells," while, Cuervo and Dice (1998) add that autophagy is "associated with the decline of different catabolic pathways." Cuervo et al. (2005) in one of their recent studies concluded that the absence of autophagy in the elderly is one of the main causes that lead to the accumulation of biological "waste" reflected in damaged proteins and organelles. This group of authors based their assumptions on the facts obtained by Melendez et al. (2003), Kuma et al. (2004), as well as Juhasz et al. (2007) in their research on mice. These authors found that the loss of autophagy gene function led to the accumulation of damaged proteins and organelles within the cells, and that this accelerated the aging of mice, and thus shortened their lifespan. On the other hand, a study conducted by Simonsen et al. (2008) proved that elevating autophagy activity increases life span in the same species of mice, since the process of autophagy saved aged cells, so that there was no accumulation of dysfunctional mitochondria.

Autophagy is an evolutionarily conserved lysosomal catabolic process. In this process, the cells break down and recycle damaged organelles, incorrectly assembled proteins, then mutated proteins and macro molecules, as well as exogenous components such as bacteria and viruses. Therefore, autophagy is a process that aims to preserve cellular homeostasis in the human body. However, it is worth emphasizing that even autophagy cannot be viewed as a unique process characteristic of all types of activities that are initiated in that process. Namely, there are three main types of autophagy: (1) microautophagy, (2) chaperone-mediated autophagy and (3) microauthofagy. The specificity of each types of autophagy is reflected in the load type and the route of delivery to the lysosome. Mijaljica et al. (2011) defined microautophagy as a process that "involves the direct engulfment of cargo in endosomal/lysosomal membrane invaginations." On the other hand, Kaushik and Cuervo (2012) described chaperone-mediated autophagy as a process that "recycles soluble proteins with an exposed amino acid motif that is recognized by the heat shock protein HSC70," while macroautophagy, which is the best characterized type of autophagy, represents a process in which cytoplasmic constituents, which are encompassed by double-membrane vesicles called autophagosomes, fuse with lysosomes to form autolysis, and there the burden is degraded or recycled (Mizushima and Komatsu, 2011; Galluzzi et al., 2017).

In summary, autophagy is an essential process that takes place in human body with the goal of removing dysfunctional and unwanted parts of cells as well as regenerating existing cells to make them newer and healthier, so autophagy represents an evolutionary self-preservation mechanism through which humans can clean and repair its body (Marx, 2015). This explains the literal meaning of autophagy that is derived from the Ancient Greek for "self-eating"—"auto" means "self" and "phagy" means "eating." From this reason, it should be easy to assume that autophagy should positively affect healthy longevity and well-being; however, there are some scientific studies to suggest that autophagy can have positive, but also negative health effects, so it is necessary to seek medical advice beforehand starting it (Schiattarella and Hill, 2016). Nevertheless, scientists still do not have a clear picture of all health implications of autophagy, so further researches are necessary, especially with the human subjects (most of researches have been conducted on non-human subjects). The part the scientists do know is connected to fact that the main benefits of autophagy are based on anti-aging principles and trying to turn the body clock back and create new and young cells. The scientists do also know that autophagy is

increased when our cells are stressed, in order to protect human body and helps in the process of enhancing healthy longevity and well-being (Alirezaei et al., 2010). Although it is the fact that autophagy occurs naturally it is very important to set up a research question if the autophagy can be stimulated by some specific triggers. Some research strongly suggests that both fasting (intermittent fasting) and calorie restriction (ketogenic diets) can stimulate autophagy in the human body (Bagherniya et al., 2018), as well as, both regular physical activity (Brandt et al., 2018) and regular sleeping (Bedont et al., 2021).

PHYSICAL EXERCISE, SLEEP, FASTING AND AUTOPHAGY: PRACTICAL SUGGESTIONS FOR WELL-BEING AND HEALTHY LONGEVITY

Movement is one of the basic needs of human being, which has sustained him during evolutionary development; however, most of the time the human being moved more than he needed to. In order to reduce the volume of heavy physical work, which was synonymous with the survival of human being for a long period of time, human being devised modern technologies that have taken over the role of human being in performing the aforementioned jobs. However, contemporary human being did not cope with the new circumstances, it can be said that human being even abused the ability to bring its movement and overall physical activity below the acceptable minimum necessary for the survival of human being as a healthy individual. If it is added to this the issue of the appearance of inorganic food on a large scale, it is clear that the diseases faced by contemporary human being and premature mortality are not a surprise.

Whether it will indulge in an inactive lifestyle and allow to be overwhelmed by the epidemic of immobility, but also all other epidemics that threaten us every day directly in front of or just around the corner, it is a main contemporary question. But it is a question that human population must not wait long to answer. There are solutions, but for them the common man must first find out and then persevere to get results, since the path to health and good energy requires certain sacrifices. Although autophagy is not an unknown term in scientific circles, it is increasingly becoming available to non-scientific audiences, especially after the guidelines that arrived from world-famous athletes, in the first place Novak Djokovic, the number one tennis racket. While waiting for stronger scientific confirmation, it is necessary to stick to the theories and knowledge that are currently available. So, the authors of this narrative review made recommendation, from the available practical and theoretical experience, to walk at least one kilometer every day, to sleep between seven and 9 h per night (for healthy adults), between seven and 8 h per night (for people over 65 years old), while in childhood and teens this period should be prolonged, not to take food for 16 h, just to drink exclusively water, tea and coffee without any additives (Pietrocola et al., 2014), between dinner at 6 pm and breakfast at 10 am the next day. On the other hand, the timetable does not need to be strict, so any individual can schedule any suitable timetable, just to keep 16 h food restrictions. For those who does not prefer to fast every day, the authors recommend a periodic fasting. This means minimum 3 days of fasting (the same food restrictions as described in the previous example) every 2 or more weeks.

Available theoretical knowledge and experience of individuals promise to raise every individual who consistently adheres to the above recommendations, in addition to biological benefits, and raising psycho-physical abilities, as well as the emergence of "youthful" energy, which gives a person the impetus to feel faster, stronger and more capable, much easier, enters into daily activities.

The fact is that a healthy, asleep and mobile citizen is a socially useful citizen. He represents a good producer, but also an equally useful consumer who, in the best way, maintains the economic chain at an adequate level. In such circumstances, that citizen is satisfied at home, satisfied on the street and satisfied at work, and society, with the majority of such citizens, is a welfare society, to which we should all aspire.

CONCLUSION

This narrative review highlights the studies that explain regular physical exercise and sleep patterns, as well as fasting, and autophagy as a strategy for healthy longevity and well-being. Currently, any of these methods have been used for achieving healthy longevity and well-being within different stage of life from childhood to old-age; however, focusing on combination of all four methods instead of using just one should be the primary aim in the process of reaching healthy longevity and well-being in full capacity. Despite all the advances that have been made to create adequate physical exercise programs, sleep patterns or nutritional protocols, the relation between different types of fasting, nutritional supplementation and regular physical exercise and sleep patterns have not yet been satisfactorily resolved to cause the best effects of autophagy and, therefore, healthy longevity and well-being. Previous researches gave some guides how to create adequate protocols to reach the best effects of autophagy, but no studies answered the most important questions how to recognize the autophagy threshold and how to use various factors such as fasting and calorie restriction as well as regular physical activity and regular sleeping to stimulate autophagy and decrease the autophagy threshold. In this way, since there are no previous studies, the first future study should create a theory of autophagy threshold, while the rest of future studies should be clinical trials that would confirm independent and joint positive effects of regular physical exercises and sleep patterns, as well as fasting and autophagy on healthy longevity and well-being.

AUTHOR CONTRIBUTIONS

SM and BM formulated the research goals and aims, developed and designed the methodology, prepared the published work, and specifically wrote the initial draft. TB prepared the published work and specifically acquired the financial support for the project leading to this publication. RM, IV, MV, JL, JV, TF, BJ, RB, and SP 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.

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The Association Between Level of Physical Activity and Body Mass Index, and Quality of Life Among Elderly Women

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The process of aging leads to changes in functional abilities, fitness levels, level of physical activity, and body mass index (BMI), all of which causes changes in the quality of life. The current study aims to determine the association between the level of physical activity (PA) and BMI, and quality of life (QoL) among elderly women. The total sample numbered 156 women, with an average age of 67.7 ± 5.6 years. To determine the level of physical activity, the self-reported International Physical Activity Questionnaire Long Form (IPAQ-LF), was used. To calculate the values of the BMI, the standard procedure recommended by the World Health Organization was used. Quality of life was evaluated using the short form of the WHOQOL-BREF questionnaire designed by the World Health Organization. All the data were processed using the statistical package for data analysis SPSS 20.0. Pearson's correlation analysis shows statistically significant relations at the level of $p < 0.01$ between PA and Physical health in Housework = 0.36, Leisure time PA = 0.27, Walking = 0.24, Moderate PA 0.43, Total PA = 0.43, while the correlations between the variables at the significance level of $p < 0.05$ were determined in PA in transportation = 0.19 and High-intensity PA = 0.16. Multiple linear regression analysis of different levels of PA as independent variables on individual domains of QoL shows that there is an association of PA and Physical health (Sig = 0.000), more precisely, Total PA is statistically the most closely related to Physical health (Sig = 0.000), and then follows PA at work and Social relations (Sig = 0.036). Similar results were obtained when BMI is added to model A. In contrast to model A, model B shows a statistically significant association between PA and BMI with the environmental domain of QoL (Sig = 0.001). The results of the current study indicate that high- and moderate-intensity physical activity both have benefits for physical health, whereas moderate PA showed higher significance levels. Results also show that elderly women with higher BMI values achieve better results in the environmental domain of QoL.

Keywords: physical activity, health-related quality of life, elderly, body mass index, obesity

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INTRODUCTION

The aging process is associated with physiological, functional and fitness changes in the human body which could impact everyday life of the individual. Previous studies confirmed that aging is related to lower functional abilities (Izquierdo and Cadore, 2014), muscle power (Ramirez-Campillo et al., 2016) and balance, which leads to a decrease in quality of life and an increase in the risk of various illnesses (Brown et al., 2012). It is well known that elderly people are less physically active compared to the adults (Tomioka et al., 2011) which could have many consequences in terms of health. Several studies confirmed that higher level of physical activity is associated with decreasing morbidity and mortality as well as increased quality of life (Brown et al., 2012; Arem et al., 2015; Ekelund et al., 2019; Kraus et al., 2019). However, the concurrent effect of physical activity and body mass index (BMI) on the quality of life in elderly women is still unclear due to quality of life complexity.

It is well known that active lifestyle leads to better results when it comes to mental health (Bernard et al., 2018), social functioning (Ku et al., 2016) and emotional roles (Delle Fave et al., 2018). Moreover, physical activity benefits have been confirmed in physical performances, psychological status, social relations, and the environment (Valenti et al., 2008), as well as physical health (Battaglia et al., 2016; Nawrocka et al., 2019). In line with that, Ekwall et al. (2009) confirmed that elderly women who regularly take part in physical activity have a better quality of life (Ekwall et al., 2009). Furthermore, better quality of life also depends on different intensities of physical activity and the frequency of exercise, both in the domains of physical and mental components (Dugan et al., 2009; Ekwall et al., 2009). Women who take part in high-intensity physical activity with increased energy consumption (>1,000 kcal/week) achieve better results for quality of life in almost all domains, primarily in emotional roles, vitality, and in the domain of mental health (Morimoto et al., 2006). Improved results for quality of life in the physical and psychological domain and the domain of the environment are also achieved by women who take part in moderate-intensity physical activity (Fox et al., 2007). Despite the fact that both high- and moderate-intensity physical activity increase the quality of life it is still questionable if elderly people with higher BMI achieve better quality of life if they perform high-intensity physical activity.

In addition to the connection between physical activity and quality of life, data indicate that there is also a certain association between BMI and quality of life (Søltoft et al., 2009; McDonough et al., 2013; Liu et al., 2016; Kolotkin and Andersen, 2017; You et al., 2018). Existing research indicates that BMI has an impact on almost all the aspects of quality of life. When it comes to the values of BMI, maximum quality of life is noted for women with BMI around 24.5 kg/m^2 (Søltoft et al., 2009). This indicates that higher BMI is in a negative relation with the quality of life of obese individuals (McDonough et al., 2013) but little is known how different physical activity levels in combination with higher BMI impact quality of life.

Some of the aforementioned studies separately focused on the association between physical activity and quality of life among the elderly (Morimoto et al., 2006; Dugan et al., 2009; Ekwall et al., 2009; Bernard et al., 2018; Delle Fave et al., 2018; Nawrocka et al., 2019; Schultchen et al., 2019), while a certain number of studies investigated the association between BMI and quality of life among the same population (Søltoft et al., 2009; McDonough et al., 2013; Liu et al., 2016; Song et al., 2016; Busutil et al., 2017; Kolotkin and Andersen, 2017; You et al., 2018). However, many elderly women have been classified as overweight or obese based on BMI despite optimal physical activity level because BMI is an approximate measure that does not take into consideration body fat distribution. Therefore, physical activity and BMI should be combined as related measures to better understand their effects on quality of life as well as which measure has a higher impact. However, the full extent to which the concurrent effect of physical activity and BMI is associated with quality of life in the elderly is uncertain due to limited evidence in current literature. Therefore, the study aimed to determine the association between physical activity and BMI, and quality of life among elderly women.

MATERIALS AND METHODS

Study Design and Procedures

The study included a questionnaire on the level of physical activity and quality of life which was filled out by elderly women. Prior to the completion of the questionnaire, the researchers provided additional explanations and instructions for the respondents regarding the way the survey questionnaire was to be completed, as well as regarding the aim and goals of the study. The respondents wrote their responses directly into the survey questionnaire, and no time limit was imposed. In ensure honesty and lack of bias when filling out the questionnaire, the respondents were informed that their responses would remain anonymous, and that the obtained results would only be used for research purposes. Incomplete questionnaires were not included in further analyses. Body mass and body height were measured following the completion of the questionnaire. Of the 194 completed survey questionnaires, 156 met the requirements for further analysis and were included in the statistical data analysis. The questionnaire also included sociodemographic questions. The research was approved by the Ethics Committee of the Faculty of Sport and Physical Education, University of Niš. All of the procedures during the study were carried out in accordance with the Declaration of Helsinki.

Participants

The population from which the sample of respondents was extracted was defined as the population of elderly women based on criteria provided by the World Health Organization (Papalia et al., 1992). The total sample consisted of 156 elderly women recruited from the region of Southern and Eastern Serbia (one of the five Serbian regions). The average age of the respondents was 67.74 ± 5.68 years, body height 164.47 ± 6.08 cm, and body mass 69.56 ± 11.43 kg. The study included only those subjects who were able to care for themselves independently, i.e., independently perform daily tasks (dressing, bathing, feeding, walking, going to the store, etc.). Including criterion was also that

subjects did not have cognitive impairments, mental disorders or dementia. The study did not include respondents with physical disabilities and severe medical conditions not related solely to the aging process (for example, malignant tumors, dementia, Alzheimer's, etc.) or respondents who have psychological disorders. Those respondents who were in the phase of recovery from acute diseases, as well as people with visual and hearing impairments were also excluded. Subjects with cardiovascular disorders identified through medical history or when completing questionnaires were also excluded from the study.

All of the respondents were fully informed about the study procedures and were told that they could at any point opt out of the study.

Measures

Physical Activity

To determine the level of physical activity, the self-reported International Physical Activity Questionnaire Long Form (IPAQ-LF) was used (Craig et al., 2003). This questionnaire evaluates the level of physical activity performed during the course of 1 week. The IPAQ questionnaire evaluates the frequency, duration, and intensity of physical activity in several domains, including: (a) leisure time physical activity, (b) physical activity around the house and garden (yard), (c) physical activity at work, and (d) transport-related physical activity. The results related to certain domains required that the points for walking, moderate physical activity, and high-intensity physical activity as part of every individual domain be added up, while the results related to certain activities required the summation of results for specific types of activities in a number of domains. The criteria for a certain level of physical activity were determined once it was taken into consideration that the IPAQ questionnaire includes questions that refer to the domain of everyday life. This results in average values for the estimation of MET-minutes. The long-form version of the IPAQ questionnaire proved to have a more acceptable level of reliability and validity (Craig et al., 2003; Tomioka et al., 2011). The reliability of the Serbian version of the IPAQ questionnaire was confirmed in the study of Milanović et al. (2014).

BMI

To calculate the values of BMI, the standard procedure involving the equation BMI = body mass (kg)/body height^2 (m^2) was used (World Health Organization, 1997).

Quality of Life

To evaluate quality of life, the short form of the WHO WHOQOL-BREF questionnaire for the evaluation of quality of life was used (Berlim et al., 2005). This questionnaire was developed by the World Health Organization based on the WHOQOL-100 questionnaire (WHOQOL Group, 1994; Szabo, 1996). The questionnaire consists of 26 items distributed over 4 domains: physical health, psychological health, social relations, and the environment. The responses to each question were given on a five-point Likert scale, whereby the respondents could select one of the following responses: (1) Not at all; (2) A little; (3) A moderate amount; (4) Very much; and (5) An extreme amount. The reliability and validity of the questionnaire were confirmed in the studies of Jude and Abdel (2009) and Kalfoss et al. (2021). The reliability and validity of the Serbian version of the WHOQoL questionnaire were determined by Ač-Nikolić et al. (2010) on a population of individuals over the age of 60. The research results indicated that the WHOQOL–BREF questionnaire (the Serbian version) is a valid and reliable instrument for the evaluation of quality of life among the elderly.

Data Analysis

For each of the applied variables of physical activity, quality of life, and BMI, descriptive statistics parameters were calculated: the means (Mean), standard deviation (Std. Dev.). Pearson's correlation analysis was used to explore bivariate relationships between PA, BMI, and QoL. Multiple linear regression was used to estimate the relationship between PA, BMI, and QoL domains. Two models were examined for each statistical analysis. Model A was adjusted for PA only, and model B was further adjusted by including BMI in the regression model. All the data were processed using the statistical package SPSS 20.0 (SPSS Inc., Chicago, IL, United States). The significance was set at the 0.05 level.

RESULTS

Table 1 shows the basic parameters of descriptive statistics. Based on the average BMI values, it can be stated that the respondents belong to the group of older women who are overweight.

Table 2 shows the values of the Pearson's coefficients of correlation for BMI and physical activity in relation to indicators of quality of life. Positive correlations (**Table 2**) were found between some domains of PA and Physical health and they range from 0.16 to 0.43. Statistically significant relations ($p < 0.01$) between PA and Physical health were found in Housework = 0.36, Leisure time PA = 0.27, Walking = 0.24, Moderate PA 0.43, Total PA = 0.43, while the correlations between the variables at the significance level of 0.05 were determined in PA in transportation = 0.19 and High-intensity PA = 0.16.

The relations between some domains of PA and Social relations are significant only in PA at work (0.17, $P < 0.05$). Significant positive relationships have been found to indicate that QoL also increases with increasing PA. PA and Psychological

TABLE 1 | Basic descriptive statistic parameters (means ± standard deviation).

BMI	26.1 ± 4.1	**Physical health**	23.7 ± 2.9
PA at work	827.5 ± 1932.3	**Psychological status**	20.2 ± 4.1
PA in transportation	579.5 ± 832.9	**Social relations**	9.7 ± 1.8
PA in housework	2924.3 ± 2235.6	**Environment**	27.3 ± 4.6
Leisure time PA	886.4 ± 1451.7		
Walking	1024.3 ± 1481.8		
Moderate PA	2895.4 ± 2332.7		
High intensity PA	1296.8 ± 1389.9		
Total PA	5264.7 ± 3504.7		

PA, physical activity; Mean, mean value; Std.Dev., standard deviation.

TABLE 2 | Pearson correlation (r) between PA level, BMI and QoL.

	Physical health	Psychological status	Social relations	Environment
BMI	0.10	–0.04	0.04	0.05
PA at work	0.11	0.08	0.17*	–0.04
PA in transportation	0.19*	0.15	0.06	0.02
PA in housework	0.36**	0.00	–0.01	0.03
Leisure time PA	0.27**	0.02	0.06	0.26
Walking	0.24**	0.13	0.09	–0.06
Moderate PA	0.43**	0.06	0.11	0.05
High intensity PA	0.16*	–0.03	0.04	0.03
Total PA	0.43**	0.08	0.13	0.04

*PA, physical activity. *$p < 0.05$; **$p < 0.01$.*

status, as well as PA and Environment, do not correlate significantly in any domain.

Multiple linear regression analysis of different levels of PA as independent variables on individual domains of QoL (**Table 3**, model A) showed that there is an association of PA and Physical health (F = 35.93 Sig. = 0.000), more precisely, Total PA is statistically the most closely related to Physical health (β = 0.435, t = 5.995, Sig = 0.000), and then follows PA at work and Social relations (F = 4,464, β = 0.168, t = 2.113, Sig = 0.036).

Similar results were obtained when BMI is added to model A (**Table 3**, model B). In contrast to model A, model B shows statistically significant association between PA and BMI and Environment (F = 11,448, β = 0.263, t = 3.383, Sig = 0.001).

DISCUSSION

The current study aimed to determine the association between the level of physical activity and BMI, and quality of life among elderly women.

Based on the parameters of descriptive statistics, it could be concluded that the level of physical activity among elderly women corresponds to the level of physical activity of similar samples in other studies (Pucci et al., 2012; Puciato et al., 2017), especially when it comes to moderate physical activity.

By analyzing the results, it could be concluded that there is a statistically significant association between the aforementioned parameters and quality of life, but only in the domains of physical activity. These results are congruent with those of existing studies which focused on the correlation between physical activity and quality of life (Morimoto et al., 2006; Dugan et al., 2009; Ekwall et al., 2009; Bernard et al., 2018; Delle Fave et al., 2018; Nawrocka et al., 2019; Schultchen et al., 2019).

The results showed a statistically significant association between total physical activity, high- and moderate-intensity physical activity with the physical health of older women, where moderate PA showed higher significance levels (p = 0.01). Similar results were obtained by Battaglia et al. (2016) who determined the effects of adapted physical activity on the psycho-physical health of elderly women. Moderate-intensity physical activity has an advantage over high-intensity physical activity in the population of elderly women. The same results were obtained in the study of Fox et al. (2007). This study points out the benefits of physical activity for quality of life in the physical and psychological domain of women taking part in moderate-intensity physical activity. On the contrary, the study by Morimoto et al. (2006) shows that women who take part in high-intensity physical activity (>1,000 kcal/week) scored better results in all domains of quality of life, and the same results were determined in the study by Puciato et al. (2017). The reason for the different obtained results can be found in the age of the participants. The studies in which high-intensity physical activity was proven to be beneficial for the various domains of quality of life all involved younger participants. When it comes to the elderly (60+, 65+ years), the benefits of moderate-intensity physical activity are greater than those of high-intensity physical activity for physical health. Certain studies do not recommend high-intensity physical activity for the elderly (McPhee et al., 2016), especially if the remaining part of the day is marked by sedentary behavior. In addition, there are also gender differences

TABLE 3 | Multiple linear regression models between PA, BMI and domain QoL.

	Model A				Model B			
	Physical health	Psychological status	Social relations	Environment	Physical health	Psychological status	Social relations	Environment
BMI	NS	NS	NS	NS	NS	NS	NS	β = 0.263 Sig = 0.001
PA at work	NS	NS	β = 0.168 Sig = 0.036	NS	NS	NS	β = 0.168 Sig = 0.036	NS
PA in transportation	NS	NS	NS	NS	NS	NS	NS	NS
PA in housework	NS	NS	NS	NS	NS	NS	NS	NS
Leisure time PA	NS	NS	NS	NS	NS	NS	NS	NS
Walking	NS	NS	NS	NS	NS	NS	NS	NS
Moderate PA	NS	NS	NS	NS	NS	NS	NS	NS
High intensity PA	NS	NS	NS	NS	NS	NS	NS	NS
Total PA	β = 0.435 Sig = 0.000	NS	NS	NS	β = 0.435 Sig = 0.000	NS	NS	NS

PA, physical activity; NS, not significant.

when it comes to choosing the type of physical activity. Men are more likely to choose high-intensity activities (Hunt et al., 2014), such as sports games, while women are more likely to take part in moderate-intensity exercise, such as walking (Kassavou et al., 2013). Our results showed significant association between walking and physical health. Since walking is an activity of moderate intensity and is positively related to the quality of life, it is recommended as an activity for elderly women (Pucci et al., 2012), especially because involves a decrease in the risk of injury that may occur in high-intensity activities. A significant association between physical activity in transport and physical health was also noted. Physical activity in transport, such as walking or cycling, etc., has benefits for human health. People who use walking as a means of transportation can meet their daily needs for physical activity (Adams, 2010).

The results of the study indicate that physical activities in the domain of housework positively correlate with physical health. Women who perform moderate-intensity housework achieve better results in terms of physical health. These data are congruent with the results of other studies (Lawlor et al., 2002; Besson et al., 2008), which also state that there is no positive correlation between this type of activity and psychological health (Wen et al., 2013).

A positive association also exists between the domain of leisure-time physical activities and physical health. In their leisure time, older women choose activities that are not imposed on them, but cause them satisfaction and affect their overall wellbeing. Leisure-time physical activity is usually of moderate-intensity and has a positive effect on physical health. Similar results were obtained in Nakamura et al. (2014) study which investigated the same problem in respondents of both sexes.

The results of the regression analysis indicate that there is an association between total physical activity and physical health, which is also explained by the results of the Pearson's correlation analysis. Further, the results indicate that there is an association between PA at work and social relations. The social domain of quality of life increases throughout lifespan (Sonati et al., 2011). Such a fact may be a specific characteristic of older women who are still employed and have good social relationships. Similar results were achieved by the study Sonati et al. (2011), which states that social relations are also influenced by socioeconomic status, level of education, and level of physical activity.

The significant association of BMI was determined only with environmental domain of quality of life. BMI and PA are positively related to environmental domain, which indicates that overweight and obese, in comparison to underweight and normally fed women, achieve better results in environmental domain of quality of life. This data is in accordance with the study results of Deng et al. (2014). In the current study, no association was determined between BMI and other domains of quality of life among elderly women. These data differ from the results of existing studies (McDonough et al., 2013; Busutil et al., 2017), in which a correlation was noted between BMI and mental health. The association between BMI and mental health is present in the younger and adult population, while there is no correlation in older women, i.e., as age increases, the correlation between BMI and mental health decreases (Huang et al., 2006).

CONCLUSION

The aim of the current study was to determine the association between physical activity and BMI, and health-related quality of life in an elderly female population. Based on the results obtained, it can be concluded that there is significant association between the aforementioned parameters and quality of life, but only in the case of domains of physical activity, i.e., physical activity contributes to improved physical health among elderly women. The results of the current study indicate that high- and moderate-intensity physical exercise both have benefits for physical health, where moderate PA showed higher significance levels. BMI and quality of life were positively associated only in the environmental domain of quality of life, that is elderly women with higher BMI achieve better results in the domain of the environment. The obtained results can be used in practice when creating an exercise program for older women, where moderate physical activity (i.e., walking) is recommended. Physical activity is also related to the domain of social relations, and it is recommended to exercise in order to encourage those relations. Further studies should also focus on the association between other anthropological characteristics and abilities, and the parameters of quality of life among elderly women.

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 Ethics Committee of the Faculty of Sport and Physical Education, University of Niš. The ethics committee waived the requirement of written informed consent for participation.

AUTHOR CONTRIBUTIONS

AĐ was the leader of the research group that conducted the study. AĐ, DŽ, ZM, MŽ, LB, and MB contributed to the conception and design of the study. SP and MB organized the database and performed the statistical analysis and wrote the first draft of the manuscript. SP, AĐ, and ZM reviewed and edited the first draft. All authors contributed to the article and approved the submitted version.

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Aggressiveness in Judokas and Team Athletes: Predictive Value of Personality Traits, Emotional Intelligence and Self-Efficacy

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Combat sports and martial arts are often associated with aggressiveness among the general public, although data on judo and/or martial arts and aggressiveness seem to be unclear. This research aims to compare athletes who have trained judo for a prolonged time (minimum 5 years) and athletes from various team sports, primarily regarding the manifestation of aggression, but also regarding personality traits, emotional intelligence, and self-efficacy. Also, the potential predictive value of personality traits, emotional intelligence, and self-efficacy for aggression within subsamples of judokas and team athletes was tested. The research findings showed that professional judo athletes are characterized by a low degree of aggression, especially low indirect and physical manifestations of aggression. In addition, the personality traits Honesty-Humility and Openness to experience are well expressed, contrary to Emotionality and Extraversion, which are less pronounced. They are also characterized by moderate general self-efficacy. On the other hand, members of team sports produced the opposite results, as they are characterized by increased aggression, pronounced traits of Emotionality and Extraversion, somewhat less pronounced traits of Honesty-Humility, Openness to new experience, and less pronounced general self-efficacy. The percentage of explained variability of aggression is slightly higher in the subsample of team sports and constitutes 49.9% of the variability, while in the subsample of judokas it constitutes 47.8% of the variability of the criteria. Practical implications, limitations, and future research directions were discussed.

Keywords: judo, team sports, HEXACO model of personality, self-efficacy, emotional intelligence

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INTRODUCTION

Judo is a Japanese martial art that is now widely recognized as an Olympic sport and it is the first martial art to be included in the Olympics in 1964. It is composed of the technical part, but also the moral and ethical part of the art (Fukuda et al., 2011). In 2012 Japan promoted martial arts (judo, kendo, and sumo wrestling) as a required subject in physical education. Schools have the possibility to select one or more martial arts, and to date, the majority of junior high schools have

chosen judo (Yogi and Kyan, 2021). In addition, for 15 years the International Judo Federation together with National Federations, Ministries (Sports/Youth/Education), and National Olympic Committees have been conducting the Judo in Schools program. It is an extracurricular program widely supported across 49 countries. Also, an Erasmus + project named "SCHOOLJUDO.EU: A EU-Wide Primary School Ecosystem for the Judo Teaching" was started recently to promote the societal value of Judo, while advocating its standardization as part of the European primary teaching ecosystem (Erasmus + project ID 400623019). While team sports are highly appreciated and widely accepted in school curricula, with a documented positive impact on socio-psychological well-being (Zuckerman et al., 2021), the inclusion of judo raises many concerns even with the existence of scientific evidence that supports the relationship between martial arts practice and positive socio-psychological responses (Theeboom et al., 2009). Since judo incorporates fighting techniques, one of the main concerns is whether it can provoke aggressiveness and how it will influence the socio-psychological wellbeing of children and students. The data associating judo and/or martial arts with aggressiveness seem to be unclear.

At the youngest age (8 years), it seems that judo attracts children that scored higher on the anger scale compared to children who train karate or children who are not involved in any sports activity (Reynes and Lorant, 2001), and those results were even more pronounced after one (Reynes and Lorant, 2002) and 2 years of judo practice compared to other groups (Reynes and Lorant, 2004). The main support for the concerns was provided by Endresen and Olweus (2005), who claimed that participation in martial arts, boxing, wrestling, and weightlifting leads to an increase or enhancement of antisocial behavior in boys aged 11 to 13. They reported a large effect size value for the Violence Scale (above 1.0) in preadolescent and adolescent boys who had been continuously training combat sports over the total period of 2 years. Another finding suggests that secondary school students who engage in martial arts and combat sports show a higher approval of violence compared to non-athletes (Mutz, 2012). Still, the result of another study shows that martial arts and combat sports practitioners (aged 13 to 16) had a lower approval of violence compared to athletes who practice team sports, which are widely included in the school curriculum (Hortiguela et al., 2017). This study is missing a control group that would include non-athletes, so it was not possible to compare it with the previous one.

Somewhat indifferent results show that the aggressiveness of judokas does not differ from the group of non-athletes in boys (Ziaee et al., 2012) and girls (Lotfian et al., 2011) aged 11 to 19 (mean 12.90 $\pm$ 2.06 and 15.49 $\pm$ 1.93, respectively). A meta-analysis was conducted to review the relation between martial arts participation and externalizing behavior in juveniles (Gubbels et al., 2016). The conclusion was that levels of externalizing behavior do not differentiate martial artists from non-athletes and team sport athletes and that only athletes who practice individual sports had significantly better results.

The most recent studies gathered evidence about a positive influence of martial arts and combat sports on aggression (Harwood et al., 2017; Hortiguela et al., 2017; Wojdat et al., 2017; Coco et al., 2018; Kostorz and Sas-Nowosielski, 2021; Lafuente et al., 2021). Evidence that martial arts decrease aggression among the youth was found for nine intervention and longitudinal studies with a detected effect size of 0.65 (95% CI: 0.11, 1.03), which indicates a medium effect (Harwood et al., 2017). Although the results of systematic reviews and meta-analyses signal positive outcomes, all authors agreed that more research on the subject is necessary.

According to Salovey and Mayer (1990), emotional intelligence consists of abilities to perceive, assess, and express emotions quickly, recognize and generate the feelings that facilitate thinking, understand emotions and knowledge about emotions, and manage emotions to improve emotional and intellectual development. Emotional intelligence is treated as a trait or as an ability and, depending on the model, it can be measured using tests or estimated using self-assessment questionnaires (Petrides, 2011). Many studies indicate that more pronounced emotional intelligence is positively associated with sport participation in terms of success (Perlini and Halverson, 2006; Crombie et al., 2009; Laborde et al., 2016), satisfaction with sports performance (Laborde et al., 2014), experience of pleasant emotions (Lane and Wilson, 2011), and physical activity levels and positive attitudes toward physical activity (Laborde et al., 2016). Non-elite athletes with higher scores on managing emotions are more likely to use distraction-oriented coping. Compared to recreational athletes, judokas have more pronounced emotional intelligence (Acebes-Sánchez et al., 2021), especially managing emotions (Mitić et al., 2011).

However, the present study prioritizes the relationship between emotional intelligence and aggression. Lower scores for the trait emotional intelligence are connected with both physical and verbal aggression in adolescents of both genders (Inglés et al., 2021). Results of some studies (Bibi et al., 2020) suggest that emotional intelligence could be a protective factor against some aspects of aggression. Two systematic reviews claim that emotional intelligence and aggression are negatively related regardless of the ages, cultures, types of aggression (García-Sancho et al., 2014), and theoretical models of emotional intelligence (Vega et al., 2021). Both studies show that people with higher levels of emotional intelligence are less aggressive. However, regardless of these data, it should be noted that there are authors (Davis and Nichols, 2016) who (rightly) emphasize that "the more the better" does not seem to be right regarding emotional intelligence, and that there is an "optimal" level of emotional intelligence. For the present study, the fact that emotional intelligence can have a moderating role in the personality-aggression relationship (Peláez-Fernández et al., 2014) should be emphasized. The effectiveness of emotional intelligence-based learning interventions in reducing different types of aggression was established (Castillo et al., 2013). If it turns out that emotional intelligence is a strong predictor of reduced aggression, it is relevant for the practical application that some studies suggest that emotional intelligence can be developed through the practice of team sports (Campo et al., 2016), but also combat sports (Szabo and Urbán, 2014).

Self-efficacy can be defined as an individual's assessment of his or her capacities to organize and execute specific actions

necessary to achieve the desired goals (Bandura, 1999), and it represents a person's confidence about goal achievement despite events, difficulties, or obstacles (Bandura, 1986). Self-efficacy can have an important role in sports success (Feltz et al., 2008) and can be improved in and through sport (Zagórska and Guszkowska, 2014). Self-efficacy, especially the social one, is associated with less aggressive behavior (Mofrad and Mehrabi, 2015). In adolescents, a significant and negative relationship between self-efficacy and overall aggression was determined, but there is a positive relationship between emotional self-efficacy and verbal aggression and hostility (Willemse et al., 2011). The relation between social self-efficacy and aggression is moderated by many different factors (Brubacher et al., 2016). In the sport context, the correlation of self-efficacy with aggressive behavior is negative in boxers, and self-efficacy was established as a significant negative predictor of aggressive behavior in boxers (Chen et al., 2019). The same authors claim that if there is a decrease in self-efficacy, the likelihood of aggressive behavior will increase.

The HEXACO model of basic personality structure (Lee and Ashton, 2008) was created during further studies of the dominant "Big five" model (McCrae and John, 1992; McCrae and Costa, 2008). It was found that, in addition to the five established personality traits (extraversion, neuroticism, openness, agreeableness, and conscientiousness), it would be necessary to include a sixth personality trait in the model. The sixth trait of personality has been confirmed and it is called "honesty/humility," so the HEXACO model consists of Honesty, Emotionality, Extraversion, Agreeableness, Conscientiousness, and Openness (Ashton et al., 2004). Athletes from team sports have higher levels of extraversion and lower levels of conscientiousness in comparison to athletes participating in individual sports (Nia and Besharat, 2010; Allen et al., 2011). More successful athletes are characterized by a positive high score on emotionality and openness to experience (Mitić et al., 2021). By comparing champions of team sports and champions of individual sports (researched using the same methodology), it can be seen that all of them are characterized by a lower level of neuroticism and a higher level of extraversion. Still, champions of team sports are more open to experiences compared to less successful team sports athletes, and individual sports champions are characterized by a higher level of agreeableness and conscientiousness compared to less successful individual sports athletes (Piepiora, 2021a,b). Concerning the differences between athletes who practice combat sports and team sports, it was found that neuroticism and conscientiousness were the personality traits that distinguish the two groups (Bojanić et al., 2019). Dimension Honesty-Humility is most closely related to Negative Valence from BigFive + 2 (Međedović et al., 2019) and it has negative effects on aggression (Book et al., 2012; Dinić and Smederevac, 2019). The most important predictor of reactive aggression is Agreeableness (Dinić and Wertag, 2018). In the sport context, a statistically significant correlation was found between aggressiveness and extraversion, agreeableness, and emotional stability, and it was determined that emotional stability was a significant predictor of aggressiveness (Trninić et al., 2008).

There is some evidence that team sports athletes are more aggressive than athletes from individual sports (including MA and CS), but these findings came from the research that differs considerably in the methodology, sample characteristics, sports included, and outcomes (Ali et al., 2013; Mashhoodi et al., 2013). The present research aims to compare athletes who have trained judo for a prolonged time (minimum 5 years) and athletes from various team sports, primarily regarding the manifestation of aggression, but also regarding personality traits, emotional intelligence, and self-efficacy. Also, the aim was to examine the predictive value of personality traits, emotional intelligence, and self-efficacy for aggression within subsamples of judokas and team athletes. We hypothesize that there will not be a significant difference in aggressiveness, personality traits, emotional intelligence, and self-efficacy between judokas and team sports athletes (football, handball, and water polo). If confirmed, it would be an important addition to the open discussion.

MATERIALS AND METHODS

Participants

The research sample consisted of 140 male respondents from Serbia (mean age 19.26), of whom 60 (42.9%) were judokas, while 80 (57.1%) were athletes who are active in team sports [football 34 (42.5%), handball 20 (25%), and water polo 26 (32.5%)]. At the time this research was conducted, all athletes included in the sample had been engaged in their chosen sport for at least 5 years, had at least 5 training sessions per week, and competed at least at the national level. Respondents completed (paper/pen) questionnaires at the scheduled time, 1 h before the start of the training session.

Instruments

The instrument used to assess aggressiveness was Questionnaire A-87 (Žužul, 1989), which consists of 15 items of different situations with five possible responses. The possible responses or reactions are the five most frequent forms of aggressive responses: verbal manifest aggression (α = 0.84), physical manifest aggression (α = 0.89), indirect aggression (α = 0.90), verbal latent aggression (α = 0.89), and physical latent aggression (α = 0.93). The reliability of the questionnaire obtained in this study by calculating the Cronbach's alpha is 0.970.

The instrument used to determine personality traits was HEXACO-PI-R (Lee and Ashton, 2006), which consists of 60 items in total. The dimensions represented were as follows: Honesty (α = 0.57), Emotionality (α = 0.74), Extraversion (α = 0.61), Agreeableness (α = 0.58), Conscientiousness (α = 0.71), and Openness (α = 0.59). The reliability of the questionnaire obtained in this study by calculating the Cronbach's alpha is 0.756.

The emotional competence questionnaire (Takšić, 2002) consists of 15 statements where respondents give their answers by choosing one of the numbers given on a five-point scale. The answers represent the respondents' assessment of the development of their abilities regarding emotional intelligence.

In addition to the overall score, the scores using the subscales of Ability to perceive and understand emotions (α = 0.59), Ability to express and identify emotions (α = 0.70), and Ability to manage and regulate emotions (α = 0.68) were also obtained. The reliability of the questionnaire obtained in this study by calculating the Cronbach's alpha is 0.770.

The instrument used to assess self-efficacy was the General Self-Efficacy Scale (GSE, Schwarzer and Jerusalem, 1995), which consists of 10 items, whereby respondents provide answers showing the extent to which the given statements are true to themselves, using a five-point Likert-type scale. The reliability of the questionnaire obtained in this study by calculating the Cronbach's alpha is 0.837.

The Perceived Social Self-Efficacy (PSSE) Scale measures people's beliefs in their capabilities to voice their own opinions with others, to work cooperatively and share personal experiences with others, and to manage interpersonal conflicts. PSSE is positively related to self-esteem, life satisfaction, and optimism (Caprara and Steca, 2005). The reliability of the questionnaire obtained in this study by calculating the Cronbach's alpha is 0.914.

Data Analysis

Descriptive measures, mean differences, hierarchical linear regression analysis, and discriminant analysis were used in the data analysis.

RESULTS

The research findings showed that professional judo athletes have statistically significant less pronounced indirect and physical manifest aggression compared to athletes from team sports (**Table 2**). Also, in relation to members of team sports, general self-efficacy is more pronounced among judokas and the obtained difference is statistically significant. In terms of personality traits, judokas have a significantly more pronounced Honesty-Humility trait and they are significantly more open to new experiences than those involved in team sports. On the other hand, judokas had a statistically significant lower level of Emotionality and Extraversion.

To check whether it is possible to distinguish judokas from athletes engaged in team sports, the method of canonical discriminant analysis was applied based on a set of variables that comprise aggression and its modalities, aspects of emotional competence, general and social self-efficacy, subjective assessment of general well-being, and personality traits according to the HEXACO model.

The values of the group centroids (average discriminant scores for each of the groups) range from −1.167 for judokas to 0.876 for athletes engaged in team sports (**Table 1**). The discriminant function was performed for sixteen factors, Wilks' Lambda = 0.490. Chi-square = 92.608, $p < 0.01$.

TABLE 1 | Chi-square and functions at group centroids of canonical discriminant functions.

Wilks' Lambda	Chi-square	Sig.	Function 1	
0.490	92.608	0.000	Judo	−1.167
			Team sports	0.876

Based on the data shown in **Table 2**, it can be concluded that judokas are characterized by a low degree of aggression, especially low indirect and physical manifestations of aggression. In addition, the personality traits Honesty-Humility and Openness to experience are well expressed, contrary to Emotionality and Extraversion, which are less pronounced. They are also characterized by moderate general self-efficacy. On the other hand, members of team sports produced the opposite results, as they are characterized by increased aggression, pronounced traits of Emotionality and Extraversion, somewhat less pronounced traits of Honesty-Humility, Openness to new experience, and less pronounced general self-efficacy.

Given that a significant number of predictor variables are present in the study, it was also examined to what extent it is possible to predict the severity of aggression and its models based on a set of predictor variables consisting of personality traits according to the HEXACO model, aspects of emotional competence—expression, recognition, and control of emotion, and general and social self-efficacy.

Prediction models were shown to be statistically significant, both on the judo sample and on the team sports sample (**Table 3**). The percentage of explained variability of the criterion variable aggression is slightly higher in the subsample of team sports athletes and constitutes 49.9% of the variability, while in the subsample of judoka it constitutes 47.8% of the variability of the criteria.

In the subsample of team athletes, a significant partial contribution to the explanation of the variability of the criterion variable aggression is made by the variables Agreeableness ($t = -3.868$, $p < 0.01$), Extraversion ($t = -3.772$, $p < 0.01$), and Emotionality ($t = -2.784$, $p < 0.01$). Beta coefficients are negative, which indicates that the expression of these personality traits is inversely proportional to the expression of aggression in team athletes.

In the subsample of judokas, a statistically significant partial contribution to the explanation of the variability of the criterion variable aggression is made by the variables Agreeableness ($t = -3.125$, $p < 0.01$) and Conscientiousness ($t = 2.339$, $p < 0.05$), which means that in this subsample a higher degree of Agreeableness leads to a lower expression of aggression (negative beta coefficient) while a higher expression of Conscientiousness leads to higher aggressiveness (positive beta coefficient).

DISCUSSION AND CONCLUSION

The results obtained in this study show that judokas display statistically significant lower overall aggressiveness compared to team sports athletes, as well as significantly lower expressed indirect and physical manifest aggression. This result is in line with previous research reporting a positive impact of martial arts on prosocial behaviors (Harwood et al., 2017; Hortiguela et al., 2017; Wojdat et al., 2017; Coco et al., 2018; Kostorz and Sas-Nowosielski, 2021; Lafuente et al., 2021). The obtained results not

TABLE 2 | Means and structure matrix of canonical discriminant functions.

	Judo	Team sports	*F*	*p*	Stand. Can. Disc. Func. Coef.
	Mean	Mean			
Verbal manifest aggressiveness	34.6667	38.3250	3.231	0.074	0.271
Physical manifest aggressiveness	22.4333	26.6500	6.469*	0.012	−0.476
Indirect aggressiveness	19.7167	26.9625	19.405**	0.000	1.300
Verbal latent aggressiveness	31.1833	35.3875	3.944	0.049	−0.389
Physical latent aggressiveness	28.1833	31.2750	1.546	0.216	−0.037
Perceiving and understanding emotions	21.3333	21.7250	0.686	0.409	0.077
Expressing and identifying emotions	23.5333	24.4750	2.361	0.127	0.316
Managing and regulating emotions	14.9000	15.0000	0.065	0.799	0.253
General Self-Efficacy	35.2833	33.2625	8.395**	0.004	−0.351
Social self-efficacy	99.3833	98.1625	0.255	0.614	−0.028
Honesty-Humility	37.0667	34.7250	5.244*	0.024	−0.195
Emotionality	25.3000	27.8250	4.625*	0.033	0.367
Extraversion	32.2333	36.1625	18.346**	0.000	0.577
Agreeableness	31.3000	33.2125	3.800	0.053	0.630
Conscientiousness	38.0333	37.4375	0.360	0.549	0.086
Openness to experience	33.5833	29.8375	13.972**	0.000	−0.337

**Differences are significant at the 0.05 level and **differences are significant at the 0.01 level.*

only justify the inclusion of judo in school curricula but also give it a certain advantage over more popular and widely accepted team sports. The data relating to significantly less pronounced physical aggression in judokas are particularly interesting and significant since they are in direct contrast to the prejudices related to martial arts, which were formed based on external observation of these sports.

This study also examined whether it is possible to distinguish judokas from athletes who play team sports based on a set of variables that comprise aggression and its modalities, aspects of emotional intelligence, general and social self-efficacy, and personality traits. Judokas, unlike team sports athletes, are characterized by more pronounced personality traits Honesty-Humility and Openness to Experiences and less pronounced traits of Emotionality and Extraversion, as well as more pronounced general self-efficacy and less pronounced physical manifest aggressiveness and indirect aggressiveness.

The more pronounced general self-efficacy of judokas can be explained by the fact that it is an individual sport, in which it is easier to develop confidence in one's value and work on achieving goals, regardless of any possible obstacles. Athletes in individual sports must rely exclusively on themselves, i.e., their abilities, while participants in team sports share the credit for both success and failure. This thesis is supported by the fact that a statistically significant difference was obtained only with regard to general, but not social, self-efficacy. This finding should be viewed in the light of previous research, which suggests that self-efficacy in martial arts—specifically in boxing—is not only important for sports performance but also has a protective role in preventing physical and mental problems (Chen et al., 2019). In terms of personality traits, judokas are significantly more open to new experiences and have a more pronounced Honesty-Humility dimension compared to those involved in team sports. This result can be at least partially and logically explained by the requirements of the sport in which the athletes are engaged. A high score on the Honesty-Humility dimension also implies manipulating others for personal gain, which is less characteristic (or necessary) for judo compared to team sports. A higher level of Openness to experience is characteristic of risky sport participants (Tok, 2011), which judo certainly is when compared to team sports. Furthermore, judokas had a statistically significant lower level of Emotionality and Extraversion. Achieving lower scores on the Emotionality scale characterizes, among other things, people who are not afraid of the possibility of physical injury and do not need to share their worries with others (Ashton et al., 2004), which are characteristics more suitable for training and competition in judo than in team sports. Also, this result is in line with the results of previous studies (Bojanić et al., 2019). Extraversion, on the other hand, has subordinating aspects: social self-confidence, social courage, sociability, and activity (Ashton et al., 2004), which are, by their nature, related to collective activities.

TABLE 3 | Hierarchical linear regression analysis.

Model	R	R Square	df	F	Sig.
Subsample: Judo	0.692	0.478	59	4.003	0.000
Subsample: Team sports	0.706	0.499	79	6.149	0.000

The research also examined whether and to what extent it is possible to predict the severity of aggression based on a set of predictor variables that comprise personality traits according to the HEXACO model, aspects of emotional competence, and general and social self-efficacy in judokas and team athletes. Interestingly, in both subsamples, the prediction models proved to be significant and explained approximately the same percentage of variance (49.9 and 47.8%) of the criterion aggression. What both models have in common is

that the personality trait Agreeableness has a significant partial contribution to explaining the aggressiveness with which it is inversely proportional. This is in line with earlier findings (Dinić and Wertag, 2018). Persons with very high scores on the Agreeableness scale are characterized by the fact that they will forgive the injustices they have suffered, judge others mildly, be willing to compromise and cooperate, and be able to easily control their nature (Ashton et al., 2004), so this finding was expected. In the subsample of team athletes, it was found that Extraversion and Emotionality, in addition to Agreeableness, are also significant predictors of aggression. Expression of these personality traits is inversely proportional to the expression of aggression. The obtained results are in agreement with the results of an earlier study (Trninić et al., 2008), in which the majority of the total sample (109 athletes) played ball sports (76) and only 15 practiced combat sports. In the subsample of judokas, in addition to the dimension of Agreeableness, Conscientiousness is also a significant predictor of aggression in such a way that more pronounced Conscientiousness leads to higher aggression.

What is surprising is the fact that emotional intelligence and generalized and social self-efficacy are not significant predictors, although this was expected based on previous research reporting an association between emotional intelligence and lower aggressiveness (García-Sancho et al., 2014; Vega et al., 2021) and significant negative predictor roles of self-efficacy in aggressiveness in boxers (Chen et al., 2019). Future research should focus on the moderating role of emotional intelligence in the personality-aggression relationship, as suggested by some authors (Peláez-Fernández et al., 2014), since the sample size was limited in this study. Regarding self-efficacy, it is necessary to find sport-specific moderators who influence the relationship between social self-efficacy and aggression, as suggested in previous studies (Brubacher et al., 2016).

The proposed suggestions for further research are directly related to the limitations of this study. These limitations primarily appertain to the sample, which is not large enough to perform analyses such as moderator effects. In addition, the sample included only male participants so it would be beneficial that future research includes females. Also, it must be stated that the sport success of athletes involved in this research was not controlled, and the objectives of the research cannot be achieved on subsamples defined on the basis of success, which would certainly be significant. Furthermore, the questionnaires used in this research are not sports-specific. The reason is that the basic thread for such research was the importance and expediency of including martial arts (specifically judo) in school curricula and that the possible general psychosocial effects, rather than sports success, were the primary value.

Despite these limitations, it is safe to consider the objectives of the research as achieved. Less pronounced aggression with all its subdomains in judokas compared to athletes who play team sports certainly breaks the prejudices related to martial arts that many people have due to the similarity of numerous techniques with manifestations of aggression outside sports facilities. The obtained results not only equate judo with team sports in terms of inclusion in the school curriculum but also favor it in a certain way. The obtained predictors of aggression in athletes who engage in different types of sports can help coaches and sports psychologists to better understand the aggressive behavior of athletes, but also to prevent it more effectively.

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 Ethics Committee of Faculty of Sport and Physical Education, University of Nis. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

NemS, DT, NM, MM, and NenS designed the experiments, analyzed and interpreted the data, edited the manuscript, and approved the final version to be published and are accountable for all aspects of the work. NemS and DT performed the experiments and wrote the initial draft of the manuscript. All authors contributed to the article and approved the submitted version.

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The Role of Personality in Prediction of Satisfaction With Life in Recreational Athletes During the First Wave of Pandemic Covid-19

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The aim of this research is to contribute to the understanding of the concept of satisfaction with life by determining the relationship between personality traits and the subjective experience of satisfaction with life in students—recreational athletes. This research is based on the biological theory of personality by Hans Eysenck and it attempts to offer explanations of a possible change in satisfaction with life in the period of great social deprivation caused by the Covid-19 pandemic. The sample of subjects consisted of 120 undergraduate students ($N = 120$) of all years and both sexes, 55 (45.8%) males and 65 (54.2%) females, at the Faculty of Sport and Physical Education, the University of Nis. The average age of the subjects was 23.63 years (SD = 2.070). Eysenck's personality questionnaire (Eysenck Personality Questionnaire, EPQ: Eysenck et al., 1885, adapted and translated by Šipka, 1985) was used for the operationalization of personality structure. The SWLS scale (Satisfaction With Life Scale, Diener et al., 1985) was used for estimating satisfaction with life. A significant regression model, which explains 11% of variance in the subjective experience of satisfaction with life in recreational athletes, was obtained. In the model, extraversion stands out as a significant predictor from the group of personality traits ($\beta = 0.279$). Neuroticism ($\beta = -0.160$) and psychoticism ($\beta = -0.122$) did not prove to be significant predictors of satisfaction with life in the structural model regardless of there being a significant negative correlation between neuroticism and satisfaction with life. The more extraverted participants had a keener subjective sense of satisfaction with life.

Keywords: personality, satisfaction with life, individual recreational sports, pandemic Covid-19, university students

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INTRODUCTION

According to a popular metaphor, the processing of information in the human brain is analogous to the processing of information inside a computer. Our mental states can, therefore, be considered as "algorithms" of information which vary in respect of entrance and exit, whereas there is no essential difference in the processing itself (Bender and Beller, 2011). However, it is an undeniable fact that there are enormous differences in how and what we perceive, how we think about

the perceived, how we feel afterwards, whether or not we are basically satisfied. Our general satisfaction, as well as the satisfaction with our own lives, is a combination of cognitive, affective and behavioral dimensions. Different personality features/dimensions determine to what extent we will be psychologically adapted to the world we live in and also how satisfied with our own life we will feel. Today's digital society offers young people numerous possibilities, but at the same time, brings frequently implicit risks, which can have consequences on personal well-being and also affect the self-evaluation of one's own satisfaction with life (Mascia et al., 2020). Certain studies have confirmed that personality traits in young people significantly contribute to the explanation of the variance of one's satisfaction with life (Tuce and Fako, 2014). It has been determined by meta-analysis of numerous studies of the relationship between personality traits and satisfaction with life that the contribution of personality traits in the explanation of satisfaction with life varies from 39 to 63% (DeNeve and Cooper, 1998). It is known that satisfaction with life is not only influenced by numerous stable personality traits but also by social environment factors. A new "variable," which has been present in our lives since 2019, the Covid-19 pandemic, has led to a number of consequences in context of mental health of the general population. As its common denominator, it includes anxiety, depression, problems with sleeping, diseases of the muscle-bone tissue due to reduced movement, abuse of alcohol and other psychoactive substances, etc. In reference to the self-protective behavior, there have been a large number of various emotional and behavioral responses to the new situation (Lep et al., 2020). Basically, it was often the case of the need to avoid loneliness because some studies have shown that a higher degree of loneliness was connected to reduced satisfaction with life (Begčević, 2021). An enhanced need for movement, going out for a walk, recreational running, going to gyms and fitness centers, was a common behavioral response to the crisis in a certain group of young people with an interest in sport. However, even before the pandemic, doing sport was not a full guarantee that mental health would remain safe from episodes of anxiety and depression. Meta-analysis which examines anxiety among athletes has pointed to an association in the 75% of the included research (Rice et al., 2016). It is a widespread opinion that athletes and "non-athletes" differ in many personality traits (Geron et al., 1986). A large number of studies have clearly shown that athletes are more independent, more objective and less anxious than those people who do not do any sport. This was confirmed by Morgan (1980) who reached a conclusion that athletes are basically extraverted and with low anxiety. With regard to determinants of satisfaction with life during the Covid-19 pandemic, we had in mind a large number of research findings which have confirmed that personal reactions to life events take predominance over the events themselves and that personality traits impact the kind of reactions one will have (Diener and Diener, 1996; Schimmack et al., 2004). Involvement in pleasant activities during the pandemic could have had an indirect effect on the feeling of satisfaction with life both on the affective and cognitive level (Gutiérrez-Cobo et al., 2021). As Pavot and Diener (2013) point out in their study, despite the many research findings, a relationship between personality traits and satisfaction with life, significant and frequently consistent as it may be, has still not been completely investigated. Based on Eysenck's theory of personality, and the social deprivation caused by the Covid-19 pandemic, we hypothesized that the structure of the subjective self-evaluation of satisfaction with life can be explained by extraversion-introversion, neuroticism, and psychoticism personality traits in recreational athletes. Since these premises indicate the need to investigate the factors which might affect the feeling of satisfaction with one's life in recreational athletes, this study will investigate multivariate relationships, the connection as well as the effects of personality traits on self-evaluation of satisfaction with one's life within the specified part of the population. This research was conducted during the Covid-19 pandemic while various epidemiological measures were in power.

Personality Traits

Among other things, in Eysenck's theory of personality (Hall and Lindzey, 1978), the importance of external, manifesting forms of behavior for the appropriate understanding of personality has been emphasized. We explain the habit of going to individual training sessions to fitness centers or gyms with the second level in the structure of personality which Eysenck named "common reactions, habits or actions inherent in one personality." The third level of organization of personality represents features or traits of personality, while the fourth and the highest level of organization of personality, Eysenck names *types of personality*. This descriptive aspect of Eysenck's biologically founded model of personality refers to hierarchical taxonomy obtained through factor analysis in which three dimensions of personality were extracted: introversion–extraversion (IE), neuroticism (N), and psychoticism (P). Eysenck names these dimensions types of personality (Hall and Lindzey, 1978). Eysenck described dimensions of personality considering their causal aspect. Thus, he determined that extraversion is based on cortical arousal which can be measured with skin irritation, brain waves or sweating. By theoretical assumption, there is an optimal level of arousal over or under which the performance gets worse. Extraversion is connected with interest in companionship and positive feelings. Diener and Larsen (1993) did not confirm the assumption that extroverts have an increased interest in companionship and positive feelings based on the length of time they spend with other people. One of the possible explanations is that dopamine effects the interest in companionship and positive feelings, making people highly sensitive to rewards. Neuroticism is based on activation threshold in sympathetic nervous system or visceral nervous system. This is the part of the brain that is responsible for the "hit or run" response while facing danger. Activation can be measured with the heart rate, blood pressure, cold hands, sweating, and muscle tension (especially in the forehead area). Neurotic people, who have a low activation threshold, experience a negative feeling (hit or run) even in the least stressful situations, they are easily triggered (Servaas et al., 2013). Emotionally stable people with a high activation threshold, experience a negative feeling only in highly stressful situations, they keep their heads even under pressure.

It is interesting to point out that physiological indicators of neuroticism do not correlate highly between each other. Namely, people react differently in stressful situations. Some sweat, others get a headache. This is called an individual specificity of response. It is also interesting that different stressors provoke a different response. This is called stimulus specificity of response. Psychoticism is connected with a tendency for psychotic episodes (or disconnecting with reality) and aggression (Nederlof et al., 2011). Although less research was done on psychoticism than on extraversion and neuroticism, researchers are completely assured that the basis of psychoticism is biological and that it is caused by increased levels of testosterone (Tajima-Pozo et al., 2015; Lodha and Karia, 2019).

Satisfaction With Life

Satisfaction with life is a construct from a domain of positive psychology. It is defined as a cognitive component of subjective well-being (Diener et al., 1999). Satisfaction with life is commonly used as a synonym for happiness (Diener and Ryan, 2009). The main focus in a large number of studies of satisfaction with life was in correlation with other psychological and social variables. A series of studies in literature indicate that many factors affect self-assessment of the quality of life in young people (Jovanović, 2016). In attempts to theoretically explain the concept of satisfaction with life, various models were developed. These models can be sorted in two categories considering the fact whether they emphasize an ascending or a descending perspective in studying the factors that have an effect on satisfaction with life (Diener and Ryan, 2009). Thus, theories based on the descending perspective, the so-called top-down models, rest on the assumption that the satisfaction with life is something that is relatively stable. In other words, there is a general tendency to experience different situations positively or negatively. This approach is commonly directed at personality traits and different cognitive evaluations as factors that affect satisfaction with life (Diener and Diener, 1996; Diener and Ryan, 2009). In contrast to this, theories based on the ascending perspective, the so-called bottom-up models, rest on the assumption that the global feeling of satisfaction forms on the basis of adding satisfactions from different domains of life, such as marriage, job and family. In contrast to the descending perspective, objective circumstances have a more important role here, and the satisfaction with life is generally seen as something relatively unstable, depending on shifts in positive and negative experiences (Diener and Diener, 1996; Diener and Ryan, 2009). The contemporary perspective of the determinants of satisfaction with life rejects an exclusive focus on either the descending or ascending perspective and points to a necessity for a kind of synthesis and integration of the previous two models. In this context, Dynamic Equilibrium Model or, as the author calls it in more recent times, Set-Point Theory (Headey, 2006a,b, 2008), represents a dominant contemporary model of the determinants of satisfaction with life. It includes both the effect of different dimensions of personality on an evaluation of satisfaction with life and specific objective indicators and subjective changes, as factors that affect satisfaction with life (Headey, 2008). Therefore, according to the contemporary understanding of determinants of satisfaction with life, dimensions of personality should certainly be viewed as the most important predictors of satisfaction with life, not disregarding the impact of different life experiences which should be considered as well (Diener, 2013; Headey et al., 2013).

Personality Traits and Satisfaction With Life in Recreational Athletes

Numerous studies have confirmed a connection between doing a physical activity and satisfaction with life as one of the components of subjective well-being. Diener et al. (1999) recognized a dramatic increase in the interest in determinants of subjective well-being as well as in scientific research of these determinants. The research shows a proven distinction between the affective and cognitive component of the subjective well-being. Also, one group of scientific papers confirmed that socio-demographic characteristics (age, gender, educational and marital status), health and income have a negligible role in explaining the variance in satisfaction with life (Campbell et al., 1976). Another group of scientific papers showed that satisfaction with life is stable through time and that it is often in correlation with similarly stable personality traits (DeNeve and Cooper, 1998; Diener et al., 2003). A study conducted by Steel et al. (2008) showed that personality traits explain the variance in subjective well-being of up to 39% or 63%, corrected from the error of measure. An integrative study which studied the stability of satisfaction with life (Schimmack et al., 2002) showed that tree personality dimensions—extraversion, neuroticism and conscientiousness—can explain 65% of the variance of satisfaction with life. Some studies showed that satisfaction with life can be viewed as the result of satisfaction with different life domains (Andrews and Withey, 1976; Campbell et al., 1976).

Sport is a very important life domain and can be viewed as a domain of satisfaction with life unrelated to work. In sports literature, the subjective point of view of an athlete is largely neglected either in favor of the objective performance score, the physical and technical qualities or is otherwise based on the concept of achievement and the goal theory (Sit and Lindner, 2005). In one study (Baudin et al., 2011), the main goal was to replicate relationships between dimensions NEO PI-R and satisfaction with life as were established in previous research (DeNeve and Cooper, 1998; Schimmack et al., 2004; Steel et al., 2008) on the sport-oriented sample; the hypothesis that extraversion and neuroticism were significant predictors of satisfaction with life was tested and confirmed here (Diener et al., 2003). In the research of subjective well-being conducted in recent years, emphasis was placed on sport, exercise and physical activity because previous studies consistently showed their connection with satisfaction with life (e.g., Huang and Humphreys, 2011; Höner and Demetriou, 2012; Richards et al., 2015; Sigvartsen et al., 2016; Dolan et al., 2017). Positive correlations between physical activity and subjective well-being were found in all age groups, including young ones (McMahon et al., 2017), students (Jetzke and Mutz, 2020), adults (Downward and Dawson, 2016; Marques et al., 2016), and the elderly (Lera-Lopez et al., 2019). One of the more significant findings

(White et al., 2017; Wiese et al., 2018; Zhang and Chen, 2019) is that even small amounts of additional physical activity lead to an increase in well-being. Recreational sports activities and spending more hours on these activities are related to higher well-being (Oishi et al., 2007; Diener and Ryan, 2009; Vinson and Ericson, 2014). Practicing sport voluntarily may also contribute to the well-being and its component life satisfaction.

Research Question

Taking into consideration the fact that Eysenck's theory of personality is biologically based and the social deprivation of all people caused by the Covid-19 pandemic, we have formulated a research question: Can the structure of the subjective self-evaluation of satisfaction with life be explained by extraversion-introversion, neuroticism and psychoticism personality traits in students- recreational athletes?

MATERIALS AND METHODS

Particpitants

One hundred twenty undergraduate students of all years at the Faculty of Sport and Physical Education, the University of Nis ($N = 120$) were surveyed. The sample consisted of 55 (45.8%) males and 65 (54.2%) females of the average age of 23.63 years (SD = 2.070), the mode of age being 23. The surveyed students were non-competitors and did individual sports, such as karate, judo, jiu-jitsu, kick box, taekwondo, power lifting, HIIT, etc. for recreational purposes. On average, they trained these sports for 11.03 years (SD = 3.42). Inclusion criteria were as follows: the subjects were healthy without having Covid-19 infections during the first wale of the pandemic; before the first wale of the pandemic, they were physically active at least three times a week, at least 1 h per session, participating in the recreational activities. The exclusion criterion was participation in competitive sports.

Instruments

Eysenck's personality questionnaire, which measures dimensions of neuroticism, extraversion and psychoticism (*Eysenck Personality Questionnaire, EPQ: Eysenck et al., 1885, adapted and translated by Šipka, 1985*) was used for operationalization of personality structure. EPQ consists of 90 dichotomous items arranged in 4 scales: E-extraversion (21 items), N-neuroticism (23 items), P-psychoticism (25 items), and L-scale (21 items). The results of research on the student population (Emić et al., 2015) showed that the reliability of the questionnaire according to Gutman-Cronbach's alpha is: P-scale = 0.61, E-scale = 0.86, and N-scale = 0.85.

SWLS-satisfaction with life scale was used as an instrument for estimating satisfaction with life (Satisfaction With Life Scale, Diener et al., 1985). The scale is made of five claims and a respondent estimates their level of agreement with the stated claims on a seven degree scale of Likert type. Scores can vary in the range of 5–35, where higher scores indicate higher satisfaction with life. SWLS-scale measures the cognitive component of personal well-being.

Procedure

The research was carried out during May 2020, with previously obtained approvals from the ethical committees of the Faculty of Sport and Physical Education, the University of Nis and voluntary consents of the students. We have provided the anonymity of the collected data. All subjects gave written informed consent in accordance with the Declaration of Helsinki. The testing was conducted in the classroom, in a paper-and-pencil test form and it lasted for 20 min.

Data Analysis

In the data analysis, descriptive measures, mean differences, and structural equation modeling were used. Statistical processing was done using the statistical packages SPSS and Amos (Arbuckle, 2014. Amos (Version 23.0) [Computer Program]. Chicago: IBM SPSS) (**Table 1**).

RESULTS

Statistically important correlations between satisfaction with life and extraversion (positive) and neuroticism (negative) were established. More extraverted recreational athletes were more satisfied with life than introverts. Also, recreational athletes with low neuroticism were more satisfied with life.

Research Question

Can the structure of the subjective self-estimation of life satisfaction in students- recreational athletes be explained with personality traits, such as extraversion-introversion, neuroticism and psychoticism?

In the modeling process, an assumed direction of the relationship between the XY variables was chosen whereby X represents personality traits as an independent variable and Y represents life satisfaction as a dependent variable.

TABLE 1 | Means, standard deviations, and correlation between variables.

	Minimum	Maximum	Mean	Std. deviation	Corr. SWLS with…
Satisfaction with life	14	35	25.65	4.840	–
Extraversion	4	21	14.27	4.268	0.293**
Neuroticism	1	21	10.11	4.883	−0.248**
Psychoticism	0	13	4.29	2.639	−0.081
Valid N (listwise)					

*Corr. = Pearson's correlation between satisfaction with life and personality traits; ** Correlation is significant at the 0.01 level (2-tailed).*

Interrelationships between personality traits were also defined. After defining the model, its testing was conducted in accordance with the hypothesis. Re-specification of the model was conducted through the analysis of statistical significance of regression coefficients and the analysis of the residuals whose high values indicate the existence of correlations which were not included in the model. The model also included relationships which were indicated by the higher residual values between variables. The best model that we established includes three dimensions of personality–neuroticism, extraversion, psychoticism and residual correlations between neuroticism and extraversion and between extraversion and psychoticism. Fitting parameters of this model proved to be best of all models tested. This model explains 11% of the variance in the life satisfaction variable (**Figure 1**).

From the value of the indicators of the model's goodness of fit which was rated as the best of all done in the analysis given in **Table 2**, it can be seen that all fit indices exceed critical values (Milas, 2009), and that χ^2 is statistically significant. However, as the connections that were not statistically significant were excluded in the previous step, it has been estimated that it would be more accurate to keep this model.

By analyzing regression coefficients (**Table 3**), it has been observed that in this combination of relationships between variables, another connection becomes irrelevant (Neuroticism ($\beta = -0.160$, $p = 0.06$), but it has been decided not to modify the existing model any further with an assumption that on a larger sample that connection may be of statistical importance, as has been established in a number of previous studies. On the basis of regression coefficients it can be concluded that all correlations are low or are in between low and medium intensity.

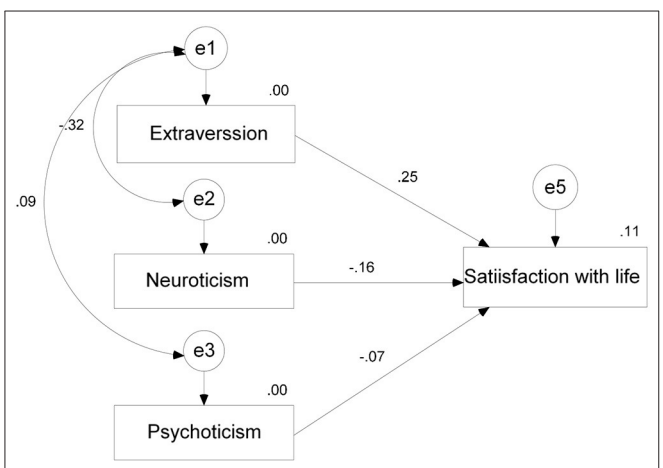

FIGURE 1 | Model–life satisfaction explained with personality traits.

DISCUSSION

A change in life circumstances which has occurred due to the Covid-19 pandemic has particularly affected, apart from physical health, people's functioning in the social segment which is the most significant factor in explaining mental health and well-being. In these altered life circumstances caused by the application of various measures for the prevention of the spread of the virus, all aspects of health, including physiological, psychological and social, were put to the test. These new circumstances on the world level have raised a large number of questions. One of these questions is the topic of interest of this work which discusses whether personality determinants such as extraversion, neuroticism and psychoticism, can overpower the confusion with the information related to the Covid-19 pandemic in young people who do spots recreationally and thus increase their subjective feeling of satisfaction with life. Based on this open question, the basic assumption of this work has been formulated–personality traits can be significant predictors of satisfaction with life regardless of the external circumstances. A negative association between neuroticism and satisfaction with life was established (Bratko and Sabol, 2006), which proves its irrelevance in the model and goes in favor of the researchers' claim about the uncertain role of personality dimensions in satisfaction with life (Sato et al., 2018). Low neuroticism is associated with higher satisfaction with life. Extraversion in our sample is positively associated with satisfaction with life and this finding is in accordance with all former research (Campbell et al., 1976; Emmons and Diener, 1985; Eddington and Shuman, 2004; Schimmack et al., 2004). However, as opposed to neuroticism, the role of extraversion in the tested model of satisfaction with life is also significant. Scientific evidence confirms that leisure time physical activity represents an important correlate with satisfaction with life (Sato et al., 2018). Individual differences in personality, established by psychological instruments, can not only be indicators of the presence or absence of psychopathology,

TABLE 3 | Regression weighs.

			Estimate	S.E.	C.R.	*P*
SWLS	<–	N	−0.160	0.085	−1.875	0.061
SWLS	<–	P	−0.122	0.158	−0.774	0.439
SWLS	<–	E	0.279	0.098	2.853	0.004

TABLE 2 | Fitting parameters.

χ^2 (6)	RMSEA	GFI	AGFI	NFI	CFI
2.833	0.124	0.988	0.884	0.908	0.926

p = 0.000.

but can also indicate other significant aspects of an individual's condition, e.g., their feeling of satisfaction with their own life. If increased neuroticism can be connected with mental health problems, does a decrease in neuroticism lead to an increase of satisfaction with life? A model of impact of personality traits on satisfaction with life proposed by Costa and McCrae (1980) emphasizes the positive impact of extraversion and a negative impact of neuroticism on satisfaction with life. Bratko and Sabol (2006) confirmed in their research an association between extraversion, neuroticism and conscientiousness with life satisfaction. Campbell et al. (1976) according to Eddington and Shuman (2004) established that demographic factors (sex, age, education, race, income, marital status) explain <20% variance in the feeling of satisfaction with life. Furthermore, it was established that satisfaction with life has a relative stability over time although it can be moderately changed as a reaction to altered life circumstances (Pavot and Diener, 1993). Achieving positive subjective well-being includes positive experiences, like satisfaction with life and positive emotions (Diener, 1984). Personality traits, extraversion and neuroticism, impact affective experiences and a direction in the thinking process, and people rely on affective experiences and cognitive processes in their evaluation of satisfaction with their own life (Schimmack et al., 2002). One of the most common definitions of personality says that personality is a set of organized, proportionately permanent psychological traits and mechanisms within a person, which affects their interactions with the environment and adaptation to the environment (Larsen and Buss, 2005). Persistent patterns of behavior and experiencing of a person can be predicted from their personality traits. Hans Eysenck (1916–1997) claimed that certain personality models (for example, Cattell's model) contain too many similar factors and that a simple three-factor model can include all personality traits. Of all personality models, his had the strongest reliance on biology. He considered personality traits inheritable and having psycho-physiological basis. He stated three main personality features: extraversion/introversion (E), neuroticism/emotional stability (N), and psychoticism (P). It was the reliance of Eysenck's theory on biology that confirmed that the optimal level of arousal of an organism can be the cause of subjective experience of life satisfaction in young people engaged in recreational sports, even in difficult social conditions. It can be said that in this way they save themselves and show that there is hope for the humankind to remain in its original form.

CONCLUSION

In conclusion, it can be said that the results are similar to the findings of other researchers which have established a significant predictive power of extraversion in the subjective experience of life satisfaction. Neuroticism and psychoticism are not significant predictors in predicting subjective feeling of life satisfaction in recreational athletes. The results represent a contribution to the understanding of the process of self-evaluation of satisfaction with life and can have a number of implications on different aspects of human life. They can also be a starting point in subsequent research of this construct. Furthermore, the results encourage people, regardless of demographic characteristics, to engage in physical activity in order to increase personal satisfaction with life.

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 Faculty of Sport and Physical Education, University of Niš, Serbia. The ethics committee waived the requirement of written informed consent for participation.

AUTHOR CONTRIBUTIONS

DŽ, JN, AĐ, BV, ŽB, and MB designed the research. DŽ, JN, and SP analyzed and interpreted the data, edited the manuscript, and approved the final version to be published and are accountable for all aspects of the work. DŽ, JN, BV, and MB performed the research and wrote the initial draft of the manuscript. All authors contributed to the article and approved the submitted version.

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Effects of Intradialytic Cognitive and Physical Exercise Training on Cognitive and Physical Abilities in Hemodialysis Patients: Study Protocol for a Randomized Controlled Trial

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The prevalence of cognitive impairment in hemodialysis (HD) patients is extremely high. Despite the well-documented benefits of interventions on cognitive function, there is a widespread call for effective strategies that will show the long-term consequences in patients undergoing dialysis. The aim of this research protocol was to investigate the effect of cognitive training combined with physical exercise on cognitive function, physical performance, and frailty indicators in the HD population. We will conduct a randomized controlled intervention trial to examine the effects of a combined non-pharmacological intervention in the form of intradialytic physical exercise and intradialytic cognitive training on cognitive function, indicators of frailty, and physical performance measures in HD patients. The group of patients receiving the study intervention will be compared to the control group receiving standard HD care. The duration of the intervention will be 12 weeks. We will use sensitive instruments (cognitive domain tests) to assess cognitive functions. The primary outcome of the study at 12 weeks will be performance on the Alertness subtest of the computerized Test of Attentional Performance. Secondary study outcomes are: Performance in other domains of cognitive function (executive function, psychomotor speed, information processing efficiency, working memory, and attention), physical fitness (10 repetition sit-to-stand test, timed up and go test, handgrip strength test, spontaneous gait speed, and stork balance test), and assessment of frailty (Edmonton Frail Scale). Study outcomes will be assessed at baseline, immediately after the 12-week intervention, and 6 months after the end of the study without specific further intervention (retention effect assessment). This study will be among the first to test the synergistic effects of a uniquely designed physical exercise and cognitive training intervention on functional status in HD patients. We believe our results will contribute to dementia prevention research by demonstrating the long-term efficacy of our combined intervention.

Clinical Trial Registration: ClinicalTrials.Gov, NCT05150444.

Keywords: cognitive functions, hemodialysis, physical activity, intradialytic training, non-pharmacological interventions

INTRODUCTION

The number of older adults is increasing worldwide, as mortality at younger ages is decreasing (World Report on Ageing and Health, 2015). In addition, 50 million people suffer from dementia, and experts predict that this number will increase to 152 million by 2050 (Patterson, 2018). Dementia affects not only the sufferers themselves, but also their families and caregivers, and represents a global economic burden (Abbott, 2011). To date, no effective pharmacological drug has been developed to reverse dementia, and the side effects of symptom alleviating drugs may not outweigh their benefits (Perneczky, 2019), therefore non-pharmacological approaches are highly needed to prevent cognitive decline and consequential dementia. Physical exercise and cognitive training have been suggested as possible strategies to protect against dementia (Livingston et al., 2020).

Most of the physical exercise and cognitive training intervention studies have been delivered in the general population. Much less is known about these effects in the population of patients with chronic diseases, in whom the disease itself and its treatment may increase the risk of cognitive decline and dementia. Patients with chronic kidney disease (CKD) are a typical example since they often suffer from hypertension, diabetes, cardiovascular diseases, and frailty that pose a risk for cognitive decline and dementia (Livingston et al., 2020; Viggiano et al., 2020). The prevalence of cognitive impairment in hemodialysis (HD) is estimated to be 30–60% (Fazekas et al., 1995; Sehgal et al., 1997; Madan et al., 2007). McAdams-Demarco et al. (2018a) found that the 10-year risk of developing dementia after starting HD is 19% in patients aged 66–70 years and increases to 28% in patients aged 76–80 years. Cognitive dysfunction also correlates with frailty in HD patients (McAdams-Demarco et al., 2015; Shen et al., 2017). A recent systematic review with meta-analysis found that the prevalence of frailty in HD patients is 46% (Lee and Son, 2021). The above findings suggest that preventive interventions are needed. Only a few studies have examined the impact of exercise programs on the preservation of cognitive function in HD patients. A 6-month home-based personalized walking exercise program in adult dialysis patients showed significant improvement in self-reported cognitive function score and quality of social interaction score compared to the control inactive group (Manfredini et al., 2017). The limitation of this study is that they used the self-reported Kidney Disease Quality of Life Short Form (KDQOL-SF), which was found in the study by Sorensen et al. (2012), as a poor indicator of neurocognitive performance in HD patients due to insufficient sensitivity. Clearly, the usage of more objective and specific measurement tools is needed.

In another study, 12 HD patients performed 3 months of tablet-based cognitive training (n-back training) during dialysis and showed improvements in Mini-Mental State Exam (MMSE) scores, Montreal Cognitive Assessment (MoCA) scores, and executive function (Noguchi et al., 2020). Limitations here were a small sample size with no control group and a significant probability of a learning effect due to the nature of used tests. McAdams-Demarco et al. (2018b) conducted a pilot study with 20 HD patients randomly assigned to a 3-month intradialytic cycling program ($n = 6$), 3-month intradialytic tablet-based brain games ($n = 7$), and a standard care control group ($n = 7$). The results showed a decrease in psychomotor speed and executive function in the control group, while the decrease was not found in the other two groups. This result is promising and it justifies the execution of larger randomized interventional studies with a better balance of confounding factors in study groups.

Considering the general lack of research in this area, the above-mentioned limitations of recent studies, aging of the CKD population and the burden of cognitive decline and frailty, further well-designed studies with non-pharmacological interventions are clearly needed. Combined cognitive and exercise training aimed at improving cognitive and executive function has been implemented and tested in the general elderly population (Colcombe et al., 2006; Levine et al., 2007; Hill et al., 2017; Jonasson et al., 2017; Butler et al., 2018) but not in HD patients. There are many unanswered questions in the dialysis population, which we aim to address in this research protocol. Therefore, the following research questions were identified:

i. What is the effect of non-pharmacological interventions in the form of combination physical exercise and cognitive training on cognitive function in HD patients?
ii. By using the combination of physical exercise and cognitive training is it possible to reduce the level of frailty in HD patients?
iii. What is the long-term effect of a short-term intervention in the form of physical exercise and cognitive training on cognitive and physical functioning in HD patients?

The study purpose is to investigate the effect of cognitive training combined with physical exercise on cognitive function, physical performance, and frailty indicators in the HD population.

MATERIALS AND METHODS

We will conduct a randomized, controlled interventional trial to examine the effects of intradialytic physical exercise in combination with intradialysis cognitive training on cognitive function, frailty indicators, and physical performance measures in population of HD patients. Main study outcome will be score on of the Test of Attentional Performance (TAP). The duration and frequency of the intervention in the form of intradialytic cycling and tablet-based cognitive training will be 12 weeks, 3 days a week. The comparator group will be HD patients under standard care, receiving only general advice on physical exercise benefits.

Participants

Participants will be recruited from the dialysis center in University Medical Centre Ljubljana. Inclusion criteria, exclusion criteria, and withdrawal criteria for the study are listed in **Table 1**.

The study will be conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki and has been

TABLE 1 | Study criteria.

Inclusion criteria	Exclusion criteria	Withdrawal criteria
HD replacement therapy >3 months	Active malignant or infectious disease	Any intercurrent illness or trauma that prevents the patient from continuing the intervention for a period longer than 14 days
Over 18 years old	Uncontrolled arterial hypertension	The occurrence of an acute illness lasting longer than 3 weeks or ending less than 3 weeks before the end of the study
Stable medical condition	Angina pectoris of Canadian Cardiovascular Society grade 2–4	Diagnosis of a malignant disease throughout the research
Able to walk independently	New York Heart Association heart failure grade 3 or 4	Cerebrovascular or other cardiovascular event (new-onset angina pectoris, myocardial infarction, symptomatic peripheral arterial obliterative disease, heart failure hospitalization)
	Severe cognitive impairment and dementia	Withdrawal of consent to participate
	History of limb amputation	
	Any other condition that could cause the patient to be clinically unstable	

HD, hemodialysis.

approved by the Slovenian Medical Ethical Committee (number 0120-474/2021/4). Participants will sign an informed consent form before participating in the study. The study was registered at ClinicalTrials.gov under NCT05150444.

Procedures

Throughout the experiment, testing procedures will be conducted in the same facility, by the same researchers, with the same equipment at a similar time of the day. Testing will be performed on non-dialysis day. Finally, the risks and benefits will be explained to each participant prior to enrollment in the study. The risks of study participation are associated with possible deterioration in health status due to physical exertion. However, there will be adequate rest between each physical performance test and physical exertion during dialysis will be adapted to individual abilities with continuous monitoring of hemodynamic status and subjective exertion throughout the dialysis procedure. There will be full coverage with physician presence in research facilities.

Study Interventions and Protocol

After the screening, recruitment, and baseline measurements, the patients will be randomized using sealed envelopes in 1:1 ratio into two groups:

- combined cognitive and exercise training (EXP) group and
- control (CON) group

The EXP group will first exercise during dialysis (three times a week; 12 weeks) for ~30 min on a customized ergometer. They will start with a 3-min warm-up, and then, the resistance will be implied to each individual according to the rate of perceived exertion of 4th to 5th grade on a 10-grade Borg scale (Bogataj et al., 2020). After a break, they will be given tablets in order to play »cognitive stimulation games« on a CogniFit platform (~30–45 min). CogniFit "brain training" requires patients to repeatedly solve cognitively challenging tasks that target specific cognitive areas. These cognitive tasks are presented in the form of colorful, visually appealing "mini-games" to promote fun and enjoyment, thereby increasing motivation and engagement. The CogniFit platform offers a wide range of games (e.g., Jigsaw, Mandala, Sudoku, Puzzles, Word Quest, Piece Making, Tennis Bowling, and Line Changer, etc.). The difficulty level of the "brain exercises" automatically adjusts to the patient's abilities as they practice and train. The cognitive areas targeted are: memory, reasoning, coordination, and attention with their subcategories. The training will be performed by a qualified kinesiologists (a professional coach experienced in prescribing and guiding the intradialytic exercise) and by a clinical psychologists with experience in cognitive testing of chronic patients. The CON group will receive standard HD care.

Graphically we present the study design in **Figure 1**. We plan to repeat the measurements 6 months after the end of the intervention to measure the longer-term retention effect of intervention.

Primary Study End Point

Cognitive Performance (Neuropsychological Assessment Battery)

Cognitive functions will be assessed with tests previously used in HD patients (Costa et al., 2014; San et al., 2017; Zimmermann and Fimm, 2017b; Jafari et al., 2020), including Montreal Cognitive Assessment (MoCA), Trail Making Test A and B (TMTA and TMTB), Symbol Digit Modalities Test (SDMT), and computerized Test of Attentional Performance (TAP).

TAP score is selected as the main outcome of this study. The rationale for the selection of the main outcome is: (i) absence of significant level of test-related learning effect (Zimmermann and Fimm, 2017b), (ii) sensitive to effects of physical exercise (Noguera et al., 2019), and (iii) attention is one of the most affected cognitive domains in dialysis patients (Dixit et al., 2013). From the TAP test battery, we will include subtests Alertness, Selective attention, Divided attention, and Sustained attention. Low to moderate training effects were reported for the TAP subtests (Zimmermann and Fimm, 2017a). The authors stated that performance remained stable in most of the TAP tasks at most of the testing occasions, suggesting that the performance in these tasks is robust and unaffected by learning effects or task repetition harassment.

MoCA (Nasreddine et al., 2005) is a global cognitive function assessment tool covering eight cognitive domains. The psychomotor speed and executive function will be measured by TMTA and TMTB (Corrigan and Hinkeldey, 1987). The SDMT will be used to assess the psychomotor speed, efficiency

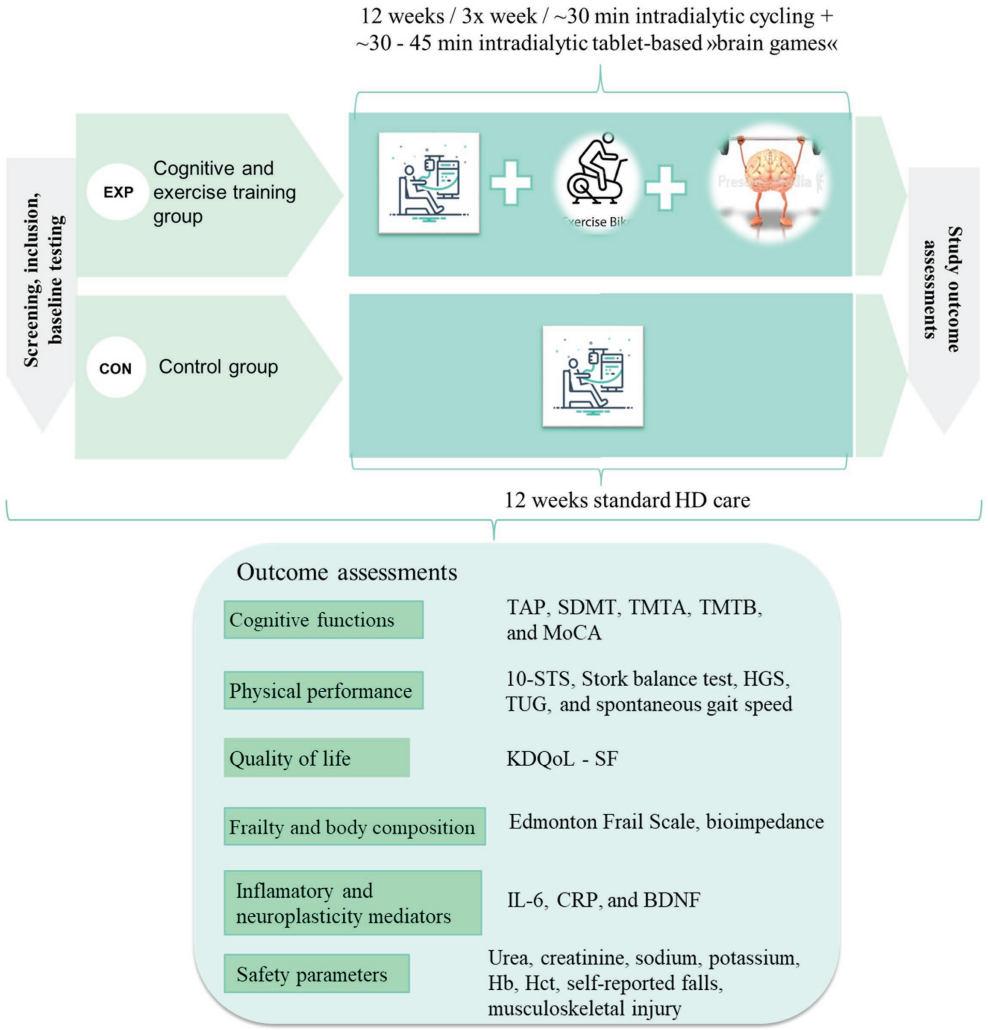

FIGURE 1 | Proposed design of the study and proposed outcome measures. EXP, experimental group; CON, control group; TAP, Test of Attentional Performance; SDMT, Symbol Digit Modalities Test; TMTA, Trail Making Test A; TMTB, Trail Making Test B; MoCA, Montreal Cognitive Assessment; 10-STS, 10 repetition sit-to-stand test; HGS, handgrip strength; TUG, Timedup and Go test; KDQoL-SF, Kidney Disease Quality of Life Short Form; BDNF, Brain-Derived Neurotrophic Factor; IL-6, Interleukin-6; hs-CRP, high-sensitivity C-reactive protein; Hb, hemoglobin; Hct, hematocrit.

of information processing, ability to switch between mental sets of the information and to maintain and manipulate information in working memory (Smith, 1982; Benedict et al., 2017). It is a reliable and valid test for assessing information processing speed, efficiency and executive functioning domains (Benedict et al., 2017).

Secondary Study End Points

Physical Performance

We will test the patients with selected functional performance tests [10 repetition sit-to-stand test (10-STS), stork balance test, handgrip strength test (HGS)], exact methods already described in our previous study (Bogataj et al., 2020), with Timed Up and Go (TUG) test (Richardson, 1991; Ortega-Pérez de Villar et al., 2018), and spontaneous gait speed (Bučar Pajek et al., 2016).

Frailty Assessment

Frailty indicator will be assessed by the Edmonton Frail Scale (Rolfson et al., 2006; Garcia-Canton et al., 2019). The Edmonton Frail Scale assesses nine subscales: cognition, general health, functional independence, social support, medication use, nutrition, mood, continence, and functional performance in 11 items. The highest score is 17 points and correlates with the highest level of frailty (Rolfson et al., 2006). A score of 0–4 points represents no frailty, a score of 5–6 represents vulnerability, a score of 7–8 represents low frailty, a score of 9 to 10 represents moderate frailty, and a score above 11 represents severe frailty (Aygör et al., 2018).

Body Composition

Phase angle, fat, and lean body mass will be assessed with bioimpedance analysis (BCM Fresenius Medical Care).

Quality of Life

The participants' quality of life will be assessed with validated Kidney Disease Quality of Life – Short Form questionnaire (Korevaar et al., 2002).

Blood Sampling and Potential Biomarkers (Biochemical Analysis)

The concentrations of the brain-derived neurotrophic factor (BDNF) will also be measured to explore the possible mechanisms underlying the effects of exercise on cognitive function. It was demonstrated that BDNF in the HD patients was significantly lower when compared to the age-matched control group (Zoladz et al., 2012). We decided to include BDNF biomarker in our analysis based on findings of Nofuji et al. (2012), reporting that the BDNF concentration was found to significantly change with physical exercise. Furthermore, a recent study showed that BDNF is associated with decreased physical performance and the prevalence of severe sarcopenia and frailty in HD patients (Miyazaki et al., 2021). Blood sampling will be performed by our staff (qualified HD nurses). Blood samples (∼7 ml) will be drawn *via* arteriovenous fistula before initiating HD procedure. Blood analysis will also include variables relevant to discuss the inflammation and HD-related laboratory parameters (such as CRP, urea, IL-6, and electrolytes).

Safety Parameters

The safety parameters assessed will be urea, creatinine, sodium, potassium, hemoglobin, hematocrit, self-reported falls, and musculoskeletal injuries.

Statistical Methods Including Sample Size Calculation

The primary outcome of this study will be the cognitive function assessed with the subtest "Alertness" of the Test for Attentional Performance (TAP, Version 2.3; Psytest, 2012).

The sample size was calculated using G*Power software (version 3.1; Faul et al., 2009) on the basis of the results of the study by Briken et al. (2014). For the calculation, the scores of the subtest alertness from the TAP test battery which were obtained from the group that completed bicycle ergometry before (376.91 ± 151.67) and after (302.64 ± 83.09) the treatment were used. The alpha error probability was set to 0.05, the 1-beta error probability to 0.80, while the effect size was taken from the previously mentioned research (0.314). A sample size of 22 participants was calculated. Allowing for a 20% attrition rate, a total number of 27 participants is required, with 14 participants assigned to each group. Analyses will be conducted according to the intention-to-treat principle.

SPSS 24.0 (SPSS, Inc., Chicago, IL, United States) software will be used for all calculations. All data will be presented with mean ± standard deviation and 95% confidence intervals when appropriate. Normality will be confirmed by using the Shapiro–Wilk test, with additional Q–Q plot visual inspection. Independent-sample t test, χ^2, or Mann–Whitney tests will be used to determine group differences in clinical and demographic variables, depending on the comparison and test assumptions. The main effects will be analyzed using a mixed general linear model (GLM), taking into account the groups (EXP and CON) and time (baseline and after 12 weeks) as factors. After determining the interaction effect, a secondary analysis will be used to determine the time effect in both groups. Additionally, the degree of effect will be determined for dependent variables by using partial eta-squared (η^2). Partial eta squared readings of 0.02, 0.13, and 0.33 were rated differences as small, moderate, and high (Pierce et al., 2004). Furthermore, in the case of unmatched baseline means, the analysis of covariance (ANCOVA) with baseline measurements entered as a covariate will be applied. For non-parametric data, a Friedman ANOVA will be applied, followed by a Sign-test separately for each scale. Statistical significance will be set at values of $p < 0.05$.

DISCUSSION

The presented study will be the first randomized controlled intervention trial combining physical and cognitive exercise in HD patients. By testing the possible beneficial effect of non-pharmacological interventions it will address a significant unmet need of dialysis patients. The foreseen achievements are to identify the benefits of combined physical exercise and cognitive training. We hypothesize that the experimental group will improve significantly and to a clinically meaningful effect size in cognitive and physical domains after the intervention compared to the control group. We will use novel instrumentation for sensitive detection of cognitive adaptation.

To the best of our knowledge, MMSE, MoCA, and Modified Mini-Mental State examination (3MS) are the most commonly used tests for cognitive screening in studies investigating the effects of different interventions on cognition in HD patients. Among the aforementioned instruments, MoCA has been shown to be the most suitable instrument for cognitive screening in the HD population with good sensitivity and specificity (Lee et al., 2018). However, the tests mentioned above are mostly used as screening tests for mild cognitive impairment and dementia and are not sensitive enough to detect intervention effects (Dong et al., 2010; Sheehan, 2012). Furthermore, all these tests are subject to learning effects, which limits the internal validity of prior studies. Accordingly, future studies should focus on selecting more specific and sensitive tests rather than using global/general cognitive tests and use the tests with low learning effect bias.

Combined cognitive and physical exercise training over a 3-month period improved executive function in older adults and was more effective than cognitive training or exercise training alone (Fabre et al., 2002; Anderson-Hanley et al., 2012). Moreover, in the pilot study (McAdams-Demarco et al., 2018b), cognitive training and exercise training performed separately were able to prevent decline in executive functions and psychomotor speed in HD patients. The results from a these limited studies in HD patients may support the hypothesis of a positive effect of cognitive and exercise training on cognitive function; however, a much better and clearer study design, especially to prevent the bias from learning effects and to secure adequate statistical

power, is needed. Suppose there truly is a positive effect of physical exercise and/or cognitive training on cognitive function in dialysis patients, it is plausible that the strongest effects may be found with a combination of both interventions.

With this in mind, it is a reasonable step to combine the use of physical exercise and cognitive training with the aim of improving the functional (cognitive and physical) status of HD patients. HD procedure is a unique opportunity for the implementation of these types of combined interventions. In our research protocol, we address the unanswered questions by implementing the combined intervention and using more sensitive low learning effect cognitive tests. This research will also demonstrate the feasibility of using the innovative cognitive platform to apply cognitive training to HD patients. Ultimately, the basic knowledge gained can be used to develop appropriate interventions to mitigate the cognitive decline and maladaptation caused by physical inactivity. Based on our findings, we could develop guidelines and exercise protocols (physical and cognitive) aimed at improving cognitive and physical performance, thus improving the quality of life of HD patients. Importantly, in case our hypotheses will be confirmed, we will be able to offer evidence-based improvement of chronic renal replacement therapy programs.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Slovenian Medical Ethical Committee. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

ŠB and JP conceptualized the study design. ŠB drafted the manuscript. JP, NT, and MP reviewed the manuscript. All authors have read and approved the final version of the manuscript.

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Can Primary School Mathematics Performance Be Predicted by Longitudinal Changes in Physical Fitness and Activity Indicators?

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Objective: To determine to what extent physical fitness indicators and/or moderate to vigorous physical activity (MVPA) may account for final mathematics academic performance (AP_{math}) awarded at the end of primary school.

Methods: School-aged youth were sampled in a repeated-measures, longitudinal design in Grade 6 (∼11 years), and again in Grade 9 (∼14 years). The youth (N = 231, 111 girls) completed a fitness test battery consisting of: flamingo balance test, standing long jump, backward obstacle course, plate tapping, sit ups, sit and reach, handgrip, and 20-m shuttle run. AP_{math} scores were obtained for all children at the end of Grade 5, end of Grade 8, and end of Grade 9 (their final year of primary school). In a sub-sample of Grade 6 youth (N = 50, 29 girls), MVPA was measured objectively via SenseWear Pro Armbands ($MVPA_{OB}$) for seven consecutive days, with measurements repeated in Grade 9.

Results: Math scores decreased from Grade 6 to 9 for both boys and girls (95%CI: −0.89 to −0.53, $p < 0.001$). $MVPA_{OB}$ was reduced by ∼45.7 min (−33%) from Grade 6 to 9 ($p < 0.01$). Significant main and interaction effects are noted for each fitness indicator ($p < 0.05$). A backward stepwise multiple regression analysis determined significant shared variance in final AP_{math} grade to the change scores from Grade 6 to Grade 9 in: ΔAP_{math}, Δbackward obstacle course, Δsit and reach, and Δsit-ups [$R^2 = 0.494$, $F(4,180) = 43.67$, $p < 0.0001$]. A second regression was performed only for the youth who completed $MVPA_{OB}$ measurements. In this sub-sample, $MVPA_{OB}$ did not significantly contribute to the model.

Conclusion: Longitudinal changes in youth fitness and their delta change in AP_{math} score accounted for 49.4% of the variance in the final math grade awarded at the end of Grade 9. Aerobic power, upper body strength, and muscular endurance share more common variance to final math grade in boys, whereas whole-body coordination was the more relevant index in girls; this finding suggests that future research exploring the relationship of AP and PF should not be limited to cardiorespiratory fitness, instead encompassing muscular and neuro-muscular components of PF.

Keywords: accelerometers, physical fitness surveillance, paediatric exercise, health-related risk factors, population health, arithmetic, children

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INTRODUCTION

Physical activity (PA) is a dynamic state of being (Reid et al., 2019) which can be defined as any bodily movement produced by skeletal muscles resulting in energy expenditure (Caspersen et al., 1985) greater than that which exceeds hibernation (Fletcher et al., 1996). Participating in regular PA is indispensable to maintaining a healthy lifestyle, in part because of the concomitant positive impacts on skeletal (Gunter et al., 2012), metabolic (Janssen and LeBlanc, 2010), cardiovascular (Fernhall and Agiovlasitis, 2008), and psychosocial functioning of the human body (Biddle and Asare, 2011). Attaining low levels of PA and the attendant poor aerobic fitness is associated with declines in academic performance (AP) (Chaddock et al., 2011), the deterioration of brain structures, cognitive abilities, and general brain function (Sibley and Etnier, 2003; Castelli et al., 2007; Chaddock et al., 2010; Donnelly et al., 2016; García-Hermoso et al., 2021). Increasing PA has therefore, long been suggested to exert a positive impact on AP, especially since learning complex movements stimulates the frontal cortex of the brain, which is also active in the learning and problem-solving process (Daly-Smith et al., 2018; Singh et al., 2019; Duffey et al., 2021).

There is a growing body of work which have found significant relationships between PA and AP (Chaddock-Heyman et al., 2013; Daly-Smith et al., 2018; Sember et al., 2020b). However, the positive effects of PA on AP may accrue most readily only when there is an adequate amount of vigorous PA included (Tomporowski et al., 2011; Phillips et al., 2015). Evidence regarding the association between PA and any broader aspect(s) of AP have (thus far) remained ambiguous, with some researchers also finding negative, or null effects in this relationship (Coe et al., 2006; Beck et al., 2016; Riley et al., 2016). These inconsistent findings may be due to a difficulty in precisely assessing both the overall amount, and intensity of, PA, which children and adolescents regularly undertake (Monyeki et al., 2018; Sember et al., 2020a).

The level of physical fitness (PF) for a given individual is related to a great many factors, including the outcome of their habitual PA habits, genetics, socio-economic status, and environment, among others. Physical fitness can be highly informative when examining the health effects of PA and AP (Sardinha et al., 2014), including recent evidence that cardiorespiratory fitness is associated with larger brains during a critical phase in children, when the brain is growing (Cadenas-Sanchez et al., 2020). For example, it has been shown that after-school PA improves children's cardiovascular endurance, which then mediates enhancements in AP (Fredericks et al., 2006). A meta-analysis (including articles from 2005 to 2015), which investigated the relationship between PF and AP asserted that cardiorespiratory fitness, speed-agility, motor coordination, and perceptual-motor skills are each highly associated fitness indicators to AP (Ruiz-Ariza et al., 2017). Moreover, several studies have identified positive relationships between cardiorespiratory fitness, body mass and AP (Eveland-sayers et al., 2009; Van Dusen et al., 2011; Rauner et al., 2013; Torrijos-Niño et al., 2014) or overall PF (Starc et al., 2017). Findings on the relationship of AP to strength and flexibility remain unclear (Chaddock-Heyman et al., 2014; Tannehill et al., 2015; Ruiz-Ariza et al., 2017; Esteban-Cornejo et al., 2019).

Although there is an abundance of scientific papers dealing with the relationship between PA and cognitive function, researchers often use indirect assessments of PA in their work. Indeed, although researchers and public health policies continue to cite PA as a primary movement/health-based indicator, it is also a highly individual one, where any two individuals may need varying doses (i.e., frequency, duration, intensity, and type of activity) to achieve the same physiological and/or health related benefits as one another (Reid et al., 2019). Notably, objective PA assessment is often not feasible for large studies involving hundreds or even thousands of participants, due to its high cost and complications arising from extracting PA data from the measuring devices (Dowd et al., 2018). Although several studies have found a significant relationship between aerobic function and AP, most have not considered longitudinal changes in PA and PF across their sample.

Thus, the purpose of this study was four-fold: (1) to determine longitudinal changes in PF, MVPA (measured objectively) and AP_{math} in a cohort of Slovenian youth across a 3-year timespan, (2) to determine whether individual PF indicators were correlated to MVPA or AP_{math} scores within a given Grade, (3) to determine whether changes in MVPA or PF indicators related to changes observed in AP_{math}, and (4) to what extent could these changes over time account for final AP_{math} score attained at the end of primary school. It was hypothesized that youth who were able to maintain higher PA and PF would maintain or achieve higher math scores at the end of their schooling period compared to those who were less active or fit.

MATERIALS AND METHODS

Research Design and Study Sample

We obtained the data for this longitudinal, cross-sectional study within *The Analysis of Children's Development in Slovenia* (ACDSi), an ongoing study used to monitor the physical and motor development of children and youth in Slovenia every 10 years for the last five decades (Jurak et al., 2013; Starc et al., 2015). The ACDSi study was approved by the Slovenian National Medical Ethics Committee (ID:138/05/13), following the Declaration of Helsinki. We obtained written, informed, parental consent and child assent before testing for each child involved in the study. Children and youth participated voluntarily and anonymously and had the option of freely withdrawing from the measurements at any time. The ACDSi study uses a sentinel approach to provide a nationally representative sample of children from 11 different locations, stratified according to their environment (e.g., village, town, industrial town, and city). The primary sampling unit is the school, and the secondary one defined as the schoolchildren's class. At each of the 11 primary school locations, research teams were divided into three test stations: anthropometry, motor and aerobic fitness and psychology.

The research team from the Faculty of Sports, University of Ljubljana collected data for this study in autumn 2013, then ∼3 years later during summer of 2016, and again in autumn 2016. In the 2013 generation of the ACDSi study, the Grade 6 sample included 231 youth (120 boys and 111 girls), aged 11 years old (born on October 01, 2002, ±6 months). The average age of all youth included in the Grade 6 sample was 11.29 ± 0.30 years (boys 11.3 ± 0.32; girls 11.29 ± 0.27), and the average age of the youth wearing SWA was 11.23 ± 0.3 years (boys 11.24 ± 0.36; girls 11.22 ± 0.25). All participants were measured again, exactly 3 years later, in Grade 9.

Experimental Measures

Physical Activity

We assessed MVPA objectively on a sub-sample of children (N = 50, boys = 21 girls = 29) wearing a multi-sensor device (SWA, Bodymedia SenseWear Pro Armband; BodyMedia Inc., Pittsburgh, PA, United States, $MVPA_{OB}$). Device specifications, data collection techniques, and standard methodology is outlined in detail elsewhere (Sember et al., 2020a). The SWA device is based on the recognition of energy expenditure patterns resulting in an estimation of PA and is considered to be a reliable measuring device in children and youth (Calabró et al., 2009; Soric et al., 2013; Stålesen et al., 2016). Participants wore the SWA on their triceps (i.e., right side of upper arm) for 1 week (Cain et al., 2013), 24 h per day, except when they were showering, bathing, or performing water-based, or sporting activities (e.g., swimming and/or competitions in other sports).

Physical Fitness

We assessed PF via the following indicators: 20-m shuttle run (peak aerobic power, $\dot{V}O_{2peak}$), polygon backward obstacle course (coordination), handgrip (muscular strength), standing long jump (power), flamingo test (balance), sit-ups (repetitive strength) plate tapping (reaction time) and sit and reach (hip joint flexibility). Details on test protocols are available elsewhere (Jurak et al., 2013; Starc et al., 2015). $\dot{V}O_{2peak}$ was estimated using Mahar's prediction equation (Mahar et al., 2011), estimated from the 20-m multistage shuttle run performance test, which was conducted following Leger's original test protocol (Leger and Lambert, 1982). Jamar's dynamometer (TEC, Clifton, NJ, United States) was used to measure handgrip strength on the child's dominant hand.

Mathematics Performance

The indicator taken to best reflect AP in Slovenian schoolchildren and youth was their math grade, awarded by their teachers at the end of the previous academic year. Math grades were recorded for all youth representing the start of Grade 6 (i.e., final score awarded at end of Grade 5), the start of Grade 9 (final score awarded at end of Grade 8), and their final mathematics mark, awarded at the end of Grade 9. The math grade represents a modest indicator of overall AP in the literature, but it is especially appropriate for the Slovenian setting, with an r = 0.50 (Flere et al., 2009) and higher levels of reliability (0.89–0.94) (Carlson et al., 2008) than other subjects or language scores (e.g., Slovenian or English), for example. In Slovenia, math grades are awarded following next-order methodology: 1 (inadequate), 2 (sufficient), 3 (good), 4 (very good) and 5 (excellent).

Data Processing

Objective physical activity ($MVPA_{OB}$) assessment of moderate-to-vigorous physical activity (MVPA) were analyzed using the Bodymedia SenseWear Professional 8.1 Software package and scored/adjusted manually where necessary. Microsoft Excel 2007 was used for removing artifacts, counts >16,000, constant values ≥0, and sequences of zeroes, where a sequence was defined as 20 or more zeroes. $MVPA_{OB}$ data was processed with BodyMedia SenseWear Armband software 3.0 (standardized for accelerometer SenseWear Armband), following the 70/80 rule (Catellier et al., 2005) and non-wear time within day (Troiano et al., 2008). We only included the data of participants who wore the SWA device at least 5 days in a row, including both weekend days, and whose wear time exceeded 90%, following methods described elsewhere (Cain et al., 2013). The SWA data was collected in 1-min epoch intervals. The main rationale for using this conservative approach was to reduce the error of under- and over-estimation of PA due to missing wear-time, often an issue in current PA child health studies. Finally, difference scores of fitness and activity indices were calculated between Grade 6 and Grade 9 before statistical analyses were conducted.

Statistical Analyses

We conducted all statistical analyses using SPSS version 27.0 (IBM Inc., Armonk, NY, United States). Data are presented as means and standard deviation, with 95% confidence intervals (CI), F-ratios and effect size where appropriate. We determined normality of distribution using the Kolmogorov–Smirnov test and Shapiro–Wilk test. Data were checked for multicollinearity and normality. Longitudinal changes in physical fitness and activity levels from Grade 6 to Grade 9 were compared using a two-way repeated-measures analysis of variance (RM ANOVA), with one within-subjects factor (time, two levels: Grade 6 and Grade 9) and one between-subjects factor (sex, two levels: male, and female), as well as the non-parametric alternative conducted for AP_{math} (Friedman test), set at the $p < 0.05$ level of significance. Two-tailed, bivariate correlations were run to query whether fitness indicators were related to $MVPA_{OB}$ using Pearson's test, calculated for each grade separately. Correlation coefficients between AP_{math}, $MVPA_{OB}$, and fitness variables were conducted using Spearman's rho (ρ). A backward, stepwise multiple regression was conducted on the entire sample of children to determine to what extent changes in individual fitness indicators shared common variance to final Grade 9 AP_{math} scores. The procedure was then conducted separately for the N = 50 $MVPA_{OB}$ sub-sample with $\Delta MVPA_{OB}$ between years as an input variable. Statistical criteria for a given index's inclusion in the model was set at the $p < 0.05$ level, and omission 'out' occurred when an index posted $p > 0.10$ during the backward step analysis; missing cases were dropped in a listwise fashion.

RESULTS

Longitudinal Changes in Physical Activity, Fitness, and Mathematics Academic Performance

Objectively assessed physical activity ($MVPA_{OB}$) decreased ∼33% (i.e., −45.7 min) from Grade 6 to Grade 9 [main effect: $F(1,49) = 6.225$, $p = 0.016$, **Table 1**], including a significant interaction effect by sex (CI: 10.1–72.2 min, $p = 0.010$).

There were significant main effects for time ($p < 0.05$, **Table 1**) in all fitness variables, for both girls and boys. By Grade 9, there were also numerous significant differences between girls and boys within that grade; the 95% confidence intervals showed that boys produced more aerobic power (measured via shuttle run, CI: 5.9–15.7 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$, $p < 0.0001$), achieved better results in the standing long jump (CI: 8.2–20.7 cm, $p < 0.0001$), produced more force in handgrip (CI: 0.8–3.3 Nm, $p = 0.001$), and balanced longer during flamingo testing (CI: 0.1–5.3 s, $p = 0.042$), whereas girls demonstrated greater hip and lower back flexibility with higher sit and reach scores (CI: 5.0–9.6 cm, $p < 0.0001$).

In terms of the longitudinal results of academic performance, assessed by mathematics grade (AP_{math}), this measure decreased from Grade 6 to Grade 9 for all youth (CI: −0.89 to −0.53, $p < 0.0001$) equivalent to ∼0.7 of a grade (i.e., −17%). The magnitude drop did not differ between boys and girls (CI: −0.32 to 0.04, $p = 0.120$).

Correlations

Physical Activity and Fitness

For Grade 6 youth, standing long jump ($r = 0.193$, $p = 0.44$) backward obstacle course ($r = 0.208$, $p = 0.030$), flamingo ($r = -0.232$, $p = 0.015$) and sit-ups ($r = 0.213$, $p = 0.025$) fitness scores were moderately correlated to $MVPA_{OB}$ (**Table 2**). When fitness indicators were separated by sex, fitness variables correlating to $MVPA_{OB}$ differed, with only flamingo test demonstrating a moderate correlation ($r = 0.375$, $p = 0.005$) in boys, and no individual variable reaching significance for girls. By Grade 9, the strength of these linear associations had increased, such that $MVPA_{OB}$ was positively correlated to standing long jump ($r = 0.305$, $p = 0.002$), sit-ups ($r = 0.288$, $p = 0.004$), handgrip ($r = 0.251$, $p = 0.011$), shuttle run ($r = 0.513$, $p < 0.0001$), and backward obstacle course ($r = 0.283$, $p = 0.004$).

Physical Activity and Mathematics Academic Performance

In Grade 6, mathematics grade (AP_{math}) was negatively correlated to $MVPA_{OB}$ ($r = -0.189$, $p = 0.050$), such that youth who recorded more PA minutes were also more likely to have lower AP_{math} scores. This relationship was true only when data were combined. Separated by sex, both boys ($r = 0.185$, $p = 0.176$) and girls ($r = 0.193$, $p = 0.161$) demonstrated no relationship between the variables. $MVPA_{OB}$ and AP_{math} were not correlated

TABLE 1 | Descriptive statistics (means ± sd) of physical activity, fitness, and academic performance (math grade).

		$MVPA_{OB}$ (minutes/day)	Shuttle run $\dot{V}O_{2peak}$	Polygon backward (s)	Standing long jump (cm)	Handgrip (Nm)	Flamingo (# falls/60 s)	Sit-ups (#/60 s)	Plate tapping (# of taps/20 s)	Sit and reach (cm)	AP_{Math} (score)
Grade 6	Combined ($n = 231$)	138.9 + 73.2	46.0 + 26.5	16.3 ± 5.1	157.4 + 21.9	20.9 + 4.2	15.9 + 7.5	37 ± 9	35.5 ± 10.2	19.3 ± 6.9	$4.2 + 0.8^{1}$
	Boys ($n = 120$)	149.4 + 72.5	45.8 + 26.3	15.9 ± 4.6	160.4 + 21.3	21.1 + 4.2	16.3 + 7.4	39 ± 9	36.3 ± 10.7	17.2 ± 6.2	$4.1 + 0.09^{1}$
	Girls ($n = 111$)	128.2 ± 72.9†	46.2 ± 26.9	16.7 ± 5.1	154.2 + 22.3	20.7 + 4.3	15.4 + 7.7	35 ± 8	34.6 ± 9.5	21.5 ± 7.1†	$4.2 + 0.8^{1}$
Grade 9	Combined ($n = 231$)	93.2 + 62.0*	53.25 + 25.1*	13.6 ± 4.3*	176.7 + 32.3*	28.9 + 4.2*	16.5 + 13.5	41 ± 10*	42.0 ± 5.7*	28.4 ± 9.5*	$3.5{+}1.0^{*2}$
	Boys ($n = 120$)	123.6 + 65.6*	63.8 + 24.6*	13.1 ± 4.1*	187.7 + 31.8*	30.8 + 7.6*	17.4 + 18.6	44 ± 11*	41.8 ± 6.5*	24.9 ± 8.3*	$3.4 + 1.0^{*2}$
	Girls ($n = 111$)	69.8 + 47.7*†	41.8 + 20.2*†	14.0 ± 4.4*	164.8 + 28.6*†	27.0 + 5.2*†	12.8 + 10.6*†	38 ± 9*	42.3 ± 4.5*	32.3 ± 9.2*†	$3.5 + 1.0^{*\dagger 2}$
End of Grade 9	Combined ($n = 231$)										$3.5 + 1.0^{3}$
	Boys ($n = 120$)										$3.4 + 1.1^{3}$
	Girls ($n = 111$)										$3.6 + 1.0^{3}$

*Aerobic power calculated from 20 m shuttle run ($\dot{V}O_{2peak}$) following the Leger protocol (Leger and Lambert, 1982), expressed in $mL{\cdot}kg^{-1}{\cdot}min^{-1}$. $MVPA_{OB}$, physical activity measured directly using SenseWear Armbands in an N = 50 sub-sample (N = 21 boys and 29 girls); AP_{math}, academic performance assessed via math grade, [1]corresponding to the final grade awarded at the end of Grade 5, [2]at the end of Grade 8 and [3]at the end of Grade 9. *Significantly different from Grade 6 ($p < 0.05$); †Significantly different from boys within that grade level ($p < 0.05$).*

TABLE 2A | Correlation coefficients for dependent measures determined for boys and girls in Grade 6.

Grade 6		$MVPA_{OB}$	Shuttle run $\dot{V}O_{2peak}$	Polygon backward	Standing long jump	Handgrip	Flamingo	Sit-ups	Plate tapping	Sit and Reach	AP_{Math}
$MVPA_{OB}$ (*r*)	All										
	Boys										
	Girls										
Shuttle run $\dot{V}O_{2peak}$	All	0.104									
	Boys	0.033									
	Girls	0.188									
Polygon backward	All	−0.208*	−0.098								
	Boys	−0.257	−0.163								
	Girls	−0.172	−0.064								
Standing long jump	All	0.193*	0.043	−0.563**							
	Boys	0.256	0.217	−0.727**							
	Girls	0.102	−0.073	−0.467**							
Handgrip	All	−0.037	−0.002	−0.090	0.207*						
	Boys	−0.103	0.067	−0.057	0.113						
	Girls	−0.004	−0.053	−0.114	0.276*						
Flamingo	All	−0.232*	−0.200*	0.388*	−0.447**	−0.084					
	Boys	−0.375**	−0.301*	0.504**	−0.556**	−0.168					
	Girls	−0.129	−0,301*	0.331*	−0.405**	−0.021					
Sit-ups	All	0.213*	0.021	−0.420**	0.475**	0.101	−0.378**				
	Boys	0.193	0.182	−0.405**	0.444**	−0.042	−0.468**				
	Girls	0.208	−0.114	−0.449**	0.486**	0.250	−0.325*				
Plate tapping	All	0.000	−0.034	−0.010	0.049	−0.045	0.060	−0.028			
	Boys	0.038	0.008	−0.138	0.275*	0.005	−0.014	−0.003			
	Girls	−0.051	−0.084	0.100	−0.227	−0.164	0.109	−0.107			
Sit and reach	All	0.085	0.116	−0.323**	0.086	0.023	−0.180	0.074	−0.046		
	Boys	0.189	0.033	−0.383**	0.229	−0.034	−0.055	0.119	0.038		
	Girls	0.078	0.157	−0.344*	0.069	0.201	−0.255	0.133	−0.044		
AP_{Math}(ρ)	*All*	*−0.189**	*0.070*	*−0.183*	*0.247***	*0.075*	*−0.104*	*0.169*	*−0.140*	*−0.014*	
	Boys	*−0.185*	*0.177*	*−0.159*	*0.205*	*−0.035*	*−0.259*	*0.230*	*−0.149*	*−0.083*	
	Girls	*−0.193*	*−0.066*	*−0.194*	*0.294**	*0.205*	*0.099*	*0.134*	*−0.127*	*0.023*	

*Aerobic power calculated from 20 m shuttle run ($\dot{V}O_{2peak}$) following the Leger protocol (Leger and Lambert, 1982) and expressed in $mL{\cdot}kg^{-1}\ min^{-1}$; $MVPA_{OB}$, physical activity measured directly using SenseWear Armbands in N = 50 sub-sample (N = 21 boys and 29 girls); AP_{math}, academic performance (math grade, corresponding to the final grade awarded at the end of Grade 5); *Significant correlation $p < 0.05$; **Significant correlation $p < 0.01$; Italics font represents non-parametric correlations (Spearman rho).*

TABLE 2B | Correlation coefficients for dependent measures determined for boys and girls in Grade 9.

Grade 9		$MVPA_{OB}$	Shuttle run $\dot{V}O_{2peak}$	Polygon backward	Standing long jump	Handgrip	Flamingo	Sit-ups	Plate tapping	Sit and reach	AP_{Math}
$MVPA_{OB}$	All										
	Boys										
	Girls										
Shuttle run $\dot{V}O_{2peak}$	All	0.513**									
	Boys	0.407**									
	Girls	0.389**									
Polygon backward	All	−0.283**	−0.425**								
	Boys	−0.280**	−0.686								
	Girls	−0.358**	−0.248								
Standing long jump	All	0.305**	0.603**	−0.321**							
	Boys	0.167	0.551**	−0.741**							
	Girls	0.204	0.546**	−0.077							
Handgrip	All	0.251*	0.330**	−0.137	0.372**						
	Boys	0.020	0.211	−0.175	0.432**						
	Girls	0.221	0.174	−0.122	0.154						
Flamingo	All	0.009	−0.256**	0.349**	−0.291**	0.001					
	Boys	−0.137	−0.432**	0.435**	−0.390**	−0.181					
	Girls	−0.075	−0.395**	0.286*	−0.442**	−0.010					
Sit-ups	All	0.288**	0.576**	−0.241*	0.588**	0.325**	−0.229*				
	Boys	0.232	0.672**	−0.469**	0.471**	0.308*	−0.206				
	Girls	0.210	0.467**	−0.107	0.597**	0.240	−0.380**				
Plate tapping	All	0.052	0.335**	−0.207*	0.286**	0.224*	−0.094	0.274**			
	Boys	0.089	0.369*	−0.281	0.372*	0.304*	−0.172	0.242			
	Girls	0.014	0.369**	−0.144	0.259	0.174	−0.036	0.305*			
Sit and reach	All	−0.168	−0.023	−0.206*	0.180	−0.159	−0.387**	0.149	0.120		
	Boys	0.220	0.231	−0.477**	0.408**	0.034	−0.485**	0.047	0.205		
	Girls	−0.129	0.204	−0.71	0.394**	−0.002	−0.218	0.407**	0.102		
AP_{Math}(ρ)	*All*	*0.576***	*−0.128*	*−0.541***	*0.014*	*−0.108*	*−0.041*	*−0.188*	*−0.048*	*0.115*	
	Boys	*−0.018*	*−0.056*	*−0.249*	*0.188*	*−0.007*	*−0.213*	*−0.149*	*−0.035*	*0.214*	
	Girls	*−0.001*	*−0.182*	*0.070*	*−0.084*	*−0.156*	*0.125*	*−0.189*	*−0.059*	*0.023*	

*Aerobic power calculated from 20 m shuttle run ($\dot{V}O_{2peak}$) following the Leger protocol (Leger and Lambert, 1982) and expressed in $mL{\cdot}kg^{-1}\ min^{-1}$; $MVPA_{OB}$, physical activity measured directly using SenseWear Armbands in N = 50 sub-sample (21 boys and 29 girls); AP_{math}: academic performance (math grade, corresponding to the final grade awarded at the end of Grade 8); *Significant correlation $p < 0.05$; **Significant correlation $p < 0.01$; Italics font represents non-parametric correlations (Spearman rho).*

TABLE 3 | Model summary for the backward stepwise linear regression on the physical fitness change scores from Grade 6 to Grade 9, exclusively.

Model	*R*	R^2	Adjusted R^2	Std. error of the estimate	Sum of squares	Degrees of freedom (df)	Mean square	*F*-statistic	Significance
A									
1	0.711	0.505	0.408	0.74268	98.020	9	10.891	19.745	0.000
2	0.711	0.505	0.483	0.74057	98.017	8	12.252	22.340	0.000
3	0.711	0.505	0.485	0.73854	97.997	7	14.000	25.666	0.000
4	0.709	0.503	0.486	0.73827	97.522	6	16.254	29.821	0.000
5	0.706	0.498	0.484	0.73948	96.659	5	19.353	35.353	0.000
6	**0.703**	**0.494**	**0.483**	**0.74060**	**95.815**	**4**	**23.954**	**43.672**	**0.000**
B									
7	0.710	0.504	0.455	0.80156	58.816	9	6.535	10.171	0.000
8	0.710	0.504	0.460	0.79732	58.790	8	7.349	11.560	0.000
9	0.709	0.503	0.465	0.79382	58.667	7	8.381	13.300	0.000
10	0.708	0.501	0.469	0.79097	58.456	6	9.743	15.572	0.000
11	0.707	0.499	0.473	0.78808	58.259	5	11.652	18.761	0.000
12	**0.704**	**0.495**	**0.474**	**0.78726**	**57.761**	**4**	**14.440**	**23.299**	**0.000**
C									
13	0.751	0.564	0.511	0.67202	43.283	9	4.809	10.649	0.000
14	0.751	0.564	0.518	0.66753	43.282	8	5.410	12.142	0.000
15	0.751	0.564	0.524	0.66316	43.279	7	6.183	14.059	0.000
16	0.751	0.564	0.530	0.65893	43.270	6	7.212	16.610	0.000
17	0.751	0.564	0.536	0.65500	43.238	5	8.648	20.156	0.000
18	0.748	0.559	0.537	0.65423	42.889	4	10.722	25.050	0.000
19	0.745	0.556	0.539	0.65269	42.622	3	14.207	33.350	0.000
20	**0.735**	**0.540**	**0.540**	**0.65972**	**41.449**	**2**	**20.724**	**47.617**	**0.000**

Data were analyzed for (A) entire sample (N = 184), (B) boys (N = 100) and (C) girls (N = 84), respectively. Final models are bolded for interest.
Predictors for each model consist of a constant, plus the change scores of: (1): tapping, shuttle run, math score, flamingo, polygon backward, handgrip, sit and reach, sit ups, standing long jump (2) tapping, shuttle run, math score, flamingo, polygon backward, handgrip, sit and reach, sit ups, (3) tapping, shuttle run, math score, polygon backward, handgrip, sit and reach, sit ups (4) tapping, shuttle run, math score, polygon backward, sit and reach, sit ups, (5) shuttle run, math score, polygon backward, sit and reach, sit ups, (6) math score, polygon backward, sit and reach, sit ups, (7) tapping, math score, shuttle run, flamingo, handgrip, polygon backward, sit and reach, sit ups, standing long jump, (8) tapping, math score, shuttle run, flamingo, handgrip, polygon backward, sit and reach, sit ups (9) math score, shuttle run, flamingo, handgrip, polygon backward, sit and reach, sit ups, (10) math score, shuttle run, handgrip, polygon backward, sit and reach, sit ups (11) math score, shuttle run, handgrip, sit and reach, sit ups, (12) math score, shuttle run, handgrip, sit ups, (13) tapping, handgrip, flamingo, shuttle run, polygon backward, math score, sit ups, standing long jump, sit and reach, (14) tapping, handgrip, flamingo, shuttle run, polygon backward, math score, sit ups, sit and reach, (15) tapping, handgrip, shuttle run, polygon backward, math score, sit ups, sit and reach, (16) tapping, shuttle run, polygon backward, math score, sit ups, sit and reach, (17) tapping, polygon backward, math score, sit ups, sit and reach, (18) tapping, polygon backward, math score, sit and reach, (19) tapping, polygon backward, math score, (20) polygon backward, math score. Final model compositions are bolded for interest.

in Grade 9, either for everyone ($r = 0.051$, $p = 0.612$), for boys ($r = 0.018$, $p = 0.908$) or for girls ($r = 0.001$, $p = 0.993$).

Physical Fitness and Mathematics Academic Performance

In Grade 6, mathematics grade AP_{math} demonstrated a low association with standing long jump ($r = 0.247$, $p = 0.010$); however, only in girls were the results of this test significantly correlated ($r = 0.294$, $p = 0.031$). By Grade 9, there were no fitness indicators which correlated significantly to math grade for that year. This was true for both sexes, even for peak aerobic power ($\dot{V}O_{2peak}$), which did not correlate to AP_{math} in Grade 9.

Physical Fitness and Activity Predictors of Final Mathematics Grade

A backward stepwise multiple regression was used to determine which indicators may have shared variance to the youths' final AP_{math} scores, awarded at the end of Grade 9, and based on the delta change scores of the fitness measures. Of all the fitness measures, only backward obstacle course, sit and reach, sit-ups, and delta change in AP_{math} remained significant to the final model [$r^2 = 0.494$, $F(4,180) = 43.67$, $p < 0.0001$, **Tables 3**, **4**]. When this model was run separately by sex, the input variables differed slightly between boys and girls, wherein shuttle run, handgrip, sit-ups and ΔAP_{math} contributed to the final model for boys [$r^2 = 0.495$, $F(4,95) = 23.299$, $p < 0.0001$], and only backward obstacle course and ΔAP_{math} contributed to the girls' model [$r^2 = 0.540$, $F(2,81) = 47.7$, $p < 0.0001$].

Determining the (possible) effect of MVPA on final AP_{math} scores required a second analysis since $MVPA_{OB}$ were obtained in a sub-sample of youth and not the entire cohort. In this scenario, $MVPA_{OB}$ attained its lowest *p*-value of 0.188, a standardized beta of −0.122, and was thus removed from the model on step 7 of 9 (**Tables 5**, **6**). Likewise, when data were separated by sex, $MVPA_{OB}$ it did not reach significance for either analysis, being removed from the model at step 3 ($p = 0.698$) and step 7 ($p = 0.315$) for boys and girls, respectively, and therefore, only combined data are detailed in subsequent tables.

DISCUSSION

The results of this study found that longitudinal fitness changes in Slovenian youth were related to changes in objectively assessed physical activity ($MVPA_{OB}$), including small associations between standing long jump and $MVPA_{OB}$. Mathematics score decreased within this 3-year timespan for both boys and girls. The final mathematics grade at the end of primary school was associated with changes in whole-body coordination (backward obstacle course), flexibility (sit and reach) and muscular endurance (sit-ups) when boys' and girls' data were combined. When separated, fitness indicators differed

TABLE 4 | Coefficients data for the first and final model for (A) entire sample (*N* = 184), (B) boys (*N* = 100), and (C) girls (*N* = 84), respectively.

		Unstandardized coefficients		Standardized coefficients B	*t*-statistic	Significance	95% confidence interval for B		Collinearity Statistics	
Model		***B***	**Std. error**				**Lower bound**	**Upper bound**	**Tolerance**	**VIF**
A1	Constant	3.628	0.129		28.070	0.000	3.373	3.883		
	Δ Math grade	0.544	0.043	0.691	12.547	0.000	0.459	0.630	0.953	1.049
	Δ Standing long jump	0.000	0.003	0.005	0.076	0.940	−0.006	0.006	0.609	1.643
	Δ Flamingo	−0.001	0.004	−0.010	−0.193	0.847	−0.008	0.007	0.967	1.034
	Δ Sit ups	−0.018	0.007	−0.163	−2.688	0.008	−0.032	−0.005	0.766	1.305
	Δ Handgrip	0.009	0.011	0.052	0.791	0.430	−0.013	0.031	0.670	1.492
	Δ Polygon backward	−0.031	0.018	−0.096	−1.759	0.080	−0.067	0.004	0.908	1.101
	Δ Sit and reach	0.017	0.010	0.096	1.681	0.095	−0.003	0.036	0.856	1.169
	Δ Shuttle run	0.002	0.002	0.064	1.142	0.244	−0.004	0.016	0.873	1.145
	Δ Tapping	0.006	0.005	0.067	1.170	0.244	−0.004	0.016	0.890	1.124
A6	Constant	3.706	0.115		32.292	0.000	3.480	3.933		
	Δ Math grade	0.546	0.043	0.693	12.790	0.000	0.462	0.630	0.975	1.026
	Δ Sit ups	−0.014	0.006	−0.121	−2.219	0.028	−0.026	−0.002	0.939	1.065
	Δ Polygon backward	−0.029	0.018	−0.090	−1.656	0.099	−0.064	0.006	0.949	1.053
	Δ Sit and reach	0.021	0.009	0.122	2.236	0.027	0.002	0.040	0.930	1.076
B7	Constant	3.526	0.177		19.953	0.000	3.175	3.877		
	Δ Math grade	0.495	0.060	0.641	8.274	0.000	0.376	0.613	0.956	1.046
	Δ Standing long jump	−0.001	0.005	−0.023	−0.199	0.843	−0.011	0.009	0.409	2.446
	Δ Flamingo	−0.002	0.005	−0.037	−0.491	0.624	−0.011	0.007	0.912	1.097
	Δ Sit ups	−0.027	0.010	−0.235	−2.631	0.010	−0.047	−0.007	0.681	1.468
	Δ Handgrip	0.022	0.015	0.141	1.416	0.160	−0.009	0.053	0.561	1.783
	Δ Polygon backward	−0.017	0.027	−0.051	−0.639	0.525	−0.071	0.036	0.824	1.214
	Δ Sit and reach	0.013	0.017	0.069	0.773	0.442	−0.020	0.046	0.702	1.425
	Δ Shuttle run	0.005	0.003	0.161	1.935	0.056	0.000	0.010	0.790	1.265
	Δ Tapping	0.003	0.007	0.040	0.476	0.635	−0.011	0.018	0.751	1.331
B12	Constant	3.638	0.144		25.256	0.000	3.352	3.924		
	Δ Math grade	0.484	0.057	0.628	8.522	0.000	0.372	0.597	0.978	1.022
	Δ Sit ups	−0.025	0.009	−0.216	−2.624	0.010	−0.043	−0.006	0.783	1.276
	Δ Handgrip	0.024	0.012	0.155	1.966	0.052	0.000	0.048	0.857	1.166
	Δ Shuttle run	0.005	0.002	0.155	1.993	0.049	0.000	0.010	0.879	1.137
C13	Constant	3.707	0.215		17.221	0.000	3.278	4.136		
	Δ Math grade	0.605	0.064	0.746	9.409	0.000	0.477	0.733	0.884	1.131
	Δ Standing long jump	0.000	0.005	0.002	0.027	0.978	−0.010	0.102	0.811	1.233
	Δ Flamingo	0.001	0.010	0.006	0.082	0.935	−0.019	0.021	0.896	1.115
	Δ Sit ups	−0.008	0.009	−0.066	−0.821	0.415	−0.026	0.011	0.906	1.103
	Δ Handgrip	−0.003	0.021	−0.011	−0.137	0.891	−0.045	0.039	0.893	1.120
	Δ Polygon backward	−0.057	0.025	−0.177	−2.246	0.028	−0.107	−0.006	0.540	1.852
	Δ Sit and reach	0.014	0.015	0.077	0.915	0.363	−0.016	0.043	0.688	1.453
	Δ Shuttle run	−0.001	0.002	−0.021	−0.2552	0.802	−0.005	0.004	0.849	1.178
	Δ Tapping	0.011	0.007	0.123	1.561	0.123	−0.003	0.026	0.795	1.257
C20	Constant	3.909	0.095		41.187	0.000	3.721	4.098		
	Δ Math grade	0.590	0.061	0.728	9.628	0.000	0.468	0.712	0.930	1.076
	Δ Polygon backward	−0.059	0.024	−0.183	−2.424	0.018	−0.107	−0.010	0.911	1.098

TABLE 5 | Model summary for the backward stepwise linear regression on the physical fitness change scores from Grade 6 to Grade 9, with the inclusion of $MVPA_{OB}$.

Model	*R*	R^2	Adjusted R^2	Std. error of the estimate	Sum of squares	Degrees of freedom (df)	Mean square	*F*-statistic	Significance
1	0.851	0.724	0.625	0.62011	28.207	10	2.821	7.335	0.000
2	0.851	0.724	0.638	0.60954	28.200	9	3.133	8.433	0.000
3	0.849	0.721	0.646	0.60258	28.081	8	3.510	9.667	0.000
4	0.849	0.716	0.652	0.59753	27.906	7	3.978	11.166	0.000
5	0.843	0.711	0.656	0.59379	27.692	6	4.615	13.090	0.000
6	0.837	0.701	0.655	0.59453	27.310	5	5.462	15.453	0.000
7	**0.827**	**0.684**	**0.647**	**0.60153**	**26.672**	**4**	**6.668**	**18.428**	0.000
8	0.815	0.664	0.635	0.61196	25.867	3	8.622	23.024	0.000
9	0.799	0.638	0.618	0.61258	24.873	2	12.436	31.749	0.000

Data were analyzed for the entire sample (N = 39). Model at which point $MVPA_{OB}$ is dropped from the analysis is bolded for interest. Data are presented only for total data set, not stratified by sex.

Predictors for each model consist of a constant, plus the change scores of: (1): MVPA, handgrip, shuttle run, standing long jump, polygon backward, sit ups, sit and reach, flamingo, math score, tapping (2) MVPA, shuttle run, standing long jump, polygon backward, sit ups, sit and reach, flamingo, math score, tapping, (3) MVPA, shuttle run, standing long jump, polygon backward, sit ups, sit and reach, flamingo, math score, (4) MVPA, standing long jump, polygon backward, sit ups, sit and reach, flamingo, math score, (5) MVPA, polygon backward, sit ups, sit and reach, flamingo, math score, (6) MVPA, polygon backward, sit ups, flamingo, math score, (7) polygon backward, sit ups, flamingo, math score, (8) polygon backward, sit ups, math score, (9) sit ups, math score.

TABLE 6 | Coefficients data for the first and final model with the inclusion of $MVPA_{OB}$.

Model		Unstandardized coefficients		Standardized coefficients *B*	*t*-statistic	Significance	95% confidence interval for B		Collinearity statistics	
		B	Std. error				Lower bound	Upper bound	Tolerance	VIF
1	Constant	5.029	0.572		8.788	0.000	3.857	6.201		
	Δ Math grade	0.650	0.092	0.786	7.087	0.000	0.462	0.837	0.803	1.245
	Δ Standing long jump	−0.004	0.006	−0.067	−0.644	0.525	−0.016	0.008	0.916	1.092
	Δ Flamingo	0.025	0.017	0.161	1.459	0.156	−0.010	0.059	0.814	1.229
	Δ Sit ups	−0.025	0.014	−0.195	−1.897	0.081	−0.053	0.003	0.850	1.176
	Δ Handgrip	0.004	0.026	0.016	0.140	0.890	−0.049	0.056	0.782	1.279
	Δ Polygon backward	−0.052	0.032	−0.179	−1.640	0.112	−0.117	0.013	0.825	1.213
	Δ Sit and reach	−0.021	0.021	−0.110	−0.997	0.327	−0.065	0.023	0.812	1.231
	Δ Shuttle run	0.003	0.004	0.096	0.819	0.420	−0.004	0.010	0.715	1.399
	Δ Tapping	0.006	0.011	0.066	0.571	0.572	−0.017	0.030	0.746	1.340
9	Constant	4.071	0.137		29.730	0.000	3.793	4.349		
	Δ Math grade	0.621	0.084	0.751	7.415	0.000	0.451	0.791	0.980	1.021
	Δ Sit ups	−0.024	0.013	−0.185	−1.828	0.076	−0.050	0.003	0.980	1.021

Data were analyzed for the entire sample (N = 39). Data are presented only for total data set, not stratified by sex.

such that for boys, aerobic power (shuttle run), upper body strength (handgrip), and muscular endurance (sit-ups) shared variance with final math score whereas whole-body coordination backward obstacle course was the more relevant fitness indicator to girls' final math score.

Longitudinal Changes in Physical Activity and Fitness

Physical activity levels in children tend to decrease with age, and a recent meta-analysis has demonstrated that between the ages 11 and 14 (which correspond to grades 6 and 9 in Slovenia), MVPA declines similarly amongst boys and girls at a rate of around 4.3% and 4.5% per year, respectively (Farooq et al., 2020). Analysis from the current investigation, and trends from the ongoing SLOfit surveillance (Jurak et al., 2020), show larger declining trends in Slovenian boys and girls, and greater differences between them. For example, girls experience a ∼15.2% annual decline, thus experiencing 2.6-times larger annual declines in MVPA than boys, who see declines of ∼5.7% annually. Although the declines in MVPA observed between Grades 6 and 9 can be possibly linked to greater school-related workloads (e.g., compulsory annual instruction time increases from 700 to 892.5 h, respectively), and the reduced hours of compulsory physical education after Grade 6 from 105 to 70 h per year, this workload increase and school-related PA is equal for boys and girls, and cannot in and of itself explain the growing sex-effect difference observed in MVPA in the present study.

Similarly, there are growing disparities between boys and girls when observing changes in aerobic power, measured via the shuttle run. In boys, this indicator of cardiorespiratory

fitness increased from 45 to 53 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ between Grade 6 and 9, whereas for girls, their values decreased from 46 to 41 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$. In the Muscatine study, both boys and girls experienced a decline of VO_{2peak} in this age period (Janz et al., 2000), although in that study, the level of oxygen consumption was much lower than our recorded level, and therefore any changes observed in MVPA for our cohort may have had greater relative effects compared to a less-fit group of children at baseline.

Coherent to the trends in MVPA, boys in our study did not experience a declining trend in any other physical fitness test (other than the flamingo balance test) whilst girls experienced improvement in all physical fitness indicators, despite recorded declines in MVPA. Indeed, girls even exceeded the boys' performance in terms of the flamingo balance test and sit-and-reach scores, whereas boys achieved higher results in standing long jump and handgrip test. These results suggest that girls may achieve higher levels of neuromuscular fitness by age 14 compared to their male counterparts, which could be linked to their earlier timing of puberty/maturation, and consequently more developed central nervous system at this age (Hoyt et al., 2020). Unfortunately, direct assessment of maturation was outside of the scope of this study, so any improvements in these measures must be considered when interpreting the data. In flexibility, girls also tended to achieve higher results throughout childhood and adolescence. By age 14, boys tended to achieve higher levels of muscular fitness which is linked to increasing muscle mass and consequent muscle power, likely because of higher testosterone levels as puberty continues to progress (Handelsman, 2017).

Mathematics Academic Performance in Primary School

In the present study, mathematics grades decreased between Grade 6 and Grade 9 from ∼4.2 to ∼3.5. This magnitude of decrease is not surprising, given that Grade 5 is the last year a generalized education teacher is the one who administers the mathematics curricula. By Grade 6, the youth are taught by a specialist mathematics teacher, and both the volume of work and difficulty level are increased dramatically compared to early primary schooling periods. Population data from national assessments indicate that a typical decrease in math grade does occur, with the average score at the end of Grade 9 being 3.3 (Perger, 2021). Therefore, our results are in-line with national standards for this academic performance metric.

Physical Fitness and Academic Performance in Children and Youth

Of all the fitness indicators, positive AP is often specifically associated with higher aerobic function (Sardinha et al., 2016). For example, on a sample of boys from Spain (Torrijos-Niño et al., 2014), the authors found that AP was positively related to aerobic fitness, and that obese boys had lower AP scores compared to overweight or normal weight boys. Unsurprisingly, their data suggest that 'academically superior' PF in children and youth are likely the result of lifestyle patterns, including discipline in school-related work and habitual daily PA, a pattern of evidence also reflected in other studies (Donnelly et al., 2016). Currently, although shuttle run (and by extension, aerobic power) epidemiological literature for children and youth is very well-documented (Tomkinson et al., 2017; Lang et al., 2019), there are few examples where negative fitness and obesity trends have been reversed, especially over the past 20 years. To this point, the Republic of Slovenia has demonstrated a net increase in CRF between 1993 and 2013 in both boys and girls, despite initial decreases observed from 1993 to 2003 (Morrison et al., 2021). Indeed, Slovenian schoolchildren universally meet or exceed international standards for CRF cut-off values for minimizing future cardiovascular health risk. Whether this higher universal fitness standard affects AP in these children and youth are yet to be determined, but the present study did not relate shuttle run aerobic power to mathematics grade *per se* for either sex within a given grade. Instead, the 3-year longitudinal changes observed in aerobic power were a predictor for final math score for boys (but not for girls), indicating both a possible reduction in statistical power when the regression was split by sex, and also the interaction effect present in that metric, where boys saw a net increase in relative function between Grade 6 to Grade 9 (from 46 ± 26 to 64 ± 25 $mL^{-1}{\cdot}kg^{-1}{\cdot}min^{-1}$), whereas girls demonstrated the reverse trend (from 46 ± 27 to 42 ± 20 $mL^{-1}{\cdot}kg^{-1}{\cdot}min^{-1}$). It would be interesting to compare these longitudinal changes in PF and AP in Slovenian schoolchildren to others across Europe, the OECD, and internationally, to determine to what degree increasing PF directly improves AP in a dose-response manner, especially for children who may be starting from a more sedentary and lower aerobic fitness standard.

Previous meta-analyses have found that, in addition to cardiorespiratory fitness, speed-agility, motor coordination, and perceptual motor skills are each highly associated with AP (Ruiz-Ariza et al., 2017), but evidence for strength and flexibility remained unclear. Certainly, some authors consider that motor competence is 'indissoluble' from cognitive competence, a model in which cognitive skills arise from motor action (AVILÉS et al., 2014), with motor coordination being one of the most important factors to the evolutionary development of children (Fernandes et al., 2016; Ruiz-Pérez et al., 2016). The present study found a small proportion of the variance in final math grade could be attributed to physical fitness components encompassing motor coordination (backward obstacle course), flexibility (sit-and-reach) and strength (sit-ups). These results support the theory of association between body-kinaesthetic intelligence and coordinative performance, which is further reinforced by neural connections existing across structural/muscular factors (Diamond and Lee, 2011). Sit-ups may have contributed to the final model because it is an isokinetic endurance test which considers not only a child's physical abilities, but also psychological characteristics like persistence, a necessary component to any learning process. Our results are consistent with a similar analysis conducted on a sample of boys from Spain (Torrijos-Niño et al., 2014), and a study where the odds ratio for effects of PF improvement on AP, and mathematics specifically, were calculated for highly fit and unfit children (Sardinha et al., 2016).

In our analysis, we were not able to prove the interrelatedness of objectively assessed PA on AP, which proposes that PF

indicators may be more insightful than PA alone when studying this phenomenon. Firstly, the information on MVPA alone cannot indicate whether a person is fit or not. This is related to the second limitation of reliability of MVPA assessment, namely, that despite the established recommendations that MVPA should be recorded for several consecutive days, this does not guarantee that actual PA is representative for long-term habitual PA during the observed days. In this regard, PF could serve as a more reliable indicator of habitual PA, since the level of PF is the direct result of long-term habitual PA as an important determinant of phenotype (Sallis et al., 1993a,b). Indeed, due to interpersonal differences in body metabolism, individuals require different frequency, intensity, and duration of PA to obtain or preserve certain levels of PF, or related health benefits (Oja, 2001). Thirdly, PF seems to be more direct indicator of physiological functioning of human organism which determines also cognitive functioning than PA, and also the effect of PA is itself moderated by PF (Lopes and Rodrigues, 2021).

Espousing Systematic Physical Fitness Monitoring in the Young

There is clear evidence that monitoring PF in children can be critical to maintaining this key health indicator (Ortega et al., 2008). Higher levels of PF are associated with greater PA (Wang, 2019), including better socialization (Li and Li, 2018) and academic performance (Sember et al., 2020b) and indeed, fitness testing is much more than just 'one more school assessment' since it helps increase awareness of how one's body moves through space. How fit a child is now can relate to how fit and active they become as adults (Kvaavik et al., 2009). Those who have high 'physical literacy' (i.e., are attuned to how their body works and what it needs to function properly), are better able to foster life-long physical activity habits (Whitehead, 2010). Importantly, skill-based fitness developments are legitimate manifestations of physical literacy development since physical literacy is a multidimensional and interactive construct comprising of the physical, behavior, cognitive and affective domain (Whitehead, 2010). Thus, PF is a critical component to physical literacy overall. Additionally, monitoring fitness in schools is an effective policy making tool since there are well-educated professionals (teachers and others) who can ensure effective and accurate student fitness measurements in a timely and accurate fashion (e.g., SLOfit) (Jurak et al., 2019). Monitoring fitness as children mature offers education and public health decision-makers opportunity to respond quickly and effectively to changes in child PF trends, a critical pillar of any public health strategy since globally, children have become more inactive and overweight (Aubert et al., 2018).

It is important to note that fitness testing *per se* should never be used to grade the student. The assessment of PF is conducted to provide professionals with accurate measures of educational achievement, the health and functional status of the children, and can act as an operational starting point for setting individual goals and tailoring curricula to individual needs. It must be clearly communicated as such to the children as well so that they treat these examinations in context. Timely testing allows for professionals to gain an understanding of the child's educational development and health status to make informed decisions regarding education or further treatment (Lloyd et al., 2010). This is an appropriate way to run effective physical education classes, where students understand the rationale for standardized testing.

Data from the current investigation were possible only because there is a concerted, ongoing effort to chart the fitness changes of the Slovenian schoolchildren population to inform policy making decisions and affect positive public health decisions. Data from fitness databases in Slovenia have contributed to finding that there was a reversal in the negative trends of child aerobic fitness (Morrison et al., 2021), charting pediatric rates of obesity (Potoènik et al., 2020), and identifying how the COVID-19 pandemic has affected child fitness overall (Jurak et al., 2021). By utilizing near real-time health status changes in youth, this study demonstrates how implementing a robust fitness surveillance monitoring program at a population level can detect meaningful changes in health status, even when societal and global perturbations dramatically alter civic life (e.g., conflicts, pandemics, and recessions). Often during times of social transition, decreases in opportunities to engage in quality physical activity may diminish one's physical fitness, especially for vulnerable populations, like the young. Data from the current investigation underscore that a variety of physical fitness indicators are related to changes in academic performance, especially for mathematics grade, and these fitness markers are heterogeneous between boys and girls. Only by continuously monitoring fitness can one make changes to regional, national, and international policies which can then have lasting trickle-down effects on longstanding societal health issues like obesity, chronic hypertension, stroke, as well as effects like cognition, academic performance, fitness, and mental health.

CONCLUSION

Girls and boys in Slovenia are becoming less physically active when progressing from Grade 6 to Grade 9. Decreases are also evident for AP in mathematics in both girls and boys during this timeframe, likely reflecting structural issues present within the Slovenian primary education system (i.e., students aged ∼6–14 years), rather than other external or physical fitness factors alone. In contrast to prevailing existing evidence which link AP with cardiorespiratory fitness lower math grades in our study are also moderately associated with indicators of muscular and neuro-muscular fitness, including changes in whole-body coordination, flexibility, and muscular endurance for the entire sample. Aerobic power, upper body strength, and muscular endurance share more common variance to final math grade in boys, whereas whole-body coordination was the more relevant index in girls; this finding suggests that future research exploring the relationship of AP and PF should not be limited to cardiorespiratory PF and should also encompass muscular and neuro-muscular components of PF. Our study suggests that PF can serve as more useful indicator for assessment of AP risks than PA, but also that the current data indicates the association between PF and PA declines with age. The reason of this decline remains unclear but directs researchers that toward adolescence, factors other than PF may be more detrimental to AP in general, and mathematics grade specifically.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Slovenian National Medical Ethics Committee (ID:138/05/13), following the Declaration of Helsinki. Written informed consent was obtained from the minor's legal guardian/next of kin (and assent from the child) to participate in the study.

AUTHOR CONTRIBUTIONS

VS: investigation, conceptualization, formal analysis, visualization, writing—original draft, writing—review and editing, and writing—approval of final manuscript. GJ: project administration, investigation, conceptualization, resources, writing—review and editing, and writing—approval of final manuscript. GS: project administration, investigation, conceptualization, resources, writing—review and editing, and writing—approval of final manuscript. SM: conceptualization, formal analysis, visualization, writing—original draft, writing—review and editing, and writing—approval of final manuscript. All authors contributed to the article and approved the submitted version.

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Exploring the Level of Physical Fitness on Physical Activity and Physical Literacy Among Chinese University Students: A Cross-Sectional Study

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Physical literacy (PL) has received considerable attention in the field of physical education and physical activity (PA) worldwide. According to recent studies, the level of physical fitness (PF) among Chinese university students is gradually decreasing. This study aims to examine the impact of the PF level (fit/unfit) on PA and PL, as well as the relationships among PF, PA, and PL, in Chinese university students. Participants comprised 798 university students (390 men; mean age, 19.2 ± 1.2 years) in Chongqing, China. Participants completed the tests of vital capacity, cardiorespiratory fitness, muscular strength, and flexibility, according to the National Physical Fitness Measurement Standards Manual (NPFMSM), as well as questionnaires on PA (time spent performing PA at various intensities) and PL. The independent *t*-tests were conducted to examine sex differences in the evaluated variables, and the Pearson's correlation between each PF test and PL attributes and PA was calculated according to sex. In addition, the independent *t*-tests were conducted to determine whether the PF level had an effect on PL attributes and PA at various intensities. Significant sex differences were found in the PF domains of vital capacity, muscular strength, and aerobic fitness, with higher scores in men than in women (all p-values < 0.05), but not in the PF domain of flexibility and total PL score. Furthermore, the PF domains of muscular strength and aerobic fitness were significantly and positively correlated with the PL attributes of confidence and physical competence in both men and women, while the PF domains of vital capacity and aerobic fitness were significantly and positively correlated with the PL attribute of motivation in men. In addition, PL was significantly and positively associated with cardiorespiratory fitness, vital capacity, muscular strength, and flexibility among participants in the fit group. These findings support advocating for increased participation in PA in university students and using PL as a tool to improve PF components.

Keywords: physical literacy, physical fitness, physical activity, university students, cross-sectional study

INTRODUCTION

Physical activity (PA) and physical fitness (PF) are causally related. The WHO recommends that young adults perform at least 60 min of moderate-to-vigorous PA (MVPA) per day, in order to obtain optimal health benefits (Chaput et al., 2020). Despite this, significant declines in PA among college students are prevalent worldwide (Hallal et al., 2012). For example, an astounding 82.5% and 89.8% of 18-year-old male and 21-year-old female Chinese university students, respectively, are physically inactive (i.e., do not meet the WHO guideline for PA) (Chen et al., 2020). In addition, according to a national survey, the prevalence of overweight status and obesity has dramatically increased in Chinese university students (Tian et al., 2016; Jiang et al., 2018). Based on the Report of Nutrition and Chronic Disease Status of Chinese Residents (2020), the body weight of Chinese men and women aged 18–24 years has increased, on average, 3.4 and 1.7 kg, respectively, compared to that in 2015. These facts are alarming, as an insufficient level of PA is closely related to overweight status, chronic disease, mental health problems, and poor social and cognitive health outcomes (Aubert et al., 2018, 2021). Therefore, it is vital to identify the current condition of PA among Chinese university students, identifying corresponding solutions to motivate university students to participate in PA.

In response to this concerning trend, the State Council issued the "National Fitness Program (2016–2020)" to monitor the PF levels in the university level and possibly set a requirement for graduation. The program aims to better meet the growing demand for participation in PA among young people, and clearly illustrates the need for university students to pay more attention to exercise, for a healthier and stronger body (Ng et al., 2014). In brief, the program comprises measurements of the body mass index (BMI), vital capacity, and performance on the sit and reach test, standing long jump, and 800/1,000 m race, with each test score, according to a predesignated criterion. Accordingly, the testing program provides a comprehensive assessment of the body composition, cardiovascular fitness, strength, endurance, and flexibility in university students.

Physical literacy (PL), a multidimensional construct, has been gaining attention in the research community, and scholars have reached a consensus for some of its defining components (Morrow et al., 2013). PL has been defined as "the motivation, confidence, physical competence, knowledge and understanding needed to value and take responsibility for engagement in physical activities for life" (Burgi et al., 2011). Accordingly, movement skills, competence, motivational constructs, and the embodied experience are highlighted as the core attributes of the PL concept (Burgi et al., 2011). PL is holistically conceived, in that its definition includes physical, cognitive, and affective domains. Thus, PL provides an innovative perspective for encouraging movement behaviors, in terms of participation in PA and the development of fundamental movement skills.

Previous studies have examined the relationship between PL and PA to emphasize the importance of PL as a means to encourage an active lifestyle throughout the life course (Niederer et al., 2011; Cohen et al., 2014). A recent theoretical exploration proposed an evidence-informed conceptual model linking PL, PA, and health outcomes, including PF, which has provided an important foundational model for empirical studies (Cairney et al., 2019). This previous report proposed reciprocal relationships between PL and PA (Cairney et al., 2019). On the one hand, PL is important for sustained participation in PA; on the other hand, the development of PL is enriched by both unstructured (e.g., free play and recreational pursuits) and structured PA (e.g., sport and physical education) (Cairney et al., 2019). The multidimensional structure of PL is considered important in maintaining lifelong participation in PA and the development of PF (Kirschenbaum et al., 1985). For example, individuals with a proficiency in fundamental movement skills are more likely to have the motivation and confidence supporting participation in PA, which leads to the development of PL later in life (Kirschenbaum et al., 1985).

The PL domains (i.e., physical competence, motivation and confidence, and knowledge) are intercorrelated with each other and are essential for supporting participation in PA during adolescence and adulthood (Peckham et al., 1983). The attributes of physical competence in the multidimensional construct of PL have close connections with the domains of PF, and as such, the two constructs are connected through common underpinning components. A previous study have evaluated the impact of a pilot PL-based intervention on PA and PF in university students and have indicated that increasing the PL level may be a promising modality to promote PA among university students (Kwan et al., 2020). In this previous study, 65 university freshmen participated in a 12-week movement skills program, and, with a cluster research design, the core domains of PL, including movement competence, confidence, motivation, and knowledge and understanding, were simultaneously examined (Kwan et al., 2020). The results demonstrated a moderate interaction effect (time by condition) for PA behaviors, as well as for cardiorespiratory fitness (Kwan et al., 2020). The findings from this pilot program suggest that increasing PL may be an effective approach to maintain PF and attenuate the decline in PA behaviors among university students (Kwan et al., 2020). However, because of the insufficient sample size, these findings need to be verified in further studies with larger sample size to provide more substantial evidence. In addition, a highly relevant assumption is that the benefit of increased PL in terms of PA and PF maintenance might differ between those with low and high PF (Kljajević et al., 2022), which can be investigated by using PF test scores to identify fit and unfit groups *via z*-score calculation (Kljajević et al., 2022). Therefore, we aimed to investigate the impact of PF level (fit/unfit) on PL and PA among university students, with a substantial number of participants. Our second aim was to evaluate the relationships among PF, PA, and PL in university students in China.

MATERIALS AND METHODS

Participants and Recruitment

This study adopts a stratified sampling method to recruit participants from four schools located in the Gaoxin district of Chongqing, China, including two universities and two colleges.

In total, 798 university students were recruited (390 men, 48.9%), with a mean age of 19.2 years. Data collection was conducted between November 2020 and December 2020. All participants had normal physical health, with no limitations in exercise participation. Informed consent was obtained prior to participation, and the study was approved by the directors of the four selected schools. In addition, ethical approval was obtained by the Institution Review Board of the Ethics Advisory Committee at Chongqing University.

Measures

Physical Fitness

The PF measurements were conducted at the four schools by trained research assistants, according to the National Physical Fitness Measurement Standards Manual (NPFMSM, University version). In total, eight domains of PF were measured, including seven tests from the NPFMSM and one calculated score. All research assistants completed a 2-h training class on the PF measurements to eliminate discrepancies and avoid the introduction of bias, and to unify data collection under consensus. Any questions from the research assistants were resolved.

Participants' weight (to the nearest 0.1 kg) and height (to the nearest 0.1 cm) were measured. BMI was calculated using the following formula: BMI = weight (kg) divided by the square of height (m). According to WHO criteria, we divided participants into four categories, namely, low weight (< 18.5 kg/m^2), normal weight (18.5–23.9 kg/m^2), overweight (24–27.9 kg/m^2), and obese (≥ 28 kg/m^2) (Chen et al., 2020).

Vital capacity was assessed by a spirometer. During the test, the participant held the handle and inhaled as hard as he/she could. Each participant completed the test twice, and the best attempt was recorded.

Aerobic fitness was measured by a long-distance race of 800 m for women and 1,000 m for men. Participants were tested in pairs, starting from a standing position. The score was recorded in minutes and seconds and was validated by two research assistants. The final grade was calculated according to the NPFMSM system, with 100 points as the highest grade.

Muscular strength was assessed *via* the standing long jump, which evaluates the development level of the participant's lower limb explosive power and physical coordination ability (Chen et al., 2020). The score was determined as the distance from the start line to the heel of the closest foot, and each participant's best of the three attempts was retained.

Flexibility was evaluated by the sit and reach test. Participants were barefoot and asked to sit on the test instrument, maintaining their legs straight at the start line. Subsequently, they benched their upper body and reached forward as far as possible. The best score of the two attempts was recorded.

Physical Activity

PA was evaluated using the International Physical Activity Questionnaire, short form (IPAQ-SF) (Hallal and Victora, 2004). The IPAQ-SF consists of seven items and provides information on the time spent performing vigorous physical activity (VPA), such as aerobics, and moderate physical activity (MPA), such as leisure cycling, walking, and sedentary activities. Participants were asked to recall the number of days (frequency) and the length of time (duration) per day that they performed each activity during the last 7 days or during a normal week. In addition, participants were asked to record the amount of time during which they were sedentary. Data from the questionnaire were summed within each category (i.e., vigorous intensity, moderate intensity, and walking) to estimate the total amount of time spent performing PAs per day. Using the official IPAQ-SF scoring protocol, the total daily PA [metabolic equivalent (MET)·min/day] was estimated by summing the product of reported time within each PA category with its corresponding category MET value, expressed as a daily average MET score (Hallal and Victora, 2004).

Physical Literacy

The Perceived Physical Literacy Instrument (simplified Chinese version) was adopted to evaluate perceived PL among Chinese university students (Ma et al., 2020). This is an eight-item questionnaire consisting of three domains, namely, confidence and physical competence (e.g., "I possess adequate fundamental movement skills"), motivation (e.g., "I appreciate myself or others doing sports"), and interaction with the environment (e.g., "I have strong communication skills"). Specifically, these three domains, respectively, reflect the need to have strong confidence and physical competence, a positive attitude in doing sports, and to know how to interact with the environment to be physically literate. Each response was rated on a 5-point Likert-type scale ranging from strongly disagree to strongly agree. Adapted from a previous Cantonese version constructed by physical education teachers in Hong Kong, the validity of the current questionnaire was confirmed through confirmatory factor analysis, with factor loadings ranging from 0.60 to 0.92 (Ma et al., 2020).

Data Collection Procedures

Data collection was conducted at the university campus between November and December 2020. This period was selected because the national PF test was conducted as a requirement for university students at this time. Participants received detailed instructions on how to complete the questionnaires. Following a standardized survey administration protocol, two trained research assistants conducted a survey of PA and PL during regular school time. Participants first completed the PF assessments and then independently completed the survey questionnaires (paper version) in the playing field.

Data Analysis

Before conducting data analysis, several important assumptions were tested, including, for continuous dependent variables, a lack of outliers, homogeneity of variance (assessed by the Levene's test), and a normal distribution. Descriptive statistics were conducted to summarize the characteristics of the study sample. The independent *t*-tests were conducted to determine whether there were differences between men and women in the evaluated variables. The Pearson's correlation between each PF test and PL attributes and PA at various intensities was calculated according to sex. In addition, differences in PL and

PA were examined according to PF level as one of the main research questions. Specifically, the total sample was divided into fit and unfit groups based on the *z*-score for the PF tests of vital capacity, cardiorespiratory fitness, muscular strength, and flexibility. Participants were assigned to the unfit group when their *z*-score was < 0, and those with a *z*-score of > 0 were assigned to the fit group. A series of independent *t*-tests were conducted to determine whether the PF level (fit/unfit) had an effect on PL domains and PA at various intensities. Data analyses were conducted using SPSS (version 23; IBM Corp., Armonk, NY, United States). A value of $p < 0.05$ was considered statistically significant.

RESULTS

Descriptive Statistics and Sex Differences

Table 1 presents the descriptive characteristics in the study population according to sex. Overall, the significant sex differences were found in the PF tests of vital capacity, muscular strength, aerobic fitness, and sedentary behavior (all *p*-values < 0.05). Men performed better than women on most PF tests, including vital capacity (mean, 4120.4 for men), muscular strength (mean, 229.0 for men), and aerobic fitness (mean, 71.1), but not flexibility, for which women showed slightly higher achievement than men (mean, 17.0). There were no significant sex differences in PL attributes, with similar scores in men and women for these variables. However, significant sex differences were observed for self-perceived PA, with women spending slightly more time walking and performing VPA, while men spent more time performing MPA. In addition, there was a significant sex difference in the time spent sitting, which was greater in women than in men.

Relationships Between Physical Fitness, Physical Literacy, and Physical Activity

The associations between PF, PL, and PA are shown in **Table 2**. The attribute of confidence and physical competence was significantly correlated with muscular strength and aerobic fitness in both men ($r = 0.11$ and $r = 0.27$, respectively) and women ($r = 0.18$ and $r = 0.15$, respectively), while the attributes of motivation and interaction with the environment were significantly associated with aerobic fitness ($r = 0.13$ and $r = 0.14$, respectively) and vital capacity ($r = 0.11$ and $r = 0.13$, respectively) in men. The total level of PL was significantly correlated with vital capacity and aerobic fitness in both men ($r = 0.11$ and $r = 0.22$, respectively) and women ($r = 0.11$ and $r = 0.11$, respectively). MVPA was negatively associated with vital capacity in men ($r = -0.18$) but was positively associated with vial capacity in women ($r = 0.20$). A positive association was also found between muscular strength and MVPA in women ($r = 0.25$). In addition, MVPA was significantly correlated with the attribute of confidence and physical competence in men ($r = 0.15$).

Figure 1 presents the differences between unfit and fit groups in PL. Participants who were assigned to the fit group for cardiorespiratory fitness, vital capacity, muscular strength, and flexibility had significantly higher total PL scores compared to those in the unfit group. Furthermore, differences between fit and unfit groups in the attributes of confidence and physical competence were also found for all fitness tests, with the exception of the vital capacity test. In contrast, differences between fit and unfit groups in the attribute of motivation only reached significance for the cardiorespiratory fitness test, and the differences between fit and unfit groups in the attribute of interaction with the environment only reached significance for the vital capacity test.

Figure 2 presents the differences between fit and unfit groups for different PA intensities. A significant difference was observed in the walking MET between the fit and unfit groups for the vital capacity test. However, there were no significant differences between fit and unfit groups for the cardiorespiratory fitness, muscular strength, and flexibility tests in terms of PA participation.

DISCUSSION

As PA is a predominant contributor to maintaining a healthier life, fostering the development of PL not only promotes lifelong PA but also plays a salient role in maintaining PF (Niederer et al., 2012). It is essential to accurately understand the associations between PF, PA, and PL as theoretically hypothesized by Cairney et al. (2019). This study evaluates the relationships among PF, PA, and PL in Chinese university students. Furthermore, to the best of our knowledge, this is the first study to investigate how the PF level, PA, and PL are interrelated in university students in China.

Significant sex differences were found in the PF tests for vital capacity, muscular strength, and aerobic fitness. In general, men performed better than women on the PF tests, with the exception of flexibility, for which women showed slightly better performance than men. This is consistent with a previous study comprising 2,614 subjects from 11 universities that showed better performance on PF tests in men than in women, which was thought to be due to a more active lifestyle in men, as opposed to a more sedentary lifestyle in women (Sun and Dai, 2006). Furthermore, given the advantages in muscle fiber structure and motor organ in women, it seems reasonable that women have better flexibility than men (Sun and Dai, 2006).

No significant sex differences were found in the PL attributes of confidence and physical competence (men: 11.3 ± 2.2; women: 11.4 ± 2.0), motivation (men: 12.1 ± 1.9; women: 12.1 ± 1.7), and interaction with the environment (men: 7.4 ± 1.7; women: 7.4 ± 1.6). These findings are consistent with those of a recent study, which also did not find any differences between the sex, although their study targeted students aged 12–18 years (Choi et al., 2018). Since their findings were based on a population with a large age variance (6 years), it is plausible that this sex equality may be maintained later in life.

Although PA participation was not statistically associated with PL, the results showed that women spent slightly more

time performing both light PA and VPA, while men preferred MPA. These findings are slightly different from those of a previous study, which found that the overall amount of PA was higher in men than in women (Longmuir and Tremblay, 2016). However, our findings do echo a previous study that specifically focused on PA in Chinese university students; according to Yan et al. (2015), men are 1.5 times more likely than women to achieve the minimum PA recommendations for university students. The present findings may differ from previous studies because of the use of the IPAQ-SF questionnaire as a subjective measure for identifying different PA intensities, as Students' subjective feelings and understanding of PA differ. Therefore, it is essential to interpret the findings with caution. The finding that women spend more time walking than men is consistent with previous studies, showing that women tend to engage in more low-intensity PAs (Zhang, 2019). Furthermore, we found

TABLE 1 | Descriptive statistics of the study sample.

Variables	Boys		Girls		Total		*p**
	N	Mean ± SD	N	Mean ± SD	N	Mean ± SD	
Age	390	18.9 ± 1.0	408	19.5 ± 1.3	798	19.2 ± 1.2	<0.001**
BMI	390	21.4 ± 4.5	408	20.9 ± 3.7	798	21.1 ± 4.1	0.125
Physical fitness							
Flexibility (cm)	390	16.8 ± 13.2	408	17.0 ± 6.5	798	16.9 ± 10.3	
Vital capacity (ml)	390	4120.4 ± 943.5	408	3579.4 ± 1092.4	798	3843.8 ± 1056.9	<0.001**
Muscular strength (cm)	390	229.0 ± 24.0	408	199.0 ± 32.1	798	213.7 ± 32.1	<0.001**
Aerobic fitness	390	71.1 ± 15.8	408	67.5 ± 14.5	798	69.3 ± 15.3	0.001*
Overall fitness level	390	0.0 ± 0.7	408	0.0 ± 0.6	798	0.0 ± 0.6	1.000
Physical literacy							
Confidence and physical competence	390	11.3 ± 2.2	408	114. ± 2.0	798	11.3 ± 2.1	0.698
Motivation	390	12.1 ± 1.9	408	12.1 ± 1.7	798	12.1 ± 1.8	0.901
Interaction with the environment	390	7.4 ± 1.7	408	7.4 ± 1.6	798	7.4 ± 1.7	0.531
Physical activity							
Walking MET-minutes/week	374	2071.6 ± 1683.9	383	2119.6 ± 1964.9	757	2095.9 ± 1830.4	0.719
Moderate MET-minutes/week	304	824.1 ± 1052.6	289	740.8 ± 764.7	593	783.5 ± 923.8	0.273
Vigorous MET-minutes/week	288	1391.5 ± 1391.6	220	1566.8 ± 2420.1	508	1467.4 ± 1906.2	0.305
Sitting time	376	323.0 ± 181.8	388	358.0 ± 179.7	764	340.8 ± 181.5	0.008*

*$p < 0.05$, **$p < 0.01$ (two-tailed).*

TABLE 2 | Pearson's correlation coefficients for physical fitness, physical activity, and physical literacy divided by gender (N = 798).

Variable		1	2	3	4	5	6	7	8	9
(1) Flexibility	Male	–								
	Female	–								
(2) Vital capacity	Male	0.09	–							
	Female	−0.26**	–							
(3) Muscular strength	Male	0.08	0.33**	–						
	Female	−0.27**	0.75**	–						
(4) Aerobic fitness	Male	0.07	0.21**	0.19**	–					
	Female	0.15**	0.10*	0.17**	–					
(5) Confidence and physical competence	Male	0.09	0.03	0.11*	0.27**	–				
	Female	−0.01	0.12*	0.18**	0.15**	–				
(6) Motivation	Male	0.04	0.11*	0.03	0.13*	0.46**	–			
	Female	0.10*	0.03	0.05	0.08	0.50**	–			
(7) Interaction with the environment	Male	0.09	0.13*	0.04	0.14**	0.49**	0.51**	–		
	Female	0.09	0.11*	0.08	0.03	0.39**	0.44**	–		
(8) Total PPL	Male	0.09	0.11*	0.08	0.22**	0.83**	0.80**	0.80**	–	
	Female	0.07	0.11*	0.14*	0.11*	0.83**	0.81**	0.74**	–	
(9) MVPA	Male	−0.04	−0.18**	−0.08	−0.06	0.15*	0.05	0.05	0.11	–
	Female	−0.04	0.20**	0.25*	−0.03	0.13	0.02	0.11	0.11	–

*$p < 0.05$, **$p < 0.01$ (two-tailed).*

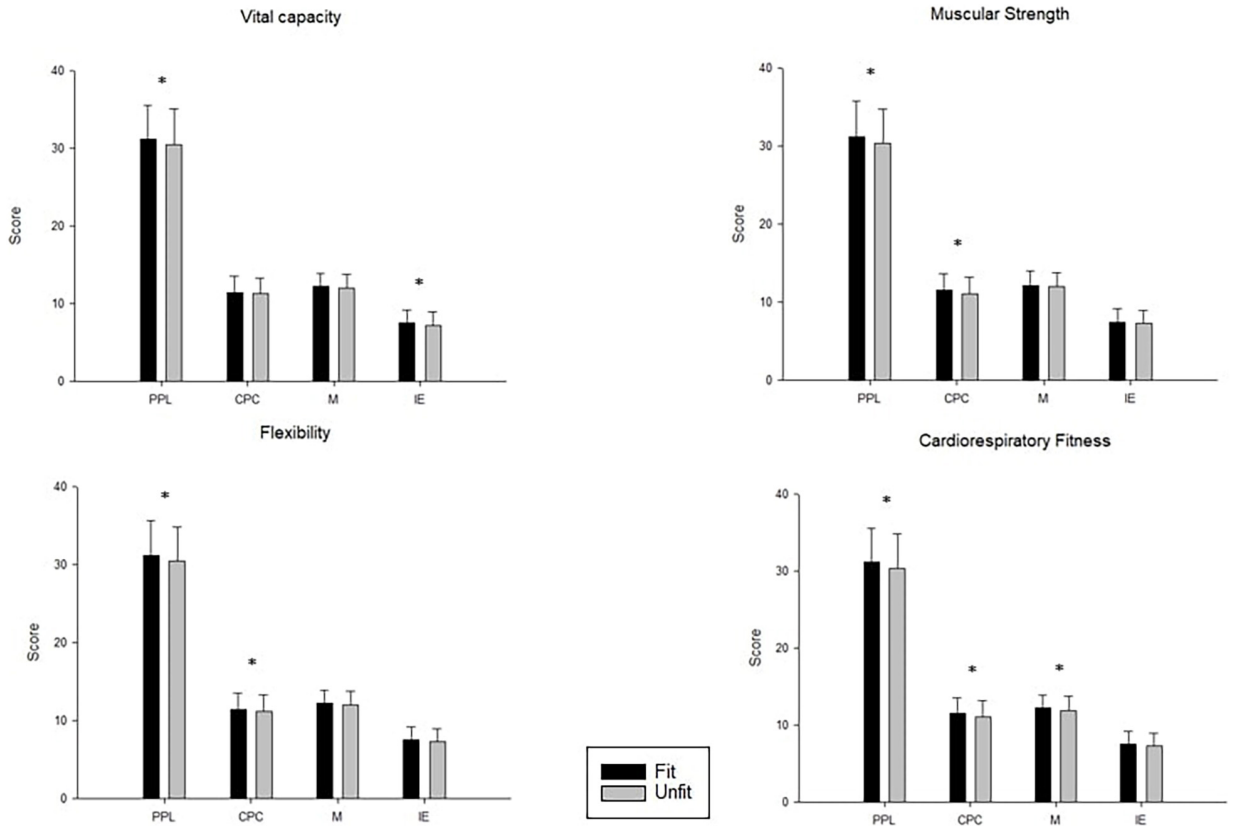

FIGURE 1 | Physical fitness groups (i.e., fit and unfit) and attribute and total physical literacy scores. *$p < 0.05$.

a significant sex difference in the sedentary time, with women spending more time sitting than boys. The sedentary time of university students is mainly spent in class and self-study. The longer accumulation of sedentary time in women may be because women place more value on academic performance and spend more time studying. This is supported by findings from a broad survey in China (Li et al., 2017), which found that women spend more time on academic study than men (7.8 vs. 6.2 h) and generally achieved higher academic performance. In addition, men are generally expected to spend more time participating in sports, which may also contribute to the observed differences between men and women (He et al., 2019). A recent review highlighted that long-term sedentary behavior is deleteriously associated with cardiopulmonary health, indicating that prolonged sedentary time may lead to cardiovascular disease morbidity and mortality (Lavie et al., 2019). In this regard, the present findings are consistent with previous reports that women score lower than men on cardiopulmonary function (vital capacity) and aerobic fitness tests.

The present results are in concordance with previous cross-sectional studies, which have indicated MVPA as significantly associated with muscle strength and vital capacity (Wrotniak et al., 2006). Remarkably, we observed a positive relationship between vital capacity and MVPA irrespective of sex (boys, $r = 0.18$; girls, $r = 0.2$). This finding is consistent with several previous studies. For example, Fuster et al. (2008) studied the relationship between PA and forced vital capacity among a group of young men and women (age, 23.2 ± 1.99) and found that, after adjusting for height, active young people were significantly better than their counterparts in the pulmonary test. Analogously, in a randomized controlled trial conducted by Rocío et al. (2013), both male and female participants showed significantly improved vital capacity after a PA promotion program compared to that in the control group.

In addition, in this study, no significant associations were observed between flexibility and PA and PL. Although flexibility is an indispensable component of PF, the existing literature describes the association between PA and flexibility as "surprisingly limited" (Patnode et al., 2010). A possible explanation for this finding may be that a positive correlation may exist only during a sensitive period. Since our current cross-sectional study targeted a specific age group (e.g., freshman and sophomore), incomplete conclusions may be drawn (Patnode et al., 2010).

In this study, we found that the overall PL score was significantly higher in the fit group than in the unfit group. These findings are consistent with the conclusions of previous studies. For example, in the abovementioned pilot study of the impact of 12-week movement skills program on core domains of PL (Kwan et al., 2020), as various PF indicators improved, the

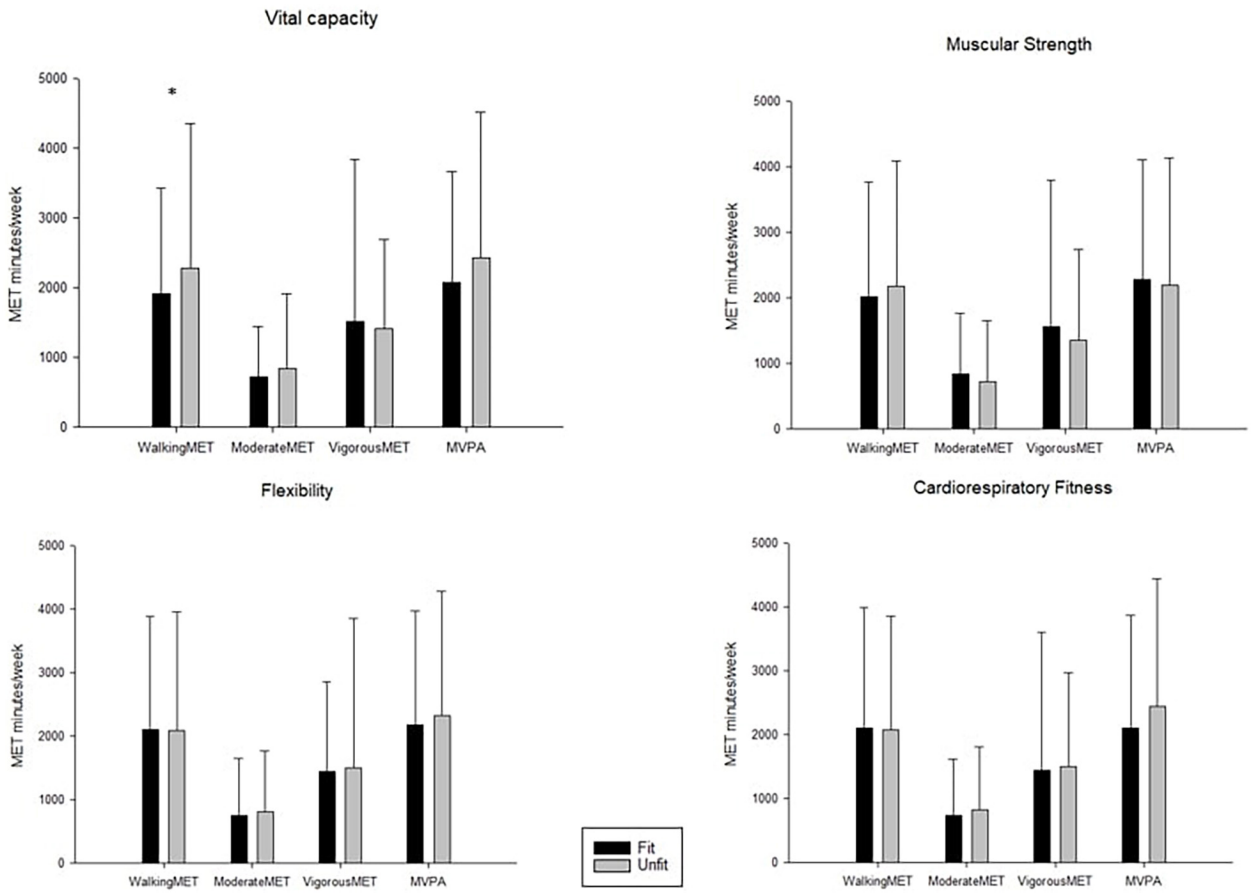

FIGURE 2 | Physical fitness groups (i.e., fit and unfit) and metabolic equivalent of different intensities of physical activity. *$p < 0.05$.

scores on the core domains of PL also improved, with a moderate interaction effect between PF and PL (Kwan et al., 2020). Physical competence is a core domain of PL. Among the attributes of PL, confidence and physical competence showed relatively positive associations with the evaluated aspects of PF. Proficiency in fundamental movement skills and confidence can better promote continuous participation in PA, and long-term PA participation will correspondingly improve PF, including cardiorespiratory fitness and muscular strength (Niederer et al., 2012).

In examining the differences in PA at various intensities according to PF level, we only found a significant difference in the walking MET between fit and unfit groups based on vital capacity. No significance differences in PAs were found between fit and unfit groups for other fitness tests. The walking MET was higher in the unfit group than the fit group. Students with low vital capacity are those who lack physical exercise; their PA time and intensity are relatively low. Accordingly, their low-intensity walking time will be correspondingly higher than that for students with higher vital capacity.

A major strength of this study is that we considered PF in a holistic manner, rather than just focusing on some aspects of PF, to study the relationships between PF, PA, and PL. The overarching PF test evaluates body composition, vital capacity, muscular strength, aerobic fitness, and flexibility. Notably, the results were obtained from a national standard test, which is considered highly reliable. In addition, the sample size of our research was relatively large. Furthermore, participants were selected by stratified sampling. The four universities involved in this study reflected different types of universities in Chongqing, with a total of 798 participants. Furthermore, this study is a pioneer in the exploration of associations among PL, PF, and PA in real-world settings. PL is a comprehensive and influential concept. At present, most of the research on this concept has remained at the theoretical level, and there are few studies on the actual measurement and application of PL.

Despite the abovementioned strengths, our study has the following limitations. First, PF measurement was performed in a school environment, and the test environment was open, hampering the accuracy of the results as compared to that with laboratory tests. As a result, our data should be interpreted with caution. Second, our sample was obtained from four universities in Chongqing, and may not fully represent all university students in China, limiting the universality of our results. Third, the use of questionnaires to collect data regarding PA and PL may involve bias.

CONCLUSION

Overall, this study shows a positive relationship between cardiovascular fitness and total perceived PL. Among the attributes of PL, confidence and physical competence showed relatively greater positive associations with the aspects of PF in Chinese university students, while no significant relationship was observed between PF and PA. Our findings support advocating for increased PA participation among university students and using PL as a tool to improve PF. Future studies are needed to target PL as an intervention to improve PA and PL in 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 Ethics Committee of Chongqing University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CZ, YL, and ML contributed substantially to most of the work, including the study design, statistical analysis, and manuscript write-up. SL supervised and instructed CZ's work, providing support on the implementation of the study and giving critical suggestions on the study design. YL participated in the study conception and design, data collection, and part of the manuscript write-up, while ML, SX, and RM helped collect and analyze the data, worked with the participants, and reviewed the literature. RS and PZ provided their suggestions on the study design and worked with universities to recruit participants. All authors contributed to the article and approved the submitted version.

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Affective Valence and Enjoyment in High- and Moderate-High Intensity Interval Exercise. The Tromsø Exercise Enjoyment Study

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Introduction: Exercise at high intensity may cause lower affective responses toward exercise compared with moderate intensity exercise. We aimed to elucidate affective valence and enjoyment in high- and moderate-high interval exercise.

Methods: Twenty recreationally active participants (9 females, 11 males, age range: 20–51 years) underwent three different treadmill running exercise sessions per week over a 3-week period, in randomized order; (1) CE70: 45 min continuous exercise at 70% of heart rate maximum (HR_{max}), (2) INT80: 4 × 4 min intervals at 80% of HR_{max}, (3) INT90: 4 × 4 min intervals at 90% of HR_{max}. Pre-tests included graded submaximal steady state intensities and a test to exhaustion for determining peak oxygen uptake and HR_{max}. Affective valence (pleasure/displeasure) was measured before, during and after the sessions using the Feeling Scale (FS). Enjoyment was assessed before and after the sessions applying the Physical Activity Enjoyment Scale (PACES) and during the sessions using the Exercise Enjoyment Scale (EES).

Results: The participants felt lower pleasure (between-sessions effect: $p = 0.02$, $_p\eta^2$: 0.13) during INT90 sessions (FS: 1.08, 95% CI: 0.35–1.92) compared with INT80 (FS: 2.35, 95% CI: 1.62–3.08, $p = 0.052$) and CE70 sessions (FS: 2.45, 95% CI: 1.72–3.18, $p = 0.03$), with no differences between INT80 and CE70 sessions ($p = 1.00$). There were higher enjoyment after INT80 sessions (PACES: 101.5, 95% CI: 95.7–107.3) versus CE70 sessions (PACES: 91.3 95% CI: 85.5–97.1, $p = 0.046$), and no differences between INT90 (PACES: 98.2, 95% CI: 92.4–103.4) and CE70 ($p = 0.29$) or INT80 ($p = 1.00$). For enjoyment during exercise, CE70 were perceived more enjoyable, and INT80 and INT90 less enjoyable in week 2 (EES: week x session: $p = 0.01$, $_p\eta^2$: 0.11; CE70: 4.3, 95% CI: 3.6–4.9, INT80: 4.6, 95% CI: 3.9–5.2, INT90: 4.0, 95% CI: 3.4–4.7) and 3 (EES: CE70: 4.2, 95% CI: 3.7–4.8, INT80: 4.8, 95% CI: 4.2–5.3, INT90: 4.3, 95% CI: 3.8–4.9) than in week 1 (EES: CE70: 3.5, 95% CI: 3.0–4.0, INT80: 5.0, 95% CI: 4.5–5.5, INT90: 4.5, 95% CI: 4.0–5.0).

Conclusion: The negative affective consequences associated with high intensity interval exercise can be alleviated by keeping the intensity at or around 80% of HR_{max} while preserving the beneficial enjoyment responses associated with interval exercise.

Keywords: training, adherence, public health, emotion, PACES

INTRODUCTION

Adherence to exercise programs is low and influenced by multiple personal and demographic factors (Stutts, 2002; Trost et al., 2002; Sequeira et al., 2011; Picorelli et al., 2014). Common reported obstacles for individuals are lack of time for- and enjoyment of exercise (Stutts, 2002; Sequeira et al., 2011). This has brought forth an interest among researchers to design effective exercise programs that are both enjoyable and time efficient (Oliveira et al., 2018).

Exercise enjoyment during and after exercise could be a mediating factor for exercise adherence (Raedeke, 2007; Ekkekakis, 2009; Jekauc, 2015), as greater enjoyment increases the likelihood of performing regular exercise (Salmon et al., 2003; Lewis et al., 2016). Exercise enjoyment after exercise, measured with the physical activity enjoyment scale (PACES) questionnaire (Kendzierski and DeCarlo, 1991), is generally reported to be higher following high intensity interval exercise compared with moderate intensity continuous exercise (Oliveira et al., 2018; Niven et al., 2020; Tavares et al., 2021). Furthermore, the enjoyment of high intensity interval exercise may improve with familiarity to the exercise modality (Smith-Ryan, 2017). A previous six weeks long study observed an initial similar exercise enjoyment between high intensity intervals [95–95% of peak heart rate (HR_{peak})] and moderate intensity continuous exercise (70–75% of HR_{peak}), but the enjoyment progressively increased over 6 weeks for those performing interval exercise, resulting in higher enjoyment compared with continuous exercise following 4 weeks of the intervention (Heisz et al., 2016). However, such time effects in enjoyment are not consistent across studies (Kong et al., 2016; Vella et al., 2017).

While enjoyment is a specific feeling evaluated by cognition, affective responses are reflexive responses for the direction of emotion (pleasure/displeasure) (Ekkekakis, 2013), and may also mediate exercise adherence (Rhodes and Kates, 2015). The two concepts are distinctively separate, but also closely related, where higher exercise enjoyment can promote positive affect and *vice versa* (Raedeke, 2007; Jekauc, 2015). The affective responses to exercise seem influenced by exercise intensity, where higher intensities increase displeasure (i.e., negative affect) (Ekkekakis and Petruzzello, 1999; Welch et al., 2007), at least when exceeding physiological markers of increased relative contribution of anaerobic metabolism (Ekkekakis et al., 2011).

The transition toward a higher relative contribution from anaerobic energy systems in terms of an anaerobic threshold (AT) have provided controversy and confusion (Hopker et al., 2011; Poole et al., 2021). Indeed, different thresholds intended to pinpoint processes associated with a relatively higher contribution from anaerobic metabolism (e.g., ventilatory threshold, lactate threshold, onset of blood lactate accumulation (OBLA), maximal lactate steady state) correspond to a range of different relative intensities in terms of percentage of maximal oxygen uptake (VO_{2max}) and maximal heart rate (HR_{max}) (Faude et al., 2009; Poole et al., 2021). The maximal lactate steady state running speed may be the most precise estimate of an AT but require multiple exercise testing sessions (Jamnick et al., 2018), making it less feasible compared with OBLA-defined estimates determined by a single graded exercise test. Of the suggested AT estimates available in the literature, an OBLA at 2.5 mmol/L blood lactate concentration (BLa) was identified as an acceptable AT definition compared with the maximal lactate steady state (Jamnick et al., 2018).

Recent meta-analyses indicate that high intensity interval exercise generates more negative affective responses than moderate intensity continuous exercise, while at the same time evoking higher enjoyment (Niven et al., 2020; Tavares et al., 2021). The intermittent nature of interval exercise provides a constantly changing stimulus, making it less monotonous, and potentially a more enjoyable experience than continuous exercise (Thum et al., 2017). Consequently, it may constitute that performing interval exercise with lower contribution from anaerobic metabolism, compared with higher, generates higher positive affect. At the same time, the intermittent structure of interval exercise may provide a more enjoyable experience than continuous exercise. Previous studies have compared high intensity interval exercise with moderate intensity continuous exercise, while to our knowledge fewer studies have compared interval exercise at different intensities (Boyd et al., 2013; Olney et al., 2018).

Moreover, lower enjoyment is reported if the interval exercise intensity is too strenuous to complete (Oliveira et al., 2013; Martinez et al., 2015). Here, higher volume high intensity intervals with long interval bouts, such as 4 × 4 min intervals (total time at high intensity: 16 min) at ∼90% of HR_{max}, are designed to not be totally exhaustive and thus could be a viable option for exercise adherence (Taylor et al., 2019). Such long interval bouts are not supramaximal, and demand lower anaerobic metabolism compared with shorter interval (<2 min) bouts with supramaximal intensities at >100% of VO_{2max} (Wiewelhove et al., 2016; Wood et al., 2016; Valstad et al., 2018). To the best of our knowledge, no previous studies have assessed affective valence and enjoyment responses to long interval bouts at different intensities.

Abbreviations: INT90, 4 × 4 min intervals at 90% of heart rate maximum; INT80, 4 × 4 min intervals at 80% of heart rate maximum; CE70, moderate continuous exercise at 70% of heart rate maximum; AT, anaerobic threshold; OBLA, onset of blood lactate accumulation; PACES, physical activity enjoyment scale; EES, exercise enjoyment scale; FS, feeling scale; RPE, rating of perceived exertion.

Thus, the aims of this study were (1) to compare affective valence and enjoyment responses before, during and after treadmill running exercise when performed as 4 × 4 min intervals at moderate-high intensity (80% of HR_{max}) and high intensity (90% of HR_{max}) and as 45 min moderate intensity continuous exercise (70% of HR_{max}), with each exercise modality performed once a week over three weeks, and (2) to assess the associations between percentage of individual AT running speed and percentage of individual AT Rating of Perceived Exertion (RPE) (corresponding to OBLA at 2.5 mmol/L) and affective valance and enjoyment during and after treadmill running exercise.

MATERIALS AND METHODS

Design

In this randomized crossover study, 20 participants performed three different treadmill running exercise sessions per week over three weeks (3 sessions × 3 weeks = 9 sessions in total), in randomized order for each week; (1) CE70: 45 min moderate intensity continuous exercise at 70% of HR_{max}, (2) INT80: 4 × 4 min moderate-high intensity interval exercise at 80% of HR_{max} interspaced with 3 min moderate intensity exercise at 70% of HR_{max} between bouts and (3) INT90: 4 × 4 min high intensity interval exercise at 90% of HR_{max} interspaced with 3 min moderate intensity exercise at 70% of HR_{max} between bouts. Prior to the exercise sessions, the participants performed a graded steady state treadmill running test to determine the AT, defined as the running speed and RPE associated with 2.5 mmol blood lactate concentration (BLa) in whole blood, followed by a test to exhaustion to determine peak oxygen uptake (VO_{2peak}) and HR_{max}. The schedule for baseline testing and exercise sessions are presented in **Figure 1**.

Immediately prior to each exercise session, the participants rated their affective valence and perceived enjoyment toward the upcoming session by answering the Feeling Scale (FS) (Rejeski et al., 1987; Hardy and Rejeski, 1989) and the PACES (Kendzierski and DeCarlo, 1991), respectively. After 55% completion of each exercise session (while still exercising), the participants answered the FS again, rated their perceived enjoyment using the Exercise Enjoyment Scale (EES) (Stanley and Cumming, 2010), and rated their perceived exertion using Borg's RPE 6–20 scale (Borg, 1974). Finally, immediately following completion of each exercise session, the participants answered the FS, PACES and rated their RPE.

Participants

Twenty-four recreationally active participants (9 females, 11 males, age range: 20-51 years) were recruited through stands and posters at the Tromsø campus of UiT the Arctic University of Norway and social media campaigns. Four of the participants withdrew from the study (reported reasons: lack of time and injuries not related to the study's intervention). Three participants underwent eight out of nine exercise sessions, where their final exercise session (two INT90 and one CE70) was canceled due to COVID-19 lockdown of university facilities at 12th of March 2020. For these three individuals, we performed intention to treat analyses by forwarding their respective mean score (CE70 or INT90) of week 1 and 2 to their respective missing exercise session in week 3. Consequently, we ended up with a sample of 20 participants for our final analyses. The participants' characteristics are presented in **Table 1**.

Prior to pre-tests, all participants were informed about the risks and benefits associated with study participation and their right to withdraw from the study at any time without providing any reason, before giving oral and written informed consent. This study was conducted in accordance with ethical standards for health research under the Declaration of Helsinki and the Norwegian Data Protection Service approved the study and storage of personal data (Approval reference number: 584805) without further regional ethical approval per applicable institutional and national guidelines for sport and exercise science.

Pre-test Procedures

Prior to the pre-tests, the participants answered the International Physical Activity Questionnaire (IPAQ) (Craig et al., 2003) to determine their physical activity level, where we calculated metabolic equivalents of task (MET)-hours per week according to suggested IPAQ scoring methods (Craig et al., 2003). We considered reaching 10.5 MET-hours per week as being physically active (i.e., meeting the minimal global recommendations for physical activity of 150 min per week (Bull et al., 2020). All participants were defined as physically active (lowest = 12 MET-hours per week, highest = 77 MET-hours per week, **Table 1**). Thereafter, the participants' body height and mass were measured using a stable stadiometer (Seca 217, Seca GmbH & Co., KG, Hamburg, Germany) and a portable weight scale (Seca 876, Seca GmbH & Co., KG, Hamburg, Germany), respectively, and body mass index (BMI) was calculated (kg/m^2).

Graded Steady State Exercise Test

Following completion of the IPAQ and body mass and height assessment, the participants were fitted with a face mask (COSMED Srl, Rome, Italy) connected to a portable cardiorespiratory analyzer (K5, COSMED Srl, Rome, Italy) attached to the participants' back and a heart rate (HR) belt (Garmin HRM3, Garmin Ltd., Lathe, KS, United States) was strapped around thorax. The respiratory and HR values were measured each 10 s and transferred via Bluetooth to a portable laptop (ThinkPad, Lenovo Group Ltd, Beijing, China), where we used the manufacturer software (Cardiopulmonary diagnostics Software, COSMED Srl, Rome, Italy) to monitor the measured values. The K5 analyzer was set in mixing chamber mode, which is found to provide valid results for tests to exhaustion when compared to a previously validated stationary cardiorespiratory analyzer (Perez-Suarez et al., 2018). Prior to attaching the K5 to the participants, the analyzer was calibrated with known gas concentrations of oxygen (16%) and carbon dioxide (5%) as well as ambient air (20°C), and the inspiratory flow was manually calibrated against the turbine using a 3 L volume syringe (Calibration Syringe, COSMED Srl, Rome, Italy).

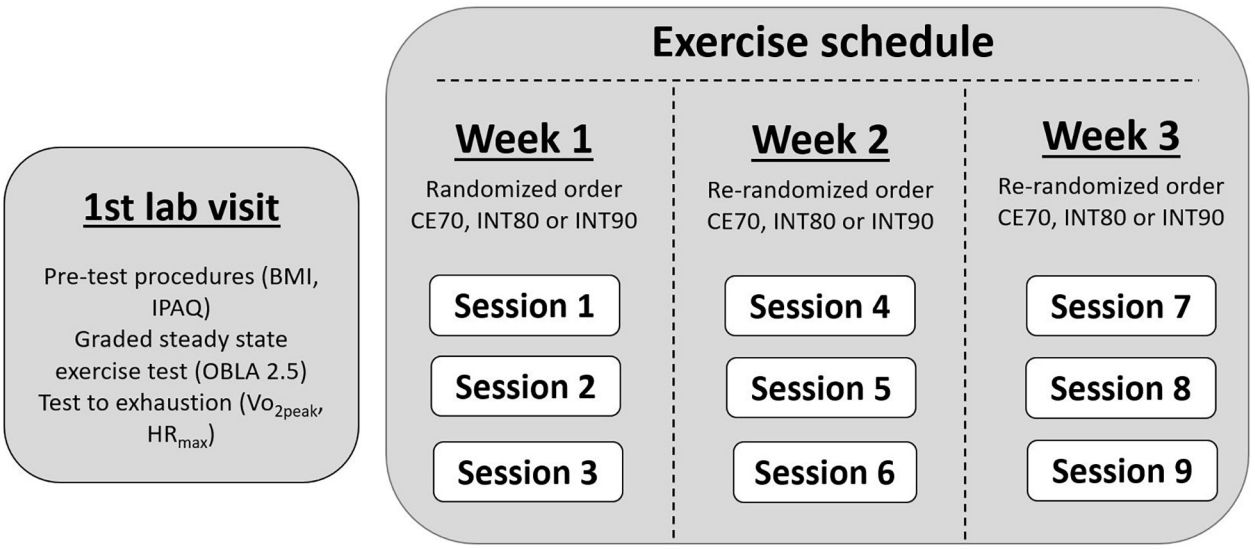

FIGURE 1 | Baseline testing and three-week exercise schedule. BMI, Body Mass Index; IPAQ, International Physical Activity Questionnaire; OBLA 2.5, Onset of blood lactate accumulation at 2.5 mmol/L; VO_{2peak}, Peak Oxygen Uptake; HR_{max}, maximal heart rate; CE70, moderate intensity continuous exercise at 70% of HR_{max}; INT80, 4 × 4 min intervals at 80% of HR_{max}; INT90, 4 × 4 min intervals at 90% of HR_{max}.

TABLE 1 | Descriptive characteristics.

	Women (*n* = 9)	**Men (*n* = 11)**	**Total (*N* = 20)**
Age (years)	31.2 ± 13.7	22.8 ± 3.3	26.6 ± 10.2
Minimum-maximum	20–51	20–32	20–51
Weight (kg)	63.7 ± 6.2	80.3 ± 9.8	72.87 ± 11.75
Minimum-maximum	55.7–75.0	68.3–100.5	55.7–100.5
Height (m)	1.68 ± 0.04	1.79 ± 0.06	1.74 ± 0.07
Minimum-maximum	1.63–1.74	1.68–1.86	1.63–1.86
BMI (kg/m^2)	22.6 ± 2.4	25.3 ± 3.5	24.09 ± 3.27
Minimum-maximum	20.1–27.9	21.0–31.9	20.06–31.90
IPAQ (METs)	44.64 ± 26.18	46.43 ± 18.82	45.62 ± 21.82
Minimum-maximum	12.0–92.0	17.3–77.8	12–92
VO_{2peak}	50.8 ± 7.5	60.0 ± 6.9	55.8 ± 8.4
($ml \cdot kg^{-1} \cdot min^{-1}$)	35.7–59.3	51.2–75.7	35.7–75.2
Minimum-maximum			
HR_{max}	184.2 ± 12.2	195.6 ± 8.6	190.5 ± 11.6
($beats \cdot min^{-1}$)	163.0–201.0	180.0–209.0	163.0–209.0
Minimum-maximum			
Respiratory values, speed and RPE at OBLA 2.5 mmol/L			
HR ($beats \cdot min^{-1}$)	164.2 ± 12.3	175.6 ± 8	171.1 ± 11.2
Minimum-maximum	143.3–178.2	164.9–188	143.3–188.0
% HR_{max}	89.0 ± 2.2	89.8 ± 2.5	89.5 ± 2.3
Minimum-maximum	85.8–92.8	85.2–92.8	85.2–92.8
VO_{2peak}	41.3 ± 5.9	45.9 ± 6.0	43.8 ± 6.3
($ml \cdot kg^{-1} \cdot min^{-1}$)	29.7–50.0	35.0–52.2	29.67–52.2
Minimum-maximum			
Speed ($km \cdot h^{-1}$)	8.5 ± 1.2	10.3 ± 1.8	9.5 ± 1.8
Minimum-maximum	6.8–10.1	8.0–13.5	6.8–13.5
RPE (Arbitrary units)	11.7 ± 1.7	13.4 ± 1.3	12.6 ± 1.7
Minimum-maximum	8.3–13.8	11.0–15.0	8.3–15.0

Data are shown as mean ± SD and range from minimum to maximum.
SD, standard deviation; OBLA 2.5 mmol/L, onset blood lactate concentration at 2.5 mmol/L; BMI, Body Mass Index; IPAQ, International Physical Activity Questionnaire; VO_{2peak}, Peak Oxygen Uptake; METs, Metabolic Equivalent of Tasks.

After being equipped with the analyzer and HR belt, the participants entered the treadmill (Woodway ergo ELG 70, Waukesha, WI, United States), which was set to a 5% inclination throughout all tests and exercise sessions. For the first 5 min, the participants warmed up by choosing the speed corresponding to walking or running at a RPE value of 10–14 on Borg's scale, corresponding to low to moderate exertion (Borg, 1982). The participants thereafter ran for 4 min on the same speed as the last minute of the warmup and subsequently completed a 30 s passive rest to measure BLa from 0.2 μL capillary non-hemolyzed blood sampled from their fingertip on a sterile single-use lancet connected to a mobile lactate analyzer (Lactate Scout + , EKF Diagnostics, Barleben, Germany) and report their RPE. Thereafter, the speed was increased by 1 $km{\cdot}h^{-1}$ and the participants ran for another 4 min before the same BLa measurement routine was carried out. The same procedure was repeated (1 $km{\cdot}h^{-1}$ speed increase, run 4 min, 30 s rest to measure BLa and reported their RPE) until the participants' BLa reached > 4 mmol/L, in which the test was terminated. BLa above 4 mmol/L was usually reached after 2–4 measurements. The AT was defined as the participants' running speed associated with a BLa of 2.5 mmol/L (Jamnick et al., 2018), and the exact value was determined by linear interpolation between the measured value below and above 2.5 mmol/L BLa. The same procedure was carried out to determine the HR and RPE corresponding to a 2.5 mmol/L BLa.

Test to Exhaustion

Following the graded steady state exercise test, which we considered sufficient as warm up prior to the test to exhaustion, the participants rested for 10 min. Start up speed was set to 1 $km{\cdot}h^{-1}$ under the final speed attained in the incremental steady state test and the participants ran for 1 min where the participants were asked after 45 s whether they could cope with a 1 $km{\cdot}h^{-1}$ increase in 15 s. They indicated a thumb up or down for yes or no, respectively. If they answered yes, the speed was increased with 1 $km{\cdot}h^{-1}$ where the same procedure was repeated (45 s, increase in 15, thumb up or down). If the participants indicated no with a thumb down, they were instructed to keep running on the treadmill until voluntary exhaustion, at which they jumped off the treadmill. Immediately after jumping off the treadmill, the participants reported their RPE. We defined exhaustion as ≥ 17 in RPE and the mean of the three highest consecutive 10 s oxygen uptake (VO_2) recordings in the test as VO_{2peak}. All participants reported ≥ 17 in RPE. A test to exhaustion is considered valid for determining HR_{max} (Berglund et al., 2019), where we defined HR_{max} as the highest HR recording in the last minute of the test.

Exercise Sessions

The week after their pre-tests, the participants reported to the laboratory to start their three exercise sessions per week over 3 weeks (in total nine sessions). Due to logistical reasons, the sessions could be performed within 24 h of a previous session. The exercise sessions were randomized each week, thus controlling for potential confounders, such as exertion from previous exercise. The three treadmill running exercise sessions were (1) CE70: 45 min moderate intensity continuous exercise at 70% of HR_{max}, (2) INT80: 4 × 4 min moderate-high intensity interval exercise at 80% of HR_{max} interspaced with 3 min moderate intensity exercise at 70% of HR_{max} between bouts, and (3) INT90: 4 × 4 min high intensity interval exercise at 90% of HR_{max} interspaced with 3 min moderate intensity exercise at 70% of HR_{max} between bouts. The interval sessions were initialized with a 10-min warmup and ended with a 3 min cool down, both at 70% of HR_{max}. Consequently, the CE70 lasted in total for 45 min, while the INT80 and INT90 lasted 38 min. The CE70 and INT90 sessions are matched in terms of work (energy expenditure) (Helgerud et al., 2007), and the INT90 and INT80 sessions by time. The participants were unaware of their randomized exercise session until they showed up in the laboratory each day. To monitor exercise intensity, the participants were equipped with a HR belt (Polar H7, Polar Electro Oy, Kempele, Finland) during all sessions, which transferred the HR values to the instructors' smartphone via Bluetooth and monitored using the manufacturer's application (Polar Beat, Polar Electro Oy, Kempele, Finland).

We chose to determine the intensity of interval exercise sessions as moderate-high (INT80) and high (INT90) according to HR because this is more accessible to the general population than measuring BLa. The CE70 condition was performed as a reference session, as it is a commonly used exercise session in the literature (Oliveira et al., 2018; Niven et al., 2020; Tavares et al., 2021) and assumed a common exercise modality in the population. In all sessions, the intensity was monitored and controlled (i.e., instructors changed speed if intensity was to high/low according to HR), and the running speed and RPE at 55% completion of each session was registered to calculate relative percentage of AT running speed and AT RPE for each session.

Outcome Measures

Feeling Scale

The participants rated their affective valence (pleasure/displeasure) using the FS before, during (at 55% completion) and immediately after their exercise sessions. The FS is a 11-point scale ranging from –5 (very bad) to 5 (very good) by answering the following question: *"How do you currently feel?"* (Hardy and Rejeski, 1989). Positive and negative affective valence in the FS are found to be associated with a good and bad feeling (Canonical correlation: $r = 0.87$) from the Multiple Affective Adjective Check List, a questionnaire that measures respondents' feelings (Zuckerman and Lubin, 1985), and shows a moderate negative correlation ($r = -0.56$) with RPE indicating another concept than physical exertion (Hardy and Rejeski, 1989). We translated the FS from English to Norwegian; first, independent translations were performed by two of the authors (TH and ES) and were thereafter compared and no divergent statement was identified. Thereafter, cognitive debriefing of alternative translations were discussed where agreement of final wording was reached and final proofreading was performed (Wild et al., 2005). The translated version can be found in **Supplementary Table 2**.

Physical Activity Enjoyment Scale

The participants filled out the PACES before and after their exercise sessions. The PACES is an 18-item questionnaire, which measures enjoyment of physical activity (Kendzierski and DeCarlo, 1991). The participants rate their agreement with each item ranging from 1 to 7. Negative values (1 as highly agree) were converted to positive values and each item score is summed; the lowest total score is 18 and the highest is 126. The PACES is reported to be valid for internal consistency (Cronbach's α: 0.96) and reliable (repeatability intraclass correlation coefficient: 0.93) in young adult women and men (Kendzierski and DeCarlo, 1991). The PACES was originally designed to be answered after an activity. We also replaced the original phrase *"Please rate how you feel at the moment about the physical activity you have been doing"* with "*. . . the activity you are about to start,*" where the participants also answered the PACES prior to their exercise sessions. The PACES is previously translated to Norwegian (Sagelv et al., 2019).

Exercise Enjoyment Scale

After 55% completion of the exercise sessions, the participants rated their enjoyment during the exercise using the EES (Stanley and Cumming, 2010). The EES is a 7-point scale ranging from 1 to 7 answering the following statement: *"Use the following scale to indicate how much you are enjoying this exercise session,"* with 1 being *"not at all"* and 7 being *"extremely."* The EES is reported to be easy to understand and is assumed to be more practical to administrate than longer enjoyment questionnaires over short periods (Stanley and Cumming, 2010), and is reported to be valid (Stanley et al., 2009) when correlated with the interested or enjoyment subscale of the Intrinsic Motivation Inventory (r = 0.82–0.85) (Ryan, 1982) and correlates moderately (r = 0.41–0.49) with the FS (Hardy and Rejeski, 1989), thus indicating another construct than affect. We translated the EES from English to Norwegian using the same procedure as for translation of the FS (described above) (Wild et al., 2005). The translated version of the EES is found in **Supplementary Table 2**.

Rating of Perceived Exertion

The participants rated their perceived exertion using Borg's 6–20 RPE scale (Borg, 1974) after 55% of completion and immediately after each exercise session. Borg's RPE is one of the most used Likert scales for measuring perceived exertion and is consistently found to reflect physiological demands of exercise (Borg, 1974, 1982; Robertson et al., 1998). The RPE ratings were "exercise anchored" (Coquart et al., 2012), where the participants were made familiar with the effort indicating low to moderate intensity from the warmup stage prior to the incremental steady state exercise test, and reported their RPE at each steady state step of the test, and finally reported RPE at maximum intensity following the test to exhaustion.

Statistical Analyses

We performed 3 by 3 [week (time) × exercise session (CE70, INT80, INT90)] repeated measure univariate analyses of variance (ANOVA) with Bonferonni-corrected *post hoc* tests to assess differences in perceptual responses (FS, EES, PACES, RPE) to the exercise sessions. Effect sizes were calculated as partial eta squared ($_p\eta^2$) where 0.01–0.05, 0.06–0.13, and ≥ 0.14 $_p\eta^2$ were considered small, medium, and large effects, respectively (Richardson, 2011). With three repeated measures (week 1, 2, 3), three exercise sessions (CE70, INT80, INT90), alpha at 0.05 and 80% power, we estimated that 15 participants were needed to observe a large week by exercise session interaction effect ($_p\eta^2$ = 0.14), and 36–18 participants to observe a medium effect ($_p\eta^2$ = 0.06–0.13); 20 participants as in our study needs an effect of $_p\eta^2 > 0.11$. Except for EES "during" and RPE "during" and "after" (all $p < 0.05$), the Shapiro–Wilk test confirmed all outcome variables (FS "before," "during," "after," PACES "before," "after") to not deviate from normal distribution (all $p > 0.10$). We considered the repeated measure ANOVAs robust enough to handle the non-normally distributed variables for appropriate interpretations. Sphericity assumptions were confirmed for most analyses (all $p > 0.05$), except for FS "before" and "after" and PACES "before (all $p \leq 0.03$), where we used Greenhouse–Geisser corrected interpretations (Girden, 1992). We performed sensitivity analyses in the repeated measure ANOVAs by only including those who performed all nine exercise sessions (n = 17). We used Pearson correlations to assess the associations between affective valence and enjoyment in exercise sessions and the session's intensity as individual percentage of AT running speed and AT RPE as all weeks collapsed in total (20 participants × 9 sessions = n = 180) and in strata of exercise session (CE70, INT80, INT90; 20 participants × 3 sessions = n = 60). We also used Pearson correlations to assess the associations between the mean perceptual responses from all exercise sessions (9 sessions) and BMI, IPAQ scores (MET-hours per week), VO_{2peak}, individual AT running speed and individual AT RPE (n = 20). To reduce false positive rates in the Pearson's correlations, we adjusted the correlation's p-values according to the Benjamin–Hochberg method (Benjamini and Hochberg, 1995) using 25% false discovery rate. We considered correlations (r) of 0.10–0.39, 0.40–69, and ≥0.70 to be small, moderate and large correlations, respectively, which is commonly used effect sizes in psychological research (Akoglu, 2018). Data are shown as mean and 95% confidence intervals (CI) unless otherwise is stated. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, version 26, International Business Machine Cooperation, Armonk, NY, United States).

RESULTS

Differences in Perceptual Responses to Exercise Sessions

Affective Valence

Mean FS scores in all exercise sessions are presented in **Table 2**. With all sessions collapsed, we observed no changes over the three weeks in FS scores before [main effect of time (weeks); p = 0.11, $_p\eta^2$: 0.04], during (p = 0.16, $_p\eta^2$: 0.03) or after (p = 0.23, $_p\eta^2$: 0.03) the exercise sessions, and there were no differences in changes over weeks by exercise sessions [time (weeks) × exercise session interaction; before: p = 0.83,

TABLE 2 | Feeling Scale responses before, during and after the exercise sessions.

		Week 1	Week 2	Week 3	Total#
FS before					
CE70	Mean (95% CI)	2.05 (1.25 – 2.85)	1.65 (0.73 – 2.58)	2.15 (1.38 – 2.92)	1.95 (1.31 – 2.59)
INT80	Mean (95% CI)	2.65 (1.85 – 3.45)	2.00 (1.08 – 2.93)	2.10 (1.33 – 2.87)	2.25 (1.61 – 2.89)
INT90	Mean (95% CI)	2.20 (1.40 – 3.00)	1.60 (0.68 – 2.53)	2.18 (1.41 – 2.94)	1.99 (1.35 – 2.63)
FS during					
CE70	Mean (95% CI)	2.30 (1.39 – 3.21)	2.20 (1.27 – 3.13)	2.85 (2.00 – 3.71)	2.45 (1.72 – 3.18)
INT80	Mean (95% CI)	2.15 (1.24 – 3.06)	2.35 (1.42 – 3.28)	2.55 (1.70 – 3.41)	2.35 (1.62 – 3.08)
INT90	Mean (95% CI)	1.05 (0.14 – 1.96)	0.85 (– 0.08 – 1.78)	1.35 (0.50 – 2.21)	1.08 (0.35 – 1.82)*¤
FS after					
CE70	Mean (95% CI)	2.40 (1.44 – 3.36)	2.35 (1.40 – 3.30)	2.70 (1.74 – 3.66)	2.48 (1.69 – 3.28)
INT80	Mean (95% CI)	2.65 (1.69 – 3.61)	2.10 (1.15 – 3.05)	2.55 (1.59 – 3.51)	2.43 (1.64 – 3.23)
INT90	Mean (95% CI)	1.75 (0.79 – 2.71)	1.30 (0.35 – 2.25)	1.78 (0.81 – 2.74)	1.61 (0.81 – 2.41)

Data are shown as mean and 95% CI. #total as mean of all three weeks.
**Difference between INT90 versus CE70: p = 0.03.*
¤Difference between INT90 versus INT80: p = 0.052.
FS, feeling scale; CI, confidence interval; CE70, moderate intensity continuous exercise at 70% of HR_{max}; INT80, 4 × 4 min intervals at 80% of HR_{max}; INT90, 4 × 4 min intervals at 90% of HR_{max}.

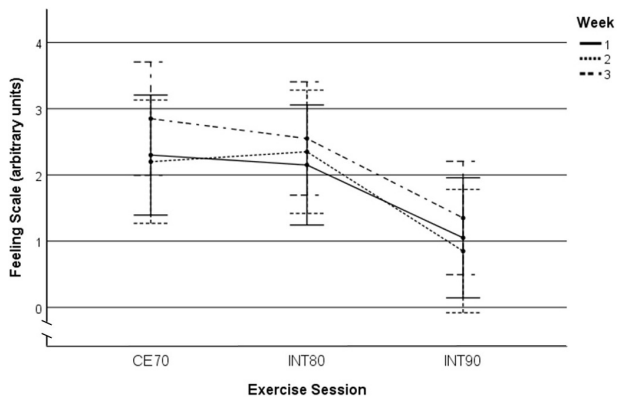

FIGURE 2 | Mean FS score during the exercise sessions in all three weeks separately. Between subject effects. $p = 0.02$, $_p\eta^2$: 0.13. *Post hoc* comparisons: INT90 vs. IN80: $p = 0.052$, INT90 vs. CE70: $p = 0.03$, INT80 vs. CE70: $p = 1.00$. Data are shown as mean and 95% CI. FS, feeling scale; INT90, interval exercise session at > 90% of HR_{max}; INT80, interval exercise session at > 80% of HR_{max}; CE70, continuous moderate intensity exercise at 70% of HR_{max}; CI, confidence interval.

$_p\eta^2$: 0.01; during: $p = 0.95$, $_p\eta^2$: 0.01; after: $p = 0.93$, $_p\eta^2$: 0.01]. We found no differences in mean FS scores of all three weeks (between-sessions' effects) between exercise sessions before ($p = 0.77$, $_p\eta^2$: 0.02) or after ($p = 0.23$, $_p\eta^2$: 0.03) the exercise sessions, while we observed a difference in mean FS scores during the exercise sessions ($p = 0.02$, $_p\eta^2$: 0.13), where the participants felt lower pleasure during INT90 sessions compared with INT80 ($p = 0.052$) and the CE70 sessions ($p = 0.03$), with no differences between INT80 and CE70 sessions ($p = 1.00$) (**Figure 2**).

Enjoyment

Mean PACES and EES scores are presented in **Table 3**. With all sessions collapsed, we observed no changes over the three weeks of PACES scores before [main effect of time (weeks): $p = 0.36$, $_p\eta^2$: 0.02] or after ($p = 0.47$, $_p\eta^2$: 0.01) the exercise sessions, and similarly, we observed no changes over weeks by exercise sessions [time (weeks) × exercise session interaction; before: $p = 0.64$, $_p\eta^2$: 0.02; after: $p = 0.38$, $_p\eta^2$: 0.04]. We found no differences (between-sessions' effects) in mean PACES scores of all three weeks between exercise sessions before ($p = 0.42$, $_p\eta^2$: 0.03), while we observed a difference in mean PACES scores between exercise sessions after the sessions ($p = 0.046$, $_p\eta^2$: 0.10) where the participants reported higher enjoyment following INT80 sessions compared with CE70 session ($p = 0.046$), but no differences were reported between INT80 and INT90 sessions ($p = 1.00$) or between INT90 and CE70 sessions ($p = 0.29$) (**Figure 3**).

For EES during the exercise sessions, there was no change in enjoyment over the three weeks with all sessions collapsed (main effect of time; $p = 0.62$, $_p\eta^2$: 0.01) but there were differences in changes over weeks by exercise sessions [time (weeks) × exercise session interaction; $p = 0.01$, $_p\eta^2$: 0.11], where participants reported lower enjoyment during the CE70 sessions at week 1 compared with week 2 and 3 (**Figure 4**). We observed marginally non-significant differences (between-sessions' effects) in mean EES scores of all three weeks between the exercise sessions ($p = 0.06$, $_p\eta^2$: 0.09), where the participants reported higher enjoyment in INT80 sessions compared with CE70 sessions ($p = 0.06$), with no differences between INT80 vs. INT90 ($p = 0.42$) or between INT90 vs. CE70 ($p = 1.00$).

Perceived Exertion

Mean RPE scores for "during" and "after" the exercise sessions are presented in **Table 4**. With all sessions collapsed, we found no changes in RPE during the exercise sessions over the three weeks (main effect of time; $p = 0.15$, $_p\eta^2$: 0.03), but there was a difference in RPE scores over the three weeks by exercise session [time (weeks) × exercise session interaction; $p = 0.008$,

TABLE 3 | Physical Activity Enjoyment Scale before- and after- and Exercise Enjoyment Scale during exercise sessions.

	Week 1	Week 2	Week 3	Total#
PACES Before				
CE70 Mean (95% CI)	90.70 (84.26 – 97.14)	89.35 (82.67 – 96.03)	89.40 (82.68 – 96.13)	89.82 (84.01 – 95.36)
INT80 Mean (95% CI)	94.75 (88.31 – 101.19)	96.40 (89.72 – 103.08)	93.85 (87.13 – 100.58)	95.00 (89.28 – 100.72)
INT90 Mean (95% CI)	96.45 (90.01 – 102.89)	92.50 (85.82 – 99.18)	91.60 (84.88 – 98.33)	93.52 (87.80 – 99.24)
PACES After				
CE70 Mean (95% CI)	90.05 (83.92 – 96.18)	92.30 (85.61 – 98.99)	91.57 (84.69 – 98.46)	91.31 (85.54 – 97.08)
INT80 Mean (95% CI)	102.95 (96.82 – 109.08)	100.45 (93.76 – 107.14)	101.10 (94.22 – 107.99)	101.50 (95.73 – 107.27)*
INT90 Mean (95% CI)	101.05 (94.92 – 107.18)	95.50 (88.81 – 102.19)	98.03 (91.14 – 104.91)	98.19 (92.42 – 103.96)
EES during				
CE70 Mean (95% CI)	3.50 (3.00 – 4.00)	4.25 (3.60 – 4.90)	4.20 (3.65 – 4.75)	3.98 (3.52 – 4.45)
INT80 Mean (95% CI)	5.00 (4.50 – 5.50)	4.55 (3.90 – 5.20)	4.75 (4.20 – 5.30)	4.77 (4.30 – 5.23)
INT90 Mean (95% CI)	4.50 (4.00 – 5.00)	4.00 (3.35 – 4.65)	4.33 (3.78 – 4.87)	4.28 (3.81 – 4.74)

Data are shown as mean and 95%CI.
#Total as mean of all three weeks.
**Difference between INT80 versus CE70: p = 0.46.*
PACES, physical activity enjoyment scale; EES, exercise enjoyment scale; CI, confidence interval; CE70, moderate intensity continuous exercise at 70% of HR_{max}; INT80, 4 × 4 min intervals at 80% of HR_{max}; INT90, 4 × 4 min intervals at 90% of HR_{max}.

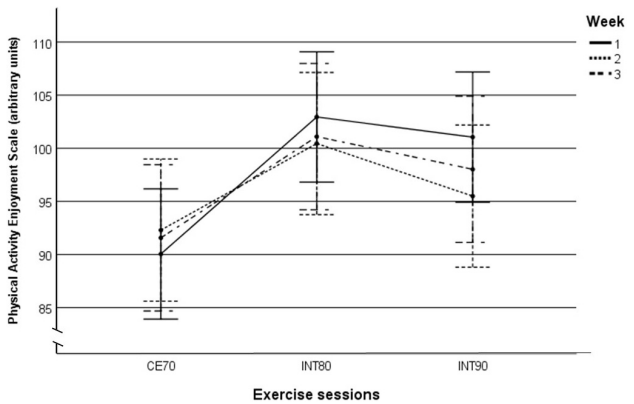

FIGURE 3 | Mean PACES scores after the exercise sessions in all three weeks separately. Between subject effects: $p = 0.046$, $_p\eta^2$: 0.10. *Post hoc* comparisons: INT90 vs. IN80: $p = 1.00$, INT90 vs. CE70: $p = 0.29$, INT80 vs. CE70: $p = 0.046$. Data are shown as mean and 95% CI. PACES, Physical Activity Enjoyment Scale; INT90, interval exercise session at > 90% of HR_{max}. INT80, interval exercise session at > 80% of HR_{max}; CE70, continuous moderate intensity exercise at 70% of HR_{max}; CI, confidence interval.

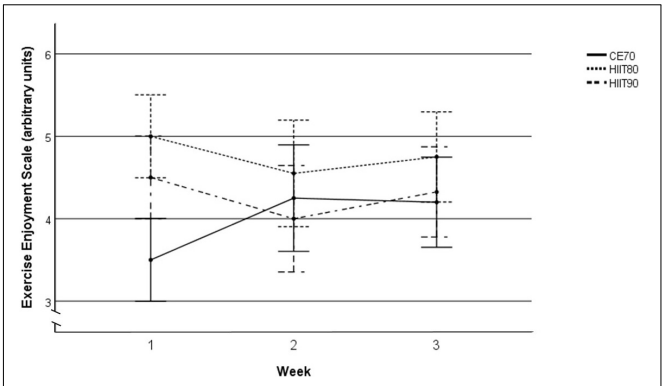

FIGURE 4 | Mean EES score during the exercise sessions in all three weeks separately. Week × exercise session interaction: $p = 0.01$, $_p\eta^2$: 0.11. Data are shown as mean and 95% CI. PACES, Physical Activity Enjoyment Scale; INT90, interval exercise session at > 90% of HR_{max}; INT80, interval exercise session at > 80% of HR_{max}; CE70, continuous moderate intensity exercise at 70% of HR_{max}; CI, confidence interval.

$_p\eta^2$: 0.12], where RPE in INT90 sessions increased from week 1 to week 2, and decreased to week 3 while RPE scores in CE70 and INT80 remained stable. There were differences (between-sessions' effect) in mean RPE scores of all three weeks between the sessions during exercise ($p < 0.001$, $_p\eta^2$: 0.76), where the participants reported higher exertion by higher intensity sessions (CE70 vs. INT80: $p < 0.001$; CE70 vs. INT90: $p < 0.001$; INT80 vs. INT90: $p < 0.001$). Similarly, for RPE scores after the exercise sessions, there was no changes over weeks with all sessions collapsed (main effect of time; $p = 0.45$, $_p\eta^2$: 0.01) and no changes over weeks by exercise session [time(weeks) × exercise session interaction; $p = 0.50$, $_p\eta^2$: 0.03], but there were differences (between-sessions' effect) in mean RPE scores of all 3 weeks after the exercise sessions ($p < 0.001$, $_p\eta^2$: 0.71), with higher exertion by higher intensity sessions (CE70 vs. INT80: $p < 0.001$; CE70 vs. INT90: $p < 0.001$; INT80 vs. INT90: $p < 0.001$).

Sensitivity Analyses

When including only those who performed all nine exercise sessions ($n = 17$), the results remained generally unchanged (data not shown), except for FS during the exercise sessions, where the differences in mean FS scores of all three weeks between exercise sessions were larger ($p = 0.001$, $_p\eta^2$: 0.17, INT90 versus INT80: $p = 0.042$, INT90 versus CE70: $p = 0.016$, INT80 versus CE70: $p = 1.00$), and for PACES after, where there were no differences in mean PACES scores of all three weeks following sessions (between-sessions' effect: $p = 0.09$, INT90 versus INT80: $p = 0.74$, INT90 versus CE70: $p = 0.84$, INT80

TABLE 4 | Rating of Perceived Exertion during- and after the exercise sessions.

		Week 1	Week 2	Week 3	Total#
RPE during					
CE70	Mean (95% CI)	10.65 (10.08 – 11.22)	10.80 (10.19 – 11.41)	10.53 (9.95 – 11.10)	10.66 (10.24 – 11.08)
INT80	Mean (95% CI)	12.15 (11.58 – 12.72)	11.75 (11.14 – 12.36)	12.15 (11.58 – 12.73)	12.02 (11.60 – 12.44)§
INT90	Mean (95% CI)	13.75 (13.18 – 14.32)	15.10 (14.49 – 15.71)	14.83 (14.25 – 15.40)	14.56 (14.14 – 14.98)*¤
RPE after					
CE70	Mean (95% CI)	11.15 (10.45 – 11.85)	10.55 (9.76 – 11.35)	10.30 (9.46 – 11.15)	10.67 (10.13 – 11.21)
INT80	Mean (95% CI)	12.75 (12.05 – 13.45)	12.15 (11.36 – 12.95)	12.55 (11.71 – 13.40)	12.48 (11.94 – 13.02)§
INT90	Mean (95% CI)	15.05 (14.35 – 15.75)	15.30 (14.51 – 16.10)	15.18 (14.33 – 16.02)	15.18 (14.64 – 15.71)*¤

Data are shown as mean and 95%CI.
#Total as mean of all three weeks.
**Difference between INT90 versus CE70: $p < 0.001$.*
¤Difference between INT90 versus INT80: $p < 0.001$.
§Difference between INT80 versus CE70: $p < 0.001$.
RPE, rating of perceived exertion; CI, confidence interval; CE70, moderate intensity continuous exercise at 70% of HR_{max}; INT80, 4 × 4 min intervals at 80% of HR_{max}; INT90, 4 × 4 min intervals at 90% of HR_{max}.

versus CE70: $p = 0.09$), however, the effect remained unchanged ($_p\eta^2$: 0.10).

Correlations Between Perceptual Responses and Relative Anaerobic Threshold Running Speed and Relative Anaerobic Threshold Perceived Exertion

Correlations between perceptual responses from all exercise sessions and the participants' percentage of AT running speed and AT RPE are presented in **Table 5**, as total ($n = 180$) and in strata of exercise sessions ($n = 60$). Scatter plots of FS during and after, ESS during and PACES after, and the participants' relative AT running speeds are illustrated in total ($n = 180$) in **Figure 5**. We found small negative correlations between FS during and after the exercise sessions, and individual relative AT running speed (during: $r = -0.36$, $p < 0.01$; after: $r = -0.34$, $p < 0.01$) (**Table 5** and **Figure 5**). We found moderate positive correlations between RPE during and after the exercise sessions, and individual relative AT running speed (during: $r = 0.72$, $p < 0.01$; after: $r = 0.72$, $p < 0.01$) (**Table 5**). There were moderate negative correlations between FS and individual relative AT RPE (during: $r = -0.42$, $p < 0.01$; after: $r = -0.36$, $p < 0.01$) (**Table 5**) and large correlations between RPE and individual AT RPE (during: $r = 0.70$, $p < 0.01$; after: $r = 0.51$, $p < 0.01$) (**Table 5**).

For stratified analyses by exercise sessions and the individual percentage of AT running speed, there was a small positive correlation between EES scores during CE70 sessions ($r = 0.27$, $p = 0.04$). In INT80 sessions, we observed a small positive correlation between RPE after the exercise sessions and the participants' individual AT running speed ($r = 0.37$, $p < 0.01$). In INT90 sessions, we found a moderate negative correlation between FS during ($r = -0.42$, $p < 0.01$) and FS after ($r = -0.50$, $p < 0.01$) the exercise sessions and individual AT running speed. We found a small negative correlation between individual AT running speed and EES during the INT90 sessions ($r = 0.26$, $p = 0.049$) (**Table 5**).

For stratified analyses by exercise sessions and individual AT RPE, there was a large positive correlation in RPE during CE70 sessions ($r = 0.60$, $p < 0.01$), and a moderate positive correlation in INT80 sessions ($r = 0.43$, $p < 0.01$), and in INT90 sessions ($r = 0.45$, $p < 0.01$). There were moderate negative correlations between relative AT RPE during the exercise sessions and FS after- ($r = -0.44$, $p < 0.01$), EES during ($r = -0.42$, $p < 0.01$), and for PACES after the INT90 sessions ($r = -0.57$, $p < 0.01$) (**Table 5**).

Correlations Between Perceptual Responses and Descriptive Participant Data

Correlations between mean perceptual responses from all exercise sessions and weeks, and descriptive participant data (VO_{2peak}, IPAQ, BMI, AT RPE) are presented in **Supplementary Table 1**. There were no correlations between perceptual responses and descriptive participant data (all $p > 0.07$), except for a moderate correlation between AT RPE and RPE after ($r = 0.49$, $p < 0.05$).

DISCUSSION

The main findings in this randomized crossover study were lower affective valence during high intensity interval exercise (INT90) compared with moderate-high intensity interval exercise (INT80) and compared with moderate intensity continuous exercise (CE70). We found higher enjoyment following interval exercise at moderate-high intensity compared with continuous exercise, while no differences were evident between interval exercise at high- and moderate-high intensity. This suggests that structuring the exercise in an interval format could provide a more enjoyable experience and the negative affective consequences associated with high intensity exercise can be alleviated by keeping the intensity below 90% of HR_{max}. In addition, we observed negative correlations between affective valance during and after exercise and individual percentage of relative AT running speed. We only observed negative correlations between exercise

TABLE 5 | Correlations of perceptual responses from all exercise sessions and weeks and relative OBLA 2.5 mmol/L speed and RPE.

	Relative OBLA 2.5 mmol/L Speed				Relative OBLA 2.5 mmol/L RPE			
All weeks	**All exercise sessions**	**CE70**	**INT80**	**INT90**	**All exercise sessions**	**CE70**	**INT80**	**INT90**
Number of observations	*n = 180*	*n = 60*	*n = 60*	*n = 60*	*n = 180*	*n = 60*	*n = 60*	*n = 60*
FS During	−0.36**	0.06	−0.18	−0.42**	−0.42**	−0.25	−0.34*	−0.37**
FS After	−0.32**	0.01	−0.25	−0.50**	−0.36**	−0.25	−0.23	−0.44**
PACES After	0.08	−0.04	−0.02	−0.24	−0.10	−0.01	−0.14	−0.57**
EES During	0.02	0.37*	−0.10	−0.26*	−0.08	0.15	−0.14	−0.42**
RPE During	−0.72**	0.19	0.18	0.32*	0.70**	0.60*	0.43**	0.45**
RPE After	−0.72**	0.20	0.37**	0.40*	0.51**	0.23	−0.01	0.20

Data are correlation coefficients (r) between perceptual responses and relative OBLA 2.5 mmol/L speed and RPE (percentage of individual anaerobic threshold as OBLA at 2.5 mmol/L) and are obtained across all weeks from all exercise sessions as total (20 participants × 9 sessions = 180) and in strata of exercise sessions (CE70, INT80, INT90: 20 participants × 3 sessions = 60).

FS, feeling scale; PACES, physical activity enjoyment scale; EES, exercise enjoyment scale; RPE, rating of perceived exertion; OBLA 2.5 mmol/L, onset blood lactate concentration at 2.5 mmol/L blood lactate concentration.

**Significant correlation at $p < 0.05$, ** significant correlation at $p < 0.01$.*

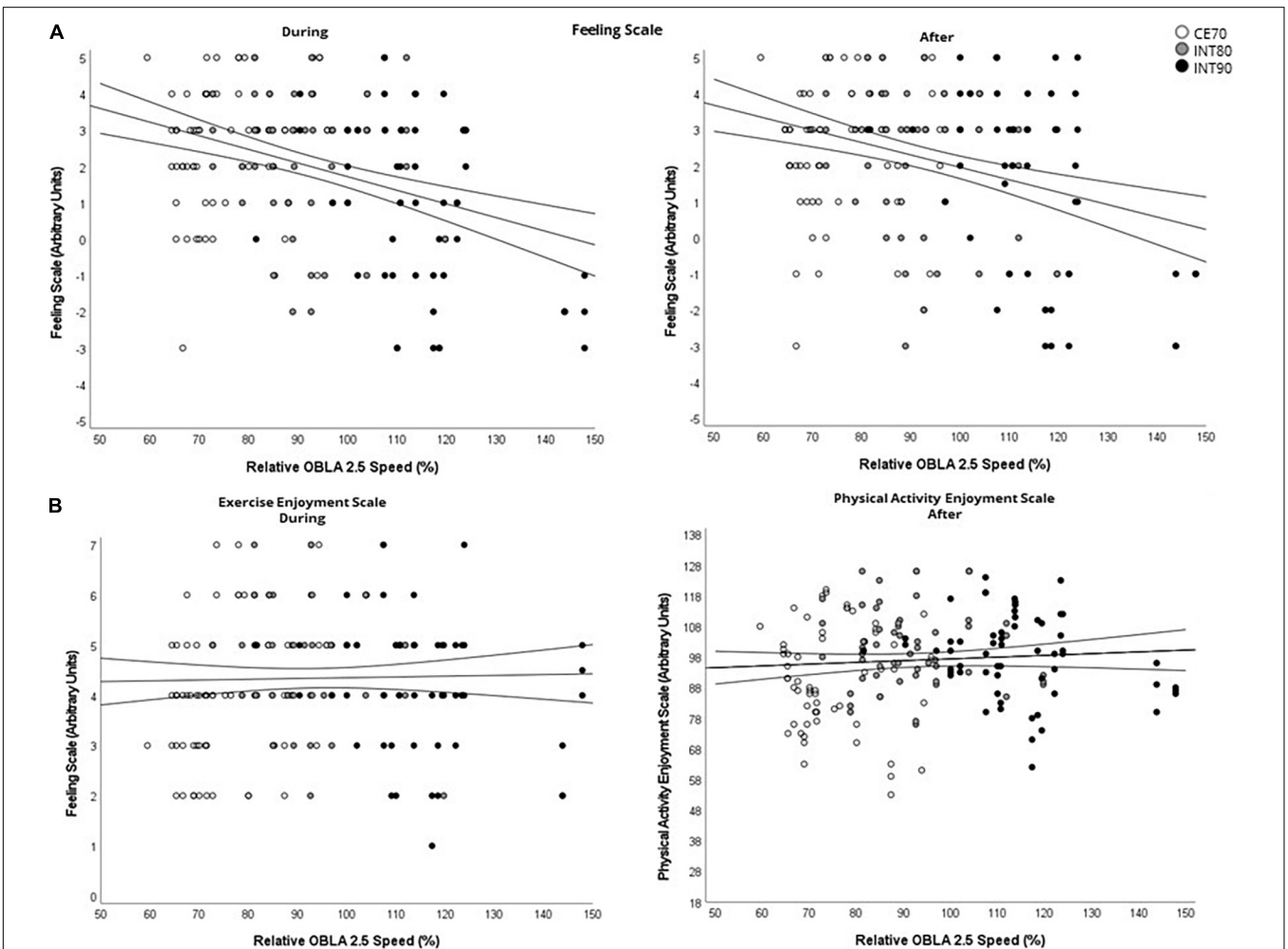

FIGURE 5 | Scatter plots illustrating the relationship between relative OBLA 2.5 running speed across all exercise sessions and weeks (n = 180) and **(A)** all FS scores; significant correlation for Feeling Scale during- (Relative OBLA 2.5 Speed: r = –0.36, $p < 0.01$) and after the exercise sessions (Relative OBLA 2.5 Speed: r = –0.32, $p < 0.01$), **(B)** all PACES and EES scores; no significant correlations. Trend line for regression and 95% CI. OBLA, onset of blood lactate accumulation; CI, confidence interval; FS, feeling scale; PACES, physical activity enjoyment scale; EES, exercise enjoyment scale; RPE, rating of perceived exertion.

enjoyment and the individual percentage of relative AT speed in the INT90 sessions.

Our findings corroborate the results of a previous study comparing affect and enjoyment at lower and higher intensities in interval sessions; in 1-min bouts at 70 and 100% of peak work rate (Boyd et al., 2013). Our study expands this work by making such patterns of affect and enjoyment also applicable for long intervals bouts. There are three recent meta-analyses comparing the affective and enjoyment responses from high intensity interval exercise, which consistently report that compared with moderate intensity continuous exercise, higher intensity interval exercise provides lower affective valence (i.e., unpleasantness) during the exercise, while higher enjoyment is reported following the exercise (Oliveira et al., 2018; Niven et al., 2020; Tavares et al., 2021). Our findings corroborate the observations of lower affect during high intensity intervals compared with moderate continuous exercise, but contrary to the consistency in the meta-analyses (Oliveira et al., 2018; Niven et al., 2020; Tavares et al., 2021), we observed no differences in enjoyment following the INT90 and the CE70 sessions. The similar exercise enjoyment observed for INT90 and CE70 is consistent with a previous study comparing similar high intensity long interval bouts of 4 × 4 min with continuous moderate intensity exercise (similar to our CE70) (Sagelv et al., 2019).

However, we observed higher enjoyment following the INT80 sessions compared with the CE70 sessions. Moreover, although non-significant ($p = 0.06$), participants reported higher enjoyment during the INT80 sessions compared with the CE70 sessions, potentially displaying a similar pattern as reported after exercise. This can be attributed to the fact that the exercise modality was intermittent while at the same time performed at moderate-high intensity. Consequently, it is possible to view the interval structure itself as a positive contribution to exercise enjoyment, where our results provide further nuance to this by displaying moderate-high intensity interval exercise as a viable option to produce high enjoyment following exercise, while at the same time produce high pleasure during the exercise.

We observed small negative correlations between relative percentage of individuals' AT running speed and AT RPE and affect during exercise (**Figure 5** and **Table 5**). These correlations were largely driven by the negative affect reported during the INT90 sessions (**Table 5**); meaning a higher proportion of the participants' individual relative AT running speed utilized during exercise had a negative influence on affect (i.e., pleasure) and enjoyment during exercise, which also had negative effect on the affect and enjoyment during the INT90 session with increasing proportion of participants' relative AT RPE (**Table 5**). This confirms the notion of lower affective valance as the percentage of individual anaerobic metabolism increases (Ekkekakis et al., 2011; Ekkekakis and Brand, 2019), which also applies for interval exercise.

We observed a week by exercise modality interaction for exercise enjoyment during exercise, where enjoyment in moderate intensity continuous exercise increased while enjoyment in the interval exercise sessions remained stable over 3 weeks (**Table 3**). The stable enjoyment in interval exercise is in line with two previous studies that examined enjoyment responses over 3 (Vella et al., 2017) and 5 weeks (Kong et al., 2016). In contrast, another study found enjoyment to progressively increase over the study duration, where higher enjoyment was reported in high intensity intervals compared with moderate intensity continuous exercise from week 4 to 6 (Heisz et al., 2016). Due to the COVID-19 lockdown, we were forced to cut our intervention short by 1 week, thus we were unable to assess whether our exercise sessions would differ by week 4. However, considering that we observed no effect of time to indicate any progressively increased enjoyment within week 3, a difference in week 4 seems unlikely. Nevertheless, our study differs from the previous studies (Heisz et al., 2016; Kong et al., 2016; Vella et al., 2017) by design; their designs were randomized paralleled groups while our study was a randomized crossover trial. Crossover designs use the same individuals as controls, thus removing a potential influence of individual variation between groups (Sibbald and Roberts, 1998). It also results in multiple treatment effects, where participants in our study had past references (experience) from all exercise session following week 1, which may have resulted in higher enjoyment during CE70 sessions in week 2 and 3 (**Figure 4**). Thus, with previous experience from high intensity intervals, moderate intensity exercise might be perceived more enjoyable as a result of lower positive affect from past experience with high intensity intervals (Ekkekakis et al., 2011; Ekkekakis and Brand, 2019).

Interestingly, there seem to be strong debates on whether high intensity intervals are appropriate for the vast majority of the population (Biddle and Batterham, 2015). A previous study indicated higher adherence in moderate intensity continuous exercise (similar to our CE70, 75% adherence) compared with 4 × 4 min intervals (60% adherence) following 12 weeks (Lunt et al., 2014). In a recent larger study (N = ∼800), exercise adherence seems similar between 4 × 4 min intervals and moderate continuous exercise following both 1 year (∼50-60% adherence in both groups), 3 and 5 years (∼50% adherence) (Stensvold et al., 2020), indicating that both exercise modalities are equally difficult to adhere to. Consequently, it may be that exercise *per se* is difficult to sustain over time, independent of exercise mode or modality.

Difference in exercise adherence between high intensity intervals and moderate intensity continuous exercise may be due to inappropriate delivery of high intensity interval exercise. In the study by Lunt et al. (2014), they instructed their participants to reach target HR within 10–20 s into the interval bouts. Due to heart rate kinetics at the onset of exercise, this likely involved high anaerobic metabolism and thus large accumulated BLa throughout the entire exercise session, with recovery periods between bouts too short for accumulated BLa clearance (Jones et al., 2010). Appropriately delivered high intensity long interval bouts allows the first interval bout to reach target HR at the end of the 4 min, thereafter, following 2 min in the remaining interval bouts (Karlsen et al., 2017; Taylor et al., 2019), as done by Stensvold et al. (2020). As such long interval bouts are designed not to be totally exhaustive, individual changes should be made if RPE ratings reaches > 17, which indicates too exhaustive interval bouts (Taylor et al., 2019). For example, the 4 min intervals of 80 and 90% of HR_{max} in our study was rated as 13 and 15 in RPE,

respectively (**Table 4**), and in the study by Stensvold et al. (2020) as 13 (CE70) and 16 (INT90), respectively, corresponding to "somewhat hard" to "hard" exertion (Borg, 1974). Thus, the lower exercise adherence of high intensity as observed in the study by Lunt et al. (2014) may be due to inappropriately delivered high intensity long interval bouts, not the high intensity long interval bouts *per se*. Nevertheless, even if cardiac drift is taken into account, it still seems that short interval bouts (60 s) at HR > 90% of HR_{max} results in lower adherence compared with intervals at ≤ 85% of HR_{max} (Arad et al., 2020), which is supported by our study where higher positive affect was observed in long interval bouts aimed at eliciting 80% of HR_{max}.

We observed no association between descriptive participant data (cardiorespiratory fitness, body mass index and physical activity level) and perceptual responses of exercise, which is in line with previous literature (Oliveira et al., 2018). As affective valance is associated with physical activity (Williams et al., 2012), we included physical activity level as descriptive participant data, which most previous studies did not measure, but mentioned as "inactive" or "active" *etc.* (Oliveira et al., 2018; Niven et al., 2020; Tavares et al., 2021). Although we observed no association between physical activity level and perceptual responses of exercise, the participants in our study reported to be highly active, where some individuals were determined to be up to four times more active than the minimal recommendations for physical activity of 150 min (Bull et al., 2020), which is far beyond the general population (Guthold et al., 2018). Thus, although we observed no differences between perceptual responses and physical activity levels, there may be actual differences in perceptual scores (potentially between inactive and active) that our study is unable to disentangle, as observed previously for body mass index between obese and non-obese women (Ekkekakis et al., 2010). Nevertheless, it is still intriguing to observe that the perceptual responses, especially during exercise, are similar to what has been reported previously for both active and inactive individuals (Oliveira et al., 2018; Niven et al., 2020; Tavares et al., 2021), suggesting that the pattern of perceptual responses in relation to relative exercise intensity are similar across physical activity levels. Consequently, our findings of the pattern for perceptual responses toward exercise are likely representable for those with lower physical activity level.

Due to low cardiorespiratory fitness in many populations (Aspenes et al., 2011; Edvardsen et al., 2013; Kaminsky et al., 2015), some have suggested that exercise professionals face challenges in finding appropriate activities for individuals with low cardiorespiratory fitness, thus being applicable for the unsustainability of higher intensity intervals (Decker and Ekkekakis, 2017). Although this is true, it is far from impossible; this depends on appropriately educated exercise professionals using relative intensity measures alongside flexible approaches to adapt the exercise according to perceptual responses (Taylor et al., 2019). Consequently, those with low cardiorespiratory fitness may simply walk at an absolute intensity corresponding to e.g., 1 $km \cdot h^{-1}$, which can correspond to 10–90% of HR_{max} depending on their cardiorespiratory fitness level (Biddle and Batterham, 2015).

Finally, no associations between descriptive participant data and affective- and enjoyment responses indicate that other factors cause the observed pattern in these responses to high intensity exercise. Physiological reasons are likely related to anaerobic metabolism (Ekkekakis and Brand, 2019). Psychological suggestions for the heterogeneous responses may include self-efficacy, or social evaluations such as appearance/social physique anxiety (Ekkekakis and Brand, 2019). Moreover, perceptual responses are likely influenced by social and cultural contexts, which involve interwoven cognitive evaluations and feelings that can be both competence- and body-related (Ekkekakis and Brand, 2019). For example, intrinsic motivation for exercise is found to mediate the association between affect and exercise (Schneider, 2018) and a previous twin study indicate that affective responses may be, to some extent, heritable (Schutte et al., 2017). Such psychological factors warrant further investigation into mechanisms that can predict exercise adherence.

Strengths

To our knowledge, this is the first study to compare affective valence and exercise enjoyment of long interval bouts at different intensities. By comparing these two (INT80 and INT90), and the traditional moderate intensity continuous exercise (CE70), it is possible to elucidate the effect of structuring the exercise in long interval bout formats allowing for higher stroke volume adaptations (Bacon et al., 2013) with lower interference of the anaerobic processes associated with high intensity. Furthermore, as mentioned above, our randomized crossover design over three weeks allowed the participants to rate their affect and enjoyment with previous experience from all three exercise sessions, while also controlling for interindividual differences. Finally, due to the many exercise sessions, we were able to display associations between individual percentage of the AT (running speed and RPE at OBLA 2.5 mmol/L) and perceptual responses during and after exercise, which corroborate the observation observed previously in continuous exercise, where participants experience lower affect as the intensity exceeds physiological landmarks of relative higher contribution from anaerobic metabolism (Ekkekakis et al., 2011; Ekkekakis and Brand, 2019).

Limitations

Compared with previous studies in recent meta-analyses (Oliveira et al., 2018; Niven et al., 2020), our participants were relatively fit in terms of cardiorespiratory fitness, body mass index and physical activity level. However, there seem to be no association between fitness level and perceptual reporting during and after exercise (Oliveira et al., 2018). As mentioned above, our participants were highly active, where differences in actual responses (e.g., affective and enjoyment scores) may differ although likely produce similar patterns in aerobic exercise modalities. Nevertheless, our study should be replicated in individuals of lower physical activity levels to draw firmer conclusions on patterns and responses toward different exercise intensities and modalities in that population.

Furthermore, we measured affect once during the exercise sessions, at 55% completion. This puts our affect assessment

between interval bout two and three in the interval sessions. Some have suggested that the FS should be measured multiple times capturing both peak intensity and peak recovery time at all interval bouts (Decker and Ekkekakis, 2017), and this may be regarded as a limitation to our study. However, as perceived exertion is influenced by both intensity and duration of exercise (Garcin and Billat, 2001), recovery periods between interval bouts will still capture exertion, thus also likely unpleasantness, within the exercise. Thus, measuring affect immediately following the second interval bout allowed us to capture the associated affect during the exercise, where we observed similar patterns as anticipated of the long interval bouts at different intensities. Similarly, presenting the EES and the FS at the same time during an exercise is suggested to influence the FS scores as the EES is a positive loaded question *("how much are you enjoying…")* (Ekkekakis et al., 2011; Decker and Ekkekakis, 2017); this may also be regarded as a limitation. To address this, we first presented the FS followed by the EES to the participants.

We included 20 participants, which are borderline sufficient statistical power to observe a "high" medium (${}_p\eta^2 \geq 0.11$) time × exercise condition interaction, but sufficient to observe a large effect (${}_p\eta^2 \geq 0.14$). There might be smaller effects that were not detectable in our study and cannot be ruled out based on this investigation. For example, the marginally non-significant ($p = 0.06$) difference in enjoyment during INT80 compared with CE70 can be assessed with higher certainty in a larger sample. However, a previous study reported a 1-unit increase in the FS during exercise to translate to 15 min higher physical activity at 6 months follow-up (Williams et al., 2012); as our FS differences during exercise are > 1-unit between exercise sessions (**Table 2** and **Figure 2**), it can be considered a relevant difference.

As we produced 180 observations for our correlation analyses between individual percentage of AT speed and AT RPE from nine exercise sessions in 20 participants, this likely caused autocorrelation (i.e., similar correlations within each individual but at different time points; week 1 and session 1, week 2 and session 4 etc.). However, as our repeated randomized crossover design allowed for past experience from all exercise sessions, this may have changed the associations over time, thus in our view justifying these analyses. Moreover, we chose OBLA at 2.5 mmol/L as our AT. There are great controversies and confusion on whether one can pinpoint an AT, or whether OBLA-determined thresholds are reproducible (Jamnick et al., 2018; Poole et al., 2021). However, we chose a feasible estimate of an anaerobic transition, allowing us to display the associations between perceptual responses during and after exercise with individual percentage of AT intensity, where our results were in line with previous literature using continuous exercise (Ekkekakis et al., 2011; Ekkekakis and Brand, 2019).

Furthermore, three participants were unable to complete their final exercise session (two INT90 and one CE70) due to the COVID-19 lockdown, where we forwarded their respective mean score (CE70 or INT90) of week 1 and 2 to their respective missing exercise session in week 3. Thus, possible changes in perceptual responses by week three for these individuals could potentially influence our results. However, as our sensitivity analyses were generally unchanged when including only the 17 participants that completed all nine exercise sessions, it is unlikely that this influenced our interpretation of the results.

Finally, although our intervention were three weeks long, such a time span is not long enough to assess any meaningful exercise adherence. Well-designed long-term studies (i.e., 3–6–12 months) assessing perceptual responses and exercise adherence with different exercise mode and/or modalities are warranted.

CONCLUSION

Structuring the exercise in an interval format could provide a more enjoyable experience and the negative affective consequences associated with high intensity exercise can be alleviated by keeping the intensity at or around 80% of HR_{max}, which may contribute to higher exercise adherence and consistency.

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

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. This study does not fall under the Health Research Act in Norway (https://lovdata.no/dokument/NL/lov/2008-06-20-44). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

TH, ES, and SP designed the study. TH and ES translated the FS and EES questionnaires. ES performed all statistical analyses and wrote the methods and results. TH was in charge of the writing process and wrote the introduction and discussion. All authors revised, read and approved the final version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.825738/full#supplementary-material

Supplementary Table 1 | Correlation matrix of mean perceptual responses from all exercise sessions and weeks and descriptive participant data, as total.

Supplementary Table 2 | Translated version of Feeling Scale (FS) and translated version of Exercise Enjoyment Scale (EES).

Supplementary File 1 | The dataset for this study.

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Prevalence and Associated Factors of Complains on Depression, Anxiety, and Stress in University Students: An Extensive Population-Based Survey in China

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Mental health issues are becoming increasingly prevalent amongst university students. However, research on the psychological profile of the general university population is relatively limited. Thus, this study analyses the current state of university students' psychological conditions; the demographic differences in depression, anxiety, and stress and the influencing factors. The objectives are to provide additional appropriate guidance in mental health for university students with different demographic characteristics. A cross-sectional study of 6,032 university students nationwide was conducted from October 2020 to January 2021. A randomized whole-group sampling method was used to select the study participants, and the 21-item Depression, Anxiety, and Stress Scale (DASS) was used. $P < 0.05$ in the final model were considered statistically significant. The number of university students with no complain of depression, anxiety, or stress was 3,751 (62.2%). The odds of developing complain of depression were higher amongst anxious respondents (AOR = 23.417, 95% CI: 19.706, 27.826) and senior year (AOR = 2.210, 95% CI: 1.657, 2.947) than their counterparts. Students with "myopia" were 1.263 times more likely to be anxious (AOR = 1.263, 95% CI: 1.042–1.530). In terms of "impaired" or not, impaired is defined as any injury, such as sprain, strain, and fracture, "impaired" university students were 1.321 times more likely to be anxious (AOR = 1.321, 95% CI: 1.064–1.641). Furthermore, history of impairment and myopia increased the odds of stress by 1.305 (AOR = 1.305, 95% CI: 1.022–1.667) and 1.305 (AOR = 1.305, 95% CI: 1.012–1.683), respectively. Myopia, physical-activity-related injury (PARI) and irrational eating habits are risk factors for complain of anxiety and stress. Males, upper grades, low parental education, and irrational eating habits are risk factors for complain of depression. Low physical activity levels are also an influential factor for complain of depression. DASS consists of interchangeable risk factors and multiple complains of DASS may coexist.

Keywords: depression, anxiety, stress, university students, epidemiological investigation

INTRODUCTION

Depression, anxiety, and stress are significant indicators for mental health and the presence of these symptoms could have a negative effect on an individual if not identified early or addressed timely (Wang et al., 2020), The period of transition from late adolescence to adulthood (Arnett, 2000) is a developmentally challenging transition for most young people in this time in many countries. During this period, these people are in the midst of the senior year of their university education (Torres et al., 2017). University years are a critical period of development and the onset of most lifelong mental disorders occurs during this period (Kessler et al., 2007).

Mental health problems account for approximately one-sixth of the global burden of disease in adolescents (Mokdad et al., 2016). Approximately 10–20% of adolescents in the world have had mental health problems. In addition, these problems have become the main reasons for the subsequent development of psychological barriers, such as those leading to risk-taking behavior and autotomy, and even the occurrence of suicide (Wagner et al., 2017; Johnson and Heiderscheit, 2018). Numerous studies showed that people who attend a university have more severe mental health problems and a correspondingly higher prevalence of psychological disorders, particularly depression, anxiety, and stress, than those of the same age who do not attend university (Cvetkovski et al., 2012). Moreover, mental health issues are becoming more prevalent amongst university students. Nearly one-half of university students have moderate levels of stress, anxiety, and depression (Regehr et al., 2013). This case causes irreparable damage to families, the country, and society.

In the United States, nearly half of the university-age individuals suffer from a mental disturbance (Han et al., 2016). Similarly, over 20% of Chinese university students have had depression, and this proportion has grown in the old days (Sontag-Padilla et al., 2018; Liu et al., 2019a,b). China is now one of the fastest-growing economies in the world (AlJaber, 2020). Along with economic development, Chinese people's living standards have increased significantly and their psychological state has changed extensively (Ye et al., 2020). In addition, China has changed many of its policies in recent years. For example, the Chinese government has abolished the one-child policy (Scharping, 2018) and simultaneously, China is still expanding its university advancement rate (Ye et al., 2020). All these changes not only reflect dramatic changes in the social environment but may also affect the psychological characteristics of Chinese university students. In addition, university students are a key force in determining a country's economic growth and success and university years are a critical period from adolescence to adulthood (Cuijpers et al., 2019). Considering the changing social roles and declining social support, university students are more vulnerable to psychological conditions than before (Auerbach et al., 2018; Liu et al., 2019a,b). Therefore, reliable estimates of the epidemic rates of mental health problems in China's changing environment are an important step in the effort to provide enhanced mental health care for university students.

In conclusion, the prevention and early treatment of mental health problems amongst university students is an important public health priority because of its effect on students' lives, public health, society's investment in university students, and the importance of university students to society's future capital (Cuijpers et al., 2019). Psychological disorders could pose a serious threat to students' academic achievement and affect their future career course of events at the same time. Therefore, identifying the factors that affect the mental health of university students is of great significance. On this basis, this study aimed to understand complain of anxiety, depression, stress and their related factors amongst Chinese university students.

MATERIALS AND METHODS

Design

According to the principle of stratified random whole-group sampling, four regions were divided in accordance with economic areas: Eastern, Central, Western, and North eastern regions. A cross-sectional study was conducted amongst Chinese university students on the prevalence of depression, anxiety, stress, and other related factors.

Sample

Stratified random whole-group sampling method was used from October 2020 to January 2021, with the head of the selected school briefing the students on the purpose of the study.

The sample size was calculated based on pre-pandemic data. According to the results of similar surveys in other regions, the incidence of stress is about 34.5% (Ramón-Arbués et al., 2020). With a precision of 1.25% and a confidence interval of 95%, the recommended sample size was 5,556 using the sample size calculation tool. Taking into account a 10% questionnaire exclusion rate, the final sample size required was 6,173.

Simultaneously, the completion of the informed consent form was explained to the students to begin completing the electronic version of the questionnaire. Students were provided with the right to refuse to participate or withdraw from the study at no cost and their privacy and confidentiality were protected. A total of 6,714 questionnaires were returned and 6,032 students were included in this study after relevant screening and elimination.

The inclusion criteria were as follows: (1) university students enrolled in rehabilitation-related majors, including Freshman, Sophomore, Junior, Senior; (2) Those who signed the electronic informed consent form. Further, the exclusion criteria were as follows: (1) Non-rehabilitation related majors; (2) Suffered from severe cardiovascular disease; (3) Suffered from specific pathologies (e.g., epilepsy, amputation, etc.); (4) Inflammatory conditions; (5) A severe fracture; (6) Students with confused response logic; (7) Students with abnormal IPAQ long form data.

Data Collection

The questionnaire included two main parts: social demographic characteristics and mental health. The socio demographic characteristics contained a series of alternating quantities commonly related to psychological puzzle amongst university students (Tao et al., 2002; Korhonen et al., 2017; Wahed and Hassan, 2017; Fernández et al., 2020; Lee and Feng, 2021;

Solmi et al., 2021), that is, gender, grade, obesity, eating habits, family background, tobacco and alcohol consumption, physical activity, and diet. The variable body mass index (BMI) was calculated from self-reported weight and height (BMI = kg/m^2). BMI is classified as follows: (1) low BMI ($\leq$18.5 kg/m^2), (2) normal BMI (18.5–23.9 kg/m^2), (3) high BMI/obese (24.0–27.9 kg/m^2), and (4) obese ($\geq$28 kg/m^2).

Physical activity was measured using the International Physical Activity Questionnaire (IPAQ) (Fogelholm et al., 2006). IPAQ is one of the widely used internationally validated questionnaires for measuring physical activity levels in adults (15–69 years). The physical activity counted in this questionnaire consists mainly of the type of activity (work, transportation, home gardening, leisure) and the intensity of the activity (walking and moderate and high intensity). This questionnaire is available in two versions (Macfarlane et al., 2011), long and short, and it has been used in studies of Chinese populations. Information on the dietary habits of university students were collected, including the frequency of intake of meat, fruits, vegetables, high-calorie drinks, tobacco, and alcohol.

Physical-activity-related injury is defined as "any injury, such as sprain, strain, and fracture, suffered in the process of participating in PAs or leisure time (Van Mechelen et al., 1992). A countable PARI event must have occurred within the past 12 months, with at least one of the following consequences: (1) having to stop the current PA (sport), (2) being unable or unable to fully participate in the next planned PA (sport), (3) being unable to attend class the next day, and (4) needing to seek medical support (Bloemers et al., 2012; Cai et al., 2018).

The psychological status assessment scale used in this survey is the simplified Chinese version of the 21-Item Depression, Anxiety, and Stress Scale (DASS-21). This scale, which was developed by Lovibond et al. in 1995, aims to distinguish and define common emotional disorders and help provide an auxiliary psychometric indicator for clinical diagnosis (Lovibond and Lovibond, 1995). DASS-21 is a streamlined edition of the DASS that has been revised to improve the efficiency of identifying and assessing symptoms of the corresponding mood disorders. Studies showed that the scale consists of three subscales, namely, depression, anxiety, and stress, containing seven questions each, for a total of 21 questions. The scale is rated on a three-point scale, 0 = not met, 1 = met or occasionally met, 2 = met or often met, and 3 = most or always. In DASS-D, 0–9 = no depression/normal, 10–13 = mild depression, 14–20 = moderate depression, 21–27 = severe depression, and >27 = very severe depression). In DASS-A, 0–7 = no anxiety/normal, 8–9 = mild anxiety, 10–14 = moderate anxiety, 15–19 = severe anxiety, and >19 = very severe anxiety. In DASS-S, 0–14 = no stress/normal, 15–18 = mild stress, 19–25 = moderate stress, 26–33 = severe stress, and >33 = very severe stress. DASS-21 is calculated by multiplying the sum of the subscale scores by two to obtain the final score for the three subscales. It has the same stable factor structure and equally good reliability as the full version of DASS, making this scale more suitable for use as a rapid screening tool in research and clinical settings (Antony et al., 1998; Crawford and Henry, 2003). The internal consistency of the three subscales ranged from 0.76 to 0.79 and that of the total scale reached 0.89 (Gong et al., 2010).

Data Collection Procedures

This study was carried out in the form of electronic questionnaire survey. After the baseline survey was conducted in different regions and colleges across the country, the responsible persons of the eligible universities were communicated with and the questionnaires were distributed. All institutions were required to ask student participants to accomplish the questionnaires during the same time period. Before filling out the questionnaire, participants were asked to sign the informed consent form after reading the information sheet of the study and instructions for completing the survey.

Data Collection Instrument and Quality Control

After a pre-survey of 40 interns was conducted at the Sixth Hospital of Sun Yat-sen University, the total scale Cronbach's alpha coefficient was 0.816, which had good reliability.

Data Analysis

The characteristics and dietary habits of the survey respondents were described by frequency and percentage. For the analysis of variability in psychological states of different subgroups, Chi-square analysis was used in the case of categorical variables, such as demographic characteristics: gender, place of birth, etc. Binary logistic regression analyses (reverse stepwise regression with an entry probability value of $p = 0.05$ and a removal value of $p = 0.10$) were also performed to identify the predictors of mental health (presence of anxiety, stress, and depression) in the sample. Data coding, processing, and analysis were completed using SPSS (version 25 for Windows, IBM Corp., Chicago, IL, United States), which accepts a significance level of $p < 0.05$.

Ethical Considerations

Prior to the commencement, this study was reviewed and approved by the Ethics Committee of the Sixth Hospital of Sun Yat-sen University (IEC Ref: E2020035). This study complied with every national and international standard for ethical research in human subjects.

RESULTS

Basic Characteristics

A total of 6,032 university students (67% female and 33% male) participated in this survey. The ages ranged from 15 to 25 years, with an average of 19.82 $\pm$ 1.429 years. The majority of students had a normal BMI (63.9%), the highest percentage was freshmen (38%) and the student population was rural (62.9%). In addition, 38.5% had a low level of physical activity and the incidence of injury was 13.1% (**Table 1**).

Dietary Habits

The eating habits of university students for the past week were surveyed and counted. Amongst these students, 1.7% did not

TABLE 1 | Statistical table of basic characteristics of university students.

Variables		n (%)
Age	Mean ± SD	19.82 ± 1.429
Gender	Male	1,989 (33%)
	Female	4,043 (67%)
Grade	Freshman	2,294 (38%)
	Sophomore	1,617 (26.8%)
	Junior	1,522 (25.4%)
	Senior	5,88 (9.7%)
BMI	Mean ± SD	21.185 ± 3.8914
BMI grouping	BMI < 18.5 (low)	1,231 (20.4%)
	18.5 ≤ BMI ≤ 23.9 (normal)	3,853 (63.9%)
	24.0 ≤ BMI ≤ 27.9 (high)	696 (11.5%)
	BMI ≥ 28 (obese)	252 (4.2%)
Myopia	Yes	4,816 (79.8%)
	No	1,255 (20.2%)
Injury	Yes	792 (13.1%)
	No	5,240 (86.9%)
Mother's educational level	Primary school and below	2,155 (35.1%)
	Junior high school or vocational high school	2,078 (34.4%)
	High school or junior college	1,017 (16.9%)
	Specialty	421 (7%)
	Bachelor's degree and above	401 (6.6%)
Physical activity (MET* minutes/week)	Mean ± SD	2282.3 ± 2762.52
PA levels	Low	2,322 (38.5%)
	Moderate	1,957 (32.4%)
	High	1,753 (29.1%)
Father's education level	Primary school and below	1,361 (22.6%)
	Junior high school or vocational high school	2,408 (39.9%)
	High school or junior college	1,236 (20.5%)
	Specialty	518 (8.6%)
	Bachelor's degree and above	509 (8.4%)

**Metabolic equivalents (MET): the ratio of a person's working metabolic rate relative to their resting metabolic rate.*

consume meat in the last 7 days and 90.3% never smoked. The highest frequency of meat and fresh fruit intake was 2–3 days a week, with the least percentage of never consuming meat and fruit. Moreover, 35.8% of university students consumed fresh vegetables 4–5 days a week, with only 1.5% not consuming fresh vegetables. The highest percentage of university students hardly consumed carbonated drinks (37.2%) and more than half did not consume coffee in the last week. Then, the highest frequency of intake of high-calorie drinks, sugar and high-fat foods was the most frequent at 2–3 days. Furthermore, the percentages of university students who never smoked nor drank were 90.3 and 85.2%, respectively, and the percentages of those who smoked or drank often or always were 1.7 and 1.1%, respectively. Overall, the university students had good eating habits, with very few having poor eating habits (**Table 2**).

Statistical Results for Depression, Anxiety, and Stress Scale

Amongst the university students surveyed, 27.3 and 33.4% had mild to very severe complains of depression and anxiety, respectively. The levels of complain of depression and anxiety were higher in males than in females ($p < 0.05$). In addition, no significant difference was observed in complain of stress scores between males and females (12.7% of males and 11.6% of females). The scores of the depression, anxiety, and stress subscales of the university students surveyed were corresponding to the grading criteria provided by the scales. Moreover, the number of university students with different degrees of complain of depression accounted for 27.3% of the total number of students in this study. The number of students with different levels of complain of anxiety accounted for 33.4% of the total number of students. Amongst the different levels of complain of anxiety, moderate complain of anxiety accounted for the highest proportion (53.9%), whilst severe complain of anxiety accounted for the lowest (11.4%). The number of students with different levels of complain of stress accounted for 12%. Amongst the different levels of complain of stress, mild complain of stress accounted for the highest proportion (47.9%), whilst very severe complain of stress accounted for the lowest (5.8%).

Amongst the different levels of stress, the number of people without stress was the highest, followed by that without complain of depression, whilst the number of people without complain of anxiety was the lowest. The number of people with complain of anxiety was the highest in the mild level classification. The number of people with anxiety was the highest in the moderate,

TABLE 2 | Statistical table of university students' eating habits.

Category	Never	Hardly ever	Sometimes	Often	Always
Meat	102 (1.7%)	341 (5.7%)	2, 022 (33.5%)	1, 791 (29.7%)	1, 776 (29.4%)
Fresh fruits	167 (2.8%)	691 (11.5%)	2, 786 (46.2%)	1, 563 (25.9%)	825 (13.7%)
Fresh vegetables	90 (1.5%)	283 (4.7%)	1, 936 (32.1%)	2, 159 (35.8%)	1, 564 (25.9%)
Carbonated beverages	1, 661 (27.5%)	2, 244 (37.2%)	1, 737 (28.8%)	287 (4.8%)	103 (1.7%)
Coffee	3, 409 (56.5%)	1, 445 (24.0%)	890 (14.8%)	186 (3.1%)	102 (1.7%)
High-calorie beverages	1, 300 (21.6%)	2, 085 (34.6%)	2, 192 (36.3%)	355 (5.9%)	100 (1.7%)
Sugar	723 (12.0%)	1, 329 (22.0%)	2, 764 (45.8%)	850 (14.1%)	366 (6.1%)
High-fat foods	1, 119 (18.6%)	1, 895 (31.4%)	2, 476 (41.0%)	407 (6.7%)	135 (2.2%)
Cigarettes	5, 445 (90.3%)	226 (3.7%)	261 (4.3%)	41 (0.7%)	59 (1.0%)
Alcohol	5, 139 (85.2%)	542 (9.0%)	285 (4.7%)	37 (0.6%)	29 (0.5%)

TABLE 3 | Total and gender-based scores for DASS-21.

DASS-21a	Categories	Total (*n* = 6,032)	Men (*n* = 1,989)	Women (*n* = 4,043)	*P*
DASS-Db	No depression	4, 384 (72.7%)	1, 391 (69.9%)	2, 993 (74.0%)	<0.01
	Mild	620 (10.3%)	177 (8.9%)	443 (11.0%)	
	Moderate	796 (13.2%)	326 (16.4%)	470 (11.6%)	
	Severe	112 (1.9%)	41 (2.1%)	71 (1.8%)	
	Extremely severe	120 (2.0%)	54 (2.7%)	66 (1.6%)	
	Score Mean ± SD	5.83 ± 7.07	6.29 ± 7.64	5.61 ± 6.77	0.001
DASS-Ac	No anxiety	4, 017 (66.6%)	1, 295 (65.1%)	2, 722 (67.3%)	0.017
	Mild	442 (7.3%)	128 (6.4%)	314 (7.8%)	
	Moderate	1, 086 (18.0%)	383 (19.3%)	703 (17.4%)	
	Severe	229 (3.8%)	82 (4.1%)	147 (3.6%)	
	Extremely severe	258 (4.3%)	101 (5.1%)	157 (3.9%)	
	Score Mean ± SD	6.07 ± 6.47	6.32 ± 7.12	5.94 ± 6.12	0.040
DASS-Sd	No stress	5, 308 (88.0%)	1, 736 (87.3%)	3, 572 (88.4%)	0.028
	Mild	347 (5.8%)	114 (5.7%)	233 (5.8%)	
	Moderate	207 (3.4%)	67 (3.4%)	140 (3.5%)	
	Severe	128 (2.1%)	49 (2.5%)	79 (2.0%)	
	Extremely severe	42 (0.7%)	23 (1.2%)	19 (0.5%)	
	Score Mean ± SD	7.03 ± 7.42	7.23 ± 7.94	6.93 ± 7.15	NS*

** NS, Not significant; DASS-21a, 21-item DASS-21 Depression, Anxiety and Stress Scale; DASS-Db, seven-item DASS-21 Depression Subscale; DASS-Ac, seven-item DASS-21 Anxiety Subscale; DASS-Sd, seven-item DASS-21 Stress Subscale.*

severe, and very-severe level classifications (**Table 3**). According to the results obtained from the DASS-21 questionnaire, 62.2% of the university students surveyed had none of the complains; 25.2% had two or more psychiatric complains and up to 10% experienced complains of anxiety, depression, and stress at the same time (**Figure 1**).

The final binary logistic regression model showed that being male, being in the fourth year, having a father with a low level of education, never eating fresh vegetables, always drinking carbonated drinks and always consuming sugar were risk factors for complain of depression. Then, myopia, impairment and always consuming high-fat foods were influential factors for complain of anxiety and stress. Furthermore, complain of anxiety, depression and stress were influential factors for one another ($p < 0.05$, **Tables 4–6**).

Factors Associated With Depression Amongst University Students

After univariate analysis was conducted, factors that had a significant effect on depression were selected for multifactorial analysis. The results showed that gender, grade, father's education, carbonated drinks, sugar intake, complain of anxiety, and stress were significantly associated with complain of depression. Females were less likely to be depressed than males (AOR = 0.781; 95% CI: 0.655–0.931). The odds of being depressed were 2.21 times higher in the fourth year than in the first year (AOR = 2.21, 95% CI: 1.657–2.947). The prevalence of complain of depression was higher amongst those whose fathers had a bachelor's degree or higher education than those whose fathers only finished primary school or below (AOR = 0.656, 95% CI: 0.466–0.923). The university students who always consumed carbonated drinks and sugars were higher than those who never did (AOR = 1.772, 95% CI: 0.940–3.338; AOR = 1.671, 95% CI: 1.083–2.577, **Table 4**).

Factors Associated With Anxiety Amongst University Students

After univariate analysis was conducted, factors that had a significant effect on anxiety were selected for multifactor analysis. The results showed that myopia, the presence of injury, high

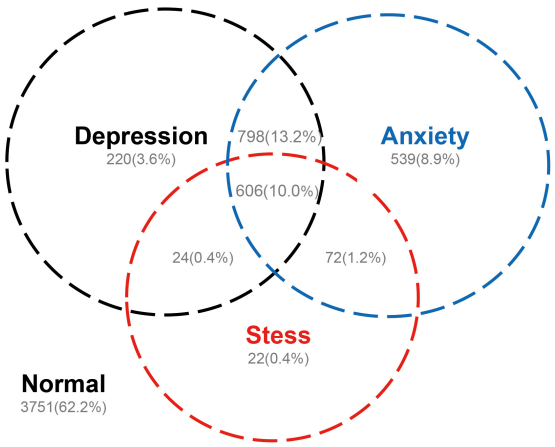

FIGURE 1 | Coexistence of complains of depression, anxiety, and stress on the basis of the results from DASS-21 (n = 6,032).

fatty-food intake, complain of depression, and stress were significantly associated with complain of anxiety. The odds of having anxiety were higher for students without myopia than those with myopia (AOR = 1.263; 95% CI: 1.042–1.530). Students with impairment were 1.321 times more likely to suffer from anxiety than those without it (AOR = 1.321, 95% CI: 1.064–1.641). University students who always consumed high-fat foods had a higher prevalence of anxiety than those who never did (AOR = 1.993, 95% CI: 1.165–3.408, **Table 5**).

Factors Associated With Stress Amongst University Students

Following the univariate analysis, factors that had a significant effect on stress were selected for a multifactorial analysis. The results showed that myopia, the presence of impairment, high fatty-food intake, complain of depression and anxiety were significantly associated with complain of stress. Students with no myopia suffered from anxiety 1.3 times more often than those with myopia (AOR = 1.305; 95% CI: 1.022–1.667). Impaired students were more likely to suffer from anxiety than the non-impaired ones (AOR = 1.305, 95% CI: 1.012–1.683). The prevalence of complain of anxiety was higher in university students who always consumed high-fat foods than in those who never did (AOR = 1.285, 95% CI: 1.211–4.312, **Table 6**).

TABLE 4 | Factors related to complains of depression of university students.

Factors	Independent variables	DASS-D		*p*	AOR (95% CI)
		Yes	No		
Gender	Male	598	1,391		1
	Female	1,050	2,993	0.006	0.781 (0.655∼0.931)
Grade	Freshman	540	1,754	<0.001	1
	Sophomore	456	1,161	<0.001	1.458 (1.185∼1.795)
	Junior	463	1,070	<0.001	1.706 (1.384∼2.104)
	Senior	189	399	<0.001	2.210 (1.657∼2.947)
Father's education level	Primary school and below	430	931	0.01	1
	Junior high school or vocational high school	638	1,770	0.003	0.728 (0.590∼0.899)
	High school or junior college	317	919	0.002	0.676 (0.528∼0.866)
	Specialty	146	372	0.059	0.734 (0.532∼1.012)
	Bachelor's degree and above	117	392	0.016	0.656 (0.466∼0.923)
Carbonated drinks	Never	358	1,303	0.003	1
	Hardly ever	558	1,686	0.871	1.018 (0.820∼1.264)
	Sometimes	568	1,169	0.002	1.432 (1.140∼1.798)
	Often	121	166	0.144	1.348 (0.903∼2.014)
	Always	43	60	0.077	1.772 (0.940∼3.338)
Sugar	Never	135	588	0.049	1
	Hardly ever	341	988	0.007	1.561 (1.132∼2.152)
	Sometimes	806	1,958	0.005	1.529 (1.137∼2.057)
	Often	255	595	0.013	1.557 (1.100∼2.205)
	Always	111	255	0.02	1.671 (1.083∼2.577)
Stress	No	1,018	4,290		1
	Yes	630	94	<0.001	7.147 (5.487∼9.311)
Anxiety	No	244	3,773		1
	Yes	1,404	611	<0.001	23.417 (19.706∼27.826)
	Constants			<0.001	0.047

DASS-D, Depression Anxiety Stress Scalees-Dpression; AOR, Adjusted odds ratio; CI, Confidence interval.

TABLE 5 | Factors related to complain of anxiety of university students.

Factors	Independent variables	DASS-A		*p*	AOR (95% CI)
		Yes	No		
Myopia	Yes	1,642	3,174		1
	No	373	843	0.017	1.263 (1.042∼1.530)
Injury	No	1,695	3,545		1
	Yes	320	472	0.012	1.321 (1.064∼1.641)
High fat category	Never	279	840	<0.001	1
	Hardly ever	569	1,326	0.048	1.262 (1.002∼1.589)
	Sometimes	927	1,549	<0.001	1.556 (1.251∼1.937)
	Often	174	233	0.001	1.807 (1.285∼2.541)
	Always	66	69	0.012	1.993 (1.165∼3.408)
Stress	No	1,337	3,971		1
	Yes	678	46	<0.001	1.824 (1.080∼18.114)
Depression	No	611	3,773		1
	Yes	1,404	244	<0.001	1.537 (1.032∼26.687)
	Constants			<0.001	0.074

DASS-A, Depression Anxiety Stress Scalees-Anxiety; AOR, Adjusted odds ratio; CI, Confidence interval.

TABLE 6 | Factors related to complains of stress of university students.

Factors	Independent variables	DASS-S		*p*	AOR (95% CI)
		Yes	No		
Myopia	Yes	601	4,215		1
	No	123	1,093	0.033	1.305 (1.022∼1.667)
Injury	No	595	4,645		1
	Yes	129	663	0.04	1.305 (1.012∼1.683)
High fat category	Never	102	1,017	0.011	1
	Hardly ever	187	1,708	0.541	1.901 (1.645∼1.259)
	Sometimes	316	2,160	0.73	1.944 (1.683∼1.307)
	Often	79	328	0.155	1.372 (1.887∼2.121)
	Always	40	95	0.011	1.285 (1.211∼4.312)
Anxiety	No	46	3,971		1
	Yes	678	1,337	<0.001	1.842 (1.125∼18.074)
Depression	No	94	4,290		1
	Yes	630	1,018	<0.001	1.432 (1.720∼9.656)
	Constants			<0.001	0.008

DASS-A, Depression Anxiety Stress Scalees-Stress; AOR, Adjusted odds ratio; CI, Confidence interval.

DISCUSSION

The DASS-21 questionnaire, although it cannot be considered as a diagnostic tool for psychological disorders, is useful to determine the prevalence of complains of anxiety, depression, and stress.

We found a high prevalence of complains of depression (34.5%), anxiety (33.4%), and stress (12%) in our population. In this survey, a high percentage (62.2%) of the university students had no complains of depression, anxiety, or stress, whilst a low percentage had moderate to severe complains. Compared with other studies (Ramón-Arbués et al., 2020), the present study showed a good overall psychological distress amongst the university students. The commonest mental health problems amongst university students were negative emotional problems (Pedrelli et al., 2015).

Studies of a diverse sample of undergraduate student populations across the globe have also found moderately high rates of mental health problems in this group (Beiter et al., 2015; Bahhawi et al., 2018). The combination of high prevalence of mental health problems and early onset of mental health problems provides particular importance in assessing and addressing mental health problems among undergraduate students. Therefore, focusing on early mental health problems

among undergraduate students may also have broad benefits for campus health services and mental health policy development (Beiter et al., 2015).

Studies worldwide have reported differences in the prevalence of psychological distress among university students. Anxiety, depression, and stress are common amongst adolescents and more common in girls than in boys (Wiklund et al., 2012). In the present survey, girls had fewer mental health problems than boys. The author suggests that the higher rate of impairment amongst males than females is one possible reason for the difference in mental health problems between the two. Students who do not live-in halls of residence are more likely to be depressed than those who do. The reason is that living in halls of residence is more connected to peers, thus reflecting the importance of social interaction and peer support in reducing depression (Werner-Seidler et al., 2017). One study also found a significant relationship between myopia and anxiety levels (Li et al., 2020).

In the present survey, complain of anxiety (33.4%) were found to be high in the university student population. The results are consistent with those in previous research conducted amongst general university students. For instance, Blanco et al. (2008) found that the most prevalent mental health problem amongst university students was anxiety.

In addition, this survey showed that students with myopia have higher levels of complain of anxiety and stress, are more likely to sit still for longer periods of time and feel more eyestrain than students without myopia (Li et al., 2018). Meanwhile, the depression levels of students in their fourth year were higher than those in the first year. In addition, senior students are a special population. They are in a critical period of transition between school and society and must make numerous and important decisions that affect their education, lives, and future careers. They may face a variety of negative life events during this critical stage, including changes in their daily lives, problems with relationships, academic difficulties, financial pressures, and the struggle to make important decisions (Zhou et al., 2012). Many issues make senior students more prone to depression than others.

With China's rapid economic development, the number of children/adolescents with obesity or those who are overweight is increasing and this problem influences their psychological wellbeing (Wang et al., 2019). The high rates of depression and anxiety with high BMI in the present survey suggested that the psychological changes in university students should be considered whilst strengthening interventions for their physical activity. Students with low annual per capita family income were significantly more depressed, family income was positively correlated with individual subjective wellbeing (Hall and Jones, 2007) and the financial stress felt by university students was negatively correlated with their subjective wellbeing (Robb, 2017). Parental education also influenced students' mental health to some extent, with more educated parents being able to better understand their children's health behavior and more willing to spend time with them (Lund et al., 2019).

A prospective study found a possible additional dose–response relationship between physical activity and depression (Dunn et al., 2001). The conclusion that physical inactivity is a risk factor for the progression of depression is supported by much evidence from longitudinal observational studies and intervention studies (Pinto Pereira et al., 2014). A significant association was found between depressive symptoms and physical activity and sedentary behavior (Kandola et al., 2020). A review revealed that the beneficial effects of physical activity in patients with depression are compared with those achieved through antidepressants and psychotherapy (Stubbs et al., 2018). Therefore, improving physical activity levels is a priority for maintaining not only physical health but also psychological health.

Regression models suggest that complain of depression, anxiety, and stress are mutual risk factors. Physiological or psychological stress could alter neuroplasticity in the brain whilst increasing the risk of depression and anxiety (Fan et al., 2019). As the three psychological states in the present study are risk factors for one another, psychological complains are possibly confounded with one another and no strict demarcation of boundaries existed; "if you have one symptom, you are likely to have the other as well" (Marshall, 2020).

Physical-activity-related injuries have psychological health effects. In addition, advances in sports medicine have reduced the mean time required for physical resume after PARIs. However, quick physical recovery may not provide ample time for mentality recovery. Meanwhile, poor eating habits, for example, are not necessarily causally related to mental health status. A strong correlation may exist between these covariates and the mental health status amongst Chinese university students. Studies showed that adults with depressive symptoms binge eat more frequently and are less physically active each day than adults without depressive symptoms (Goldschmidt et al., 2014). Symptoms of depression, stress, and anxiety by themselves, without necessarily meeting the full diagnostic threshold for depression, anxiety, and stress disorders, are sufficient to influence health behavioral practices. Individuals with increased psychological symptoms experience more negative emotions and may engage in poor health behaviors in an attempt to reduce distress and/or mitigate the effects of negative emotions (Halperin et al., 2010). All university students, regardless of their psychological state, are likely to be equally susceptible to the effects of their psychological state on health behavior, indicating that maintaining a good psychological state is important for these students.

The innovation of this study is that, firstly, the survey deals with the psychological condition of university students, explores the factors affecting their psychological status including complain of depression, anxiety, stress, paving the way for research related to the mental health of university students.

Secondly, the study had a large sample size and the preliminary literature review provides a good basis for conducting the questionnaire at a later stage. Finally, the method of having student self-reporting is the most practical and cost-effective method at the national level.

However, there are limitations to the study, firstly, there may be recall bias or reporting bias using self-reported questionnaires, particularly in terms of the number of injuries sustained in the past 12 months, and students may not be reporting the most accurate information. Secondly, this study has a cross-sectional design and causal relationships could not be determined. Thus, the diagnosis of psychological symptoms requires other instruments to be formalized. Finally, this study only included university students from rehabilitation-related disciplines nationwide. Future investigations in the areas of depression, anxiety, stress, and other psychological conditions ought to attempt to address these restrictions. Since our research was conducted during COVID-19, we did not consider COVID-19 as a potential risk and analyze its impact on students.

At all events, the findings suggested the necessity to protect and promote the mental health and wellbeing of university students (where applicable).

CONCLUSION

In this survey, complain of depression, anxiety and stress were more common; complain of anxiety were more severe than the other two. In some cases, these complains coexist. In addition, the factors associated with these complains were explored. Gender, myopia, impairment, father's education, fresh vegetables, high-fat foods, and sugar intake were all closely related to psychological distress amongst university students. The findings could contribute to the prophase intervention of psychological disturbances in the university student population, thereby promoting psychological health and wellbeing in this population.

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.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee of The Sixth Hospital of Sun Yat-sen University (IEC Ref: E2020035). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

YW and YY designed and planned the study. YY acquired and analyzed the data. YY, WY, and JY drafted the manuscript. WY and YX polished and edited the manuscript. YW and DW supervised the whole study. All authors contributed to the concept and design of the study and read and approved the final manuscript for publication.

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Correlation of Motor Competence and Social-Emotional Wellbeing in Preschool Children

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Introduction: The relations of motor skills to different developmental domains, i.e., cognitive, emotional, and social domain, are well-documented in research on children with poor motor competence and children with disabilities. Less conclusive evidence on interaction of motor and social or emotional development can be seen in research on typically developing children. The purpose of this study was to determine a correlation between motor skills and social-emotional functioning in typically developing preschool children and to identify differences in social-emotional functioning in children with different levels of motor competence.

Methods: A total of 125 preschool children (67 boys, 58 girls, average age 5.1 years) participated in this study. To assess children's motor skills, we used the Test of Gross Motor Development–Second Edition that measures locomotor and object-control skills. To screen child's social and emotional functioning, we used the Ages and Stages Questionnaire–Social Emotional: Second Edition. Spearman's correlation analysis was used to determine association between motor skills and social-emotional functioning. Difference in social-emotional functioning between groups of preschool children with High and Low motor competences was calculated using Mann-Whitney *U*-test.

Results: The main result of this study is weak correlation of child's motor skills to social-emotional functioning. Furthermore, preschool children with High and Low motor competences do not differ in risk for social and emotional difficulties.

Conclusion: Further research on typically developing children is needed to have more conclusive evidence on interaction of motor and social or emotional development.

Keywords: skill, development, association, proficiency, movement

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INTRODUCTION

Motor competence is defined as the degree of proficiency of an individual in performing different motor skills (Bardid et al., 2021). Motor competence is positively associated with health-related physical fitness and may help enhance the development of long-term health outcomes in children and adolescents (Cattuzzo et al., 2016). Children with higher motor competence have a lower risk of having body fatness and higher oxygen uptake in future (Lima et al., 2017). Children with negative or reduced positive changes in fitness and motor competence during childhood are at higher risk of being overweight or obese (Rodrigues et al., 2016). A large proportion of children are not able to

perform locomotor and object-control skills with proficiency expected for their developmental level (Eather et al., 2018). It is believed that the level of motor skills is a very important and underrated part of the causal mechanism responsible for adult health risk behaviors and physical inactivity (Stodden et al., 2008).

Motor skills can be developed in positive environment combining structured and unstructured physical activities (Dapp et al., 2021). Children with higher level of motor skills tend to be more active and engage in more physical activity than those with poorer motor skills (Williams et al., 2008). In recent studies, there is clear evidence of decline in physical activity every year of child's life from early childhood onward (Farooq et al., 2020). Reduced physical activity may put skill development, physical fitness, and health at risk.

Emergence of each motor skill lays the foundation for development since it enables new opportunities for learning. With postural control, children can reach and see new parts of the environment; with locomotor skills, they can access new places; and with object-control skills, they can interact with different objects and enhance opportunities for social interaction (Adolph and Hoch, 2020). Thus, adequate motor skills are considered important for child's overall development, i.e., physical, cognitive, and social-emotional development (Kuzik et al., 2020).

Socio-emotional development in children occurs most often in a predictable order (Cicchetti et al., 1995; Freeman et al., 2014; Martoccio et al., 2014). Recent theories regarding the correlation between emotions and behavior emphasize the fact that the way an individual behaves socially is influenced by emotional experience and expectation because emotion constitutes the primary motivational component for mental and physical action and behavior (Izard, 2009).

The emotional and social wellbeing of preschool children refers to the way they think and feel about themselves and other people. It also comprises the capacity to adapt to daily tasks and issues while maintaining a happy and satisfying life growing up. Within emotional and social development, we must observe the following developmental characteristics and processes: temperament, emotional development in expressing one's own and understanding other people's emotions, development of attachment, socio-cognitive development in understanding the concept of self and understanding relationships with others, development of self-regulation, and development of sociability (Starc et al., 2004). The emergence of these socio-emotional skills helps children feel more confident and competent in developing relationships, building friendships, resolving conflicts, persisting when faced with challenges, coping with anger and frustrations, and managing emotions (National Research Council, 2000). A child who is able to establish a relationship with others and is motivated to learn will experience success in school and life.

Emotional development results in the ability to regulate one's emotions and the impact of emotions on behavior. Children learn through interaction with environment on how to modify and regulate emotions, deal with frustration, encounter danger, and experience fear and anxiety, and as a result, they become successful in interpersonal functioning (LaFreniere, 2000). Good social and emotional functioning provides a solid basis for good adaptation in school, which, in turn, reinforces the child's sense of belonging, thus correlating with the positive affect, academic self-efficacy, and academic achievement (Nix et al., 2013).

Motor, social-emotional, and cognitive functioning are connected at the neurophysiological level (Cheung et al., 2021). The neural pathways in the central nervous system for motor, social-emotional, and cognitive development overlap and work simultaneously. Regulation of these systems happens through overlapping neural networks in the prefrontal cortex and cerebellum in behavior adjustment (Cheung et al., 2021). Nevertheless, performed movements, manifested motor skills, and how they relate to physical, emotional, social, and cognitive skills are still poorly understood. Some researchers even criticize that the relationship of motor skills and emotional factors such as anxiety is examined more on intuition and clinical experience rather than through systematic research (Piek et al., 2010). Some have well-documented on the relationships of motor skills and different developmental domains, i.e., cognitive, emotional, and social domain, in children with autism spectrum disorders (for review, refer to Ohara et al., 2019), children with developmental disabilities (e.g., specific learning disorder, speech/language impairment, and intellectual disability) (Kim et al., 2016; MacDonald et al., 2017; Cheung et al., 2021), or children with developmental coordination disorder (Emck et al., 2009; Lee et al., 2020). Less conclusive evidence on interaction of motor and social or emotional development can be seen in research on typically developing children. The primary purpose of this study was to determine a correlation between motor skills and social-emotional functioning in typically developing preschool children. The secondary purpose was to determine differences in social-emotional functioning in children with different levels of motor competence.

MATERIALS AND METHODS

This research is a part of a national, population-based study on physical activity and motor skills in preschool children (Vukelja et al., 2022). In capital city region, three kindergartens were randomly invited to participate in additional social-emotional screening. The measurements were conducted in two visits to kindergarten during 2 months period. At first visit, parents signed informed consent and filled the questionnaires. At second visit, children's motor skills were evaluated.

A total of 125 children (67 boys and 58 girls, average age 5.1 years) aged between 5 and 6 years (preschool groups) from public kindergarten participated in this study. Child was included in this study if parent signed the informed consent. All study procedures were approved by the institutional ethical committee (reference number 2014-100). Children were divided into two subgroups based on their level of motor skill, according to the manufacturer's normative values (Ulrich, 2000): children with gross motor quotient score 89 and below were placed to group Low motor competence ($N = 37$), and children with value 90 and above were placed to group High motor competence ($N = 88$). Sample size for a Spearman's correlation was determined by using power analysis. The power analysis was conducted (G*Power

version 3.1.9.6, Universitat Kiel, Germany) using a two-tailed test, with an alpha of 0.05, a power of 0.80, and a medium effect size of 0.3. As Spearman's rank correlation coefficient is computationally identical to Pearson's product-moment coefficient, the power analysis was conducted using software for estimating power of a Pearson's correlation. Based on the aforementioned assumptions, the required sample size was determined to be 67.

We used the Ages and Stages Questionnaire: Social Emotional: Second Edition (ASQSE) to screen child's social and emotional functioning (Squires et al., 2015). Parents filled the questionnaires based on their child's social and emotional behavior in everyday activities. This set of questionnaires assesses functioning and risk based on seven key domains, namely, self-regulation, compliance, adaptive functioning, autonomy, affect, social-communication, and interaction (subdomains include interaction with adults and interaction with peers). Social-emotional components are assessed through partial and overall score that represents the risk: the higher the score, the greater the risk of social-emotional functioning and need for further evaluation and additional follow-up actions. ASQSE was adapted in Croatian language (Masnjak et al., 2016). Reliability of ASQSE is 0.89, the internal validity is 0.84, validity is 0.83, sensitivity is 0.81, and specificity is 0.83 (Squires et al., 2015). Scores are calculated for each of seven domains, two subdomains for interaction with adults and peers and as overall social-emotional score (ASQSE score).

The Test of Gross Motor Development–Second Edition (TGMD2) was used to assess children's motor skills. TGMD2 was found valid and reliable for use in children aged 3–10 years (Ulrich, 2000). TGMD2 consists of twelve tests, which are divided into two groups of locomotor and manipulative skills. Locomotor tests evaluate running, galloping, hopping, leaping, side-sliding, and jumping for distance. Manipulative tests evaluate efficiency in baseball striking, dribbling, ball catching, kicking, overhead throwing, and underarm rolling. This test showed high-reliability characteristics (Cronbach's alpha: 0.82–0.94) (Ulrich, 2000). Testing was conducted using the same measurs, with warm-up procedure of 5 min running in circle followed by 2-min dynamic stretching. Each child performed one familiarization trial and two test trials. Movements were recorded and analyzed retrospectively. Each skill is scored, and the raw scores are summed into locomotor and manipulative raw skill score. Raw skill scores are standardized according to age and gender into three variables, namely, standardized locomotor (TGMD2 LOC), manipulative (TGMD2 MAN), and overall motor score or gross motor quotient (TGMD QUOTIENT).

A statistical analysis of study data was carried out using IBM SPSS Statistics for Windows (version 24.0, IBM Corp., Armonk, NY, United States). The Kolmogorov-Smirnov test (KS) was used to check the normality of distribution. All KS values were significant ($p < 0.01$), with ASQSE score being 0.14, self-regulation 0.16, compliance 0.43, adaptive functioning 0.34, autonomy 0.23, affect 0.28, social communication 0.36, interaction with adults 0.25, and interaction with peers 0.30. Since the data were not distributed normally in socio-emotional variables, Spearman's correlation analysis was used to determine association between motor competence and social-emotional functioning. Based on the work by Dancey and Reidy (2007), Spearman's correlation coefficients are classified as follows: weak 0.10, moderate 0.40, and strong 0.70. Difference in social-emotional functioning between preschool children with high vs. low level of motor competence was calculated using Mann-Whitney *U*-test. A level of statistical significance was set at $p < 0.05$.

RESULTS

Mean values and standard deviation of socio-emotional and motor competence variables are presented in **Table 1**.

Table 2 presents correlations between the motor competence and social-emotional functioning scores. Results show weak correlations between all variables. A weak significant correlation was found between social interaction and child's overall ($r_s = 0.19$) and locomotor ($r_s = 0.21$) skills ($p < 0.05$). When children were divided into High and Low motor competence groups based on

TABLE 1 | Mean values and standard deviation of motor competence and socio-emotional variables.

	Mean	Std. Dev.
ASQSE score	39.34	27.11
Self-regulation	15.04	10.07
Compliance	1.92	3.22
Adaptive functioning	4.12	7.10
Autonomy	5.40	4.94
Affect	3.84	4.72
Social communication	3.28	3.83
Social interaction	6.60	6.97
Social interaction with adults	3.84	4.92
Social interaction with peers	1.80	3.88
TGMD2 LOC	10.32	2.11
TGMD2 MAN	7.90	1.93
TGMD QUOTIENT	94.60	9.58

Mean, Arithmetic mean; Std. Dev, standard deviation; ASQSE score, overall social-emotional score; TGMD2 LOC, standardized locomotor score; TGMD2 MAN, standardized manipulative score; TGMD QUOTIENT, overall motor score.

TABLE 2 | Spearman's correlation coefficients of TGMD2 scores and ASQSE score and ASQSE subdimensions.

	TGMD2 LOC	TGMD2 MAN	TGMD QUOTIENT
ASQSE score	0.07	0.06	0.04
Self-regulation	0.15	−0.04	0.04
Compliance	0.05	−0.09	−0.07
Adaptive functioning	0.03	0.08	0.05
Autonomy	−0.12	0.04	−0.07
Affect	0.08	0.09	0.10
Social communication	0.19*	0.14	0.21*
Social interaction	0.07	0.08	0.07
Social interaction with adults	0.14	0.03	0.10
Social interaction with peers	−0.07	0.06	−0.04

**Significant at $p < 0.05$.*

TABLE 3 | Mann-Whitney *U*-test in ASQSE variables of high and low motor competence group of preschool children

		Mean Rank	Sum of Ranks	Mann-Whitney *U*	*p*-value
ASQSE score	Low	60.46	2237.00	1534.00	0.61
	High	64.07	5638.00		
Self-regulation	Low	60.00	2220.00	1517.00	0.54
	High	64.26	5655.00		
Compliance	Low	66.03	2443.00	1516.00	0.45
	High	61.73	5432.00		
Adaptive functioning	Low	61.45	2273.50	1570.50	0.72
	High	63.65	5601.50		
Autonomy	Low	66.84	2473.00	1486.00	0.42
	High	61.39	5402.00		
Affect	Low	60.50	2238.50	1535.50	0.59
	High	64.05	5636.50		
Social communication	Low	54.00	1998.00	1295.00	0.04*
	High	66.78	5877.00		
Social interaction	Low	59.95	2218.00	1515.00	0.52
	High	64.28	5657.00		
Social interaction with adults	Low	61.07	2259.50	1556.50	0.67
	High	63.81	5615.50		
Social interaction with peers	Low	64.38	2382.00	1577.00	0.72
	High	62.42	5493.00		

**Significant at $p < 0.05$.*

their overall motor score, the Mann-Whitney *U*-test did not show significant differences in ASQSE variables (**Table 3**).

DISCUSSION

The main result of this study is weak correlation of child's motor skills with social-emotional functioning. Furthermore, preschool children with high and low motor competences do not differ in risk for social and emotional difficulties.

Previous research studies on relation of motor skills and other development areas such as social, emotional, cognitive, and speech are dominantly related to children with developmental difficulties and disorders. Piek and associates in a series of paper found motor skill competence was linked to cognitive, social, and emotional functioning (Skinner and Piek, 2001; Piek et al., 2006; Piek et al., 2008). In children with developmental coordination disorder, small-to-moderate correlation was found between motor coordination skills and emotional and behavioral difficulties (Emck et al., 2009; Lee et al., 2020) and moderate correlation between motor coordination skills and anxiety and depression (Piek et al., 2008). In addition, motor skills were found to be related to cognitive skills in children with developmental coordination disorder (Asonitou et al., 2010) and to social and speech skills (Hsu et al., 2004) and adaptive social and communication skills in children with autism (MacDonald et al., 2013). In our study, we found significant but low correlation between overall and locomotor skills and social functioning. Nevertheless, there are some inconsistent findings within population of children with disabilities. Fine motor skills, but not gross motor skills, were related to cognitive and social skills in pre-kindergarten children with developmental disabilities (Kim et al., 2016), and motor skills were related to socialization, communication, and daily living skills in young male, but not female, children with developmental disabilities (MacDonald et al., 2017). On the contrary, we found no significant correlation of interaction with adults or peers and motor skills and weak correlation of communication with motor skills. In a review on association between motor skills and social skills in children with autism spectrum disorders (Ohara et al., 2019), 75% of analyzed studies reported association between overall motor skill scores and social skills. Two of these studies reported that, as compared with gross motor skills, fine motor skills tended to have stronger correlations with social skills. One study reported that fine motor skills were significantly related to adaptive social and communication skills, but no significant correlations between social skills and gross motor skills (MacDonald et al., 2013). In this study, there were low correlations of gross motor skills with social skills. Among fine motor skills, manual dexterity tended to relate most to social skills (Ohara et al., 2019). Fine motor skills and manual dexterity were not measured in our study, while correlation of object-control skills with social skills was small. Not all studies in children with disabilities show consistent relations; one that included children with autism showed motor skills are not related to social interaction (Dadgar et al., 2017). In our study on typically developing preschool children, motor skills were not related to social interaction with adults or peers. Furthermore, in the study by Ecevit and Şahin (2021) on typically developing preschool children, no relevant correlations were found between their motor and social skills. In our study, the difference in communication skills found in comparison of children with high vs. low motor competences suggests that children with high motor competence might prefer body movements to verbal communication. Based on our results, we cannot be conclusive on the interdependence of motor skills and communication and interaction skills of a child.

Although the relationship between different developmental domains shows relatively high level of consistency in children with difficulties, research on typically developing children is lacking. Cheung et al. (2021) reported that both fine and gross motor skills contribute to social-emotional skills in younger and older children with disabilities and in older typically developing children. Also, motor skills of children were related to their academic performance. In children with and without developmental coordination disorder (Lee et al., 2020), correlation values of Movement Assessment Battery for Children test scores and problems in emotional functioning ranged from trivial to moderate, with the highest being depression ($r = -0.468$). The authors concluded that motor coordination difficulties in children cause peer relationship difficulties, mental health problems, and emotional problems such as depression and anxiety. In our study, weak insignificant correlation was found with motor skills and total social-emotional score of subdimensions of emotion, such as self-regulation, compliance, adaptive functioning, autonomy, and affect. Also, children with high and low motor competence did not have different risks

for emotional functioning in abovementioned areas. Previous research studies on relationships of motor skills and other developmental domains imply that children with poor motor competence are at greater risk of developing cognitive, speech, social, and emotional difficulties. In our study, children with low motor competence did not have higher risk of emotional or social problems. From the perspective of preschool teachers, this finding has positive result; if poorer motor skills in typically developing children are not related to emotional or social functioning, then developmental delay in one area potentially does not imply delay in other developmental areas. The weak correlation findings in our study may be due to different testing procedures focusing more on gross motor skill rather than fine motor skills and balance.

There is a lack of research on relationship between motor skills and social-emotional behavior in typically developing children and its findings are still contradictory. Researchers argue that focusing on the extreme end of the motor skill continuum might overestimate the relationship between constructs in the general population (Rigoli et al., 2012). More research on typically developing children is needed to have more conclusive evidence on interaction of motor skills and social or emotional development. Most of the correlation analyses were done using large variety of tests for motor competence and/or social-emotional skills. Regarding motor competence testing, there are more than forty different test batteries used around the world. Some of them focus on fine motor skills, other to coordination, and some on combined skill and motor abilities testing. For example, Movement Assessment Battery for Children–Second Edition (Movement ABC-2; Henderson et al., 2007) is constructed to identify, describe, and guide treatment of motor impairment and is composed of manual dexterity, manipulative skills, and balance testing. Bruininks-Oseretsky Test of Motor Proficiency–Second Edition (BOT-2; Bruininks and Bruininks, 2005) is a set of fine motor tests, coordination and balance, speed, agility, and strength, while Test of Gross Motor Development–Second Edition (Ulrich, 2000), which was used in this research, is composed of six locomotor (i.e., running, galloping, hopping, leaping, side-sliding, and jumping for distance) and six manipulative (i.e., baseball striking, dribbling, ball catching, kicking, overhead throwing, and underarm rolling) skills. Therefore, the use of different tests for motor competence and social-emotional functioning is the possible reason for differences in the correlation values.

Motor skills may potentially differ in the developmental trajectories through which cascading changes in social-emotional functioning can occur. Nevertheless, research on relationship between different developmental domains does not imply a causal inference. Randomized controlled trials including motor coordination exercises or sport participation appear to be effective in improving social and behavioral outcomes (Griffiths et al., 2010; Piek et al., 2015). There is a need for preschool-level intervention measures for children who face greater difficulty with movement. For typically developing children, holistic approach to development of motor, social, and emotional skills can be recommended. Common misconception is that motor skills appear in natural manner during early childhood. Compared with cognitive skills, for example, systematic motor skills development is sometimes neglected. Motor skills should be learned and practiced and equally valued as other skills in preschool educational settings. Teachers can apply traditional games and preschool activities in which all developmental domains are targeted and child-oriented approach is nurtured. Development of locomotor and object-control skills in early childhood may contribute to physical activity level later in future. There is consistent evidence that motor competence is associated with increased physical activity levels during the early childhood and adolescent years as well as long-term physical activity and motor skill performance (Loprinzi et al., 2015). Research show that children with higher level of object-control skills have up to 20% higher chance to being physically active in the adolescence (Barnett et al., 2009). Competence in object-control skills is considered a cornerstone of improved future physical activity and healthier lifestyles (Pienaar et al., 2021). Early childhood is the best time to develop motor skills, which will present foundation for lifelong physical activity. Within preschool environment, it is important to promote and organize activities to improve motor skills and everyday physical activity and healthy lifestyle behaviors. These could include a systematic sequence of development of basic motor skills that are organized through play in a way that encourages the social, emotional, and cognitive development of the child.

This study has limitations. Due to the lack of associations between children's motor and social-emotional skills in our population of children enrolled in kindergarten program (about 60% of all preschool children), we were unable to draw generalized conclusions to population of all preschool-aged children. Specific test batteries for motor skills and social-emotional functioning also contributed to differences in relative size and its significance. Further investigation on the relationship of motor skills and social-emotional functioning in typically developing preschool children is needed.

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 Scientifical and Ethical Board of Faculty of Kinesiology University of Zagreb. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

MM collected the data and participated in writing methods and introduction section. SS designed the research,

revised the manuscript, wrote introduction and discussion, analyzed the data, and wrote the manuscript with MM. Both authors have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

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Effect of Neuromuscular Training Program on Quality of Life After COVID-19 Lockdown Among Young Healthy Participants: A Randomized Controlled Trial

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Study in the period of coronavirus disease 2019 (COVID-19) lockdown and the effect of different exercise training programs on the quality of life (QoL) dimension are limited. This randomized control study as a part of which the impact of an 8-week neuromuscular training program on the 90 healthy young individuals' QoL after COVID-19 lockdown was assessed using a short form of the WHOQOL-BREF questionnaire comprising of four domains (physical health, psychological health, social relations, and the environment). The intervention group (NT) (n = 47) took part in a neuromuscular training program consisting of dynamic neuromuscular stabilization and whole-body vibration training. In contrast, the control group (CG) (n = 43) did not participate in any programmed physical activity. From pre- to post-intervention test, the NT group significantly and substantially improved [mean change (95% CI)] all the QoL domains, physical for 12.78 scores (8.89, 16.64), psychological for 13.12 scores (9.51, 16.74), social relationships for 20.57 scores (16.12, 25.02), and environmental for 24.40 scores (21.45, 27.35). These results suggest that the NT program could enhance QoL in young and healthy participants following COVID-19 lockdown.

Keywords: COVID-19, exercise, well-being, neuromuscular training, quality of life

INTRODUCTION

In an effort to curb coronavirus disease 2019 (COVID-19) spread, governments across the world have adopted different public health policies (Nussbaumer-Streit et al., 2020), some of which have had an adverse impact on mental health and quality of life (QoL) (Battaglia et al., 2016; Ku et al., 2016; Bernard et al., 2018; Delle Fave et al., 2018; Nawrocka and Polechoński, 2019; Brooks et al., 2020). Extant study on mental health in the context of COVID-19 epidemic and government-imposed restrictions on movement and social contact indicate that such policies

have had a detrimental effect on emotional and social functioning (Pfefferbaum and North, 2020) and mental health (Gunnell et al., 2020; Hossain et al., 2020), thus increasing the incidence of depression, anxiety, post-traumatic stress, anger, and confusion (Pieh et al., 2020), and risk of psychosocial strain (Ammar et al., 2021). Pandemics are also linked to a variety of sociopsychosocial stresses induced by quarantine and significant changes in daily routine, such as the limited potential for physical activity (PA) (Ammar et al., 2020; Carriedo et al., 2020; Maugeri et al., 2020; Pišot et al., 2020; Trabelsi et al., 2021; Schoofs et al., 2022). As during lockdown, PA levels decreased considerably in the most population groups (among young people in particular), the resulting lifestyle that exacerbated these mental and physical health issues (Yanovski et al., 2000; Altena et al., 2020; Clay and Parker, 2020; Jiménez-Pavón et al., 2020). COVID-19 confinement has made it difficult to comply with the WHO guidelines stipulating 150 min of moderate-to-mild PA per week or 75 min of intensive PA per week (World Health Organization, 2020). Consequently, given the well-established link between a low-level PA lifestyle and mental health and, thus, QoL, it is important to investigate if these adverse impacts can be reversed by a short-term training program.

Previous studies on this topic indicate that exercise and physical training have a significant positive impact on QoL (Spirduso and Cronin, 2001; de Vreede et al., 2007). Similarly, ample body of evidence confirms that different depression symptoms are inversely correlated with physical fitness (Galper et al., 2006; Tolmunen et al., 2006; Valtonen et al., 2009). More recently, Becofsky et al. (2015) reported that lack of fitness is more strongly linked to the risk of depression than being overweight.

Indirect and direct benefits of PA and exercise for physical health and overall well-being are well-known (Stathi et al., 2002; Lehnert et al., 2012). Nonetheless, in the last few decades, there has been a growing interest in the effects of exercise or PA interventions on mental health and QoL dimensions (Becofsky et al., 2015). The results obtained by Khosravi (2020) suggest that regular PA can help to minimize the risk of developing mental health issues (namely, depression, anxiety, and stress), while findings published by Sui et al. (2009) and Kandola et al. (2019) indicate that being physically active might help to avoid symptoms of depression. Following a randomized controlled experiment, Martin et al. (2009) similarly concluded that there was a substantial and positive association between the quantity of PA and improvements in physical and mental health measured *via* QoL parameters. When the benefits of a 24-week resistance training program were investigated by McLafferty et al. (2004), most participants reported significant improvements in overall mood and marked reduction in anger, confusion, and mental tension, after completing the experimental program. More recently, it was reported that the intervention group was more satisfied with their health and QoL compared to the controls with improvement in body weight and body mass index (BMI) and the authors posited that these benefits of exercise could have contributed to QoL improvements (Colak and Baskan, 2020). Askari et al. (2020) adopted aerobic exercise intervention with the multidimensional approach in addition to normal care and found that this intervention was beneficial in alleviating different categories of depression (physical, emotional, and cognitive), while improving the participants' psychological health and social interactions aspects of QoL. Several researchers have also explored the link between exercise intensity, type of exercise, and QoL domains. Low-intensity jogging, cycling, aerobic exercises, swimming, walking, and dancing have been shown to diminish depression and anxiety symptoms (Guszkowska, 2004). Stracciolini et al. (2020) and Su et al. (2021) similarly noted that participation in different sports activities can improve mental health and anxiety QoL scores. Moreover, findings from Slimani et al. (2020) study yielded that low-intensity PA can also help minimize the negative psychological effects of isolation. West et al. (2004) and Nguyen et al. (2021) concurred with this view and proposed alternative PA programs like Hatha yoga, unsupervised exercise, and African dancing as a means of improving psychological and mental health, suggesting that such activities should be promoted to enhance QoL.

As most of the aforementioned studies were conducted on samples drawn from the general population, it is important to investigate the link between PA and QoL in young and healthy individuals. As to the best of the authors' knowledge, the effects of complex neuromuscular training (NT) in this cohort have never been investigated, especially in the context of COVID-19 lockdown, these gaps are addressed in this study. Therefore, this study aimed to determine the effects of 8-week NT on four QoL dimensions in a group of untrained healthy young individuals after COVID-19 lockdown with the hypothesis that an 8-week intervention consisting of three NT exercise sessions per week should result in significant increases in psychological dimensions and QoL.

MATERIALS AND METHODS

Study Design and Procedures

This randomized control study evaluated the effects of an 8-week experimental training program on quality of life of faculty of sport and physical education students at the University of Novi Sad, Serbia. The initial and final evaluations were performed on the 2 days preceding and following the 2 months intervention period, respectively. Participants performed a 2-months neuromuscular training (NT) intervention program with dynamic neuromuscular stabilization (DNS) protocol and whole-body vibration training (WBVT), while the control group (CG) did not exercise or use any training intervention or other habitual training during 8 weeks. Experimental programs were valid when the participants finished at least 80% of all the training sessions. To guarantee the quality and correct execution of training protocols, professional coaches and researchers supervised all the training programs.

Participants

A gender-balanced group of 90 healthy young participants (age 24.02 $\pm$ 2.07 years; height 174.98 $\pm$ 8.98 cm; and weight 68.16 $\pm$ 12.28 kg) was enrolled in this study. Exclusion criteria

TABLE 1 | Characteristics of participants.

Variables	TOTAL (n = 90)	NT (n = 47)	CG (n = 43)
Gender (male/female)	45/45	24/23	21/22
Age(years)	23.94 ± 1.9	23.73 ± 2.05	24.16 ± 1.89
Weight (kg)	66.8 ± 12.0	67.41 ± 12.51	68.17 ± 11.63
Height (cm)	174.9 ± 8.98	174.92 ± 9.44	174.87 ± 8.39
BMI (kg/m^2)	22.0 ± 2.6	21.85 ± 2.44	22.18 ± 2.87

Data is presented as AM ± SD. AM, arithmetic mean; SD, standard deviation; NT, neuromuscular training group; CG, Control group.

were: (i) history of neurological or musculoskeletal disorders; (ii) clinical conditions that could impair balance; (iii) a regular PA practice during lockdown; and (iv) using drugs, alcohol, and other substances. The study sample was randomly divided into the NT group (n = 47) and the CG group (n = 43). At baseline no significant differences ($p > 0.05$) were found between the groups in age, height, weight, and BMI (**Table 1**). Each subject, after explanation of the experimental protocol, provided a written informed consent before participating in this study, in accordance with the Declaration of Helsinki and approved by the Novi Sad University Human Research Ethics Committee (ethical approval number: 234/2020). The flow diagram of participants through this study is given in **Figure 1**.

Measures

Quality of Life

In this study, QoL was assessed using the short form of the WHOQOL-BREF questionnaire (World Health Organization, 1998) comprising of 26 items pertaining to four domains: physical health, psychological health, social relations, and the environment. Each item was rated by the respondents on a five-point Likert scale (1—Not at all; 2—A little; 3—A moderate amount; 4—Very much; and 5—An extreme amount). As the WHOQOL-BREF reliability and validity have been confirmed in prior study (Kalfoss et al., 2021), it was adopted in this study without further evaluations or modifications.

Training Intervention

In Serbia, the first case of COVID-19-positive patient was reported on 6 March 2020 and national authorities declared a state of emergency on 15 March 2020 to keep people at home, minimizing physical contacts, namely, restrictions of closing universities, schools, fitness centers, sports facilities, parks, and entertainment centers. In different periods during March, April, and May, restrictions were applied by the official complete ban from leaving homes for all the age groups. According to the national lockdown strategy, most of the restrictions were finished by the end of May 2020 (Vuković et al., 2021) when the research training program was started.

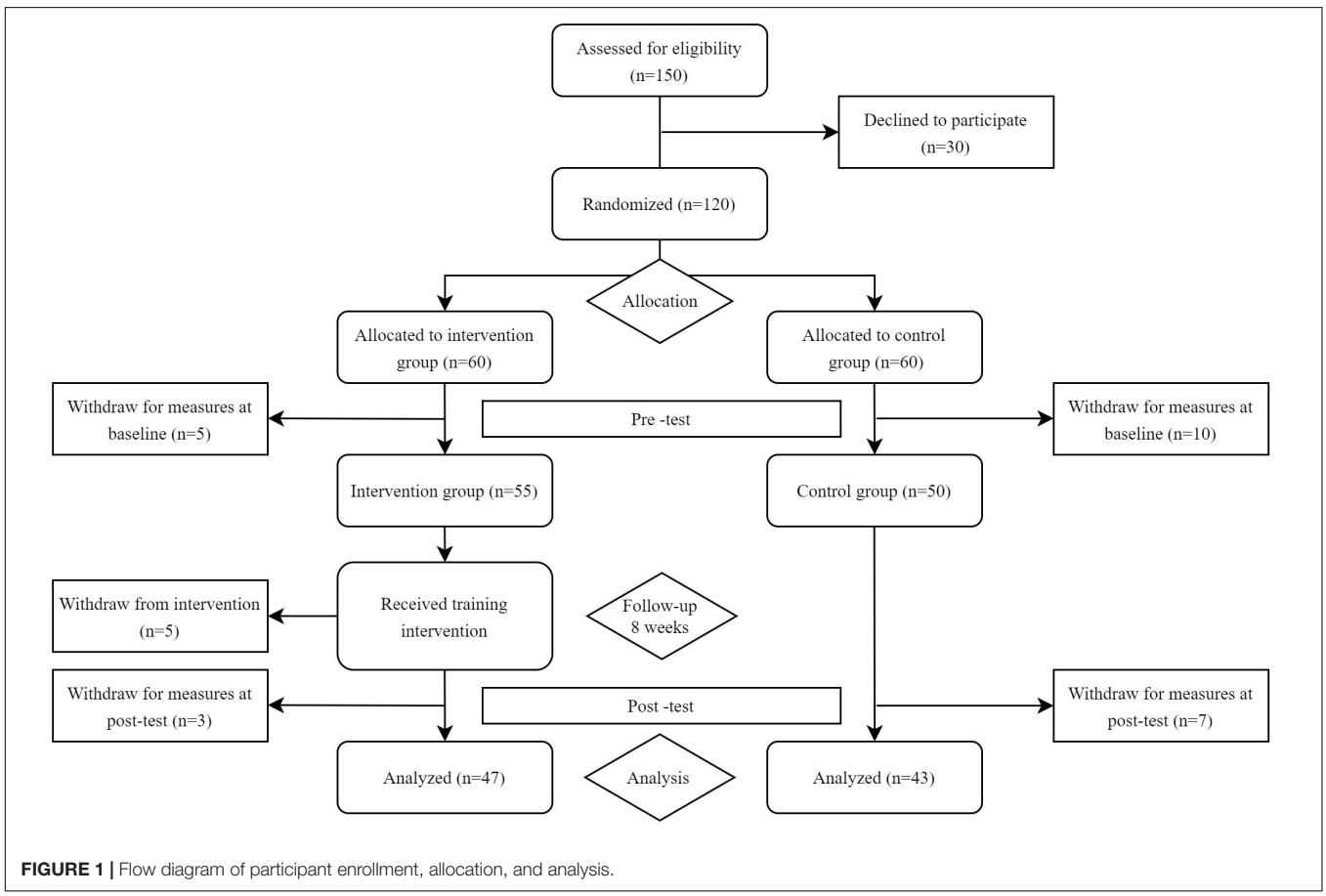

FIGURE 1 | Flow diagram of participant enrollment, allocation, and analysis.

During the 2 months, participants' training consisted of 3 weekly training sessions. The protocol consisted of a 50-min exercises program with a warm-up and cool-down period per training session. The structural core of training included 20 min of DNS training and a 20-min WBVT. Both protocols were designed in line with the previous research and training recommendations. Exercises in WBVT were performed on Power Plate Next Generation vibration platform (Power Plate North America, Chicago, Illinois, United States). The program consisted of 6–8 exercises (static and dynamic) for balance and postural stability (PS). Exercise progressively increases by the level of difficulty. During the training process, the frequency was also increased in range from 20 to 35 Hz in the last week of the experiment (1.8 Hz increase per week); duration of exercise ranged from 20 to 60 s (5 s increase per week) followed by 1-min seated rest. Resting periods between sets were constant from the start to the end of the training process. Basic principles and the procedures were adapted from previous research (Torvinen et al., 2002; Jordan et al., 2005; Fort et al., 2012; Piecha et al., 2014). WBVT followed by a 20-min period of DNS training including specific movement exercises according to the DNS approach accompanied by breathing exercises and in line with principles from previous studies (Frank et al., 2013; Mahdieh et al., 2020). To ensure that each exercise was executed correctly, participants were supervised by the coaches and the research team. The control group did not participate in any exercise, training, or sport-specific program during the 8-week experiment.

Data Analysis

G*power 3.1 power analysis software (Heinrich-Heine-University, Düsseldorf, Germany) determined the minimum total sample size ($n = 50$) given the critical $F = 4.04$, an effect size $f = 0.20$ (partial $\eta^2 = 0.04$), $p = 0.05$, $1 - \beta = 0.80$, groups and time points = 2, and correlation among the measurements = 0.50. Data are presented as mean and 95% CIs unless otherwise stated. A *t*-test for independent samples tested whether the baseline study outcomes differed among the groups. A 2 (pretest vs. post-test) × 2(NT vs. CG) mixed ANOVA model evaluated the 8-week effects of neuromuscular training on the QoL domains (physical, psychological, social relationships, and environmental). The Kolmogorov–Smirnov test confirmed normality of residuals, and the Levene's and Box's tests accepted the homogeneity of the variances and covariance matrices, respectively. We inspected whether mean changes (95% CI) from initial to final testing in each QoL domain significantly depended on whether subjects completed NT or not using a time*group interaction effect. Given a significant time*group interaction effect, the simple main effects of time followed (*post-hoc*) which tested the significance of mean changes [95% CI] from initial to final testing within the groups with a Bonferroni adjusted p values and 95% CIs. Partial eta squared (partial η^2) is reported as the effect size measure for the interaction effects and classified as small (0.01), moderate (0.06), and large (0.14) (Cohen, 2013). The Hedges's g_{av} with 95% CIs designated the size of simple main effect of time and interpreted as small (± 0.20), moderate (± 0.50), and large (± 0.8). The level of significance was set at $p \leq 0.05$. All the statistical analyses were performed with the SPSS statistical software (SPSS 23.0, IBM Incorporation, Chicago, Illinois, United States).

RESULTS

Baseline values of physical ($p = 0.47$), psychological ($p = 0.47$), social relationships ($p = 0.74$), and environmental ($p = 0.61$) QoL domains were similar across the groups (**Table 2**). Both the groups achieved, on average, similar levels of QoL.

The 8-week-mean changes of all the QoL domains significantly differed between the NT group and CG to a large extent [physical: $F_{(1,88)} = 16.19$, $p < 0.001$, partial $\eta^2 = 0.16$; psychological: $F_{(1,88)} = 32.21$, $p < 0.001$, partial $\eta^2 = 0.27$; social relationships: $F_{(1,88)} = 76.45$, $p < 0.001$, partial $\eta^2 = 0.47$; and environmental: $F_{(1,88)} = 151.57$, $p < 0.001$, partial $\eta^2 = 0.63$]. On average, the NT group significantly and substantially improved all QoL domains [mean change (95% CI)], physical for 12.78 scores (8.89, 16.64), psychological for 13.12 scores (9.51, 16.74), social relationships for 20.57 scores (16.12, 25.02), and environmental for 24.40 scores (21.45, 27.35). In CG, no significant mean changes, however, were observed in any QoL domains after 8 weeks ($p > 0.05$), except mean scores for social relationships QoL domain which significantly lowered for −7.75 scores (−12.40, −3.10) to a moderate extent. **Figure 2** illustrates the comparison of effect sizes for 8-week-mean changes within the groups and the space above the green line presents large improvements.

DISCUSSION

The purpose of this study focusing on a group of healthy young individuals was to determine the effects of 8-week NT administered after COVID-19 lockdown on all the four QoL dimensions. Baseline results confirmed previous studies that indicate a low level of mental and psychological domains in people during COVID-19 lockdowns (Bonichini and Tremolada, 2021; Epifanio et al., 2021; Ferreira et al., 2021). Analysis of their results and comparison with the control group revealed that participation in the NT program could lead to QoL enhancement in young healthy participants. These results also concur with the findings reported in extant literature focusing on the link between PA and QoL in the general population (Stracciolini et al., 2020; Su et al., 2021) and specifically during COVID-19 (Slimani et al., 2020).

TABLE 2 | Baseline values of outcomes for neuromuscular training (NT) group ($n = 47$) and control group (CG) ($n = 43$).

Outcomes	NT	CG
	Mean [95% CI]	Mean [95% CI]
Physical QoL (score)	49.16 [46.65, 51.68]	47.92 [45.61, 50.24]
Psychological QoL (score)	51.33 [48.89, 53.78]	50.10 [47.57, 52.62]
Social Relationship QoL (score)	52.31 [48.82, 55.79]	53.10 [49.79, 56.41]
Environmental QoL (score)	49.53 [47.38, 51.68]	50.29 [48.26, 52.32]

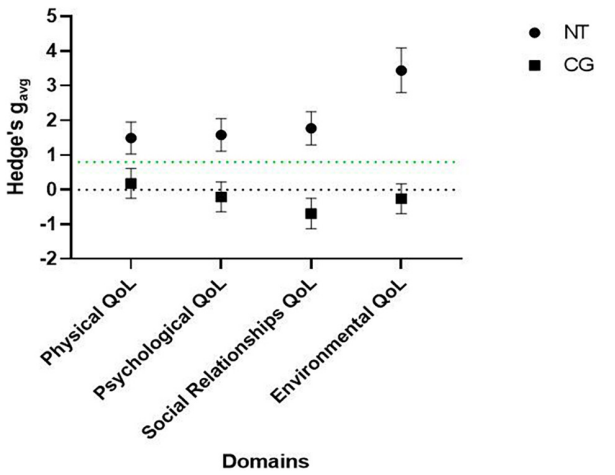

FIGURE 2 | Effect sizes with 95% CIs (Hedges's gav) for pre-post changes of Physical, Psychological, Social Relationships, Environmental QoL domains in the NT and CG.

Dynamic neuromuscular stabilization and vibration training present a multidimensional approach that combines different breathing, core strength, and stabilization exercises with specific exercises performed on a vibration platform. Even though they adopted a different methodology, both Prem et al. (2013) and Montoro et al. (2018) noted that diaphragmatic breathing exercise and vibration training could improve QoL in both the short term and long term. Similarly, Guszkowska (2004) and Slimani et al. (2020) observed that even moderate exercise (as was the case in our study) can lead to marked improvements in QoL.

In this respect, this study provides a modest contribution to the ongoing discussions about the side effects of COVID-19 lockdown on QoL and its specific domains, indicating that NT could lead to improvement in QoL parameters and minimal negative mental health consequences in circumstances similar to the pandemic. Given the well-established link between PA (whether as a part of an exercise program or a generally active lifestyle) and QoL dimensions, namely, physical health (Battaglia et al., 2016; Nawrocka et al., 2019) mental wellness and psychological well-being (Bernard et al., 2018; Trabelsi and Ammar, 2021), environmental domain (Valenti et al., 2008; Ku et al., 2016), and emotions (Delle Fave et al., 2018), it is reasonable to assume that PA would be beneficial following a prolonged period of physical inactivity, as was the case during COVID-19 lockdown. This hypothesis was supported in this study, as an 8-week intervention consisting of just three NT exercise sessions per week resulted in significant increases in psychological dimensions and QoL. Thus, we argue that incorporating NT programs into daily lifestyle would be essential to support mental health in all populations, especially among young people, to combat the adverse effects of lifestyle caused by COVID-19 lockdown or circumstances similar to the pandemic. Furthermore, varied exercise routines should be customized to the participant's fitness level, and a progressive strategy of intensity and workout volume should be used (Chtourou et al., 2020). In addition, main educational authorities should pay much more attention to providing enough knowledge and improving health literacy in conditions like COVID-19 lockdown (Geets Kesic et al., 2021).

When interpreting these findings, it is important to note some of the study limitations, including the relatively small sample size and the fact that the intervention was conducted after COVID-19 lockdown, during which all participants significantly reduced their PA levels. Nonetheless, as all our research subjects were young and healthy individuals, recruited from the same social setting, it is possible that the same intervention would yield different results in cohorts with different socioeconomic and demographic characteristics. Finally, we acknowledge that, since the participants were not asked to report on their activity levels outside of the study protocol, our results could be influenced by variations in their daily routine. However, those activities were not included organized, systematic, and planned PA. Therefore, including accelerometer, mobile application or wearable sensors in future studies would clarify the intervention-induced effects.

CONCLUSION

This study aimed to determine the effects of 8-week NT on four QoL dimensions in a group of untrained healthy young individuals after COVID-19 lockdown. Our findings indicate that, due to the beneficial effects of our intervention on all four QoL domains, the NT and different PAs should be considered for inclusion in public health policy to lessen the adverse effects of lockdown or situation similar to the pandemic.

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 Ethics Committee of the Faculty of Sport and Physical Education, University of Novi Sad Human Research Ethics Committee guidelines (ethical approval number: 234/2020). The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

DMar and DMac: conceptualization, editing, and revision. DMac, DK, and DJ: methodology. DMad and GS: validation. DMac: formal analysis. DM and MS: investigation. DM and DK: writing—original draft preparation. ZG, DJ, VP, and AP: writing—review and editing. DM, GS, and DMad: supervision. ZG and DM: revision and correction of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Individual Dispositions and Situational Stressors in Competitive Sport: The Role of Stress Mindset in the Cognitive Appraisals Processes

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Personality has widely been documented to play an important role in the cognitive appraisal and stress processes. Emerging studies highlight the stress mindset as a new concept that could add to the understanding of individual differences in stress experiences. This study aimed to examine the relative contribution of Big Five personality dimensions and stress mindset in accounting for measures of cognitive appraisals of stress among the competing athletes. The study was conducted on a sample of 125 collegiate athletes of both genders who actively compete in sport. All the participants were regular undergraduate or graduate students at the Faculty of Kinesiology of the University of Zagreb. A questionnaire including demographic information about athletes and their sport career, stress mindset measure (SMM), situation-specific cognitive appraisal scale, sources of stress scale, and personality scale measured by IPIP-50 was administered in an online form using the Google Forms platform. Multivariate hierarchical regression procedures resulted in somewhat different predictor structures accounting for cognitive appraisals of threat, loss, and challenge, used as criterion variables. The set of Big Five personality dimensions and stress mindset measure proved to have a significant additive contribution to the explanation of each of the three cognitive appraisal criterion variances. The study results support the current body of literature suggesting a unique role of the stress mindset construct in explaining individual differences in cognitive stress appraisal among athletes above and beyond general personality dimensions.

Keywords: stress, cognitive appraisals, personality dimensions, stress mindset, competitive sport

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INTRODUCTION

It is widely understood that experiencing stress can have both positive and negative effects on wellbeing in various aspects of one's life (Folkman and Moskowitz, 2000), sport being just one of them. It appears that due to the challenging and result-orientated nature of sport (McCarthy and Giges, 2017), stress is almost an inevitable experience among athletes, especially those that regularly compete (Scanlan et al., 1991). The effects of stress on athletes are, however, diverse. Stress can aid to athlete's determination and motivation (Fletcher et al., 2011), but it can also lead to burnout

(Gustafsson et al., 2011), overtraining (Meehan et al., 2004), and poor performance (Gould et al., 1999). Therefore, it is not surprising that appropriate ways of managing stress are necessary for experiencing success in sport (Hoar et al., 2006).

According to the dominant conceptual framework for the analysis of stress processes—transactional theory of stress and coping (Lazarus and Folkman, 1984, 1987; Lazarus, 2000, 2006), stress includes a transaction between the person and the situation that one finds challenging, as well as the judgment of personal resources for handling these challenges (Lazarus and Folkman, 1984, 1987). The theory introduced the concepts of cognitive appraisals as central processes connected to experiencing stress. Cognitive appraisal stands for the evaluation of the meaning the environmental factors have on one's wellbeing. There are two main types of appraisals, namely, primary and secondary appraisals. Primary appraisal relates to the assessment of the complexity of the situation and the meaning it has on one's wellbeing (Folkman, 1984, 2010). According to Lazarus and Folkman (1984), there are three types of primary appraisals—the situation can be assessed as irrelevant for an individual, benign-positive with a potential to enhance wellbeing, or stressful, that is, the situation presents a threat to wellbeing. The situation appraised as stressful can be related to the perception of harm/loss (the situation has already left damage to one's wellbeing), threat (the damage is possible), or challenge (the situation can lead to growth and development). The secondary appraisal is related to the evaluation of one's resources for dealing with the situation and the level of control over it that one possesses (Folkman, 1984).

It is worth pointing out the subjective and situational nature of cognitive appraisals. An objectively same situation can be appraised differently depending on one's resources and various psychological and social characteristics (Lazarus, 2006). Several personal (e.g., self-confidence and personality) and situational (e.g., the predictability and novelty of the situation) characteristics have typically been reported as important antecedents to cognitive appraisals. Research has found significant relationships between personality and cognitive appraisals. For instance, higher neuroticism was found to be associated with experiencing stress of higher intensity, lower perception of control over the stressors, and a higher chance of appraising stressful situations as threatening (Shewchuk et al., 1999; DeLongis and Holtzman, 2005; Kulenović and Buško, 2006; Semmer, 2006; Tong et al., 2006). On the contrary, conscientiousness, agreeableness, openness, and in part extraversion were reported to be associated with appraising situations as challenging, as well as with higher perception of control and available resources (Penley and Tomaka, 2002; Semmer, 2006; Schneider et al., 2012).

Stress mindset appeared in recent literature as a construct that could advance the understanding of stress experiences. It has been defined as the extent to which one believes that stress has enhancing ("stress-is-enhancing mindset") or debilitating consequences ("stress-is-debilitating mindset") in a range of life's areas (e.g., health, productivity; Crum et al., 2013). The authors suggest that our experiences of stressful events depend on whether we believe that stressful experiences are generally threatening or represent an opportunity for progress. Compared with situation-specific account of cognitive appraisal, stress mindset refers to the general view on stress. A person can evaluate an event as a stressful and threatening one (cognitive appraisal) but believe that positive outcomes are possible and the whole experience will make one stronger ("stress-is-enhancing mindset"; Crum et al., 2013, 2017). Thus, a stress-is-enhancing mindset seems to be linked to better cognitive flexibility when dealing with stressors and lower levels of cortisol (Crum et al., 2013). Kilby and Sherman (2016) found that in comparison with the ones holding stress-is-debilitating mindset, the ones holding stress-is-enhancing mindset more often appraise stressful events as a challenge. Recent studies have found that a stress-is-enhancing mindset is connected to experiencing stress less intensely among students (Keech et al., 2018) and police officers (Keech et al., 2020). Stress mindset has also been linked to depression, anxiety, and wellbeing (Jiang et al., 2019; Huebschmann and Sheets, 2020). There seems that a stress-is-enhancing mindset could potentially have a soothing effect, i.e., a positive effect on wellbeing when one is experiencing stress.

This research examines the relative contribution of personality dimensions and stress mindset in explaining stress appraisals in athletes. As mentioned before, sport represents a challenging environment, and athletes are regularly exposed to various organizational (e.g., leadership and quality of the environment in which they train), competitive (e.g., preparation and rivalry), and personal (e.g., balancing sport and private life) sources of stress (Wagstaff et al., 2019). Therefore, gaining insight into the relevant antecedents of stressful experiences in the sports setting seems to be conceptually and practically valuable. It is theoretically interesting and important to evidence whether this new concept of stress mindset plays a unique role in accounting for stress appraisals over and above well-known personality dimensions. Given the suggested nature of the stress mindset construct, eventual findings on its relevance in explaining athletes' stress experiences could then be useful in fostering more efficient stress management strategies.

METHODS

Participants

The participants were student athletes from the Faculty of Kinesiology, University of Zagreb. All participants were actively involved in sports at the time the research was conducted. The sample consisted of 125 students ($M = 22.31$ years, $SD = 2.27$, 32% female). In terms of the level of sport performance, 58 (46.4%) athletes in the sample participated in sport at the amateur level, 58 (46.4%) at the semi-professional level, and 9 (7.2%) at the professional level. The highest percentage (38.4%) of participants were involved in their sport for 6–10 years. Most participants (45.6%) trained every day of the week. Regarding the level of competition, 46 (36.8%) participants competed at the country level, 47 (37.6%) at the national level, and 18 (14.4%) at the international level, with 14 (11.2%) participants reported as not competing at the time of the data collection. Slightly less than half of the participants stated that they competed once a week in the past 6 months ($N = 61$; 48.8%).

TABLE 1 | Main descriptive statistics and intercorrelations of the study variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13
(1) Gender	–												
(2) Level of performance	0.10	–											
(3) Training frequency	0.04	0.69**	–										
(4) Competition frequency	0.10	−0.10	0.03	–									
(5) Extraversion	0.06	−0.01	0.04	0.03	–								
(6) Agreeableness	−0.39**	−0.06	0.03	0.06	0.06	–							
(7) Conscientiousness	−0.35**	−0.20*	−0.20*	−0.06	−0.05	0.27**	–						
(8) Emotional stability	−0.03	0.09	0.07	0.14	0.47**	0.08	0.16	–					
(9) Intellect	−0.10	−0.18*	−0.14	−0.09	0.13	0.11	0.29**	0.01	–				
(10) Stress mindset	−0.08	0.08	0.02	0.13	0.37**	0.12	−0.00	0.45**	−0.15	–			
(11) Cognitive appraisal of loos	0.03	0.04	−0.04	−0.10	−0.16	−0.13	−0.06	−0.47**	0.06	−0.43**	–		
(12) Cognitive appraisal of threat	−0.20*	0.07	0.10	0.01	−0.30**	0.13	−0.08	−0.39**	−0.08	−0.38**	0.58**	–	
(13) Cognitive appraisal of challenge	0.05	0.05	−0.06	0.18*	0.23**	0.06	0.13	0.23*	0.06	0.55**	−0.16	−0.17	–
M (SD)	–	–	–	–	35.22 (7.40)	40.22 (6.28)	37.78 (6.86)	36.21 (7.46)	38.25 (4.96)	15.34 (8.20)	4.14 (3.69)	6.10 (3.35)	6.14 (4.26)
Theoretical range	1–2	1–3	1–5	1–6	10–50	10–50	10–50	10–50	10–50	0–32	0–18	0–18	0–18
Total range	1–2	1–3	1–5	1–6	13–50	23–50	21–50	18–50	27–48	0–32	0–15	0–16	0–16
Cronbach's α	–	–	–	–	0.85	0.84	0.82	0.87	0.65	0.91	0.81	0.77	0.82
K–S	–	–	–	–	0.06	0.10**	0.07	0.07	0.08	0.10**	0.17**	0.13**	0.10**

*$p < 0.05$, **$p < 0.01$; gender codes: 1, females; 2, males; Level of performance codes: 1, professional; 2, half-professional; 3, amateur; K–S, Kolmogorov–Smirnov z-statistic.*

Measures

Stress Mindset Measure

The stress mindset measure (SMM; Crum et al., 2013) was used to assess participants' general way of thinking about stress. Participants were instructed to rate how strongly they agree with eight statements on a 5-point Likert type scale (0 "strongly disagree" to 4 "strongly agree"). The total score was computed as the sum of scores on all items, varying in the theoretical range from 0 to 32. A higher score on the scale indicates more enhancing beliefs about stress and a lower one indicates more debilitating beliefs about stress. For the purpose of this research, the scale was translated into Croatian using the back-translation method. This adaptation replicated previous findings on the dimensionality of the measure and showed high reliability of the scale on the Croatian sample (Cronbach's alpha, $\alpha = 0.91$).

Sources of Stress

To identify the main sources of stress in participants' recent sport experience, we administered a list of potential stressors classified into the following seven categories: injuries, rivalry, poor performance, training for competition, pressure to prove oneself, high self-expectations on performance, and personal desire to prove oneself. Participants were instructed to choose one of those seven briefly described categories of problems appraised as most stressful in the context of their competitive sport participation during the past 6 months. The list was based on a comprehensive analysis of published papers conducted by Wagstaff et al. (2019). Keeping in mind the selected category of sources of stress, the participants approached the further part of the questionnaire.

Primary Cognitive Appraisal

Appraisals of event stressfulness were measured by three 6-item scales of emotions reflecting loss, threat, and challenge appraisals (Kulenović and Buško, 2006). Items were rated on a 4-point intensity scale ranging from 0 "not at all" to 3 "very much" with reference to the selected sources of stress in competitive sports. Total scores on each scale were computed as the sum scores on respective items, varying in theoretical range from 0 to 18. Cronbach's alpha internal consistencies obtained in this research were 0.81, 0.77, and 0.82 for the loss, threat, and challenge appraisals, respectively.

International Personality Item Pool

Croatian translation of the 50-item International Personality Item Pool was administered (IPIP, Goldberg, 1999; Mlačić and Goldberg, 2007). The measure consists of 50 short statements intended to assess each of the Big Five personality dimensions: extraversion, agreeableness, conscientiousness, emotional stability, and intellect. Each dimension is encompassed by 10 items rated on a 5-point Likert type scale from 1 "completely incorrect" to 5 "completely true." The Cronbach's alpha coefficients in this study were as follows: $\alpha = 0.85$ for extraversion, $\alpha = 0.84$ for agreeableness, $\alpha = 0.82$ for

TABLE 2 | Positions of group centroids on the first canonical discriminant function.

				Discriminant function 1
	Group			Group centroid
	Selected category of stressors	*n*	%	
1	Injuries	31	24.8	0.040
2	Rivalry	8	6.4	1.525
3	Poor performance	25	20.0	−0.499
4	Training for competition	9	7.2	−0.014
5	Pressure to confirm oneself	16	12.8	0.622
6	High expectations on performance	12	9.6	0.515
7	Personal desire to prove oneself	24	19.2	−0.707

N = 125; n, group sizes.

conscientiousness, $\alpha = 0.87$ for emotional stability, and $\alpha = 0.65$ for intellect.

The survey form also included several demographic items: age, gender, and information about some aspects of participants' sport experience [i.e., sport, level of sport performance, years of sports participation, training frequency (per week), level of competition, and frequency of competing in the past 6 months].

Procedure

The study was conducted in June–July 2020, during the first lockdown period due to COVID-19 pandemic. Google Forms platform was used for data collection. The target population of active athletes attending the Faculty of Kinesiology in Zagreb were recruited by invitation for participation sent *via* e-learning system and students' social networks (Facebook). Participants followed a link to the online survey. Along with basic information on the study purpose and general instructions given on the first page of the instrument, participants were guaranteed anonymity of their contribution and were informed about the option to withdraw from the study at any time. The final sentence of the instruction page informed respondents that by selecting the "Next" button, they confirmed that they had read the information about the research and that they were willing to participate in it. The research project under which the study was conducted has been approved by the Ethics Committee of the Faculty of Humanities and Social Sciences, University of Zagreb.

Data Analysis

Along with descriptive and reliable statistics of all the study variables, canonical discriminant analysis was performed to examine the extent of differences in selected background, individual dispositions, and cognitive appraisal variables among groups defined by category of stressors declared by participants. Hierarchical regression procedures were implemented in answer to the main study question. All the analyses were done using IBM SPSS statistical software, v. 26.0.

RESULTS

The study aimed to examine the relative importance of personality dimensions and stress mindset in accounting for three stress appraisal measures in athletes. Main descriptive statistics and intercorrelations of all the study variables are given in **Table 1**. Relatively low average scores are obtained on all cognitive appraisal measures, whereas the mean stress mindset score is positioned close to the center of the theoretical range of the composite scale, suggesting no inclination toward the positive or negative way of thinking about stress. Average personality scale scores seem to correspond reasonably well to figures usually found in students athlete population. Certain departure from normality was observed for several scales as indicated by shapes of distributions and Kolmogorov-Smirnov *z*-values. However, the indices of skewness and kurtosis varied within a tolerable range (from −0.89 to 0.89 for skewness, and from −0.97 to 0.97 for kurtosis), which made the execution of the planned multivariate analyses justified.

Consistent with general postulates of the transactional stress and coping theory, we examined whether the differences can be observed in individual disposition, situation appraisal, and sport-related background variables depending on the sorts of stressors participants declared as most taxing in the given timeframe. Apart from the theoretical rationale behind this question, the statistical treatment of the data concerning the main problem of this research depended on the outcomes of these analyses. Canonical discriminant analysis was performed to test the multivariate differences between 7 groups of participants defined by the selected categories of stressors. The analysis revealed statistically significant albeit not particularly marked intergroup differences with only one significant discriminant function accounting for 37% of total intergroup variability (Wilks' $\Lambda = 0.388$, $\lambda = 0.392$, $r_c = 0.531$, $p < 0.05$). Standardized discriminant function and structure coefficients suggested that the contribution of cognitive appraisal, disposition, and background measures to intergroup differences were modest (e.g., r's of 0.40 and −0.323 for intellect and challenge appraisals, respectively), or negligible (e.g., r's of −0.069 and 0.175 for stress mindset and threat appraisals, respectively).

As shown in **Table 2**, certain intergroup separation can be observed, especially for the second group compared with the third and seventh categories of stressors, as indicated by the positions of the group centroids on the derived discriminant function. However, taking into account rather small group sizes and considerable overlap of their score distributions, along with mostly insignificant univariate tests of differences among the groups on the same set of variables, we deemed reasonable to assume that the choice of stressor type did not present relevant source of sample heterogeneity in terms of cognitive appraisals and personality structure examined. Hence, all the succeeding regression analyses were performed on the total sample.

To examine the contribution of personality dimensions and stress mindset in explaining the cognitive appraisal variance, three hierarchical regression analyses were performed. The analyses were performed in three steps. To control for the main background and sport-related variables, the first step included

TABLE 3 | Hierarchical regression analyses: the additive role of personality dimensions and stress mindset in accounting for cognitive appraisals of stress.

Sets of predictor variables	Step 1	Step 2	Step 3
	β	β	β
	Criterion: cognitive appraisal of challenge		
Gender	0.01	0.07	0.13
Level of performance	0.21	0.24	0.16
Training frequency	−0.21	−0.21	−0.14
Competition frequency	0.21*	0.20*	0.16*
Extraversion		0.20*	0.07
Agreeableness		0.04	−0.01
Conscientiousness		0.15	0.18*
Emotional stability		0.07	−0.12
Intellect		0.02	0.12
Stress mindset			0.58**
R^2	0.06	0.15*	0.38**
ΔR^2	0.06	0.09*	0.23**
	Criterion: cognitive appraisal of threat		
Gender	−0.20*	−0.20*	−0.23*
Level of performance	0.05	0.08	0.12
Training frequency	0.03	0.08	0.10
Competition frequency	0.07	0.05	0.01
Extraversion		−0.14	−0.06
Agreeableness		0.11	0.13
Conscientiousness		−0.09	−0.10
Emotional stability		−0.35**	−0.25**
Intellect		−0.03	−0.09
Stress mindset			−0.31**
R^2	0.05	0.25**	0.32**
ΔR^2	0.05	0.21**	0.07**
	Criterion: cognitive appraisal of loss		
Gender	0.03	−0.03	−0.06
Level of performance	0.10	0.18	0.22
Training frequency	−0.09	0.02	0.04
Competition frequency	−0.11	−0.11	−0.15
Extraversion		0.10	0.17
Agreeableness		−0.11	−0.09
Conscientiousness		0.05	0.04
Emotional stability		−0.53**	−0.43**
Intellect		0.06	−0.01
Stress mindset			−0.31**
R^2	0.02	0.26**	0.32**
ΔR^2	0.02	0.24**	0.07**

*$p < 0.05$, **$p < 0.01$; $N = 125$; ΔR^2, change in the explained criterion variance after a new block of variables was entered into equation; β, standardized regression coefficients.

gender, level of sport performance, training frequency, and competition frequency. The choice of the background variables was governed by research findings on the relationships of these variables with the stress experiences in competitive sports (Mellalieu et al., 2006). In the second step, five personality dimensions were added, and the third step included just the stress mindset variable. The results of these analyses are shown in **Table 3**.

In the first hierarchical regression analysis, the criterion was the cognitive appraisal of challenge. The set of sport-related and background variables, entered in the first step of the analysis, did not account for a significant portion of criterion variance, albeit the individual contribution of competition frequency reached a significance level ($\beta = 0.21$, $p < 0.05$). Introducing personality dimensions in the second step of the analysis managed to increase the explained criterion variance ($\Delta R^2 = 0.09$, $p < 0.05$) with extraversion as the only predictor variable with marginally significant contribution ($\beta = 0.20$, $p = 0.05$). The stress mindset variable introduced in the third step explained an additional, statistically and substantially significant amount of variance of the challenge appraisal ($\Delta R^2 = 0.23$, $p < 0.01$). Along with modest contribution of competition frequency ($\beta = 0.16$, $p < 0.05$) and conscientiousness ($\beta = 0.18$, $p < 0.05$), stress mindset appeared as the strongest predictor of challenge appraisals in the final regression equation ($\beta = 0.58$, $p < 0.01$). Thus, athletes who competed more frequently score higher on conscientiousness, and those who think more positively about stress are more likely to perceive stressors as a challenge. The entire model explained approximately 38% of the challenge appraisal variance [$F(10, 114) = 7.08$, $p < 0.001$].

In the second hierarchical regression analysis, cognitive appraisal of threat was included as a criterion. Again, the first step model did not reach a significance level, although regression weight for gender appeared marginally significant ($\beta = 0.20$, $p < 0.05$). In the second step of the analysis, the set of personality dimensions explained a significant portion of the additive criterion variance ($\Delta R^2 = 0.21$, $p < 0.01$). Along with gender ($\beta = 0.20$, $p < 0.05$), emotional stability ($\beta = -0.35$, $p < 0.01$) proved as a significant predictor in this step. The stress mindset was added to the equation in the final step with the additional 7% of the explained criterion variance ($p < 0.01$). In this step, along with stress mindset ($\beta = -0.31$, $p < 0.01$), emotional stability ($\beta = -0.25$, $p < 0.01$), and gender ($\beta = -0.23$, $p < 0.05$) remained as statistically significant individual predictors, such as in the previous step. Thus, male athletes, those who thought more positively about stress and who score higher on trait emotional stability, were less likely to experience stressors as threatening. The set of predictor in the final regression equation explained 32% of the threat appraisal variance [$F(10, 114) = 5.37$, $p < 0.01$].

In the third hierarchical regression analysis, cognitive appraisal of loss was included as a criterion. Predictors entered in the first step did not account for a significant portion of criterion variance. Personality dimensions introduced in the second step significantly increased the explained criterion variance ($\Delta R^2 = 0.24$, $p < 0.01$), and emotional stability ($\beta = -0.53$, $p < 0.01$)

was shown to be the only significant predictor. After the stress mindset was entered in the third step of the analysis, an additional 7% of loss appraisal variance was explained ($\Delta R^2 = 0.07$, $p < 0.01$). Emotional stability ($\beta = -0.43$, $p < 0.01$) was shown as independent predictor, along with the stress mindset ($\beta = -0.31$, $p < 0.01$). Thus, following the figures in the final equation, athletes with lower scores on the emotional stability dimension ($\beta = -0.43$, $p < 0.01$), and those who think more negatively about stress ($\beta = -0.31$, $p < 0.01$) are more likely to perceive stressors as a loss. The whole model accounted for 32% of the loss appraisal variance [$F(10, 114) = 5.42$, $p < 0.01$].

DISCUSSION AND CONCLUSION

This research dealt with potential sources, types, and intensity of stress athletes tend to experience in competitive sport. Grounded in the transactional theory of stress (Lazarus and Folkman, 1984, 1987; Lazarus, 2000, 2006), the study aimed to examine the role of personal antecedents of the stress processes in accounting for the stressful experiences in athletes. In addition to personality dimensions as widely established and theoretically relevant antecedents, we sought to examine the additive contribution of a relatively novel construct of stress mindset (Crum et al., 2013, 2017) in explaining individual differences in cognitive appraisals of loss, threat, and challenge in athletes.

Consistent with the basic hypotheses of Lazarus's theory and the empirical literature in the area, our results confirmed the contribution of Big Five personality dimensions as a significant set of predictors in accounting for each of the cognitive appraisals examined (e.g., Shewchuk et al., 1999; Vollrath, 2001; Penley and Tomaka, 2002; Kulenović and Buško, 2006; Kaiseler et al., 2012; Schneider et al., 2012). Specifically, emotional stability, conscientiousness, and extraversion showed to have significant independent contributions in explaining the variance of cognitive appraisals. Furthermore, the predictive power of personality was higher with threat and loss appraisals compared with challenge appraisals, which can also be said to be a well-documented finding (e.g., Gallagher, 1990; Shewchuk et al., 1999; Penley and Tomaka, 2002; Schneider, 2004; Tong et al., 2006; Kaiseler et al., 2012; Schneider et al., 2012; Kilby et al., 2018). Emotional stability was shown as a relatively strong independent predictor of loss and, to a lesser extent, threat appraisals, whereas extraversion and conscientiousness proved as significant predictors of challenge appraisal in this research.

The key finding of this study is that the stress mindset contributes to explaining cognitive appraisal variance, above and beyond the contribution of personality. Hence, our results suggest that the stress mindset might have a distinct role in accounting for stress experiences, rather than being merely a manifestation of personality. Thus, our findings add to the recent empirical literature confirming associations between beliefs about stress and perceiving a stressful situation as challenge, threat, and loss (Kilby and Sherman, 2016; Kilby et al., 2018). Moreover, the results showed that personality traits were more important in explaining cognitive appraisals of stress as loss and threat, while the stress mindset has proven to be more important in explaining challenge appraisals. Finally, it is also worth noting that sports competition context variables selected in this study to describe some situational aspects of athletes' potentially stressful experiences did not make any difference in terms of accounting for stress appraisal criteria. Thus, the results generally suggest that stressful experiences in competitive athletes have more in common with their individual dispositions including this newly introduced concept of stress mindset than with situational features describing the intensity of their engagement in sports, such as performance or competition level.

Study Limitations and Suggestions for Future Research

Several methodological limitations should be mentioned. In the first place, multivariate treatment of the data conducted in answer to the main study questions would preferably call for a larger research sample. Namely, certain inconsistencies and variations in the obtained regression model parameters between the steps of the analyses seem to be at least partly due to the relatively small sample size. Hence, the eventual instability or, in other words, the uncertain size of sampling error attached to the presented regression coefficients could have been reflected in the correctness of the final results and, consequently, in the soundness of the presented interpretations. Moreover, a larger sample would allow for a more accurate estimate of sample heterogeneity, especially in terms of individual and intergroup differences in scores on the scales used in the study depending on the stressor category.

Furthermore, although online questionnaires have certain advantages such as time savings due to ease of distribution and automatic storage of data ready for analysis and minimal costs associated with material distribution (Llieva et al., 2002; Wright, 2005), online questionnaires are accompanied by disadvantages, such as inability to control the participants' focus on completing the questionnaire and the conditions in which participants complete it. It is also difficult to control whether the same participants repeatedly responded to the questionnaire.

In addition, the retrospective nature of this research should also be noted as another possible limitation of this research. Research participants were required to recall their stress experiences over the past 6 months. This time frame may be a possible source of inconsistency. Namely, in the research, we relied on the ability of participants to accurately remember and set in time their feelings and stress experiences. However, it is possible that, for example, some participants referred to a stressor that happened few months before the study and did not remember their stress experience as accurately as participants whose stress problems were closer to the time of participation in the study. Nevertheless, we decided to set a longer time period given the peculiarities of the period in which the research was conducted. Namely, at the time of data collection, trainings and sports competitions were suspended due to COVID-19 crisis for approximately 3 months. However, as mentioned

earlier, since the competitive stressors in the research are related to competitive sports in general, i.e., not related to specific competition, even in the absence of competition and training, we deemed that athletes could have struggled with various competitive stressors.

Although this research confirmed the significance of the stress mindset in accounting for cognitive appraisals besides the contribution of general personality dimensions, the extent to which its role is unique in relation to some narrower personality traits known to be associated with stress reactions such as optimism, self-efficacy, and resilience still remains unexplored. Nevertheless, providing that further empirical evidence proves the uniqueness of the stress mindset construct, the findings on its importance for the stress and adjustment processes would be of practical use too. In view of initial experimental evidence (Crum et al., 2013), the insights into the role of stress mindset might thus serve to design effective interventions intended for enhanced coping with stress among athletes.

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. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

DČ contributed to the formulation of the research idea, data acquisition, data analysis and interpretation, and writing of the manuscript. MKV contributed to literature research, data analysis, interpretation of results, and writing of the manuscript. VB contributed to the conceptual design, data analysis, interpretation of results, and writing of the manuscript. All authors contributed to the article and approved the submitted version.

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SYSTEMATIC REVIEW
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Effects of Traditional Chinese Fitness Exercises on Negative Emotions and Sleep Disorders in College Students: A Systematic Review and Meta-Analysis

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Background: The purpose of this study was to systematically review the effectiveness of regular traditional Chinese fitness exercises on negative emotions and sleep disorders in college students, and to provide evidence-based evidence and new ideas for the negative emotions and sleep disorders among the college students.

Methods: A systematic search using 5 English (PubMed, Embase, Scopus, EBSCO, and the Cochrane Library) and 4 Chinese (CNKI, WanFang, VIP, and CBM) databases were initiated to identify randomized controlled trials (RCT) assessing the effect of traditional Chinese fitness exercises on negative emotions and sleep disorders among college students. Standardized mean differences (SMD) and their 95% confidence intervals (*CI*) were used to determine the pooled effect of the intervention. The Cochrane bias risk assessment tool was used to evaluate the methodological quality and the data were analyzed with Review Manager 5.4.

Results: A total of 12 RCTs were included, including 1,052 subjects. The results showed a potential beneficial effect of traditional Chinese fitness exercises on reducing depression [SMD = −0.93, 95 %*CI* (−1.76, −0. 10)], anxiety [SMD = −0.74, 95%*CI* (−0.93, −0.54)], and the sleep disorders [SMD = −2.77, 95%*CI* (−4.57, −0.97)] symptoms, and these effects were better than in the control group.

Conclusion: The findings of this review suggested the traditional Chinese fitness exercises could improve both the negative moods and sleep disorders compared with that of healthy students, the effect on college students with mild to moderate psychological symptoms was obviously improved. The SCL-90 scale is better than the SDS scale in evaluating the improvement effect of traditional Chinese fitness exercises on depression. It was the best intervention program on negative emotions and sleep disorders among college students, with the intervention lasting 5 sessions per week for 30–60 min/session for over 12 weeks.

Keywords: traditional Chinese fitness exercises, negative emotions, sleep disorders, college students, meta-analysis

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BACKGROUND

Stress-associated negative emotions and sleep disorders in college students are serious problems that can affect academic outcomes as well as the overall well-being of the student (So et al., 2019). In a DATE mental health survey among 126,000 Chinese college students, approximately 20.23% of the participants previously experienced, or were currently experiencing, different degrees of stress-induced psychological disorders. Of these, anxiety, depression, and sleep disorders accounted for the largest proportion (Jiao et al., 2021). Currently, legally prescribed medication and psychological counseling are the two best treatment methods for college students' psychological illnesses; however, the negative side effects associated with these treatments such as high dependence (Haack et al., 2013) as well as high costs have prevented students from seeking help or continuing treatment. Therefore, many students give up treatment, leading to an increased prevalence of psychological illness year by year.

China's national traditional fitness exercises are a set of fitness systems with oriental characteristics, such as qigong, healthy preservation, martial arts, and swordsmanship, etc. (Yeung et al., 2018). These exercises have been practiced for over 4,000 years. The goal of these exercises was, and is, to promote longevity and health (Jahnke et al., 2010). The main traditional Chinese fitness exercises currently practiced includeTai Chi(太极), Baduanjin(八段锦), Yijinjing(易筋经), Wuqinxi(五禽戏), Liuzijue(六字诀), Dunqianggong(蹲墙功), Zhanzhuanggong(站桩功), etc. These exercises are vigorously promoted by the Qigong Center of the General Administration of Sports of the People's Republic of China and are safe, effective, economical, and environmentally-friendly (Sun et al., 2022; Tong, 2022). Because of this, these traditional exercises are very popular among people of all ages in China. In recent years, the quantitative effect of these exercises on health has been gaining more focus, and thus, more active practitioners. For example, individuals who practice Qigong or Tai-Chi do so primarily to promote physical and psychological wellbeing and to treat various health conditions (Toneti et al., 2020). Thus, traditional Chinese fitness exercises have been increasingly used as complementary and alternative therapies to manage psychological stress and mood disorders (Trkulja and Barić, 2020). In China, traditional Chinese fitness exercises have been incorporated into college physical education courses, promoting the physical and mental health development of Chinese college students. The inclusion of such exercises has been welcomed and enjoyed by thousands of college students (Zou et al., 2017; Guo et al., 2018).

The limbic system of the human brain is responsible for emotion regulation. Specifically, it is responsible for controlling the function of the hypothalamic-pituitary-adrenal (HPA) axis. Preliminary studies have shown that traditional Chinese fitness exercises that focus on a slow breathing rate can reduce the HPA axis activities that are related to stress, adjust the balance of the autonomic nervous system, and enhance parasympathetic functions to improve insomnia, anxiety, depression, and other negative moods (Yeung et al., 2018). As traditional Chinese fitness exercises can reduce the degree of muscle tension, skin electricity, heart rate, and breathing rate, and improve the brain wave α level and the physical and mental problems of anxiety, compulsion, pain, and mood improvement, many studies have suggested that they should be used as an alternative and complementary therapy (Jahnke et al., 2010). Together these data imply that traditional Chinese fitness can alleviate the symptoms of depression, anxiety, and insomnia in college students. Additionally, previous studies have shown that traditional Chinese fitness exercises can increase human melatonin levels and enhance the cell function of granulocytic neutrophils and natural killer cells in the blood, thus improving the human sleep quality as well (Cui and Bai, 2014).

Based on the positive effects of traditional Chinese fitness exercises such as Tai Chi(太极), Baduanjin(八段锦), Yijinjing(易筋经), Wuqinxi(五禽戏), Liuzijue(六字诀), Dunqianggong(蹲墙功), Zhanzhuanggong(站桩功), on the mental health of college students (Lu, 2017), many Chinese universities have begun offering an elective courses in Chinese traditional fitness (Ma et al., 2021). These courses were especially popular during the online learning period of the COVID-19 epidemic where college students used these exercises as an effective means to improve their physical and mental health (Zhang, 2020). Research on the use of traditional Chinese fitness exercises to improve the psychological state of college students has achieved certain results (Shuai et al., 2018; Lu and Wang, 2020; Tan and Tan, 2020; Wang et al., 2020), however, many of these studies are confounded by small sample sizes, and low methodological quality as well as different outcome indicators. In this study, a meta-analysis of the current and previously published traditional Chinese fitness literature was used to conduct a comprehensive and quantitative analysis to determine the ability of traditional Chinese fitness exercises to improve negative emotions and sleep disorders in college students. This work further aims to provide scientific guidance for college students' practice behaviors using the traditional Chinese fitness exercises.

METHODS

This meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline (Moher et al., 2009).

Search Strategy

Total 2 reviewers independently searched the literature using the following English and Chinese databases: PubMed (all years), Embase (all years), The Cochrane Library (all years), Scopus (all years), EBSCO (all years), the Chinese National Knowledge Infrastructure (CNKI, all years), Wanfang (all years), the Chinese BioMedical Literature on disc (CBMdisc, all years), and the Chinese Scientific Journal (VIP, all years). The searches were conducted from inception through October 2021.Discrepancies between the 2 reviewers (ZY, CY) were discussed until consensus was reached, any disagreements regarding the inclusion would be discussed and resolved with the third reviewer (GYJ). The search terms used in this study was based a previous related meta-analysis: Chinese traditional exercise, Qigong(气功), Tai Chi(太极), Baduanjin(八段锦), Yijinjing(易筋经), Wuqinxi(五禽戏), Liuzijue(六字诀), Dunqianggong(蹲墙功), Zhanzhuanggong(站

桩功) anxiety, depression, emotion regulation, sleep disorders, college student, randomized controlled trial, clinical trial, RCT. Chinese translations of these terms were used in Chinese databases. A complete record of search strings is provided in the **Supplementary Material**. A manual search of reference lists of all included studies and relevant reviews was conducted to further identify relevant studies (**Supplementary Table 1**).

Inclusion and Exclusion Criteria

Types of Studies

Studies had to be randomized controlled trials (RCTs), and the language of studies is unlimited. A study was defined as RCT if the participants were allocated to experimental and control groups randomly. Repeated publications, review, systematic evaluation, conference summary, Meta-analysis, dissertations, narrative studies, observational or qualitative studies were excluded.

Types of Participants

Studies focusing on college students with mean age over 18 years old were included. College students of healthy or mild to moderate psychological symptoms and no motor dysfunction were included.

Types of Intervention

Studies had to use any type of traditional Chinese fitness exercises as an intervention with comparison, and the control group had to routine lifestyle. Studies integrating traditional Chinese fitness exercises with other forms of intervention or simply using other forms of intervention were excluded.

Types of Outcome Measures

The outcome indicators of studies were related scales that measure the effect of traditional Chinese fitness exercises on negative emotions (e.g., anxiety, depression) and sleep disorders in college students.

Study Selection and Data Extraction

A total of 2 reviewers independently screened the studies based on the titles, abstracts, and full texts. Discrepancies between the 2 reviewers (ZY, CY) were discussed until consensus was reached, any disagreements regarding the inclusion would be discussed and resolved with the third reviewer (GYJ). 2 reviewers extracted and summarized the following relevant data from all the original articles: (1) the basic characteristics of included studies (i.e., authors, study design, publication date, and country where the trial was performed), (2) the basic characteristics of participants (i.e., mean age, gender, number, sample size, and psychological status), (3) study intervention and comparison group (the types of exercise, single intervention time, frequency, and duration), and (4) outcome parameters.

Quality Assessment

A total of 2 reviewers independently assessed the risk of bias of all the included studies using the Cochrane Risk of Bias Assessment Tool (Higgins et al., 2011), which includes the following 7 domains: (1) random sequence generation, (2) allocation concealment, (3) blinding of participants and personnel, (4) blinding of outcome assessment; (5) incomplete outcome data, (6) selective reporting, and (7) other biases (Higgins et al., 2011). There are 3 grades for each domain: low risk of bias, unclear risk of bias, and high risk of bias. Basically, the possibility of various bias is small, the methodology quality is A; partially meets the standard, the methodology quality is B; completely does not meet the standard, the possibility of bias is high, the methodology quality is C (Chen et al., 2018). Any disagreements regarding the risk of bias assessment would be discussed and resolved with the third author.

Data Analysis

The Review Manager 5.4 was applied to perform the meta-analysis. The intervention effect size in each study was presented by the standardized mean differences (SMD) with 95% confidence intervals (CI). Use of SMD allows for the comparisons across included studies where they used different psychometric instruments to measure the same outcome (Deeks et al., 2008; Orwin and Vevea, 2009).The included studies were anticipated to be heterogeneous because of the different characteristics of intervention and control types. To account for the potential heterogeneity, a random-effects model was used throughout data synthesis. I^2 statistic was used to assess heterogeneity. Studies with an I^2 statistic of >75% were considered to have a high degree of heterogeneity; studies with an I^2 statistic of 50–75% were considered to have a moderate degree of heterogeneity; and studies with an I^2 statistic of <50% were considered to have a low degree of heterogeneity (Higgins et al., 2003). Subgroup analysis on primary outcomes based on intervention plan, psychological healthy level, and scale type was conducted where necessary. In addition, the publication bias was evaluated using the funnel plot asymmetry if 10 trials (at least) were covered in a meta-analysis. Results were considered statistically significant when $p < 0.05$.

Patient and Public Involvement

No patient involved.

RESULTS

Search Results

After searching multiple databases, a total of 821 studies were identified. After removing 671 irrelevant or duplicate records based on titles, the remaining 150 studies were further evaluated according to the following eligibility criteria:(1) Studies with inconsistent intervention or control measures, (2) studies that were inconsistent with the research content, (3) studies that had no original data and full text, and (4) studies that were inconsistent with the study design, reviews, and systematic evaluations, or studies that had an inappropriate sample size were excluded. Using these exclusion criteria, 131 studies were removed prior to analysis. Additionally, 7 studies were excluded due to inconsistent outcome indicators. In total, 12 studies were included for subsequent analyses in this review (**Figure 1**).

Description of Included Studies

The basic characteristics of all the included studies are shown in **Table 1**. In the 12 included RCTs, all of them were conducted in

TABLE 1 | Characteristics of included study ($n = 12$).

Author (year)	Study design	Country/ Region	Study participants	Psychological status	Sample size (finished, N) and gender (M/F)	Intervention (frequency)	Control	Relevant outcome (measurements)
Rao (2014)	RCT	China	College student (mean age TCFE: 20.70 ± 1.10 CON: 20.60 ± 1.20)	Healthy	N: 198 TCFE: 95 33/62 CON: 103 32/71	Tai Chi (12 weeks, 60 min/session, 5 times per week	Wait list	(1)(2)
Huang (2016)	RCT	China	College student (mean age TCFE: 18.68 ± 1.76 CON: 18.67 ± 1.50)	Sleep disorders	N: 50 TCFE: 22 NA CON: 28 NA	Tai Chi (24 weeks, 60 min/session, 5 times per week)	Wait list	(2)(3)
Yan and Wei (2017)	RCT	China	College student (mean age: NA)	Healthy	N: 100 TCFE: 50 NA CON: 50 NA	Baduanjin (12 weeks, 30 min/session, 5 times per week)	Wait list	(1)
Cui and Bai (2014)	RCT	China	College student (mean age: NA)	Sleep disorders	N: 60 TCFE:30 NA CON: 30 NA	Liuzijue (8 weeks, 60 min/session, 5 times per week)	Wait list	(2)
Wei et al. (2017)	RCT	China	College student (mean age: NA)	Healthy	N: 120 TCFE: 60 NA CON: 60 NA	Yijinjing (12 weeks, 30 min/session, 5 times per week)	Wait list	(1)
Su (2014)	RCT	China	College student(mean age:NA)	Healthy	N: 206 TCFE: 101 NA CON: 105 NA	Baduanjin (13 weeks, 60 min/session, 5 times per week)	Wait list	(1)(2)
Liu et al. (2017)	RCT	China	College student (mean age TCFE: 20.27 ± 1.76 CON: 20.84 ± 1.30)	Healthy	N: 62 TCFE: 30 14/16 CON: 32 16/16	Dunqianggong (4 weeks, 30 min/session, 7 times per week)	Wait list	(1)
Wang et al. (2020)	RCT	China	College student (mean age: NA	Mild to moderate psychological symptoms	N: 60 TCFE: 30 NA CON: 30 NA	Wu Qin Xi (24 weeks, 60 min/session, 7 times per week)	Wait list	(4)(2)
Guo (2019)	RCT	China	College student (mean age TCFE: 19.03 ± 0.89 CON: 19.25 ± 0.67)	Mild to moderate psychological symptoms	N: 70 TCFE: 35 NA CON: 35 NA	Zhanzhuanggong (14 weeks, 50 min/session, 5 times per week)	Wait list	(1)
Chen et al. (2019)	RCT	China	College student (mean age: NA)	Mild to moderate psychological symptoms	N: 36 TCFE: 18 NA CON: 18 NA	Tai Chi (16 weeks, 60 min/session, 3 times per week)	Wait list	(5)
Cheng et al. (2016)	RCT	China	College student (mean age TCFE: 21.10 ± 1.40 CON: 21.00 ± 1.60)	Mild to moderate psychological symptoms	N: 30 TCFE: 15 7/8 CON: 15 8/7	Wu Qin Xi (12 weeks, 40–60 min/session, 3 times per week)	Wait list	(6)
Zhang (2021)	RCT	China	College student (mean age: NA)	Mild to moderate psychological symptoms	N: 60 TCFE: 30 NA CON: 30 NA	More than 2 kinds of traditional fitness exercises (12 weeks, 60 min/session, 7 times per week)	Wait list	(4)(7)

RCT, Randomized Controlled Trial; N, number; M, male; F, female; TCFE, Traditional Chinese Fitness Exercises; CON, Control Group; (1) SCL-90(The Symptom Chcklist-90); (2) PSQI(Pittsburgh Sleep Quality Index); (3) STAI(State Trait Anxiety Inventory); (4) SDS(Self-Rating Depression Scale); (5) CES-D(Center for Epidemiological Studies-Depression);(6) HAMD(Hamilton Depression Scale); (7) SAS(Self-rating Anxietyscale Scale).

People's Republic of China ($n = 12$, 100%), and 12 studies were published in Chinese. The 12 studies involved a total of 1,052 students aged over 18 years old (516 in the experimental group and 536 in the control group), and all studies ($n = 12$, 100%) included both male and female participants. Among12 studies, Tai Chi (太极) was applied in 3 studies (Rao, 2014; Huang, 2016; Chen et al., 2019), Baduanjin (八段锦) was applied in 2 studies (Su, 2014; Yan and Wei, 2017), Yijinjing (易筋经) was applied in 1 studies (Wei et al., 2017), Wuqinxi (五禽戏) was applied was applied in 2 studies (Cheng et al., 2016; Wang et al., 2020), Liuzijue (六字诀) was applied in 1 studies (Cui and Bai, 2014), Dunqianggong (蹲墙功) was applied in 1 studies (Liu et al., 2017), Zhanzhuanggong (站桩功) was applied in 1 studies (Guo, 2019), more than 2 kinds of traditional Chinese fitness exercises was applied in 1 studies (Zhang, 2021). The psychological status of college students in 5 studies was healthy. In an additional 5 studies, the college students where characterized as having mild to moderate psychological problems. College students in the last

two studies were characterized as having sleep disorders. In all of the studies, the practice period ranged from 4 to 24 weeks with single exercise sessions ranging from 30 to 60 minutes. The frequency of practice for all studies ranged from 2 to 7 times per week. 7 scales were used to assess the intervention outcome measures.

Study Quality Assessment

Table 2 and **Figures 2A,B** presents the methodological quality of all included studies. The generation of random allocation was adequately conducted in all study. Among the 12 included RCTs, the studies quality gradeAhad3 studies (Rao, 2014; Su, 2014; Guo, 2019), the studies quality grade B had had 9 studies (Cui and Bai, 2014; Su, 2014; Huang, 2016; Liu et al., 2017; Wei et al., 2017; Yan and Wei, 2017; Chen et al., 2019; Wang et al., 2020; Zhang, 2021), and no grade C. The results showed that the allocation hidden uncertainty of the 12 included studies and the risk bias of the blind setting were relatively high. Regarding the allocation concealment, there were only 3 studies (Rao, 2014; Su, 2014; Guo, 2019) clearly described the allocation concealment. In addition, since there is less trial reported to blind their participants, personnel, and outcome assessors or they did not blind them, these 2 domains were also the major sources that increase the risk of bias. However, a low risk of bias was reported in most studies for the incomplete outcome data ($n = 11$) and selective reporting ($n = 12$), and there were no other biases described in these studies.

Outcomes

Effects of Traditional Chinese Fitness Exercises on Depression Among College Students

A total of 8 studies ($n = 538$) examined the effect of traditional Chinese fitness exercises on depressive (Cheng et al., 2016; Liu et al., 2017; Wei et al., 2017; Yan and Wei, 2017; Chen et al., 2019; Guo, 2019; Wang et al., 2020; Zhang, 2021). This suggested that the effect of traditional Chinese fitness exercises on reducing depression among college students (SMD =-0.93, 95% *CI* [−1.76, −0.10]), and the depression improvement of experimental group was better than the control group ($p < 0.05$). Heterogeneity among studies was high ($I^2 = 94\%$). Because of no sources of heterogeneity were found in the sensitivity analysis, so, the subgroup analysis was conducted from 3 aspects of intervention plan (single intervention time, intervention frequency, intervention duration), psychological healthy level, and scale type to further explore the sources of heterogeneity (**Figure 3A**).

The subgroup analysis based on the intervention plan showed that, the effect size of 30–60 min (SMD = −2. 15, 95% *CI* [−4.00, −0.30]) was higher than the 60 min (SMD = −0.27, 95% *CI* [−1.25, 0.72]) in the single intervention time (**Figure 3B**). The effect size of 5 times a week (SMD = −1.51, 95% *CI* [−2.40, −0.62]) was the largest in the intervention frequency, effect size of 7 times a week (SMD = −0.91, 95% *CI* [−1.52, −0.30]) followed, and the effect size of 3 times a week (SMD = −0.09, 95% *CI* [−6.94, 7.13]) was the lowest (**Figure 3C**). The effect size of over12 weeks (SMD = 0.03, 95% CI [−2.78, 2.85]) was higher than 12 weeks (SMD = −1.54, 95% *CI* [−2.21, −0.87]) in the intervention duration. The difference between groups was statistically significant ($p < 0.05$) (**Figure 3D**). This suggested that the best intervention plan of traditional Chinese fitness exercises to improvement the depressive of college students is practiced over 5 sessions/week for 30–60 min/session for over 12 weeks.

The subgroup analysis based on the psychological healthy level showed that, compared with college students who physical and psychological healthy [SMD = −0.84, 95% *CI*(−1.19, −0.5)], those who mild to moderate psychological symptoms showed higher effect size [SMD = −0.98, 95% *CI* (−2.68, 0.73)] (**Figure 3E**). The difference between groups was statistically significant ($p < 0.001$). This suggested that the significantly effect of the traditional Chinese fitness exercises on depression in college students with mild to moderate psychological symptoms than in healthy college students.

The depression scales used in this review, included SCL-90 scale ($n = 4$), HAMD scale ($n = 1$), SDS scale ($n = 2$), and CES-D scale ($n = 1$). Because only one study was included in this review using HAMD scale and CES-D scale, the subgroup analysis was not possible, so the scale type was divided into 2 subgroups, namely SCL-90 and SDS. The subgroup analysis based on the scale type showed that, The effect size of the SCL-90 scale [SMD = −1.25, 95% *CI* (−1.99, −0.51)] is higher than the SDS scale [SMD = −1.21, 95% *CI* (−2.04, −0.37)] (**Figure 3F**). The difference between groups was statistically significant ($p < 0.001$). This suggested that the SCL-90 scale is better than the SDS scale when evaluating the improvement effect of traditional Chinese fitness exercises on depression in college students.

Effects of Traditional Chinese Fitness Exercises on Anxiety Among College Students

A total 6 studies ($n = 462$) examined the effect of traditional Chinese fitness exercises on anxiety (Huang, 2016; Liu et al., 2017; Wei et al., 2017; Yan and Wei, 2017; Guo, 2019; Zhang, 2021). The pooled results showed that the significantly effect of traditional Chinese fitness exercises on reducing anxiety among college students compared to control group (SMD = −0.74, 95 %*CI* [−0.93, −0.54], $p < 0.001$). Heterogeneity among studies was high ($I^2 = 82\%$). Through sensitivity analysis, it was found that one study (Guo, 2019) has a great impact on heterogeneity. After excluding this study, the results show that there is no heterogeneity in the other 5 studies ($I^2 = 0\%$) (**Figure 4**).

Effects of Traditional Chinese Fitness Exercises on Sleep Disorder Among College Students

A total 4 studies ($n = 574$) examined the effect of traditional Chinese fitness exercises on sleep disorder (Cui and Bai, 2014; Su, 2014; Huang, 2016; Wang et al., 2020). The pooled results showed that the significantly effect of traditional Chinese fitness exercises on reducing sleep disorder among college students compared to control group (SMD = −2.77, 95% *CI* [−4.57, −0.97], $p < 0.05$). Heterogeneity among studies was high ($I^2 = 97\%$). Through sensitivity analysis, it was found that one study (Cui and Bai, 2014) has a great impact on heterogeneity. After excluding this study, the results show that there is no heterogeneity in the other 4 studies ($I^2 = 0\%$) (**Figure 5).**

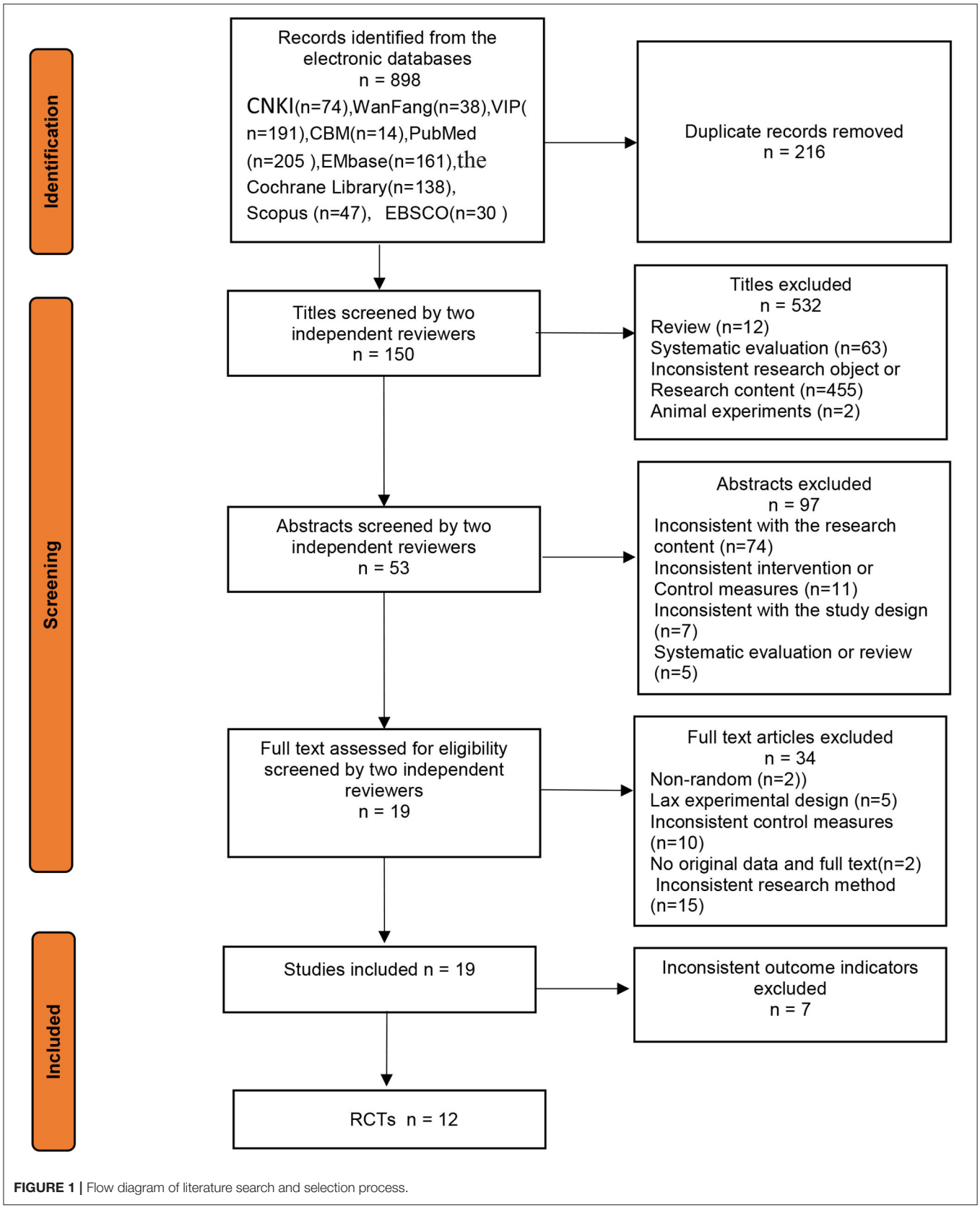

FIGURE 1 | Flow diagram of literature search and selection process.

TABLE 2 | Risk of bias summary.

Trials	Random sequence generation	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other bias	Studies quality grade
Rao (2014)	Low	Low	High	Low	Low	Low	Low	A
Huang (2016)	Low	Unclear	High	High	High	Low	Low	B
Yan and Wei (2017)	Unclear	Unclear	High	High	Low	Low	Low	B
Cui and Bai (2014)	Unclear	Unclear	High	High	Low	Low	Low	B
Wei et al. (2017)	Unclear	Unclear	High	High	Low	Low	Low	B
Su (2014)	Low	Low	High	Low	Low	Low	Low	A
Liu et al. (2017)	Low	Unclear	High	High	Low	Low	Low	B
Wang et al. (2020)	Unclear	Unclear	High	High	Low	Low	Low	B
Guo (2019)	Low	Low	High	Low	Low	Low	Low	A
Chen et al. (2019)	Unclear	Unclear	High	High	Low	Low	Low	B
Cheng et al. (2016)	Unclear	Unclear	High	High	Low	Low	Low	B
Zhang (2021)	Unclear	Unclear	High	High	Low	Low	Low	B

Publication Bias

Publication bias was observed by Review Manager 5.4, and funnel plot symmetry indicates that there is no publication bias. As it is shown in **Figure 6**, the left and right sides of the funnel plot are basically symmetrical, most of the studies focus on the middle and upper parts of the funnel plot, but there are single studies outside of 95% *CI*, this suggests that there may be some publication bias.

DISCUSSION

Study, life, job, and family stressors are the common place worldwide. However, these stressors are becoming an increasingly prevalent source of psychological distress for contemporary college students. Previous studies on college students have shown that continuous mental tension and stress can lead to the onset of various negative emotions such as anxiety, depression, irritability, fear, and sleep disorders (Yang et al., 2021). Furthermore, some studies have found that sleep disorders can increase the risk of anxiety and depression (Bonnet and Arand, 2000). If the negative psychological emotions of college students are not properly alleviated, it will seriously affect the study and life of college students, and even endanger the stability of society. If the negative psychological emotions experienced by college students are not properly alleviated, they have the potential to seriously affect both the educational outcomes and life of college students. In recent years, many studies have confirmed that traditional Chinese fitness exercises can effectively alleviate college students' negative emotions and sleep disorders through the cooperation of mind and body (Wang et al., 2014a; Li et al., 2019; Wu et al., 2019). These exercises, in combination with slow breathing, aid in the relaxation of psychological pressure and cultivate spirituality; both concepts that are understood to reflect the idea of "disease prevention" in traditional Chinese medicine. Traditional Chinese fitness exercises are comprehensive mind-body exercises that have been widely applied to treat college students with negative emotions and sleep disorders. The current study systematically reviewed the previous literature and provided an objective evaluation on the effects of traditional Chinese fitness exercises on college students with negative emotions and sleep disorders.

Following the eligibility criteria, 12 RCTs comprising a total of 1,052 college students were included in this review. Although there is considerable heterogeneity within the included studies, the overall effect was positive with a statistical significance, indicating that traditional Chinese fitness exercises had an advantage over control intervention on improving negative emotions and sleep disorders of college students. Negative emotions include depression, anxiety, fear, tension, and sadness, among which depression and anxiety are the most common (Wang et al., 2020). At present, various clinical scales have been used to evaluate the degree of depression, anxiety, and sleep disorder of college students. In this review, 8 studies (Cheng et al., 2016; Liu et al., 2017; Wei et al., 2017; Yan and Wei, 2017; Chen et al., 2019; Guo, 2019; Wang et al., 2020; Zhang, 2021) showed that traditional Chinese fitness exercises had significantly effects on depression of college students compared with control group, and the difference between groups was statistically significant ($p < 0.05$),These data are consistent with the results reported by Yang et al. (2019) who showed that physical and mental exercise had significantly effects on depression.

Then, a detailed subgroup analysis based on different intervention plans, psychological health levels, and scale type found that the improvement effect of traditional Chinese fitness exercises on college students with mild to moderate psychological symptoms was superior relative to healthy controls. This result showed that the SCL-90 scale is better than the SDS scale when evaluating the improvement effect of traditional Chinese fitness exercises on depression among college students. Additionally, the results showed that five 30–60 min sessions per week for 12 weeks was the best traditional Chinese fitness exercise plan to improve the depression of college students.

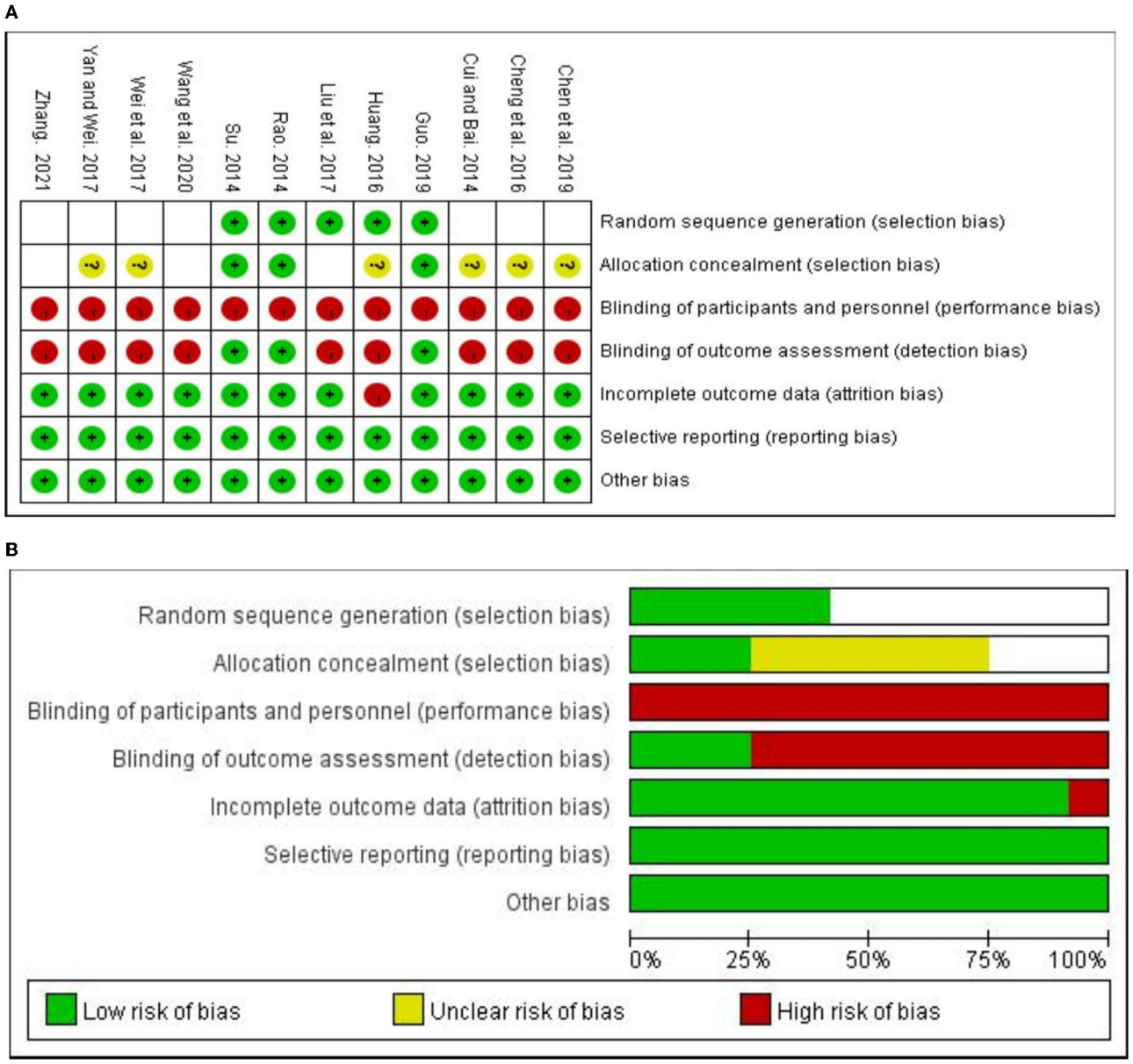

FIGURE 2 | Risk of bias summary **(A)** and graph **(B)**.

In addition, six studies (Huang, 2016; Liu et al., 2017; Wei et al., 2017; Yan and Wei, 2017; Guo, 2019; Zhang, 2021) that investigated the effect of Chinese traditional fitness exercises on anxiety experienced by college students showed that the exercise group reported significantly less anxiety relative to the control group. These results were consistent with the findings of Hua and Sun (2021) who showed that the significantly effects of physical and mental exercises on anxiety, depression, and stress in college students. However, due to the limited number of studies in each group and the relatively poor study quality, the reanalyzed results may not be accurate and should be treated with caution.

Recent studies have shown that traditional Chinese fitness exercises can effectively reduce sleep disorders, thus highlighting their use as an alternative or in combination with existing therapies to treat disorders of this type (Wang et al., 2014b). Four studies (Cui and Bai, 2014; Su, 2014; Huang, 2016; Wang et al., 2020) on the effect of Chinese traditional fitness exercise on sleep disorders showed that traditional Chinese fitness exercises had significantly effect on sleep disorders of college students compared with control group, and the difference between groups was statistically significant ($p < 0.05$). It is hypothesized that these improvements may be due to the alleviation of brain fatigue and tension through the reduction of negative emotions via

routine traditional Chinese fitness practice; the routine use of which promotes habits that are beneficial for the improvement of physical and psychological health (Baron et al., 2013; Yeung et al., 2018). Together these data show that in college students, despite considerable heterogeneity within the included studies, traditional Chinese fitness exercises have a significant ability to improve the onset and effect of negative emotions and sleep disorders to promote healthy wellbeing.

Meta-analysis studies are highly observational and may be affected by various factors such as bias (Wang et al., 2014b). Thus, this review has some limitations that should be carefully considered. Firstly, as the intervention measure assessed was traditional Chinese fitness exercises, no studies carried out outside of China and were published in English were included in this review; therefore, some studies could have been missed. Furthermore, as this meta-analysis was limited to Chinese college students, it is possible that our findings may not reflect the global sociodemographic distribution of all students and their relationship to stress as well the ability of traditional Chinese exercises to alleviate it. Secondly, the 12 RCTs included in the study are not detailed enough in terms of their method of randomization, allocation concealment, blind method setting, outcome indicators, and loss of follow-up reports – all of which may be due to the low quality of the original literature. Thirdly, due to the small number of studies included in this review, it is impossible to robustly analyze all relevant indicators. Additionally, due to the small sample size, there exists a relatively high risk of bias and heterogeneity that are unable to overcome relatively weak methodologies. Lastly, studies that found neutral or negative results are not often published and as such were not included in the current meta-analysis and may reduce the accuracy of our results.

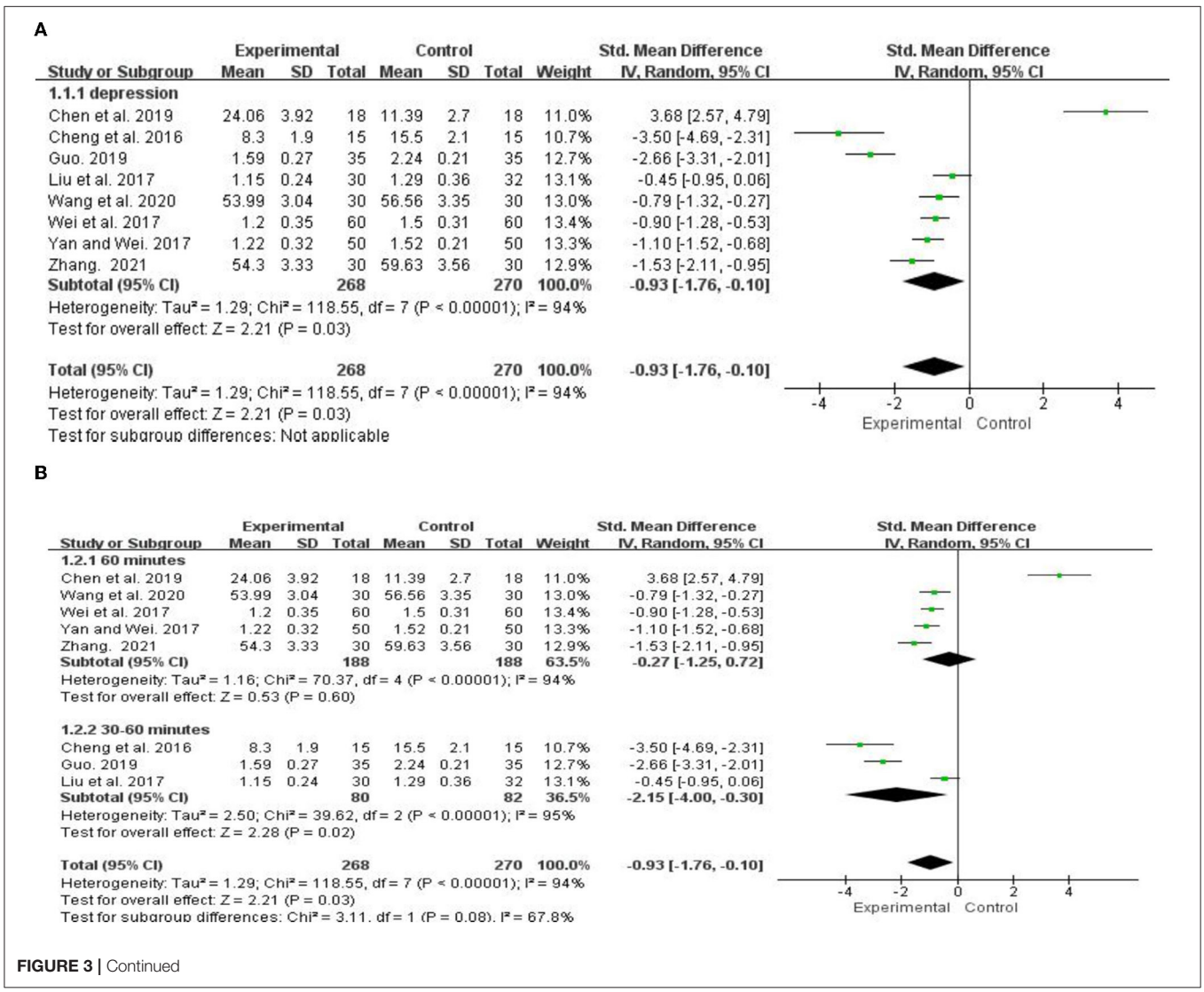

FIGURE 3 | Continued

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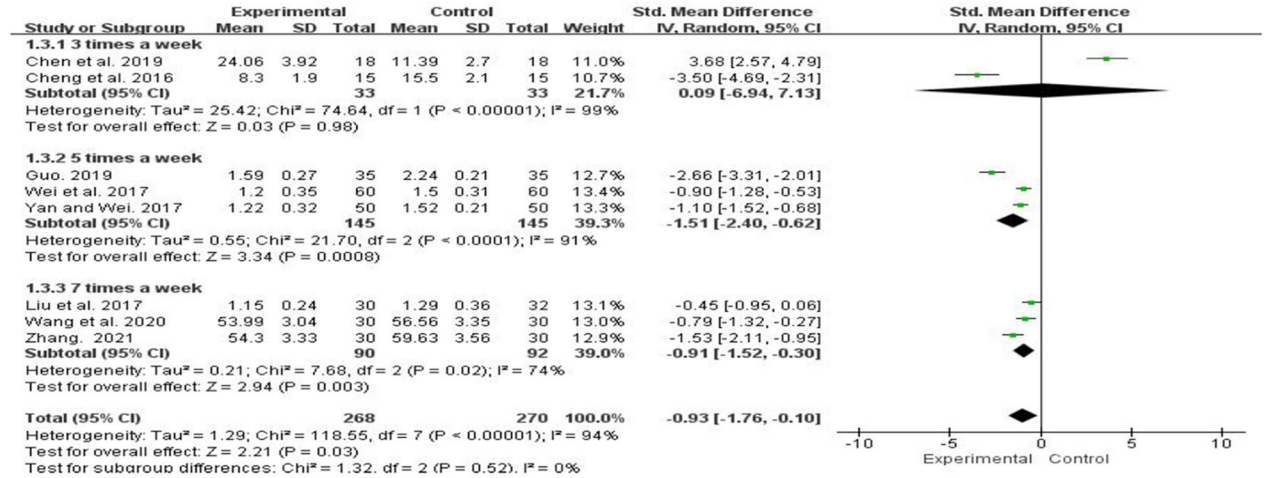

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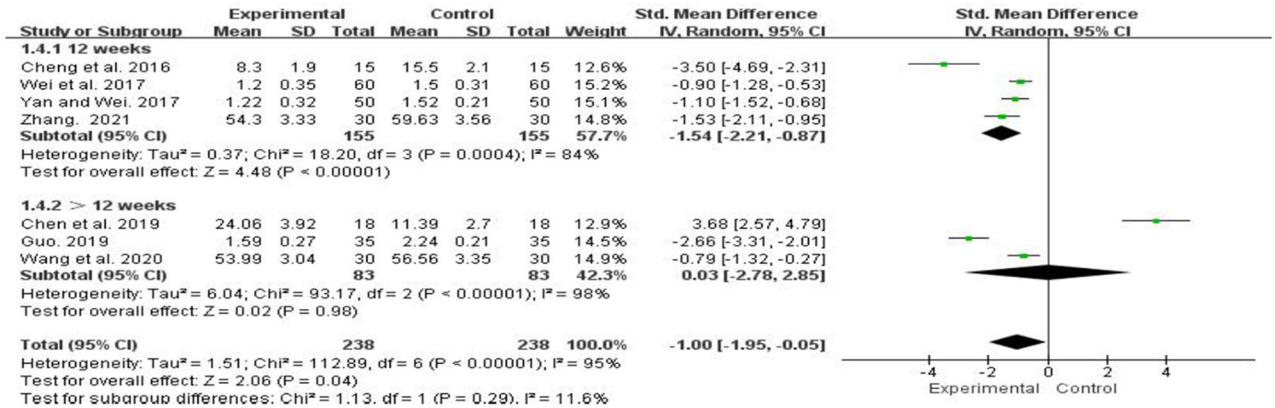

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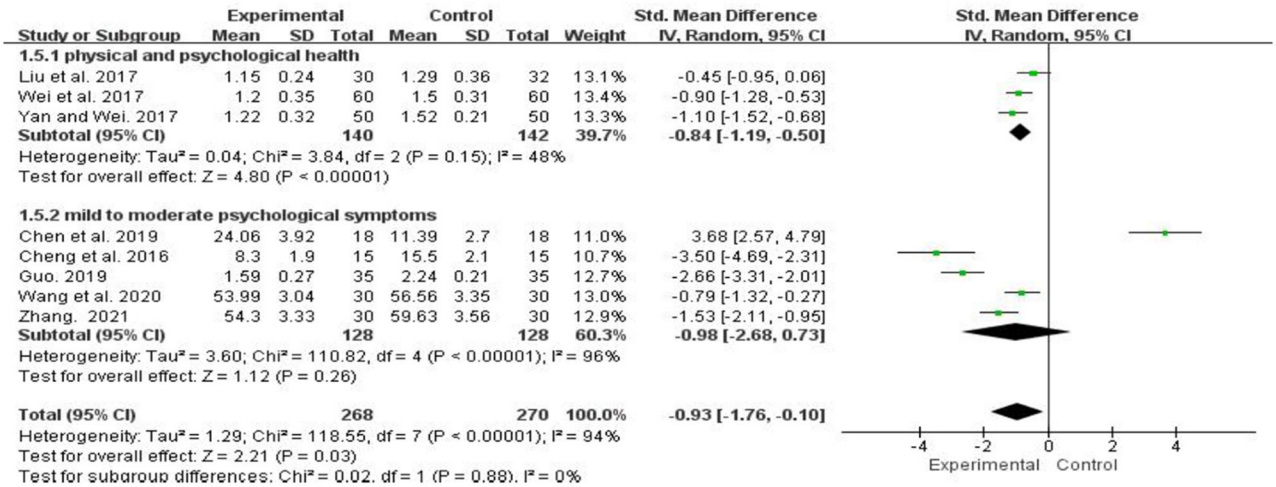

FIGURE 3 | Continued

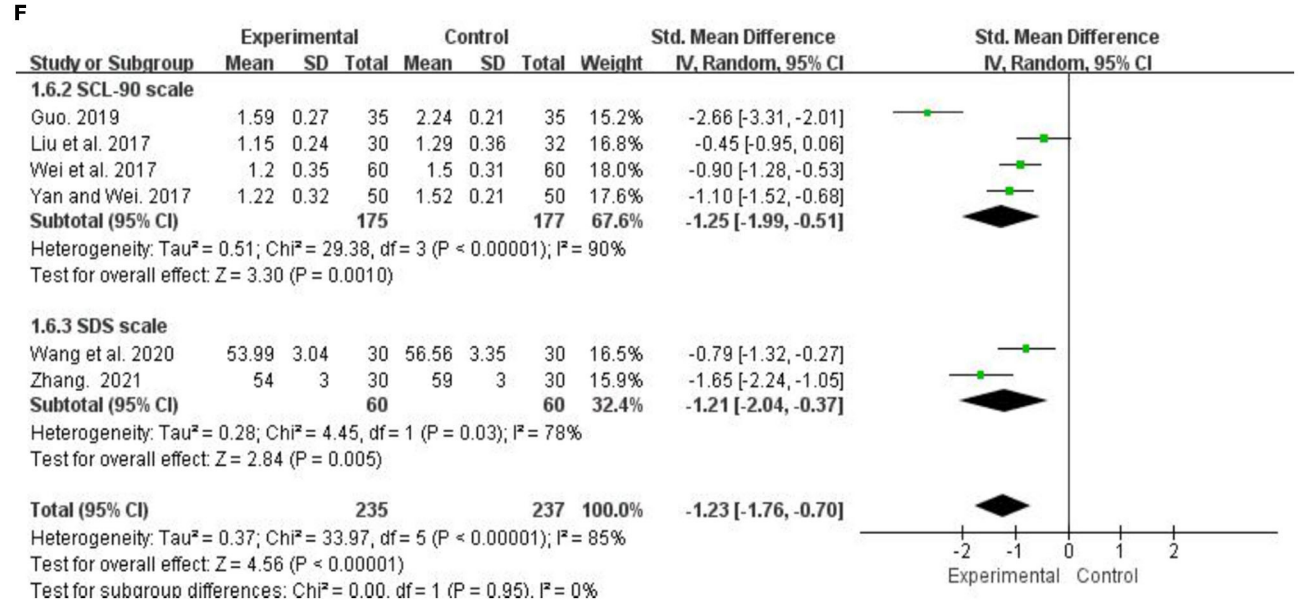

FIGURE 3 | Meta-analysis of traditional fitness exercises on depression **(A)** among college students. CI, condence intervals; IV, inverse variance. Forest plot for subgroup analysis base on single intervention time **(B)**. Forest plot for subgroup analysis base on intervention frequency **(C)**, intervention duration **(D)**, psychological health level **(E)**. Forest plot for subgroup analysis base on scale type **(F)**.

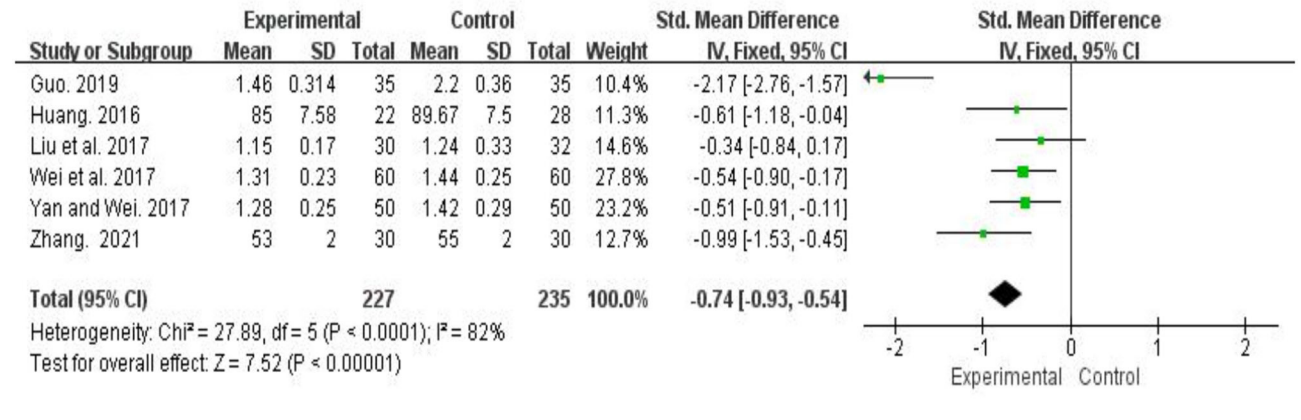

FIGURE 4 | Meta-analysis of traditional fitness exercises on anxiety among college students.

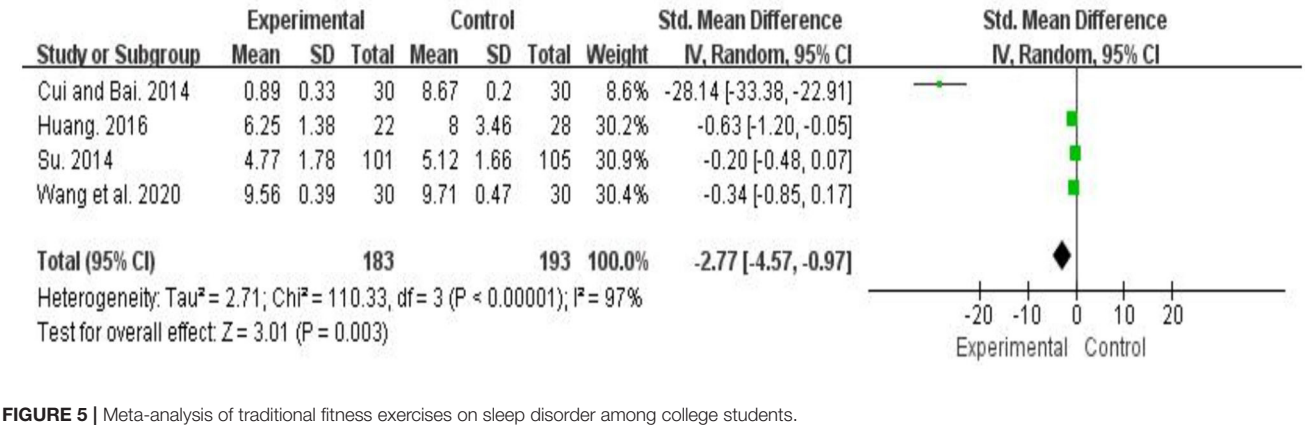

FIGURE 5 | Meta-analysis of traditional fitness exercises on sleep disorder among college students.

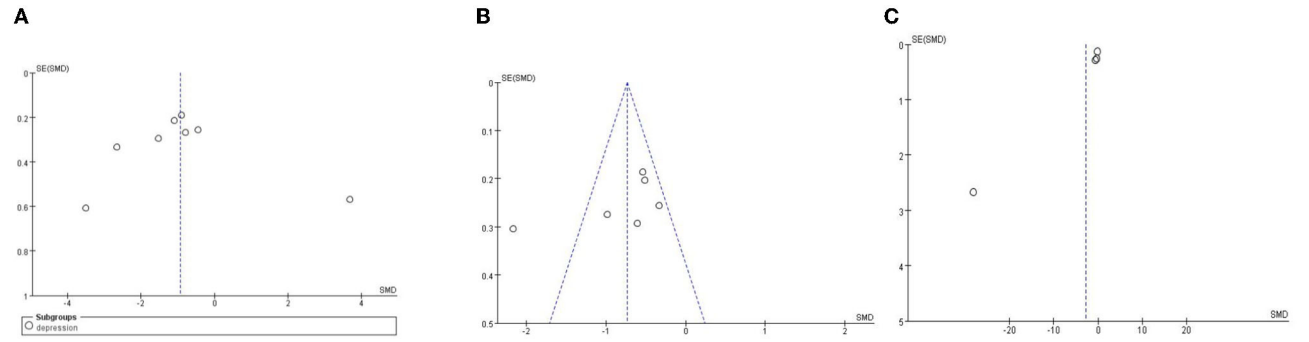

FIGURE 6 | Publication bias analysis of depression **(A)**, anxiety **(B)**, sleep disorder **(C)**.

CONCLUSION

In conclusion, the results of this systematic review and meta-analysis demonstrated that traditional Chinese fitness exercises can improve depression, anxiety, and sleep disorders in college students relative to those who did use these practices. Future research should focus on carrying out high-quality, highly powered RCTs of college students that take into account different degrees of psychological symptoms as well as varying geographic locations. Additionally, exercise intensity should also be included as a quantifiable parameter to assess the effectiveness of different traditional Chinese exercises.

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**.

AUTHOR CONTRIBUTIONS

TY: conceptualization, formal analysis, and writing—original draft. YG and YC: formal analysis and writing—review and editing. YZ and YC: screening and formal analysis. YG, YZ, and YC: writing—review and editing. 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/fpsyg.2022.908041/full#supplementary-material

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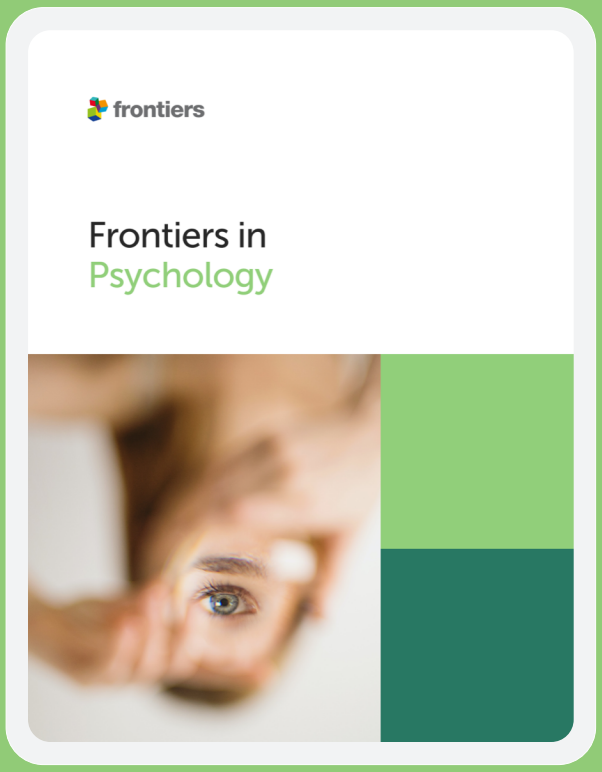

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