PHYSICAL ACTIVITY, HEALTH EQUITY AND HEALTH-RELATED OUTCOMES

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PHYSICAL ACTIVITY, HEALTH EQUITY AND HEALTH-RELATED OUTCOMES

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Table of Contents

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EDITORIAL
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Editorial: Physical Activity, Health Equity and Health Related Outcomes

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Editorial on the Research Topic

Physical Activity, Health Equity and Health Related Outcomes

It is now established that physical activity (PA) decreases the risk of developing long term non-communicable chronic diseases such as cardiovascular disease, cancer, and diabetes (1). Low PA levels combined with increased risks of major causes of mortality in most countries has led to characterizing physical inactivity as a global pandemic (2). Disability-adjusted life years due to low PA levels have almost doubled from 8.61 million in 1990 to 15.7 million in 2019 (2). Understanding determinants of sedentary lifestyle behavior and physical inactivity health risks and implications across different populations remains one of the biggest public health challenges (3). PA behavior is socially patterned with lower participation rates among women, different racial/ethnic groups, people with less education, worse access to health care and health insurance, people with physical, mental, and cognitive disabilities or older adults.

The American College of Sports Medicine (ACSM) has developed a national roadmap that supports achieving health equity through a physically active lifestyle (4). The actionable, integrated pathways that provide the foundation of ACSM's roadmap include the following: (1) communication-raising awareness of the issue and magnitude of health inequities and conveying the power of PA in promoting health equity; (2) education-developing resources to improve cultural competency for health care providers and fitness professionals as well as developing new community-based programs for lay health workers; (3) collaboration-building partnerships and programs that integrate existing infrastructures and leverage institutional knowledge, reach, and voices of public, private, and community organizations; and (4) evaluation-ensuring that ACSM attains measurable progress in reducing PA disparities to promote health equity.

This special issue of Frontiers in Public Health "*Physical Activity, Health Equity and Health Related Outcomes*" produced topical research conducted within different populations (Armenia, China, Colombia, the UK, and the US). Wide range of analyses included PA and sedentary behaviors prevalence, associations and mapping of chronic disease risks such as obesity and diabetes risks in cities and community groups, disparity in PA access and built environment and various socio-economic and demographic statuses determinants. Three studies analyzed health inequities and PA during the Covid-19 pandemic.

Tcymbal et al. analyzed current levels of physical inactivity and sedentary behaviors among the adult population of Armenia. Their data revealed that sedentary behavior was more common among men, students, people who were retired, unemployed, residents of Yerevan, and adults aged under 30 and over 45 years. A study conducted in the UK population (Rogers et al.) analyzed whether lockdown had a disproportionate impact on PA behavior in groups who were, or who perceived themselves to be, at heightened risk from COVID-19. Finally, Zhou et al. investigated the

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changes in PA and sedentary time among Chinese youths at different stages after the COVID-19 outbreak. They revealed that COVID-19 had both immediate and longer-term impacts on self-reported PA and sedentary behaviors among Chinese youths. These studies concluded that policies on maintaining or improving PA intensity during lockdowns should consider vulnerable groups of adults including those with chronic diseases or self-perceptions of being at risk and the importance of access to green or open spaces in which to exercise. Relevant efforts should alsoget youths physically moving again.

Two studies in the Special Topic collection analyzed the associations between built environment, neighborhood walkability and access to free or low-cost facilities and PA in the US population. Budd et al. studied the associations among overall perceived neighborhood walkability, racial discrimination stress, and having a chronic health condition. They also evaluated whether overall perceived neighborhood walkability moderates the association between racial discrimination stress and having a chronic health condition. Their data found that the overall perceived neighborhood walkability was inversely associated with racial discrimination stress, but not associated with having a chronic health condition. They concluded that perceived neighborhood crime safety, but not infrastructure or aesthetics, matters when it comes to the link between racial discrimination stress and having a chronic health condition among Hispanics/Latinos. Moreover, another research in the US population assessed whether access to free or low-cost recreational facilities was associated with meeting the AHA PA guidelines (Andrade et al.). Their results revealed that having access to free or low-cost recreational facilities such as parks, walking trails, bike paths and courts was associated with meeting the American Heart Association PA guidelines. Thus, increasing prevalence and awareness of neighborhood recreational facilities could assist in access to these facilities and increase the ability of individuals to meet PA guidelines.

Two studies were conducted in the Colombian population. Panciera-di-Zoppola et al. analyzed PA levels among ethnic groups in La Guajira, Colombia based on ethnic and sociodemographic factors. They revealed that participants of ≥47 years of age, and those with only a primary education presented a lower probability of complying with PA recommendations, while those who lived in large municipalities (Riohacha) displayed a larger probability of compliance. Furthermore, their data showed that Indigenous and Afro-Colombian people in a low social class were more likely to comply with PA recommendations, while residing in a smaller municipality (Manaure) was associated with a lower PA compliance. On the other hand, Acosta et al. demonstrated that low levels or PA and sedentary behaviors are prevalent among a large proportion of populations with high risk of type 2 diabetes living in Bogota and Barranquilla, Colombia. Their analysis in these two large cities recommends urgent PA interventions among high-risk populations to reduce type 2 diabetes risk.

Finally, two studies conducted in the Chinese population analyzed health equity among rural residents with various socio-economic and demographic statuses in Yunnan Province (Li et al.) and the joint associations of socioeconomic status or PA on obesity measures (Pan et al.) in an urban setting. Their studies suggested that more attention should be paid to females, the aged, ethnic minorities, farmers, the divorced or widowed, residents with low income and low educational level, and those with chronic diseases. Also, women were more susceptible to obesity concerning low socioeconomic status and that adequate PA may be a potential target for mitigating the negative effect of low socioeconomic status on obesity in women. Ensuring equity and equality has also been analyzed in terms of receiving medical care and drug welfare in disadvantaged communities in Chinese patients with chronic diseases in Gansu, Sichuan, Hebei, and Zhejiang using the Bivariate Theil-T Index method (Tang et al.). Understanding PA determinants in the context of health equity and health related outcomes is key to developing targeted successful public health interventions which ultimately reduce disease risks across wide range of populations.

AUTHOR CONTRIBUTIONS

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

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Prevalence of Physical Inactivity and Sedentary Behavior Among Adults in Armenia

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Physical inactivity and sedentary behavior are risk factors for developing non-communicable diseases. This study analyzed current levels of physical inactivity and sedentary behaviors among the adult population of Armenia. Data were collected through a national STEPS survey of non-communicable diseases risk factors on a nationally-representative sample of 2,380 participants aged 18–69 years in Armenia in 2016. The Global Physical Activity Questionnaire was used to assess physical activity levels. Two out of ten people (21.6%) in Armenia did not meet the minimum levels of physical activity recommended by WHO to protect health. 13.2% of population spent over 8 h per day sitting, 47.2% were inactive at work and 32.4% did not do any transport-related physical activity. Only 13.8% of participants were physically active during leisure time. Specific groups with relatively high levels of physical inactivity were older adults, residents of Yerevan, people with lower levels of education, the unemployed and people who were retired. Sedentary behavior was more common among men, students, people who were retired, unemployed, residents of Yerevan, and adults aged under 30 and over 45 years.

Keywords: physical inactivity, sedentary behavior, physical activity levels, prevalence, GPAQ, adults

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INTRODUCTION

It is clear that physical activity (PA) is essential for the maintenance of physical and mental health (1–3). Physical inactivity can be defined as not achieving the minimum levels of physical activity, as recommended by the World Health Organization (WHO) (2). Investing in policies that encourage physical activity can directly contribute to the achievement of the 2030 Sustainable Development Goals, and the WHO's Global Action Plan for Physical Activity 2018–2030 (4) as well as the European Physical Activity Strategy 2016–2025 (3) and encourage countries to strengthen monitoring and surveillance of physical activity to help guide national policy action.

Physical inactivity is a key risk factor for the development of many non-communicable diseases (NCD) such as heart disease, stroke, type 2 diabetes and breast and colon cancer (1, 4). PA can also be beneficial to mental health and increase social inclusion (5, 6). While meeting the WHO recommended levels of physical activity can protect health (2), there are indications that sedentary behavior is also an independent risk factor for many NCDs (7–11). Sedentary behavior (SB) can

be defined as "any waking behavior characterized by an energy expenditure ≤1.5 METs while in a sitting or reclining posture" (12). It is important to be clear that SB is not a synonym for physical inactivity, rather, they are both separate and independent risk factors for chronic diseases (9, 13).

In Armenia, the prevalence of NCD-related mortality has been increasing (14). The prevalence of risk factors for NCDs such as unhealthy diet and physical inactivity is high and around half of adults (51.2%) are overweight or obese (15). Consequently, the prevention and control of NCDs are a priority of the Armenian Government. In order to address this issue, quality data related to risk factors such as physical inactivity and sedentary behavior are essential to enable the development of effective and targeted policies, strategies, and interventions to promote health and prevent NCDs.

The WHO STEPwise approach to surveillance (STEPS) survey of NCD risk factors was developed to collect high quality, nationally representative data which can be used to help guide policy development for the prevention and control of NCDs. It allows assessment of the prevalence of behavioral risk factors, such as physical inactivity and SB, as well as biological risk factors, such as raised blood pressure blood cholesterol, and glucose levels (16). Analysis of data collected through the STEPS survey enables estimation of population PA levels and prevalence of SB for different socio-demographic groups at the country level.

In 2016, Armenia implemented the STEPS survey for the first time. Based on the data collected, the current study aimed to provide the first national estimate of PA levels and sedentary behaviors for the Armenian population disaggregated by socio-demographic factors such as gender, age, location of residence, level of education and occupation.

METHODS

Study Design and Sampling

Data were collected through the national STEPS survey of NCDs risk factors conducted in 2016. The survey was implemented according to the WHO STEPS methodology (17). It involved interviews of participants to assess behavioral risk factors and health history related to NCDs (Step 1), physical/anthropometric measurements (Step 2) and biochemical measurements (Step 3). The sample was defined using a multi-stage cluster sampling method based on demographic data regarding the adult population of Armenia (14). The STEPS survey methodology, translated questionnaire, informed consent of participation and informative letter were approved by the Ethics Committee of the National AIDS Prevention Center of Armenia and the WHO (14). The measurements were obtained during face-to-face interviews. Data collectors were previously trained by WHO experts (14).

Abbreviations: GPAQ, Global Physical Activity Questionnaire; MET, metabolic equivalent of task; NCD, non-communicable disease; PA, physical activity; SB, sedentary behavior; WHO, World Health Organization.

Data Collection Instrument

The STEPS instrument includes the Global Physical Activity Questionnaire (GPAQ) which has been validated and assessed to be suitable and acceptable for monitoring physical activity at the population level (18). The GPAQ allows assessment of the frequency and duration of PA in three domains: at work, for transportation and for leisure or recreational activities. It also differentiates between moderate- and vigorous-intensity PA for the work and recreational PA domains (19). This enables calculation of the time spent on PA in each of the domains separately as well as total amount of PA, reported in minutes per week or in metabolic equivalent of task (MET). One MET is equivalent to a caloric consumption of 1 kcal/kg/hour which is the energy cost of sitting quietly (20). According to the GPAQ analysis guide, 4.0 MET equates to a moderate MET minute value for work-related and recreational PA, 8.0 MET equates to a vigorous-intensity value for work-related and recreational PA, and 4.0 MET equates to transportation-related PA (20).

The information collected through the GPAQ allows estimation of the proportion of the population that are meeting the WHO global recommendations on PA for health. According to the recommendations, adults aged over 18 years should either achieve a minimum of 150 min of moderate-intensity physical activity, or 75 min of vigorous-intensity physical activity, or an equivalent combination of moderate- and vigorous-intensity physical activity that is the equivalent of at least 600 MET-minutes per week. It is also recommended to include muscle-strengthening activities involving major muscle groups on at least 2 days per week (2). The GPAQ has an additional item for recording time spent in sedentary activities and collects information on the socio-demographic characteristics of participants including sex, age, occupational status, educational levels, and location of residence (19).

Data Collection Process

The STEPS survey in Armenia was conducted among the 18–69 years old population from 13 September through 25 December 2016. The interviewers visited over 5 600 households and completed 2 380 interviews. The response rate was 42%. Main reasons for the somewhat low response rate were refusals to participate in the interviews (especially in the capital), and to much smaller extent errors in the addresses recorded in the unified population register.

From the total sample, 31 participants did not provide socio-demographic information and 100 participants provided incomplete or implausible responses to PA questions (e.g., more than 16 h of physical activity per day) and were excluded from the final dataset.

Data Analysis

For comparative purposes, the sample was divided into four age groups: 18–29, 30–44, 45–59, and 60–69. Educational levels were recoded into three levels: (1) secondary school (or lower) completed; (2) high school completed; (3) college/university (or higher degree) completed. The proportion of the population in Armenia was 36.5% rural and 63.5% urban (14). 35.6% of the population (more than half of

TABLE 1 | Socio-demographic characteristics of the study population.

	Percentage of population (weighted), %
Gender	
Men	52
Women	48
Age group	
18–29	34.3
30–44	29.3
45–59	26.6
60–69	9.8
Education	
Secondary school (or lower)	48.2
High school	26.1
College/University (or higher degree)	25.7
Residence	
Yerevan	41.5
Urban	23.5
Rural	34.0
Occupation	
Employed	38.7
Student	7.0
Homemaker	25.0
Retired	5.1
Unemployed	22.8

all urban residents) lived in the capital city, Yerevan, which makes it unique from the perspective of access to a PA promotive environment, despite being in cities with more sport facilities, studies have shown that inhabitants of urban sprawls have higher level of physical inactivity (21, 22). Therefore, the sample was divided into three groups according to location of residence: rural, urban and Yerevan residents. The sample was also divided into five groups by occupation: "Employed," "Student," "Homemaker," "Retired," and "Unemployed."

SB was defined as sitting for over 8 h daily as studies have indicated that this amount of SB can be harmful to health and increase the risk of NCDs and all-cause mortality (7, 23, 24).

Pearson's Chi-square test was used for comparison of proportions and Wilcoxson rank test or Kruskal-Wallis test used for comparison of continuous variables such as average amount of PA and sedentary time. Data were weighted to account for cluster design, age, sex, and non-response by age and gender. Statistical analysis was conducted in R version 3.4.3 using the Survey package (25).

RESULTS

The study sample consisted of 2,249 (52% male) subjects aged 18–69 years. Socio-demographic characteristics of population are presented in **Table 1**.

TABLE 2 | Indicators of physical activity and sedentary behavior for gender.

	Gender		
	Men	Women	*p*-value
Meet WHO recommendations on PA, % (95% CI)	77.5 (73.4–81.6)	79.4 (76.3–82.5)	$p = 0.42$
No work related PA, % (95% CI)	46.5 (40.6–52.5)	47.9 (43.7–52.1)	$p = 0.67$
No transport PA, % (95% CI)	35.4 (29.3–41.6)	29.1 (25.5–32.6)	$p = 0.03$
No recreation related PA, % (95% CI)	85.4 (81.8–88.9)	87.1 (84.7–89.5)	$p = 0.41$
No vigorous PA, % (95% CI)	69.2 (65.0–73.3)	89.5 (87.5–91.5)	$p < 0.001$
Sedentary behavior, minutes (95% CI)	248 (224–271)	208 (195–221)	$p = 0.004$
Sitting more than 8 hours per day, % (95% CI)	15.6 (12.0–19.3)	10.6 (8.0–13.2)	$p = 0.009$
Average amount of PA in minutes per day, mean (95% CI)	222 (198–247)	194 (180–208)	$p = 0.25$
Average amount of PA in MET/min/week, mean (95% CI)	7,983 (7,097–8,870)	5,791 (5,372–6,210)	$p = 0.02$

General Description of Physical Activity Level and Sedentary Behavior in Armenia

21.6% (95% CI: 18.7–24.4) of adults did not meet the WHO PA recommendations of at least 600 MET-minutes per week. Almost half of participants (47.2%, 95% CI: 43.1–51.2) were inactive at work and around one third (32.4%, 95% CI: 28.2–36.5) were not active for transport purposes (e.g., walking or cycling). Less than 15% of participants were physically active in leisure time. 78.9% (95% CI: 76.4–81.4) of the population did not engage in any vigorous-intensity activity. The average amount of total PA time per day was 209.0 min (95% CI: 193.4–224.5), and the median PA time per day was 120 (IQR: 30–345) minutes. The mean PA in MET-minutes per week for the adult population of Armenia was 6932.5 (95% CI: 6381.6–7483.5) and the median was 3520 (IQR: 840–10846) MET-minutes per week. Mean sitting time per day was 228.6 minutes (95% CI: 213.8–243.4) and the median was 180 (IQR: 120–330) minutes. 13.2% (95% CI: 10.7–15.7) of the population spent more than 8 h per day sitting.

Socio-Demographic Factors

Gender

In general, men were more physically active (see **Table 2**). They did significantly more physical activity than women when calculated in MET-minutes per week ($p = 0.02$). 30.8% of men engaged in vigorous-intensity PA which was three times higher than women ($p < 0.001$). The only indicator for which women were more active than men was for transport-related PA ($p = 0.03$). Conversely, men overall spent more minutes sitting per day ($p = 0.004$). 15.6% of men spent more than 8 h per day sitting, compared to 10.6 % of women, $p = 0.009$.

TABLE 3 | Indicators of physical activity and sedentary behavior for age.

	Age				
	18–29	**30–44**	**45–59**	**60–69**	***p*-value**
Meet WHO recommendations on PA, % (95% CI)	81.1 (76.9–85.4)	80.7 (76.8–84.7)	74.1 (69.1–79.2)	73.6 (68.4–78.8)	$p = 0.013$
No work related PA, % (95% CI)	51.0 (45.2–56.7)	40.7 (35.3–46.2)	45.7 (40.2–51.3)	57.1 (51.2–63.0)	$p < 0.001$
No transport PA, % (95% CI)	26.4 (20.8–32.0)	32.5 (26.4–38.7)	39.1 (33.6–44.6)	34.7 (29.1–40.2)	$p < 0.001$
No recreation related PA, % (95% CI)	80.9 (76.7–85.1)	85.5 (81.2–89.9)	91.6 (89.3–93.9)	92.1 (89.4–94.9)	$p < 0.001$
No vigorous PA, % (95% CI)	81.0 (76.4–85.5)	72.6 (68.0–77.2)	79.6 (75.6–83.6)	88.8 (85.2–92.5)	$p < 0.001$
Sedentary behavior, minutes (95% CI)	233.5 (212–255)	209.6 (188–231)	232.7 (213–252)	257.2 (235–279)	$p = 0.002$
Sitting more than 8 h per day, % (95% CI)	13.5 (9.6–17.4)	11.4 (7.6–15.2)	13.9 (10.2–17.7)	15.9 (11.2–20.6)	$p = 0.49$
Average amount of PA in minutes per day, mean (95% CI)	184 (160–208)	249.3 (224–275)	209.2 (186–232)	174.6 (148–202)	$p = 0.001$
Average amount of PA in MET/min/week, mean (95% CI)	5,830 (5,010–6,650)	8,532 (7598–9465)	7,141 (6,293–7,988)	5,434 (4,539–6,331)	$p < 0.001$

Age

The analysis showed that there are statistically significant differences between age groups for all indicators of physical activity and sedentary behavior except proportion of people sitting more than 8 h per day (see **Table 3**).

Young people aged 18–29 years had low levels of PA. While only 18.9% did not meet WHO recommendations, in terms of total amount of PA and SB they were closer to the oldest age group than to the 30–44 year old group.

The most active age group were people between 30 and 44 years old. They were significantly more engaged in work-related and vigorous-intensity PA, achieved more PA per day (249.3 min), per week (8532 MET-min), and spent less time sitting per day (209.6 min).

People aged 60–69 years were the least active age group. 57.1% did no work-related PA and only 7.9% were active for recreation or leisure. The average amount of time spent sitting per day was 257.2 min and average amount of PA was 174.6 min per day. 26.4% did not meet WHO recommendations on PA.

Residence

There are statistically significant differences between rural, urban, and Yerevan residents for all indicators of PA except time spent on sedentary activities per day (see **Table 4**). Yerevan residents showed the lowest levels of PA between the three population groups: 56.7% did not do any work-related PA, 19.4% spent more than 8 h per day sitting, 28% did not meet WHO recommendations. People from rural areas were the most active. Only 14.8% of them did not meet WHO recommendations, less than 8% spent more than 8 h per day sitting, and the average amount of total PA was 260.9 min per day. However, they mostly did work- and transport-related physical activity; only 8.9% did PA for recreation or leisure which was half of the level of Yerevan residents (18.1%).

Education

People with a higher level of education were more engaged in leisure-time PA and more likely to meet WHO recommendations on PA (see **Table 5**). People with lower levels of education were more engaged in vigorous-intensity PA and achieved a higher average amount of PA. The proportion of people sitting more than 8 h per day was significantly higher among people with a college/university or higher degree (17.8%).

Occupation

There are statistically significant differences between occupational groups for all physical activity and sedentary behavior indicators (see **Table 6**). The most inactive group was "unemployed"; 33.6 % did not meet WHO recommendations on PA. Other groups which were also in the low-level PA category were "retired" people, which consisted mostly of older adults who were less physically active. This group had very low engagement in recreation PA—4.9%. "Employed" and "homemaker" groups were more engaged in work-related physical activity. Homemakers had the lowest levels of sedentary behavior with only 5.3% sitting more than 8 h per day and an average sitting time of 179.6 min per day. Among students, 86.1% met WHO recommendations on PA, although this group had the lowest average amount of PA (4009 MET-minutes per week).

DISCUSSION

This study presents information on prevalence of physical inactivity and sedentary behavior in Armenia for the first time. In general, the level of physical inactivity in Armenia is slightly

TABLE 4 | Indicators of physical activity and sedentary behavior for residence.

	Residence			
	Yerevan	**Urban**	**Rural**	***p*-value**
Meet WHO recommendations on PA, % (95% CI)	72.0 (66.0–78.0)	79.7 (75.5–84.0)	85.2 (82.2–88.1)	$p < 0.001$
No work related PA, % (95% CI)	56.7 (48.2–65.2)	48.9 (43.0–54.8)	34.6 (29.4–40.0)	$p = 0.024$
No transport PA, % (95% CI)	37.1 (28.9–45.3)	34.4 (28.9–40.0)	25.4 (20.6–30.2)	$p < 0.001$
No recreation related PA, % (95% CI)	81.9 (77.2–86.5)	86.6 (83.0–90.1)	91.1 (88.3–93.9)	$p = 0.001$
No vigorous PA, % (95% CI)	83.0 (79.0–87.0)	85.3 (81.4–89.2)	69.8 (65.4–74.1)	$p = 0.001$
Sedentary behavior, minutes (95% CI)	248 (215–281)	216 (196–236)	213 (200–227)	$p = 0.52$
Sitting more than 8 h per day, % (95% CI)	19.4 (13.9–25.0)	10.9 (7.5–14.3)	7.4 (4.8–9.9)	$p < 0.001$
Average amount of PA in minutes per day, mean (95% CI)	170.9 (139–203)	198.8 (176–222)	260.9 (238–284)	$p < 0.001$
Average amount of PA in MET/min/week, mean (95% CI)	5,676 (4,552–6,800)	6,325 (5,482–7,167)	8,832 (7,997–9,667)	$p < 0.001$

TABLE 5 | Indicators of physical activity and sedentary behavior for education groups.

	Education level			
	Secondary school	**High school**	**College/University**	***p*-value**
Meet WHO recommendations on PA, % (95% CI)	75.2 (70.9–79.5)	81.6 (77.6–85.6)	81.2 (76.6–85.2)	$p = 0.03$
No work related PA, % (95% CI)	45.5 (40.4–50.6)	45.2 (39.2–51.2)	52.3 (45.3–59.2)	$p = 0.15$
No transport PA, % (95% CI)	35.7 (30.7–40-8)	29.7 (24.7–34.7)	28.7 (22.2–35.2)	$p = 0.03$
No recreation related PA, % (95% CI)	88.9 (86.2–91.6)	89.3 (86.5–92.2)	77.9 (72.9–82.9)	$p < 0.001$
No vigorous PA, % (95% CI)	76.0 (72.3–79.8)	78.7 (74.0–83.4)	84.6 (80.4–88.7)	$p = 0.018$
Sedentary behavior, minutes (95% CI)	225.2 (207–243)	226.3 (210–243)	237.2 (208–266)	$p = 0.9$
Sitting more than 8 h per day, % (95% CI)	11.7 (8.6–14.8)	11.5 (8.5–14.6)	17.8 (12.6–23.1)	$p = 0.02$
Average amount of PA in minutes per day, mean (95% CI)	219.8 (198–241)	227.0 (200–254)	170.3 (148–193)	$p = 0.027$
Average amount of PA in MET/min/week, mean (95% CI)	7,447 (6,698–8,196)	7,614 (6,567–8,660)	5,277 (4,522–6,033)	$p = 0.012$

lower than the estimated average globally. A study of physical activity that included data from 168 countries estimated that 27.5% of the pooled sample were physically inactive (26). In Armenia, 21.6% of the population's did not meet the WHO recommendations of being physically active for at least 150 min per week. In terms of the Armenian population, this amounts to around 620 000 people whose health is at-risk due to physical inactivity.

The proportion of people who were physically inactive at the workplace was 47.2%, meaning that half the population have sedentary jobs. It is therefore essential that opportunities for PA be provided for people during working hours. This could include development of workplace health promotion policies which prioritize opportunities for PA throughout the day, supported by the development of infrastructure for PA and targeted interventions to encourage people to be active during working hours.

Another important finding is the low level of involvement in leisure-time PA. The rate of physical inactivity during leisure time in Armenia was 86.2%. These results are comparable

TABLE 6 | Indicators of physical activity and sedentary behavior for different occupation groups.

	Employed	Student	Homemaker	Retired	Unemployed	*p*-value
Meet WHO recommendations on PA, % (95% CI)	81.6 (77.2–85.9)	86.1 (78.6–93.7)	83.8 (79.9–87.6)	68.5 (60.9–76.0)	66.4 (60.2–72.5)	$p < 0.001$
No work related PA, % (95% CI)	42.3 (36.0–48.5)	69 (56.2–81.7)	38.6 (33.1–44.0)	55 (46.2–63.9)	58.7 (52.2–65.2)	$p = 0.67$
No transport PA, % (95% CI)	35.2 (28.4–42.0)	19.1 (10.2–28-0)	29.2 (24.0–34.3)	38.9 (31.8–46.0)	32.6 (26.8–38.4)	$p = 0.03$
No recreation related PA, % (95% CI)	82.8 (78.6–87.1)	69.6 (58.4–80.8)	88.1 (85.1–91.2)	95.1 (92.6–97.5)	93.2 (90.6–96.0)	$p = 0.001$
No vigorous PA, % (95% CI)	75.5 (71.5–79.6)	74.3 (63.1–85.5)	80.1 (75.3–85.0)	92.3 (87.2–97.4)	83.1 (78.0–88.1)	$p = 0.014$
Sedentary behavior, minutes (95% CI)	227.5 (202–253)	255.2 (204–307)	179.2 (165–194)	284.9 (250–320)	268.4 (244–292)	$p < 0.001$
Sitting more than 8 hours per day, % (95% CI)	13.7 (9.7–17.7)	18.4 (7.8–29.0)	5.3 (2.9–7.8)	18.6 (11.4–25.7)	19.1 (14.0–24.1)	$p < 0.001$
Average amount of PA in minutes per day, mean (95% CI)	239.2 (210–268)	125.9 (96–155)	249.6 (224–275)	155.5 (119–192)	143.7 (122–165)	$p < 0.001$
Average amount of PA in MET/min/week, mean (95% CI)	8,232 (7,155–9,310)	4,009 (2,982–5,036)	8,064 (7,082–9,048)	4,633 (3,500–5,766)	4,701 (3,893–5,509)	$p < 0.001$

to low- and middle-income countries and differ from high-income countries where leisure time PA is a major component of total PA undertaken by adults (27–29). Increasing the promotion and availability of sports and recreational facilities are a recommended priority area for health promotion in Armenia. More opportunities for PA during leisure time can be achieved through the development of infrastructure for recreational PA, investing in maintenance of existing parks, and encouraging sports clubs and facilities to develop programs and initiatives that promote physical activity and participation in sports for health.

The survey results also enabled the assessment and comparison of physical inactivity and sedentary behavior for different socio-demographic groups. Insufficient PA levels were more prevalent among older adults, Yerevan residents, as well as people who were unemployed, retired, or had a lower level of education. Total amount of PA was significantly lower among women, adults under 30 years old and over 60 years old, people with college or university degree, students, Yerevan and urban residents. Men spent more time sitting as did people under the age of 30 and over the age of 45, Yerevan residents, students, retirees and unemployed people.

Between men and women, no major differences were found in the proportion of people that did not meet WHO recommendations on PA. However, total amount of PA was significantly higher for men. This is consistent with results from other countries and the global trend (26, 29–31). Assessment of sedentary behavior time showed that despite their higher overall level of physical activity, men spent significantly more time sitting than women; 15.6% of men spent more than 8 h per day sitting which may have an adverse impact on health, independent of physical activity levels (7, 9, 11, 23, 24). Therefore, interventions to promote PA must target both men and women but different approaches may be required.

In developing countries, it has previously been observed that people in rural areas are more active in comparison with those living in urban areas (29, 32–34). This tendency was also found in Armenia where the highest level of physical inactivity and sedentary behaviors were in Yerevan, the capital city. Yerevan residents were less engaged in work- and transportation-related PA. Often in larger cities there are more opportunities for leisure time PA, however, 81.9% of the Yerevan population did not engage in any recreational PA. This indicates the need for additional measures to promote recreational PA and increasing accessibility of sports or recreational facilities should be taken into account in urban planning.

Another risk group with lower levels of PA is unemployed people. These results similar to other studies (35, 36). Unemployed people also spent more time sitting per day (over 4.5 h on average) and this segment of the population had the highest proportion of people who spent more than 8 h per day sitting (19.1%). This group should be targeted by interventions to increase PA and reduce SB which could include initiatives such as discounted user fees of recreational facilities to increase opportunities for participation in recreational PA.

Students in Armenia were significantly less active than other adults and spent more time sitting when compared with employed people and homemakers which is typical in other countries (28, 37, 38). Other studies showed that low PA levels of students has been associated with the university lifestyle, time spent studying for exams and academic pressure (39). Studying and preparing for exams require a lot of sitting time. Increasing PA levels of students may require strategies to increase transport- and recreation-related PA. There is potential to increase active transport to colleges and universities by prioritizing walking and cycling as part of urban planning and providing a range of recreational facilities to engage all students in leisure time physical activity.

The overall results of the study revealed a fairly high level of physical inactivity among the Armenian population. Health policymakers should prioritize elaboration of national policy

documents on PA promotion. Development and implementation of programs for the promotion of PA and reducing of SB should be organized on national level and cover all at-risk groups. Leisure-time PA promotion can be a strategy to increase overall level of PA in the country.

Advantages of this study are a large and nationally-representative sample and the use of a standardized, validated questionnaire, and methodology. The use of GPAQ for monitoring current levels of PA and SB allowed the identification of those groups most at-risk due to high levels of physical inactivity and SB which provides important information for policy makers, researchers and health professionals when planning and implementing PA interventions. However, the GPAQ is a self-reported questionnaire and because of this the study has certain limitations. The understanding of vigorous- and moderate- intensity PA is subjective and responses may differ slightly depending on the participant or the interviewer conducting the survey. Also, in everyday life people generally do not track exactly how much time they have spent on a particular type of physical activity so responses depend on memory and a general estimate. Therefore, people may under- or over-report their physical activity and sedentary time. The use of objective methods to assess physical activity (such as accelerometers), even just in a sub-sample of the population to validate the responses to the questionnaires, could help to make the results more valid and reliable, and it is recommended that the inclusion of objective measurements be explored in future STEPS surveys and other studies of population physical activity levels. Another limitation is that the GPAQ allows to collect only amount of time spent sitting without specification of the activities performed during sedentary behavior (reading, watching TV, at the computer/tablet/mobile, etc.) or if person sits more at work or during leisure time. This information could help in developing more specific and effective interventions to reduce sedentariness. It should also be noted that although GPAQ has been validated extensively in various populations, it was not specifically validated for the Armenian population. This is also a limitation of the study and may be the subject of further research.

CONCLUSIONS

This study provides baseline information on physical inactivity and sedentary behavior of the adult population in Armenia. This information could be highly useful for policy makers to develop a national action plan for physical activity and to guide the development of national PA guidelines to enable health professionals to promote PA. It could be used in urban planning, health promotion campaigns, and interventions targeted at specific groups in the population. Special attention should be paid to increase opportunities for recreational PA. The results of this WHO STEPS survey enable the identification of at-risk groups with high levels of physical inactivity and sedentary behavior, therefore providing information to develop more targeted, effective, and cost-effective PA interventions. This important baseline study provides the information needed to monitor and evaluate actions taken to increase PA and sedentary behavior and their impact on population PA levels as well as assessments of any resulting policy changes in Armenia.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee of the National AIDS Prevention Center of Armenia and the WHO. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AT, IR, and JB contributed conception and design of the study. DA supervised data collection. BM organized the dataset. AT and IR performed the statistical analysis. AT wrote the first draft of the manuscript with support from SW, IR, and JB. All authors contributed to manuscript revision, read and approved the submitted version.

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Behavioral Change Towards Reduced Intensity Physical Activity Is Disproportionately Prevalent Among Adults With Serious Health Issues or Self-Perception of High Risk During the UK COVID-19 Lockdown

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Objectives: We assessed whether lockdown had a disproportionate impact on physical activity behavior in groups who were, or who perceived themselves to be, at heightened risk from COVID-19.

Methods: Physical activity intensity (none, mild, moderate, or vigorous) before and during the UK COVID-19 lockdown was self-reported by 9,190 adults between 2020-04-06 and 2020-04-22. Physician-diagnosed health conditions and topic composition of open-ended text on participants' coping strategies were tested for associations with changes in physical activity.

Results: Most (63.9%) participants maintained their normal physical activity intensity during lockdown, 25.0% changed toward less intensive activity and 11.1% were doing more. Doing less intensive physical activity was associated with obesity (OR 1.25, 95% CI 1.08–1.42), hypertension (OR 1.25, 1.10–1.40), lung disease (OR 1.23, 1.08–1.38), depression (OR 2.05, 1.89–2.21), and disability (OR 2.13, 1.87–2.39). Being female (OR 1.25, 1.12–1.38), living alone (OR 1.20, 1.05–1.34), or without access to a garden (OR 1.74, 1.56–1.91) were also associated with doing less intensive physical activity, but being in the highest income group (OR 1.73, 1.37–2.09) or having school-age children (OR 1.29, 1.10–1.49) were associated with doing more. Younger adults were more likely to change their PA behavior compared to older adults. Structural topic modeling of narratives on coping strategies revealed associations between changes in physical activity and perceptions of personal or familial risks at work or at home.

Conclusions: Policies on maintaining or improving physical activity intensity during lockdowns should consider (1) vulnerable groups of adults including those with chronic diseases or self-perceptions of being at risk and (2) the importance of access to green or open spaces in which to exercise.

Keywords: physical activity (exercise), COVID-19, SARS-CoV2, lockdown, chronic condition, mixed method approach, perceptions of risk, obesity

INTRODUCTION

The pandemic spread of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) (1) was declared a Public Health Emergency of International Concern by the World Health Organization on 30 January 2020[1] and by the end of April 2020 the virus had infected more than 3 million people worldwide, causing more than 200,000 deaths[2]. In order to limit the spread of Coronavirus disease 2019 (COVID-19), governments across the globe imposed varying degrees of social distancing advice and nationwide lockdowns. On 23 March 2020 the UK government enacted measures that were included in the Coronavirus Act 2020 and recommended that everyone must stay in their homes unless (i) shopping for essentials such as food and medicine, (ii) requiring medical assistance, (iii) caring for vulnerable people, (iv) traveling to and from work if absolutely necessary and (v) to carry out one form of exercise (e.g. walking, running, cycling) each day, either alone or with people who live together. Some adults aged 70 and over and those with specific underlying health conditions including asthma, heart disease, diabetes, and being seriously overweight were also advised to follow stricter social isolation recommendations. In this paper we refer to the combined package of measures as "lockdown".

There have been growing concerns that the lockdown has placed limitations on opportunities for individuals to be physically active[3] (2). It is well-established that physical activity (PA), a modifiable behavior, is protective against non-communicable diseases (3–5) and that reduced levels of PA may have a negative impact on the control of chronic health problems including metabolic, cardiovascular, musculoskeletal, pulmonary, and psychiatric conditions; all of which are also often better controlled when PA is included as part of the management plan (6).

The tradeoff between protection from COVID-19 and increased risk of inactivity presents already vulnerable populations with a potential "no-win" situation; for instance, where the consequence of protection from acquiring SARS-CoV-2 infection is increased inactivity and associated downstream health impacts. Longer term, it is also possible that changes in PA behaviors could serve to increase the size of the population that is vulnerable to severe complications from COVID-19 in subsequent epidemic waves. Furthermore, a recent study showed that physical inactivity was one lifestyle-related risk factor for severe COVID-19 requiring hospital admission (7). In this study we identify whether the UK's lockdown measures have had disproportionate impacts on PA intensity in groups who are, or who perceive themselves to be at risk of worse outcomes of COVID-19 disease. This study takes the form of a UK-wide survey of adults aged 20 and over.

[1]Available online at: https://www.who.int/news-room/detail/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov).

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MATERIALS AND METHODS

Online Survey

Anonymous survey data were collected online between 2020-04-06 and 2020-04-22, roughly mapping to weeks 3–5 of the lockdown in the UK. The survey included 49 questions which covered a broad range of topics including (1) Demographics, (2) Health and Health Behaviors, (3) Adherence to COVID-19 Control measures, (4) Information sources used to learn about COVID-19, (5) Trust in various information sources, government and government decision-making, (6) Rumors and misinformation, (7) Contact & Communication during COVID-19 and (8) Fear and Isolation.

The survey was publicized using a "daisy-chaining" approach in which respondents were asked to share and to encourage onward sharing of the survey's Uniform Resource Locator (URL) among friends & colleagues. The study team directly targeted a number of faith institutions, schools and special interest groups and also used Facebook's premium "Boost Post" feature. A "boosted" post functions as an advert which can be targeted at specific demographics. We boosted details of the survey and it's URL to a target audience of 113,280 Facebook users aged 13 and over and living in England, Wales, Scotland and Northern Ireland. Participants were also provided with URL links to a set of freely available summary reports and analyses which were periodically updated in near-real time.

We used an ODK XForm (https://getodk.github.io/xforms-spec/) deployed on Enketo smart paper (https://enketo.org/) via ODK Aggregate v.2.0.3 (https://github.com/getodk/aggregate). Form level encryption and end-to-end encryption of data transfer were implemented on all submissions.

Disability and Classification of Health Conditions

Participants were assessed for disability by asking about difficulties in six activities of daily living (ADLs) (8) including bathing, dressing, walking across a room, eating (such as cutting up food), getting in and out of bed, and using the toilet (including getting up and down). Disability was defined by the presence of at least one ADL. We also explored depressive symptomatology with the question "In the past 2 weeks, how often have you felt down, depressed, or hopeless?". Options were "not at all", "several days", "more than half the days", and "every day". Participants were classified as currently depressed if they reported feeling this way either "more than half the days" or "every day". To determine whether patients had any previous or current chronic disease(s) diagnosis (CDD), participants were asked "Has a doctor ever diagnosed you with any of the following?". The question allowed for multiple chronic diseases to be selected from a list that included diabetes type 1, diabetes type 2, lung disease, cancer, stroke, heart disease, high blood pressure (hypertension) and obesity.

We additionally asked participants to provide (in narrative text form) details about any other medical conditions that they

felt would increase their risk of getting seriously ill if they were to catch coronavirus. We chose to recode any participant who mentioned asthma as having a lung disease because the topic of "Asthma" accounted for around 25% of the open text responses to this question (Determined by structural text modeling, see below) and because asthma was mentioned directly by 678 participants (**Supplementary Figure 1**). The majority of people who reported having a doctor's diagnosis of lung disease also mentioned asthma (63.4%, $n = 225$, **Supplementary Table 1**) suggesting that they operationalized asthma as a lung disease and may have been referring to asthma when they reported their prior diagnosis of lung disease. 8.3% ($n = 453$) of people who did not report having "lung disease" did however mention asthma in the free text.

Analysis

We handled missing data by performing multiple imputation by chained equations using the *mice* package for R and 20 imputed data sets were completed for all relevant fields including highest educational qualifications, age (20–34; 35–54; 55–69; 70+), gender, whether living alone, household income, presence of ADLs, self-rated depression and pre-existing chronic diseases. Pearson's χ^2 test was used to detect factor variables with statistically significant differences between the groups when the data were grouped according to baseline (pre-COVID-19) PA levels. Due to significant differences according to baseline PA, all further analyses were corrected for baseline PA. The main response variable for statistical association tests was any change in PA intensity from pre-COVID-19 lockdown to the time of survey participation. This value was calculated by comparing baseline PA ("Before the outbreak began, what type of exercise did you regularly do?", options "None", "Mild [e.g. walking short distances, doing DIY etc.]", "Moderate [e.g., A gentle workout, Digging the garden, Dancing]", & "Vigorous [e.g., Running/Jogging/Hiking, Cycling, Weightlifting]") to PA during COVID-19 lockdown ("What type of exercise are you doing now?", options as for baseline). Participants were classified as doing the "Same", "Less", or "More" than their usual PA intensity. In order to detect factors which were associated with change in PA intensity during lockdown we used the "nnet" R package applied to a multinomial log-linear model via neural networks (9) to the imputed data set, pooling the results of the 20 separate analyses using Rubin's rules.

Topic Modeling

We used Structural Text Modeling (STM) (10) to identify key topics in the data on self-perceived medical risk factors (see above) and also to determine whether changes in PA intensity were associated with participants' other perceptions of risk from COVID-19. STM employs machine learning (ML) approaches to explore open ended survey questions in a highly structured and reproducible way (10). The goal of STM is to identify topics and perspectives in free-text data, for instance by highlighting specific diseases, themes or perspectives being reported in the survey. This is functionally analogous and equivalent in results to the type of human coding of text data performed by anthropologists and ethnographers; but unlike more conventional topic modeling, STM makes it possible to link topic models to metadata and quantitative data in a way that is directly amenable to statistical modeling (10, 11). All STM was performed using the "stm" package for R (11). STM was applied to data from the open-ended survey question "On 23rd March 2020, the Prime Minister Boris Johnson announced a complete lockdown in the UK. Tell us what you have been doing to help you cope during this difficult time?". The text data were processed into a corpus and transliterated to lower-case. Numbers, common punctuation and stop-words (such as "I", "me", "that's", and "because") were stripped and data were trimmed to include only words which appeared in 20 or more responses to the survey. The corpus was then bound to the quantitative data from the survey and the STM was optimized to determine the number of topics which maintained the balance between high semantic coherence (i.e. the topics were clear and understandable) and exclusivity (vocabulary and themes had little cross-over between topics). The topics were then labeled manually (this and defining the number of topics of interest were the only subjective components of the process) by first examining the word usage within topics (weighted by exclusivity) and then assessing a number of representative perspectives (quotes) from each of the topics. Expected text proportions (ETP) were defined as the proportion of the total corpus which related to each topic. Between-topic correlations were measured using the semiparametric procedure described in the R package "huge" (High-Dimensional Undirected Graph Estimation). Tests for statistical associations between the PA data set and the STM topics used regressions of the STM, where the between group ETPs were the outcome variables and the survey PA question data, including the change in PA intensity were the explanatory variables.

Patient and Public Involvement

This study is a collaboration between two continuing National Institute of Health Research (NIHR) funded programmes of research including (i) The Emergency and Epidemic Data Kit [EDK] and (ii) Anthropological Exploration of Facilitators and Barriers to Vaccine Deployment and Administration During Disease Outbreaks (AViD). Both projects have been developed and guided from the earliest stages by patient and public involvement and stakeholders have been included in all stages of the research. The open source survey software used in this study was developed in collaboration with a global community of researchers, data scientists and field epidemiologists, including members of the public, not-for-profit organizations and partners from low and middle income countries. A group of around 15 lay members of the UK public, including both younger and older people, were asked to review and recommend changes to the content of the survey before it was fully deployed.

RESULTS

The survey consisted of 9,456 participants. The majority of respondents (78%) were female and most (82%) were aged between 35 and 69 years. There was a relatively normal

distribution of household incomes but a large proportion of the participants (62%, $n = 5{,}502$) were educated to degree level or higher. Participants lived across the UK including 6% in Scotland, 5% in Wales, 1% in Northern Ireland and of those from England, 35% in London and the South-East regions. Ethnically, 95% of participants were white, with just 3.7% being from black and minority ethnic (BAME) backgrounds. 0.9% of respondents opted not to reveal their ethnicity. Ethnicities were not included as a covariate in statistical analyses as the numbers in each group were too small. Participants who were transgender, gender fluid, or non-binary, and those who indicated that they did not wish to reveal their gender ($n = 73$) were grouped together under the term "all other genders" for statistical reasons, although we acknowledge that this grouping does not fully recognize the individuality, granularity and diversity of the gender identities of our participants. The prevalence of adults carrying out moderate or vigorous PA on a regular basis was similar to that previously reported for adults living in England[4].

After filtering the data (**Supplementary Table 2**) we retained 9,190 participants for analysis and demographic characteristics of the filtered sample are given in **Table 1**. At least one data point was missing and therefore imputed in 3,294 (35.8%) responses. The percentages (and number) of imputed data points were as follows: education (2.6%, $n = 237$), gender (0.7%, $n = 60$), access to garden (0.3 %, $n = 23$), school age children (0.7%, $n = 67$), income (13.2%, $n = 1{,}214$), depression (0.8%, $n = 69$), diabetes type I (18.2%, $n = 1{,}671$), diabetes type II (15.5%, $n = 1{,}429$), lung disease (15.5%, $n = 1{,}426$), cancer (17.5%, $n = 1{,}610$), stroke (20.0%, $n = 1{,}840$), heart disease (18.5%, n = 1,704), hypertension (9.6%, $n = 879$), and obesity (14.7%, $n = 1{,}353$). Full details of the number of observations contributing to the multinomial regression analysis, including a breakdown of observed and imputed numbers of observations by change in PA intensity are provided in **Supplementary Table 3**.

All statistical testing used the group who had not changed PA intensity as the reference group.

Approximately 36% of participants ($n = 3{,}318$) reported a change in their PA behaviors during lockdown, with 25.1% ($n = 2{,}302$) doing less and 11.1% ($n = 1{,}016$) doing more than before the pandemic. After correcting for baseline PA intensity, there were significantly increased odds for women (compared to men) to have started doing less intense PA under lockdown (OR 1.25, 95% CI 1.12–1.38, $p = 0.001$). This was also the case for people who did not have access to a garden (OR 1.74, 95% CI 1.56–1.91, $p < 0.001$) or whom lived alone (OR 1.20, 95% CI 1.05–1.34, $p = 0.016$). Decreasing age had a linear relationship to the odds of changing PA behaviors in either direction (**Figure 1**, **Table 2**). Lung diseases were significantly associated with increased odds of change toward doing less intense PA (OR 1.23, 95% CI 1.08–1.38, $p = 0.006$). Hypertension (OR 1.25, 95% CI 1.10–1.40, $p = 0.004$), depression (OR 2.05, 95% CI 1.89–2.21, $p < 0.001$) and disability from one or more ADL (OR 2.13, 95% CI 1.87–2.39, $p < 0.001$) were all significantly associated with change toward less intense PA behaviors (**Table 2**, **Figure 1**). Participants from the wealthiest group (OR 1.73, 95% CI 1.37–2.09, $p = 0.003$) and those living with school aged children (OR 1.29, 95% CI 1.10-1.49, $p = 0.011$) had increased odds of changing to do more intense PA compared to, respectively, the least wealthy group and those living without children of school age.

To investigate the role of self-perceived risks on PA behaviors during lockdown, we used STM to reveal 10 topics in the 8,642 survey responses which constituted the corpus of text on the coping-strategies of the study participants. The 10 key topics we identified were (T1) "Perceptions of risk/working or living in risk environments/already had COVID-19", (T2) "Adherence to guidelines/social distancing", (T3) "Activities around the house", (T4) "Social media/online activities", (T5) "Staying home & only leaving house to shop", (T6) "Positivity/ Health/Exercise", (T7) "Mental Health/Anxiety/Nonchalance", (T8) "Balancing work, family and caring", (T9) "Exercise", and (T10) "Gardening & outdoor life". Representative perspectives (in the form of quotes) from the topics are provided in **Supplementary Table 4**. Some of these topics were correlated (**Figure 2**), suggesting that participant narratives may have had thematic overlaps between correlated topics. The correlation between Topics T3 "Activities around the house" and T9 "Exercise" suggest that a substantial proportion of participants who discussed doing exercises like yoga, running or walking also discussed keeping busy around the house with tasks such as cooking, knitting, gardening and reading, or doing jigsaws. Those whose responses included T6 "Positivity/Health/Exercise", a topic which included references to maintaining routines, keeping in touch with friends and staying active, potentially also talked about T2 "Adherence to guidelines/social distancing".

Topic T1 "Perceptions of risk…" included quotes which referenced working in high risk settings such as the national health service and also references to living with vulnerable family members. A number of quotes from T1 also came from individuals who claimed to have had suffered from COVID-19 either previously or at the time of participation in the study. Topic T1 appeared to correlate closely with T8 "balancing work, family and caring" and with T7 which included comments about the effect of the pandemic on the mental health of the participants. T7 included both very anxious and surprisingly nonchalant or fatalistic comments. Topics T1 and T7 were both in turn correlated with Topic T5, which described how some participants had stayed home entirely, leaving only to shop for necessities.

When we performed a statistical analysis of how change in PA intensity related to coping strategies during lockdown, the STM expected text proportions revealed that "Perceptions of risk…" (topic T1) were mentioned in 9.7% (9.3–10.1%) of responses from participants who had not changed, in 8.1% (7.1–9.0%, $p = 0.001$) of responses from people doing more PA and in 11.2% (10.4–11.9%, $p < 0.001$) among participants doing less PA (**Figure 3**). Compared to the ETPs of the group which maintained the same level of PA intensity, topics T3 "Activities around the

[4]Health Survey for England 2016 Physical activity in adults Available online at: healthsurvey.hscic.gov.uk/media/63730/HSE16-Adult-phy-act.pdf.

TABLE 1 | Demographic characteristics of the sample, by baseline PA intensity.

Variable	Group	PA Intensity before lockdown[a]				Total[b]	*p*-value[c]
		None (*N* = 288)	Mild (*N* = 3,111)	Moderate (*N* = 3,874)	Vigorous (*N* = 1,917)	(*N* = 9,190)	
PA intensity during lockdown *n* (%)	None	172 (23.2%)	390 (52.7%)	132 (17.8%)	46 (6.2%)	740 (8.05 %)	<0.001
	Mild	76 (2.3%)	1,999 (60.5%)	977 (29.6%)	252 (7.6%)	3,304 (35.95 %)	
	Moderate	31 (0.8%)	641 (17.0%)	2,587 (68.7%)	505 (13.4%)	3,764 (40.96 %)	
	Vigorous	9 (0.7%)	81 (5.9%)	178 (12.9%)	1,114 (80.6%)	1,382 (15.04 %)	
PA Change during lockdown *n* (%)	Same	172 (2.9%)	1,999 (34.0%)	2,587 (44.1%)	1,114 (19.0%)	5,872 (63.9 %)	< 0.001
	Less	0 (0.0%)	390 (16.9%)	1,109 (48.2%)	803 (34.9%)	2,302 (25.05 %)	
	More	116 (11.4%)	722 (71.1%)	178 (17.5%)	0 (0.0%)	1,016 (11.06 %)	
Age *n* (%)	20-34	21 (3.4%)	157 (25.4%)	195 (31.6%)	245 (39.6%)	618 (6.72 %)	< 0.001
	35-54	116 (3.5%)	1,060 (32.4%)	1,221 (37.3%)	877 (26.8%)	3,274 (35.63 %)	
	55-69	126 (3.0%)	1,456 (34.4%)	1,952 (46.1%)	702 (16.6%)	4,236 (46.09 %)	
	70+	25 (2.4%)	438 (41.2%)	506 (47.6%)	93 (8.8%)	1,062 (11.56 %)	
Gender *n* (%)	Female	224 (3.1%)	2,474 (34.6%)	3,146 (44.0%)	1,299 (18.2%)	7,143 (77.73 %)	< 0.001
	Male	55 (2.9%)	598 (31.2%)	675 (35.3%)	586 (30.6%)	1,914 (20.83 %)	
	All other genders	8 (11.0%)	21 (28.8%)	22 (30.1%)	22 (30.1%)	73 (0.79 %)	
Living alone *n* (%)	No	226 (3.0%)	2530 (33.0%)	3246 (42.4%)	1659 (21.7%)	7,661 (83.36 %)	< 0.001
	Yes	62 (4.1%)	581 (38.0%)	628 (41.1%)	258 (16.9%)	1,529 (16.64 %)	
Education *n* (%)	GCSE/O-level	47 (5.1%)	399 (43.0%)	377 (40.6%)	105 (11.3%)	928 (10.1 %)	< 0.001
	A level/Highers	86 (3.4%)	963 (38.2%)	1,089 (43.2%)	385 (15.3%)	2,523 (27.45 %)	
	Degree	143 (2.6%)	1640 (29.8%)	2,314 (42.1%)	1,405 (25.5%)	5,502 (59.87 %)	
Access to a garden *n* (%)	Yes	249 (3.0%)	2,792 (33.5%)	3,593 (43.1%)	1,699 (20.4%)	8,333 (90.67 %)	<0.001
	No	36 (4.3%)	310 (37.2%)	271 (32.5%)	217 (26.0%)	834 (9.08 %)	
School aged children *n* (%)	No	220 (3.1%)	2,493 (34.8%)	3,088 (43.1%)	1367 (19.1%)	7,168 (78 %)	<0.001
	Yes	67 (3.4%)	594 (30.4%)	755 (38.6%)	539 (27.6%)	1,955 (21.27 %)	
Household Income *n* (%)	< £15,000	59 (5.7%)	455 (43.8%)	420 (40.4%)	105 (10.1%)	1,039 (11.31 %)	<0.001
	£15,000–£24,999	36 (2.4%)	583 (38.8%)	669 (44.5%)	215 (14.3%)	1,503 (16.35 %)	
	£25,000–£39,999	49 (2.7%)	641 (35.1%)	783 (42.9%)	351 (19.2%)	1,824 (19.85 %)	
	£40,000–£59,999	57 (3.4%)	491 (29.5%)	698 (42.0%)	417 (25.1%)	1,663 (18.1 %)	
	£60,000–£99,999	27 (2.0%)	376 (28.3%)	526 (39.5%)	401 (30.2%)	1,330 (14.47 %)	
	More than £100,000	12 (1.9%)	154 (25.0%)	220 (35.7%)	231 (37.4%)	617 (6.71 %)	
Disability (ADL) *n* (%)	No	208 (2.4%)	2,879 (32.7%)	3,808 (43.3%)	1,897 (21.6%)	8,792 (95.67 %)	<0.001
	Yes	80 (20.1%)	232 (58.3%)	66 (16.6%)	20 (5.0%)	398 (4.33 %)	
Depression *n* (%)	No	238 (2.9%)	2,746 (33.4%)	3,516 (42.8%)	1,716 (20.9%)	8,216 (89.4 %)	<0.001
	Yes	48 (5.3%)	344 (38.0%)	328 (36.2%)	185 (20.4%)	905 (9.85 %)	
Diabetes type I *n* (%)	No	222 (3.0%)	2,400 (32.3%)	3,126 (42.0%)	1,689 (22.7%)	7,437 (80.92 %)	0.014
	Yes	5 (6.1%)	37 (45.1%)	23 (28.0%)	17 (20.7%)	82 (0.89 %)	
Diabetes type II *n* (%)	No	201 (2.8%)	2,264 (31.5%)	3,049 (42.5%)	1668 (23.2%)	7,182 (78.15 %)	<0.001
	Yes	46 (7.9%)	302 (52.2%)	188 (32.5%)	43 (7.4%)	579 (6.3 %)	
Lung Disease *n* (%)	No	179 (2.8%)	1,996 (31.5%)	2,678 (42.3%)	1485 (23.4%)	6,338 (68.97 %)	<0.001
	Yes	57 (4.0%)	553 (38.8%)	573 (40.2%)	243 (17.0%)	1,426 (15.52 %)	
Cancer *n* (%)	No	201 (2.9%)	2,206 (32.1%)	2,880 (41.9%)	1,593 (23.2%)	6,880 (74.86 %)	0.026
	Yes	24 (3.4%)	247 (35.3%)	324 (46.3%)	105 (15.0%)	700 (7.62 %)	
Stroke *n* (%)	No	202 (2.8%)	2,305 (32.0%)	3,033 (42.1%)	1,656 (23.0%)	7,196 (78.3 %)	<0.001
	Yes	15 (9.7%)	62 (40.3%)	58 (37.7%)	19 (12.3%)	154 (1.68 %)	
Heart disease *n* (%)	No	201 (2.8%)	2,250 (31.8%)	2,990 (42.3%)	1,630 (23.1%)	7,071 (76.94 %)	<0.001
	Yes	28 (6.7%)	186 (44.8%)	150 (36.1%)	51 (12.3%)	415 (4.52 %)	
Hypertension *n* (%)	No	162 (2.6%)	1,817 (29.6%)	2,639 (43.0%)	1,523 (24.8%)	6,141 (66.82 %)	<0.001
	Yes	94 (4.3%)	952 (43.9%)	866 (39.9%)	258 (11.9%)	2,170 (23.61 %)	
Obesity *n* (%)	No	145 (2.3%)	1,811 (28.7%)	2,771 (44.0%)	1,577 (25.0%)	6,304 (68.6 %)	<0.001
	Yes	105 (6.8%)	803 (52.4%)	480 (31.3%)	145 (9.5%)	1,533 (16.68 %)	

[a] *PA Intensity before lockdown shows percentage of each class doing different PA intensity before lockdown.* [b] *Total shows percentage of each class in the total sample of 9,190 participants.*

[c] *P-value: Pearson's Chi Squared Test.*

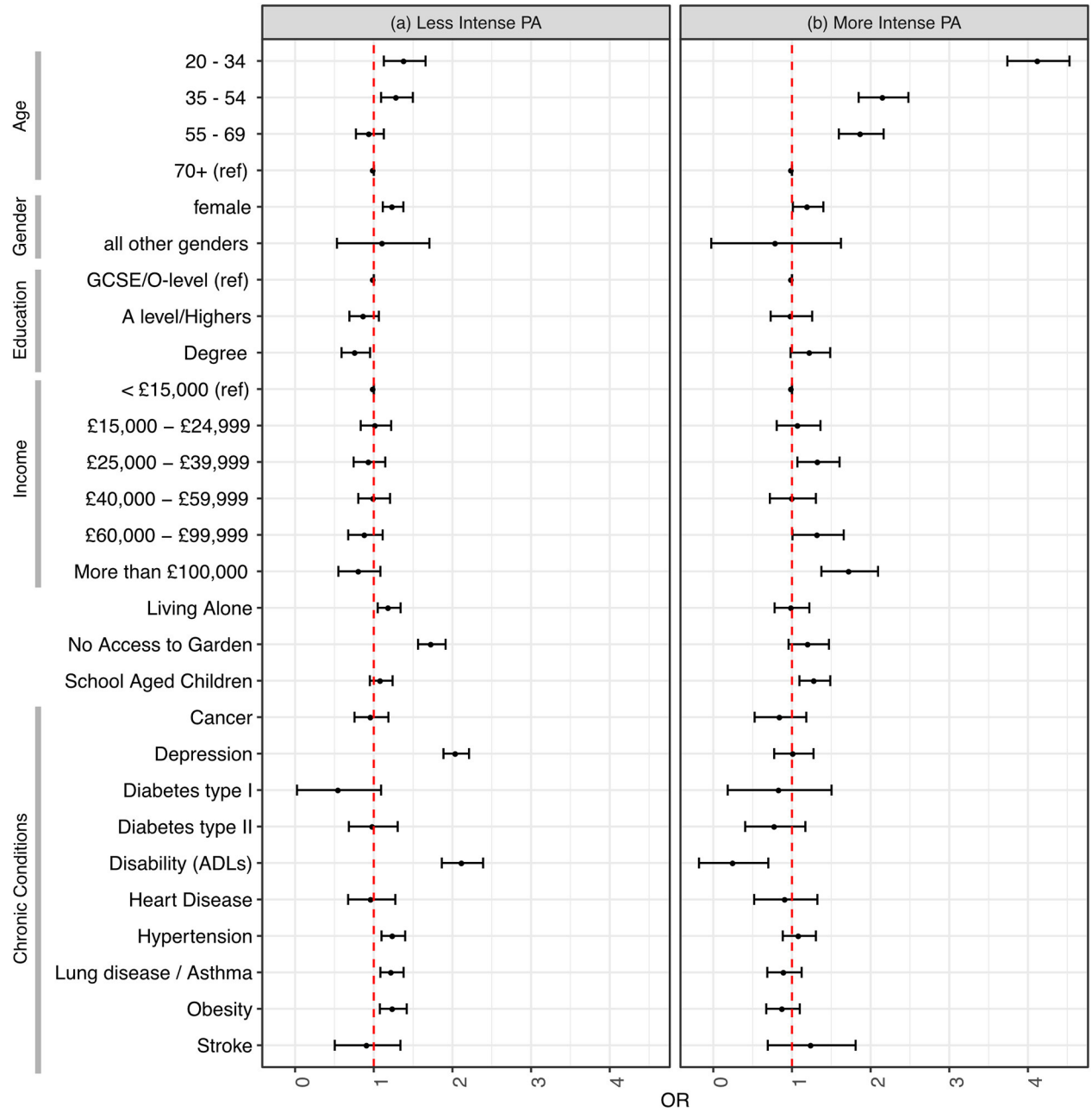

FIGURE 1 | Odds ratios for having changed toward **(a)** less intense and **(b)** more intense physical activity since the UK COVID-19 lockdown began. The reference group is study participants who continued to do the same intensity of physical activity. All odds ratios are corrected for baseline physical activity intensity and all other variables.

house" ($p = 0.01$) and T10 "Gardening and outdoor life" ($p = 0.006$) had lower ETPs among those doing less intense PA during lockdown. Topic T7 "Mental health…" had a lower ETP ($p < 0.001$) among those doing more intense PA, whilst the ETP of T8 "Balancing work, family and caring" was higher among this group ($p = 0.006$). Topic T9 "Exercise" was notably much higher in the group which reported doing more intense PA under lockdown ($p < 0.001$).

DISCUSSION

In this large UK-wide survey of adults aged 20 and over we show that the majority (>60%) of the study sample succeeded in maintaining their normal PA intensity level during the study period of COVID-19 lockdown. Among those who changed their PA levels, more than twice as many people reduced their PA intensity as increased it. Adults who reported having

TABLE 2 | Odds ratios for change in intensity of physical activity toward (a) less intense and (b) more intense physical activity since the UK COVID-19 lockdown began.

		Corrected for age and sex		Fully Corrected[a]	
Variable	**Group**	**OR[b]**	***P***	**OR[b]**	***P***
(A) LESS INTENSE PHYSICAL ACTIVITY					
Age	20–34	1.47 (1.23–1.70)	0.002	1.39 (1.13–1.66)	0.014
	35–54	1.24 (1.06–1.41)	0.016	1.30 (1.09–1.50)	0.012
	55–69	0.93 (0.76–1.10)	0.395	0.95 (0.77–1.13)	0.575
	70 +	REF	-	REF	-
Gender	Female	1.27 (1.15–1.40)	<0.001	1.25 (1.12–1.38)	0.001
	All other genders	1.41 (0.85–1.96)	0.232	1.12 (0.53–1.71)	0.707
	Male	REF	-	REF	-
Education	GCSE/O-level	REF	-	REF	-
	A level/Highers	0.89 (0.70–1.07)	0.194	0.88 (0.69–1.07)	0.172
	Degree	0.74 (0.57–0.91)	0.001	0.77 (0.59–0.95)	0.005
Income	< £15,000	REF	-	REF	-
	£15,000-£24,999	0.90 (0.71–1.09)	0.277	1.03 (0.83–1.22)	0.781
	£25000-£39,999	0.78 (0.59–0.97)	0.011	0.95 (0.74–1.15)	0.581
	£40,000-£59,999	0.79 (0.60–0.98)	0.013	1.01 (0.80–1.21)	0.961
	£60,000-£99,999	0.67 (0.46–0.87)	<0.001	0.89 (0.68–1.11)	0.317
	> £100,000	0.60 (0.35–0.85)	<0.001	0.82 (0.55–1.08)	0.139
Living alone	Yes	1.35 (1.22–1.49)	<0.001	1.20 (1.05–1.34)	0.016
Access to garden	No	1.86 (1.70–2.03)	<0.001	1.74 (1.56–1.91)	<0.001
School Aged Children	Yes	0.95 (0.82–1.09)	0.507	1.09 (0.95–1.24)	0.222
Health conditions	Cancer	1.00 (0.83–1.16)	0.977	0.97 (0.76–1.19)	0.787
	Depression	2.22 (2.07–2.38)	<0.001	2.05 (1.89–2.21)	<0.001
	Diabetes type I	0.84 (0.54–1.14)	0.263	0.56 (0.02–1.09)	0.035
	Diabetes type II	1.13 (0.95–1.32)	0.195	0.99 (0.68–1.30)	0.967
	Disability (ADLs)	2.54 (2.29–2.80)	<0.001	2.13 (1.87–2.39)	<0.001
	Heart Disease	1.02 (0.83–1.22)	0.835	0.97 (0.67–1.27)	0.861
	Hypertension	1.29 (1.17–1.42)	<0.001	1.25 (1.10–1.40)	0.004
	Lung disease/Asthma	1.25 (1.12–1.38)	0.001	1.23 (1.08–1.38)	0.006
	Obesity	1.33 (1.20–1.47)	<0.001	1.25 (1.08–1.42)	0.012
	Stroke	0.98 (0.72–1.23)	0.855	0.92 (0.50–1.34)	0.701
(B) MORE INTENSE PHYSICAL ACTIVITY					
Age	20-34	5.60 (5.24–5.96)	<0.001	4.13 (3.74–4.53)	<0.001
	35-54	2.89 (2.61–3.17)	<0.001	2.16 (1.85–2.48)	<0.001
	55-69	1.95 (1.67–2.22)	<0.001	1.88 (1.60–2.17)	<0.001
	70 +	REF	-	REF	-
Gender	Female	1.12 (0.93–1.30)	0.251	1.21 (1.01–1.40)	0.059
	All other genders	0.89 (0.08–1.69)	0.765	0.80 (-0.03–1.62)	0.593
	Male	REF	-	REF	-
Education	GCSE/O-level	REF	-	REF	-
	A level/Highers	1.05 (0.79–1.30)	0.742	0.99 (0.73–1.26)	0.960
	Degree	1.43 (1.19–1.68)	0.003	1.23 (0.98–1.49)	0.103
Income	< £15,000	REF	-	REF	-
	£15,000-£24,999	1.18 (0.91–1.44)	0.237	1.08 (0.81–1.36)	0.570
	£25,000-£39,999	1.52 (1.26–1.77)	0.001	1.34 (1.07–1.61)	0.034
	£40,000-£59,999	1.24 (0.96–1.51)	0.127	1.01 (0.72–1.30)	0.938
	£60,000-£99,999	1.68 (1.38–1.98)	0.001	1.33 (1.01–1.66)	0.086
	> £100,000	2.26 (1.92–2.59)	<0.001	1.73 (1.37–2.09)	0.003
Living alone	Yes	0.89 (0.69–1.09)	0.233	1.00 (0.78–1.22)	0.999
Access to garden	No	1.11 (0.86–1.35)	0.418	1.21 (0.96–1.47)	0.14

(Continued)

TABLE 2 | Continued

Variable	Group	Corrected for age and sex		Fully Corrected[a]	
		OR[b]	*P*	OR[b]	*P*
School aged children	Yes	1.36 (1.18–1.55)	0.001	1.29 (1.10–1.49)	0.011
Health conditions	Cancer	0.69 (0.44–0.94)	0.004	0.85 (0.53–1.18)	0.346
	Depression	0.87 (0.63–1.11)	0.260	1.02 (0.77–1.27)	0.853
	Diabetes type I	0.57 (0.16–0.98)	0.009	0.84 (0.18–1.50)	0.612
	Diabetes type II	0.60 (0.33–0.86)	<0.001	0.79 (0.41–1.17)	0.221
	Disability (ADLs)	0.22 (–0.21–0.66)	<0.001	0.26 (–0.18–0.70)	<0.001
	Heart Disease	0.64 (0.36–0.92)	0.002	0.92 (0.52–1.32)	0.688
	Hypertension	0.81 (0.64–0.99)	0.020	1.09 (0.88–1.30)	0.405
	Lung disease/Asthma	0.73 (0.53–0.92)	0.001	0.91 (0.69–1.12)	0.370
	Obesity	0.73 (0.56–0.91)	0.001	0.89 (0.67–1.10)	0.265
	Stroke	0.63 (0.28–0.99)	0.012	1.25 (0.69–1.81)	0.433

[a] *Fully corrected model was adjusted for baseline physical activity intensity and all other variables.*
[b] *All odds ratios are compared to the baseline group of those who maintained their physical activity intensity.*

a doctor's diagnosis of obesity, hypertension, lung disease (including asthma) or who indicated depression or disability were more likely to be doing less intensive PA compared to their activity before the epidemic. Compared to the oldest age group (70+), younger age groups were significantly more likely to have changed and to be doing either more, or indeed less intense PA since the lockdown began. Being female, living alone or being without a garden were also associated with doing less intensive PA during the study period, but having school-aged children was associated with doing more. Importantly, we found these associations were independent from all identified confounders.

Analysis of open-ended text data about participants' lockdown coping strategies revealed that people who expressed sentiments about personal, work-related or household risks were more likely to have exhibited a PA behavior change toward less intense activity. This is important because subjective perceptions of risk may act as a conditioning factor that influences decision-making and behavioral change. The strengths of this study include the large population sample of adults who provided information on a wide range of demographic factors and health conditions in addition to PA behaviors before and during the COVID-19 lockdown. Our mixed methods approach allowed us to capture not only objective medical risks for COVID-19 from doctor diagnosed conditions, but also participants' self-perceived risks which make less intensive PA more likely. We applied a recently described ML approach to the codification of topics from open-ended questions, eliminating much of the subjectivity that is usually associated with anthropological & ethnographic approaches to text-mining.

Limitations of the study do exist, in particular because the study findings are not generalizable. The sampling approach was non-random, meaning that the sample was unlikely to fully reflect the demographics of the UK population. As with many epidemiological surveys, participants were disproportionately likely to be highly educated, white and female. The study relied on self-reported information (e.g. intensity of PA, medical conditions) leaving it susceptible to response bias (e.g. imprecise recall, influence of social desirability), however we minimized this where possible, for instance by giving examples of different types of physical activity, with corresponding intensities and asking about medical conditions that had been diagnosed by a physician. Whilst the ML approach we used for text mining was fully reproducible and largely autonomous, topic labels were added manually and the findings of this part of the work should be interpreted with reference to the perspectives presented in **Supplementary Table 4**. This study is observational and therefore causal links between the outcomes and exposures cannot be assumed. Confounders which were not included in the study, or any that were misclassified, may lead to residual confounding. A significant limitation is that we could not assess the role of ethnicity, which is particularly important because there is substantial evidence that there is a disproportionate effect of COVID-19 on minority ethnic groups (12, 13) and because people from minority ethnic groups have worse health than the overall population, especially among those over 60 (14).

The extent to which adults in the UK will revert back to their usual PA regimes once lockdown measures are relaxed is unclear, but the potential for multiple lockdowns being necessary over a protracted period could lead to prolonged periods of low PA in a substantial proportion of the population. This is concerning because it is well-established that insufficient levels of PA are associated with poor mental (3) and physical (4, 5) health and with premature mortality (6). Furthermore, a reduction in PA levels for even short durations (e.g. a decrease in step-counts per day for 2 weeks) are associated with indicators of poor health including reduced insulin sensitivity, cardiorespiratory fitness, muscle mass, and increased central fat (15, 16). The results of our current study suggest that the health of adults who have disabilities, depression, obesity, hypertension and lung disease may be disproportionately impacted because they are more likely to reduce the intensity of their PA during periods of lockdown. These findings are important because PA is therapeutic in the management of many diseases (6). For example, we observed that adults with disabilities had more than twice the odds (compared

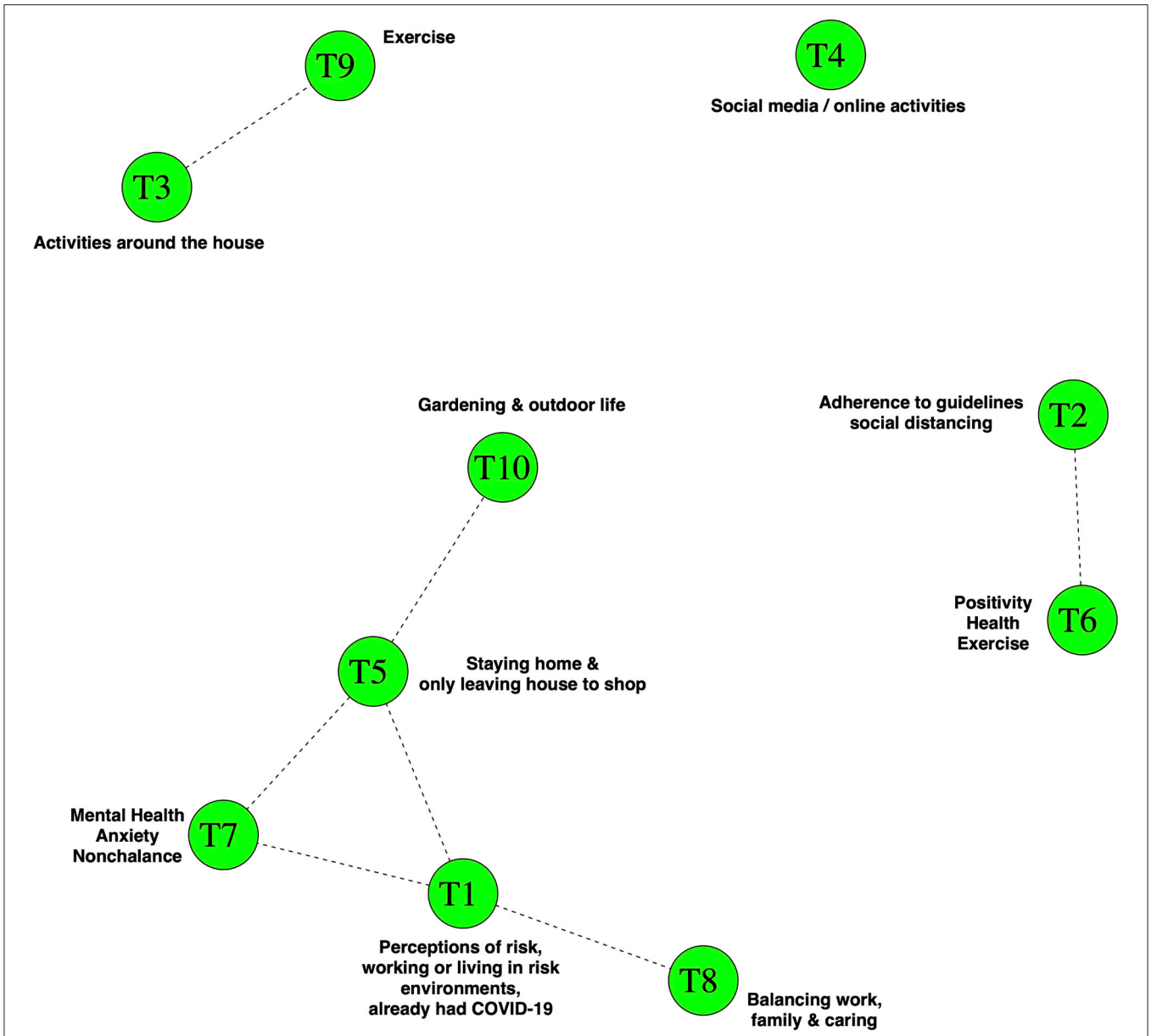

FIGURE 2 | Topic Correlations in the structural topic model for the corpus of text describing coping strategies. Nodes show topics and lines show positive correlations between the topics. There was a close correlation between topic T1 "Perceptions of risk, working or living in risk environments, already had COVID-19" and topics relating to mental health & anxiety (topic T7), strict adherence to social isolation practices (topic T5) and the balancing of ongoing work and family commitments (topic T8). Participants whose responses were focussed toward discussion of more intense PA (topic T9) or activities (including PA) around the house (topic T3) were less likely to also focus on T1, T7, T8, or T5. The topic correlation cut-off was 0.01.

to people without disabilities) of having reduced PA intensity during lockdown. This could lead to increased incidence and progression of disablement in older or diseased populations (17).

Recently published recommendations for self-isolation suggest that during periods of lockdown, individuals should attempt to increase their PA (even if only by a little) and exercise every day in order to improve physical cardio-respiratory fitness in case they were to contract coronavirus and become severely ill.[1] This advice may be even more pertinent for those who are at higher risk of complications from underlying health conditions such as obesity and lung conditions, or for those without gardens. Our findings suggest that these sub-populations are more likely to be doing less than before the lockdown. New advice that promotes home-based exercises such as including extra daily step counts[1] and more intensive forms of PA (18) should be considered as part of any new public health guidelines for self-isolation and future lockdowns. Targeting PA health messaging to address the potential harms of subjective risks may also be key, given that those who have little or no known objective clinical risk in the current epidemic may change PA

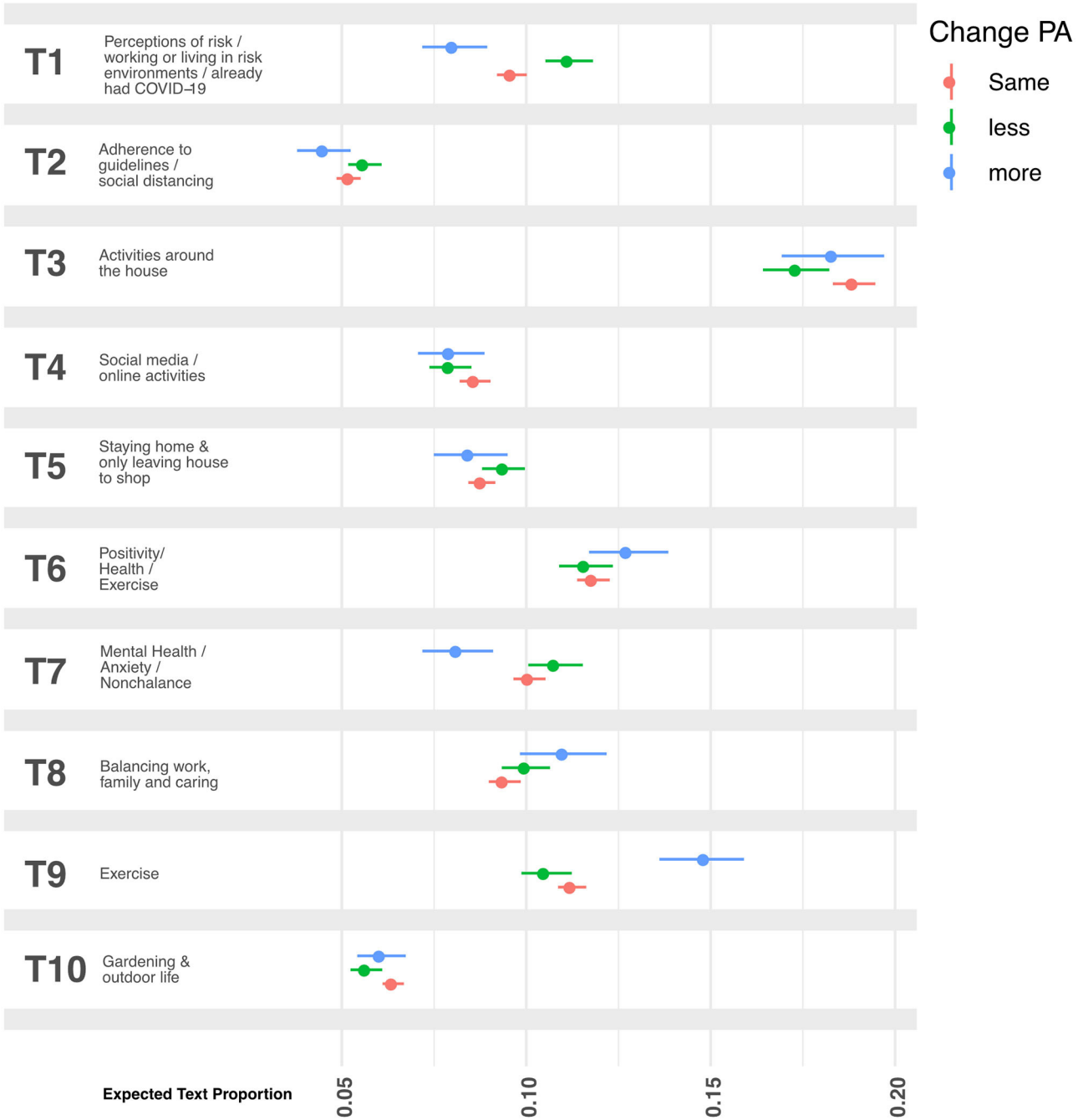

FIGURE 3 | Expected text proportions in open-ended narratives on participants' coping behaviors. Participants were asked to describe their coping behaviors during the UK COVID-19 related lockdown. Perceptions of risk, working or living in risk environments, and already having had COVID-19 (topic T1) were mentioned in 9.7% (9.3–10.1%) of responses from participants who had not changed, in 8.1% (7.1–9.0%, $p = 0.001$) of responses from people doing more PA and in 11.2% (10.4–11.9%, $p < 0.001$) among participants doing less PA. Topic T3 ($p = 0.01$) and T10 ($p = 0.006$) had lower ETPs in the PA group doing "less". Topics T7 and T8 had, respectively, lower ($p < 0.001$) and higher ($p = 0.006$) in the PA group doing "more". Topic T9 "Exercise" was notably much higher in the group which reported doing more intense PA under lockdown ($p < 0.001$). All analysis used the group which had not changed PA intensity as the reference.

behavior in light of their perception of risk, thereby driving the development of clinical risk factors and as a consequence potentially suffering more severe sequelae of SARS-CoV-2 infections during future epidemics.

During the first phase of UK lockdown, many public parks and gardens, exercise equipment in parks and other open spaces were closed. During this period, exercise outside the home was permitted only once a day and it is possible that this left too

little opportunity for many to maintain their normal PA. In this survey we have identified the lack of access to a garden during lockdown as a substantial risk factor for doing less intense PA. This is likely because those without gardens simply had more limited opportunities for PA than those who had access to private outdoor space. In any future lockdown, policy-makers should ensure that public open spaces are kept open and made available for PA use by people who have no access to a garden.

To date, studies examining changes in PA before and during COVID-19 lockdown are limited in number but the results of this study are in line with recent findings from an online survey (n = 1,047) of participants from across different continents, which indicate that home confinement due to COVID-19 could negatively impact participation in PA such that it was associated with a 35% reduction (equivalent to 2.45 days) in the number of days per week walking (19).

We conclude that Lockdown measures due to COVID-19 were associated with a change in PA intensity in 37% of study participants. Reduction in the intensity of PA was common and adults with obesity, hypertension, lung disease, disability and depression had increased odds of doing less intense PA than other groups. Participants more frequently expressed sentiments and perspectives on risk when they had changed toward less intense PA. Future research questions and policy should examine how adults with existing chronic health conditions or perceptions of risk can maintain a healthy PA regime (taking in to account the role of accessible outdoor spaces) whilst being confident that they are not, by doing so, placing themselves, their family or their community at increased risk from SARS-CoV2.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: LSHTM Data Compass: https://doi.org/10.17037/DATA.00001753.

ETHICS STATEMENT

The study was approved by the London School of Hygiene and Tropical Medicine Observational research ethics committee (Ref: 21846). All data were fully anonymous and the study team had no means by which they could identify individual respondents. All participants provided consent to participate in the study by ticking a box on the survey web-form. All questions in the survey were optional (excepting age and number of people in the household), meaning that participants could skip questions if they did not want to divulge specific data.

AUTHOR CONTRIBUTIONS

NR, SL, and CR conceptualized the study. NR, HB, LE, RE, SL, and CR designed the survey. HB and CR deployed the survey and curated the data. NR, NW, and CR performed the analysis. NR and CR wrote the manuscript. All authors reviewed the manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2020.575091/full#supplementary-material

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Measurement of the Equality of the Drug Welfare Induction Level of Chinese Patients With Chronic Diseases in Gansu, Sichuan, Hebei, and Zhejiang Based on the Bivariate Theil-T Index Method

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Objectives: This study aimed to measure the induction level of drug welfare in Chinese patients with chronic diseases using a bivariate Theil index.

Design: The bivariate Theil-T index was used to hierarchically decompose the relevant survey data, and the contribution rate of the intragroup gap and the intergroup gap to the total gap was investigated to better understand the current drug welfare induction level of Chinese patients with chronic diseases.

Setting: The study was based in Gansu, Sichuan, Hebei, and Zhejiang provinces in China.

Participants: Survey data was from patients with chronic diseases in 20 hospitals in four provinces.

Primary and secondary outcome measures: Data was collected through a questionnaire designed by the research team after expert consultation. Using the variables represented by the index system to decompose the Theil index from the two dimensions of the region and urban and rural areas. SPSS 22.0 was used for reliability and validity analysis and Theil index calculation.

Results: The overall level of drug welfare induction in Chinese patients with chronic diseases had a high degree of equalization. The overall Theil index was 0.0003, but there were still some differences among groups.

Conclusions: To improve the drug welfare equalization induction level of patients with chronic diseases in China, the government should start from western rural areas, and policy should target the provinces that were in a disadvantaged position within the region to promote the equalization of drug welfare induction level for patients with chronic diseases in China.

Keywords: patients with chronic diseases, drug welfare induction, bivariate Theil-T index, measurement of equalization, health equality

INTRODUCTION

With the change of the human disease spectrum, chronic diseases currently account for the majority of global morbidity, and mortality (1, 2). It is expected that by 2020, chronic non-communicable diseases (chronic diseases) will become the leading cause of death and disability in humans (3, 4) and the most crucial disease burden in China. Chronic diseases have brought many challenges and burdens to patients and the health system. Whether the drug needed for treatment is obtained and affordable is the most significant way to effectively control the incidence and mortality of chronic diseases.

Chronic diseases, also known as non-communicable diseases (NCDS), are ongoing and often incurable diseases or conditions that require ongoing medical care and affect a person's daily life (5, 6). It reported that 80–92% of older adults have at least one chronic illness and 50–77% have two or more (7). Cardiovascular disease, arthritis, and diabetes are common chronic diseases. Some studies indicate that heart disease and cancer together account for nearly 46% of all deaths (8). Older people with arthritis found that they have trouble with their normal activities (9, 10). Diabetes is the leading cause of kidney failure, lower-limb amputation not due to injury, and new cases of blindness among adults (11). Moreover, it has also been reported that ∼63% of all deaths in the world are attributed to NCDs, and this causes great socioeconomic harm to all countries, particularly developing countries (12).

The disease characteristics of chronic diseases determine that patients with chronic diseases need to take drugs for a long time, and the cost of medicines accounts for the vast majority of medical expenses. Due to the fragility of their social status, chronically ill patients are often at the most disadvantaged position for access to basic health services, especially medicines, which will directly affect their health and drug welfare effects. The expenditure of chronic disease drugs brings many challenges and burdens to the patients themselves and the health system (13). Whether the drugs needed for treatment can be obtained and can afford them is the most important to effectively control the incidence and mortality of chronic diseases. In addition, the equalization of basic public goods is an important goal for the future development of Chinese society. As a special commodity, medicines belong to the category of quasi-public products, and ensuring the fairness of medicines is an important basis for achieving the health of the whole people.

The Chinese government is aware of the seriousness of this problem. Since the new medical reform in 2009, the state has successively introduced and implemented relevant drug policies, such as the basic drug system, the zero-rate policy for essential drugs, and the centralized procurement of drugs in public hospitals. It is of vital importance to improve the level of drug welfare in Chinese patients. One of the landmark initiatives is the issuance of a national essential medicines system with the specific goal of improving the supply of medicines and ensuring equitable access to essential medicines. Since the implementation, the overall burden of medicine for patients with chronic diseases has improved (14), but it still faces a severe situation. The survey showed that patients with type 2 diabetes (T2DM) who used oral antidiabetic drugs (OADs) in China had a heavy financial burden, with direct treatment costs and opportunity costs accounting for 56% of the patient's disposable income (15).

The main contributions of this research include three aspects: First, due to the widespread urban-rural differences and regional differences in China, and the different socio-economic systems in different regions, we have carried out the level of drug welfare sensing for chronically ill patients through the hierarchical decomposition of the bivariate Theil index. Dimensional research. Secondly, we make full use of the survey data to reflect the actual situation more intuitively, and try to study the equalization of the drug welfare level from the perspective of Chinese chronic disease patients. Third, we seek to provide empirical support to policy makers to develop more effective drug policies and establish more effective public health management systems.

The rest of this article is organized as follows. The second part describes the samples and research methods. The third part analyzes the decomposition results of the bivariate Theil index. The fourth part discusses the empirical results. The fifth section summarizes the main conclusions.

BACKGROUNDS IN DRUG WELFARE

Domestic and foreign research on "drug welfare" generally refers to "Pharmacy Benefit Management" (PBM), which is a management coordination organization between insurance institutions, pharmaceutical companies, hospitals, and pharmacy. PBMs have the potential to secure lower drug prices and to improve rational prescribing (16). PBMs decides on the use of medicines in formulas and negotiates with pharmaceutical manufacturers and pharmacies on behalf of insurance companies. Through these activities, PBMs provides value by curbing drug spending (17).

Grabowski and Mullins analyzed the cost-effectiveness of drug welfare management in the United States, and proposed that PBM as a drug welfare management agency, through the control of hospital medical expenses and doctor behavior, control of medical insurance costs and the main profit of the pharmaceutical supply chain, the most important purpose was to improve patient utility (18). Tara L. Jenkins conducted a retrospective administrative analysis using the Oklahoma Health Care Pharmacy and Medical Claims Database, and the results showed although total health care expenditures increased after a monthly pharmacy benefit in a Medicaid population was expanded, a subpopulation of recipients identified as high pharmacy users before the expansion did not have a statistically significant increase in medical expenditures, and their pharmacy welfare status had not been significantly improved (19). Sean et al. explored the reasons why the private sector in Canada was unable

Abbreviations: BMI, Body mass index; T, Total gap; T_{Br}, Gap between regions; T_{Bc}, Gap between cities; T_{Wr}, Gap within the region; T_{Wc}, Gap within urban and rural areas; T_{WrBc}, Gap within the region between urban and rural areas; T_{Wrc}, Gap within the region within urban and rural areas; T_{WcBr}, Gap within urban and rural areas between regions; T_{Wcr}, Gap within urban and rural areas within the region.

to implement prescription drug cost control measures through semi-structured telephone interviews with relevant experts, and suggested that employees and employers needed to be educated to have more collaboration and data sharing between each other. It also required external government intervention to help transform the established norms of private drug program design with a view to improving employee private drug benefits (20). Lohrberg et al. analyzed the definition and role of QoL in German drug welfare assessment, and the use of QoL as a drug welfare standard emphasized the importance of defining QoL definitions and methodological regulations (21).

By combing the literature, it can be found that the research on drug welfare in the academic community mostly starts from the single dimension of the fairness of health resources, and lacks multi-dimensional exploration. We reviewed the relevant literature on the evaluation of drug welfare effects. Based on relevant theories and methods, combined with the characteristics of prevention and treatment of chronic diseases, and the uniqueness of patients with chronic diseases, from the perspective of multi-dimensional research, we studied the drug welfare induction level of chronic disease patients from four aspects: drug accessibility sensing level, drug price sensing level, drug fairness sensing level, and drug health sensing level.

METHODS

Measuring Instruments

The National Natural Science Foundation project hosted by the author, "Optimization of Health and Precision Poverty Alleviation Policy Based on the Improvement of the Drug Welfare Effect of Poverty Chronic Patients," has made a detailed study on the construction of the evaluation index system for the drug welfare level of patients with chronic diseases in China [Min (22) "Study on the Evaluation and Promotion Strategy of the Drug Welfare Effect of Patients with Chronic Diseases in 10 Provinces Based on the Topsis Method;" Yini (2018) (23) "Study on the Drug Welfare Effect of Patients with Chronic Diseases Based on the Two-Step Clustering Method"]. So according to the four aspects of patients' drug welfare induction level mentioned before, this study established an evaluation index system for drug welfare effects of chronic diseases patients (**Table 1**). The weight of each index was obtained by Delphi expert consultation method. The evaluation index system is shown in **Table 1** and will not be discussed in this paper.

Design of Questionnaire

According to **Table 1**, the questionnaire on the drug welfare effect of patients with chronic diseases was compiled, which consisting of five parts: (1) Personal situation questionnaire (2) Drug accessibility questionnaire (3) Drug price effect questionnaire (4) Drug Fair Effect Questionnaire (5) European five-dimensional health scale. Except for personal situation, the other four parts were based on the chronic disease patients in **Table 1**.

- Part 1 included the basic sociodemographic information of hukou nature, gender, ethnicity, age, marital status, education level, occupation, average monthly income (yuan), type of medical insurance, employment status, current main source of income, health file, health checkup, types of chronic disease.
- Part 2 has six questions for knowing about the situation of drug accessibility induction level equalization.
- Part 3 has six questions for knowing about the situation of drug price effect induction level equalization.
- Part 4 has four questions for knowing about the situation of drug fair effect induction level equalization.
- Part 5 has five questions for knowing about the situation of drug health effect induction level equalization.

There are positive indicators and inverse indicators in the questionnaire. For the positive indicators, the larger the score is, the better the indicators. For the inverse indicators, the smaller the score is, the better the indicators. For the inverse indicators, the method of taking the reciprocal of the original indicator is adjusted. There are two reverse indicators in this article, namely, "I5: The cheap drugs needed are not accessible and I6: The expensive drugs needed are not affordable." This article has made relevant adjustments before using the data, and the rest of the indicators are all positive indicators. The questionnaire is detailed in **Appendix 1**.

Participants and Sampling

Our research was conducted in both eastern and western region in China, provinces with higher and lower per-capita gross domestic product were sampled. In 2018, Zhejiang province was ranked the fifth in terms of per capita GDP among the 31 provinces or municipalities in the mainland in China, with a GDP per capita of 99,000 yuan. Hebei province was the 20 th(48,000 yuan). Among the eastern regions, we selected Zhejiang province and Hebei province as the sample area with relatively high and low economic level among the eastern regions, which could better represent the areas in eastern China. At the same time, in the western region, Sichuan province, and Gansu province were ranked the 18 th (49,000 yuan) and 28 th (31,000 yuan) on per capita GDP, which could better represent the areas in western China.

Thus, four provinces were selected, two from each of these two regions. In total, 20 hospitals were sampled in our study. Each province was sampled according to their geographical distribution, and five hospitals were then randomly selected from each province. In each hospital, trained data collectors went to check patients' messages. After each interview, which lasted ∼15 min, the participant received a small gift of thanks. Approximately 50 patients per hospital were selected for this study. Through questionnaire survey, relevant data of patients with chronic diseases were obtained, and informed verbal consent was obtained from the respondents; according to the scope of the items covered by the questionnaire, a face-to-face questionnaire survey was conducted with individuals who were in the hospitals. Finally, Members of 1,000 patients were interviewed and the response rate was 99.2%.

A total of 992 patients reported their messages about drug welfare induction level, of which 29 were excluded because they were not having chronic diseases. The total number of residents included in the analysis was 963. We used the simple random

TABLE 1 | Weighting evaluation system for equalization of drug welfare induction in patients with chronic diseases.

Target layer	Index level one	Index level two	Weights
X: Drug welfare effect induction level equalization	A1: Drug accessibility effect induction level equalization	I1: The number of medical service institutions that can be reached within 15 min	0.1064
		I2: The needed drug can be purchased in public medical heath institutions	0.1127
		I3: The needed drug can be purchased in retail pharmacies	0.1032
		I4: The needed drug can be purchased in online pharmacies	0.0694
		I5: The cheap needed drug is not accessible	0.3105
		I6: The expensive needed drug is not affordable	0.2978
	A2: Drug price effect induction level equalization	I7: The percentage of drug expenditure out of household disposable income	0.2664
		I8: Drug expenditure spent in public health institutions	0.2518
		I9: Drug expenditure spent in retail pharmacies	0.1275
		I10: Drug expenditure spent in online pharmacies	0.0203
		I11: The percentage of outpatient drug expenses	0.1956
		I12: The percentage of hospitalization drug expenses	0.1384
	A3: Drug fair effect induction level equalization	I13: Medical insurance reimbursement level of medical expenses	0.2732
		I14: Second reimbursement level of drug expenses	0.2537
		I15: Level of self-paying drug affordability	0.2177
		I16: Resident satisfaction of prescriptions	0.0725
	A4: Drug health effect induction level equalization	I17: EQ-5D-5L rating scale	0.6896
		I18: BMI	0.3104

sampling formula to calculate the sample size of chronic disease patients in four provinces, because we only had limited literature and more parameters were needed in the stratified sample size calculation formula (24). After we got the total sample needed, we allocated the sample size in selected hospitals using probability proportionate to size sampling (PPS) (25).

The simple random size calculation formula (26):

$$N = \frac{Z_{\alpha}^{2} * \pi(1-\pi)}{E^{2}}$$

Let E = 0.05, Z = 1.96, α = 0.05,π(1-π)= 0.5. Taking incomplete questionnaires into account, we should survey about 384 chronic disease patients. Obviously, the sample size of this study meets the requirements.

This study used SPSS 22.0 software to summarize the results of the 963 questionnaires collected and performed reliability and validity analysis. The results of the study showed that the Cronbach's α value of the 18 evaluation indicators involving the equalization of drug welfare induction in patients with chronic diseases was 0.733, and the Cronbach's α value based on the standardized project was 0.741, both of which were >0.7. Therefore, the questionnaire indicators may be considered to have high validity. The KMO value was 0.791, and the $p < 0.001$, further indicating that the questionnaire was valid.

Measurements

We first use the weighted summation method to evaluate the level of equalization. Then the bivariate Theil-T index is used to decompose it hierarchically. Through layer decomposition, we can examine the overall difference structure from different perspectives. The contribution rate of the intra-group gap and the inter-group gap to the total gap can better understand the current equalization of the drug welfare level of chronic disease patients in China. See **Figure 1** for details.

Theil Index: Definition and Decomposition

The statistical methods commonly used to measure the level of equalization of pharmaceutical welfare (public service) include the coefficient of variation method, the Gini coefficient method, and the Theil index method. All of the above methods can provide relatively scientific reference results to a certain extent, but it is difficult to accurately reflect the difference in the level of urban-rural equalization or the difference between urban and rural areas. Compared with other equalization measurement tools, the Theil index has obvious technical advantages: First,

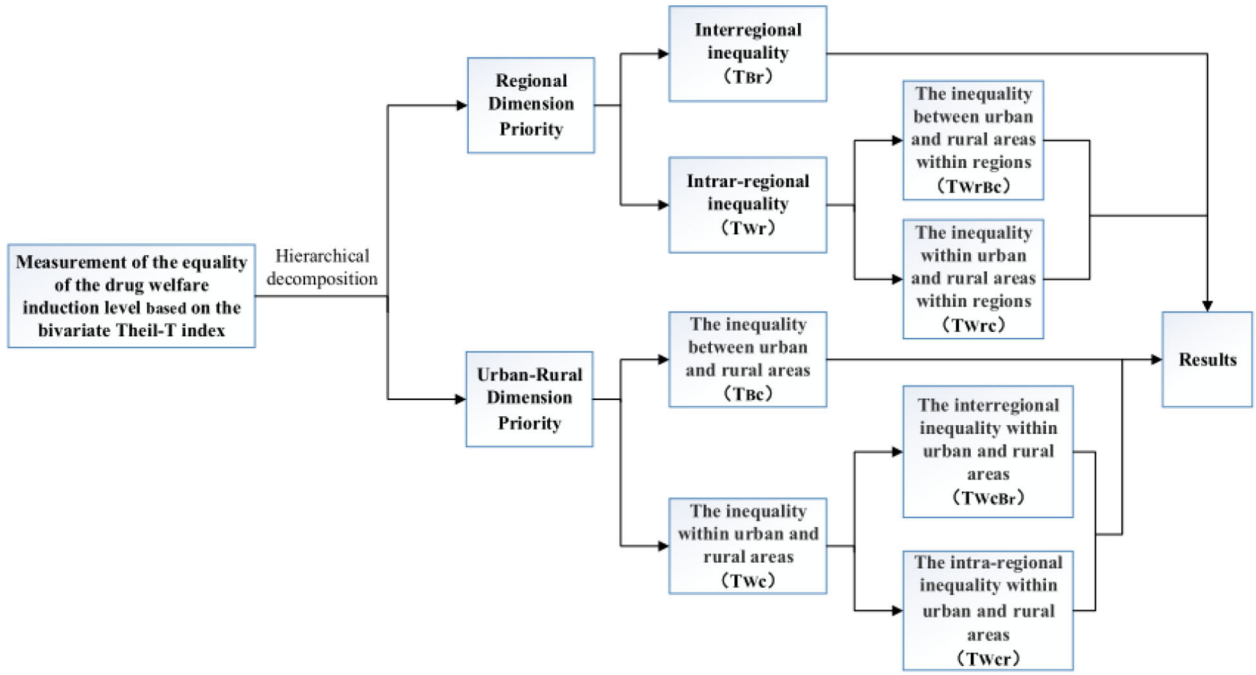

FIGURE 1 | Decomposition of bivariate Theil-T index of drug welfare induction level in patients with chronic diseases.

compared with the Gini coefficient equalization measurement tool, the Theil index equalization measurement tool is more laterally reorganized in the analysis process. The problem of decomposability emphasizes the degree of equalization of the population according to different group criteria. Second, compared with the equalization measurement tool of the coefficient of variation, the measurement index of the Theil index equalization can achieve unevenness in the measurement process. Steady reduction, more focused on the analysis of conduction sensitivity problems in the process of unequal (27).

The Theil T index (28) was used to quantify inequality at a district level. This index has been widely used to measure inequality in different health and social outcomes. For example, it has been used to measure income inequality in Latin America (29) or inequality in access to improved water in different world regions (30). Theil-T is a population weighted index that is sensitive to health differences further from the average rate (31).

In China, urban-rural differences and regional differences are large, and the use of the bivariate Theil index has innovative practical significance. At the same time, combining the two variables can examine the combined effect of the two on the level of equalization. Based on comprehensive considerations, this paper uses the bivariate Theil- T index in the Theil index equalization measurement tool to equalize the drug welfare induction level of chronic disease patients in China.

Due to its decomposability, the Theil index can be decomposed by intraregional differences and interregional differences, thereby measuring the contribution of intraregional differences and interregional differences to the total differences (32–36). For this study, the Theil-T index refers to the degree of unequal distribution of drug welfare in patients with chronic diseases in different regions or in urban or rural areas relative to the population, that is, the perceived degree of unequal drug welfare per capita.

Bivariate Theil-T Index With Regional Dimension Priority

The bivariate Theil-T index adopts with priority to the regional dimension; that is, all the unequal indicators expressed by the Theil index are first decomposed according to the regional dimension. The first level is decomposed into interregional inequality (between western region and eastern region) and intra-regional inequality (within western region or within eastern region). At the second level, the intra-regional inequality is decomposed into the inequality between urban and rural areas within regions, and the inequality within urban and rural areas within regions (37, 38), which is shown in **Figure 2**.

This paper uses four provinces of China (Gansu Province, Sichuan Province, Hebei Province, Zhejiang Province) as the basic research unit. The four provinces are divided into two groups according to geographical regions: the western region and the eastern region. The provinces included in each region are shown in **Table 2**.

Accordingly, the bivariate Theil-T index with hierarchical decomposition, giving priority to the regional dimension, is expressed as follows (39):

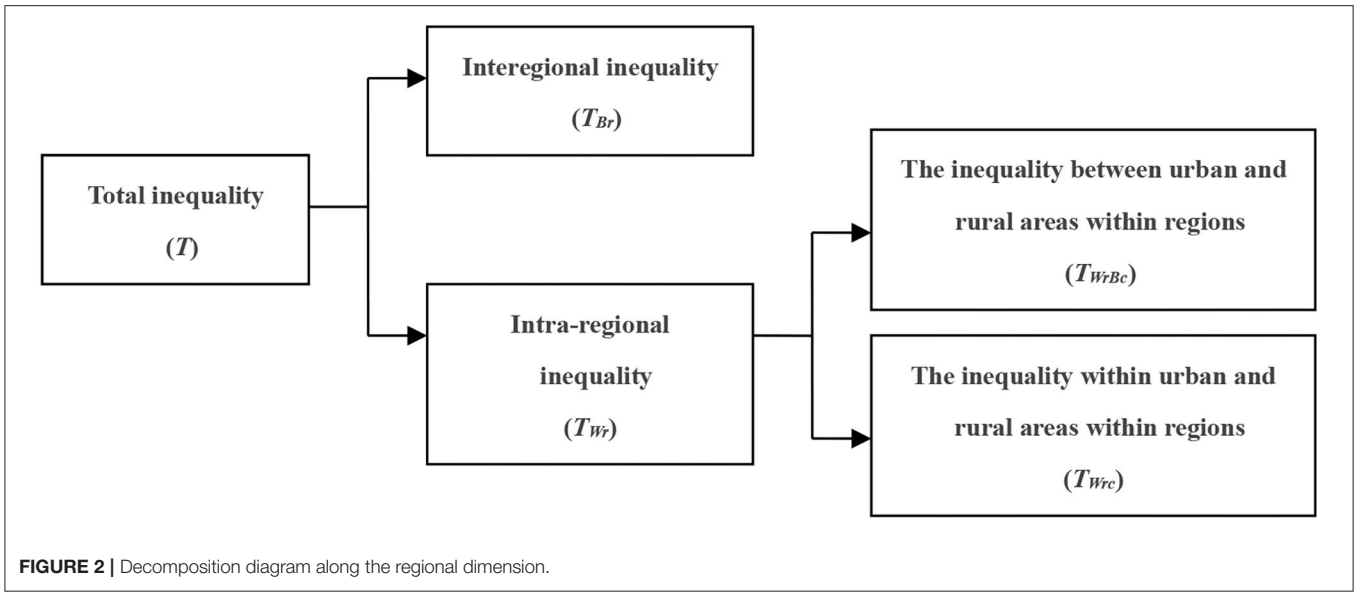

FIGURE 2 | Decomposition diagram along the regional dimension.

TABLE 2 | The two major regional divisions of China and representative provinces included.

Region	Representative provinces
Western region	Gansu, Sichuan
Eastern region	Hebei, Zhejiang

$$T = T_{B_r} + T_{W_r} = T_{B_r} + T_{W_r B_c} + T_{W_{rc}} = \sum_r \left(\frac{Y_r}{Y} \log \frac{Y_r/Y}{N_r/N}\right) + \sum_r \left(\frac{Y_r}{Y}\left(\sum_c \left(\frac{Y_{rc}}{Y_r} \log \frac{Y_{rc}/Y_r}{N_{rc}/N_r}\right)\right)\right) + \sum_r \sum_c \left(\frac{Y_{rc}}{Y}\left(\sum_i \left(\frac{Y_{rci}}{Y_{rc}} \log \frac{Y_{rci}/Y_{rc}}{N_{rci}/N_{rc}}\right)\right)\right) \quad \text{(Formula1)}$$

where T is the total Theil index, which measures the overall degree of inequality; T_{Br} and T_{Wr}, respectively, indicate the degree of inequality of drug welfare induction in patients with chronic diseases among and within regions; T_{WrBc} and T_{Wrc}, respectively, indicate the degree of inequality of drug welfare induction in patients with chronic diseases between urban and rural areas and between provinces and towns; *r, c,* and *i,* respectively, represent the regional grouping (east and west), urban and rural, and provinces in the *r* region (Gansu Province, Sichuan Province, Hebei Province, and Zhejiang Province), total population of the sample area of the N_{rci} representative group, and total level of drug welfare induction of the patients with chronic diseases in the sample area of the Y_{rci} representative group, where:

$$N_r = \sum_c N_{rc}, N_{rc} = \sum_i N_{rci}, Y_r = \sum_c Y_{rc}, Y_{rc} = \sum_i Y_{rci}, Y = \sum_r \sum_c \sum_i Y_{rci}, N = \sum_r \sum_c \sum_i N_{rci}.$$

The values of the five indicators *T,* T_{Br}, T_{Bc}, $T_{Wrc,}$ and T_{Irc} c are between 0 and 1. The larger the value is, the lower the degree of equalization. The smaller the value is, the higher the degree of equalization.

Bivariate Theil-T Index of Urban-Rural Dimension Priority

This decomposition method uses the Theil index method to measure the equalization of drug welfare in patients with chronic diseases. At the first level, the decomposition concerns the inequality between urban and rural areas and the inequality within urban and rural areas. At the second level, the inequality within urban and rural areas is decomposed into the interregional inequality within urban and rural areas and the intra-regional inequality within urban and rural areas, as shown in **Figure 3**.

Thus, the bivariate Theil-T exponential decomposition formula that prioritizes the urban-rural dimensions is:

$$T = T_{B_c} + T_{W_c} = T_{B_c} + T_{W_c B_r} + T_{W_{cr}} = \sum_c \left(\frac{Y_c}{Y} \log \frac{Y_c/Y}{N_c/N}\right) + \sum_c \left(\frac{Y_c}{Y}\left(\sum_r \left(\frac{Y_{cr}}{Y_c} \log \frac{Y_{cr}/Y_c}{N_{cr}/N_c}\right)\right)\right) + \sum_c \sum_r \left(\frac{Y_{cr}}{Y}\left(\sum_i \left(\frac{Y_{cri}}{Y_{cr}} \log \frac{Y_{cri}/Y_{cr}}{N_{cri}/N_{cr}}\right)\right)\right) \quad \text{(Formula 2)}$$

where T_{Bc} and T_{Wc} indicate the degree of inequality of drug welfare in patients with chronic diseases between urban and rural areas, respectively. T_{WcBr} and T_{Wcr} indicate the degree of inequality of drug welfare of patients with chronic diseases in urban and rural areas in different regions, respectively. The other

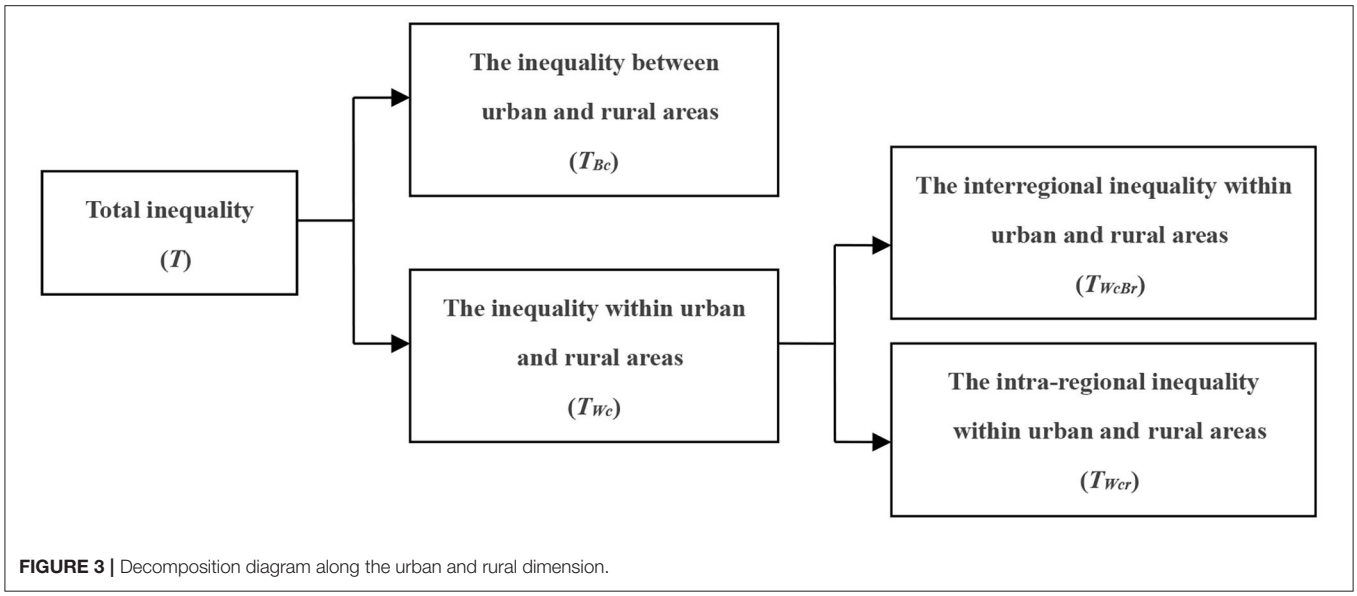

FIGURE 3 | Decomposition diagram along the urban and rural dimension.

variables have the same meaning as above. Thus,

$$N_c = \sum_r N_{cr}, N_{cr} = \sum_i N_{cri}, Y_c = \sum_r Y_{cr}, Y_{cr} = \sum_i Y_{cri},$$
$$Y = \sum_c \sum_r \sum_i Y_{cri}, N = \sum_c \sum_r \sum_i N_{cri}$$

RESULTS

Bivariate Theil-T Index Hierarchical Decomposition Calculation of Drug Benefits in Patients With Chronic Diseases—The Regional Dimension

By substituting the research data into formula 1, the hierarchical decomposition results of the bivariate Theil-T index with priority to the regional dimension can be obtained (see **Table 3**).

The Regional Dimension Decomposition Results of the Total T-Values

In this paper, the total *T*-value of the equalization of the drug welfare induction level in patients with chronic diseases is calculated as follows: total $T = 0.0003$, which is close to 0. Therefore, the level of the drug welfare response of Chinese patients with chronic diseases is relatively equal overall.

The Regional Dimension Decomposition Results of the T-Values of Each Index

After decomposing the *T*-value according to each indicator, the *T*-values of "I1: The number of medical service institutions that can be reached within 15 min," "I6: The expensive needed drug is not affordable" and "I14: Second reimbursement level of drug expenses" are higher than the other indicators, the values are 0.0050, 0.0046, and 0.0054, respectively, and the *T*-values are all >0.0040 (see **Figure 4**), which means that the level of equalization of the drug welfare level of these three indicators is relatively low.

The Results of the Internal Composition of the Interregional Inequality of the T-Values of Each Indicator

In The internal composition of the interregional inequality, **Table 3** lists the weighted logarithm of the mean value of the sensory level of the drug welfare indicators in the patients with chronic diseases in the eastern and western regions during the calculation of the *T*-value of the interregional inequality (the perceived level of welfare is proportional to the total level of welfare induction). **Table 3** shows that except for the *T*-values of the indicator "I17: EQ-5D-5L" in the eastern and western regions, the *T*-values of indicators I1, I2, I4-I12, and I14 (see **Table 1** for the meanings of the specific indicators, the same below) are all positive in the eastern region, suggesting that the level of drug welfare induction of patients with chronic diseases in the eastern region is at a high level as measured by these indicators. That is, the level of drug welfare induction of patients with chronic diseases in the eastern region is higher than the national average for these indicators. The opposite is found for the indicators above in the western region, and all of their values are negative, indicating that patients with chronic diseases in the western region have less than the national average level of welfare induction in terms of these indicators and therefore a low level of welfare.

The Internal Decomposition Results of the Intra-Regional Inequality of the T-Values of Each Indicator

In the decomposition of intra-regional disparity, the second-order decomposition of the urban and rural dimensions of the indicators "I1: The number of medical service institutions that can be reached within 15 min," "I6: The expensive drug needed is not affordable," "I14: Satisfaction with the second reimbursement level for drug expenses," and "I16: Satisfaction with the rationality of prescriptions by medical institutions" is different from that of the other indicators in the inequality within urban and rural

TABLE 3 | Theil index decomposition results of perceived drug welfare level in patients with chronic diseases with regional dimension priority.

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16	I17	I18	Total
T	0.0050	0.0005	0.0004	0.0033	0.0033	0.0046	0.0016	0.0009	0.0004	0.0013	0.0010	0.0007	0.0016	0.0054	0.0025	0.0016	0.0002	0.0001	0.0003
T_{Br}	0.0000	0.0000	0.0002	0.0010	0.0007	0.0015	0.0000	0.0000	0.0000	0.0008	0.0001	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0001
Weighted logarithm ①(western)	−0.0031	−0.0018	0.0065	−0.0143	−0.0119	−0.0174	−0.0027	−0.0029	−0.0027	−0.0126	−0.0037	−0.0003	0.0023	−0.0099	0.0025	0.0001	0.0000	0.0021	−0.0034
Weighted logarithm (eastern)	0.0031	0.0018	−0.0063	0.0153	0.0126	0.0189	0.0027	0.0029	0.0027	0.0133	0.0038	0.0003	−0.0023	0.0104	−0.0025	−0.0001	0.0000	−0.0020	0.0035
T_{Wr}	0.0049	0.0005	0.0002	0.0023	0.0026	0.0031	0.0016	0.0008	0.0004	0.0005	0.0009	0.0007	0.0016	0.0049	0.0025	0.0016	0.0002	0.0001	0.0002
T_{WrBc}	0.0023	0.0002	0.0001	0.0008	0.0000	0.0004	0.0003	0.0004	0.0001	0.0001	0.0003	0.0004	0.0007	0.0007	0.0008	0.0004	0.0001	0.0000	0.0001
Urban and rural areas in the western region	0.0007	0.0002	0.0000	0.0008	0.0000	0.0002	0.0000	0.0004	0.0000	0.0001	0.0003	0.0003	0.0003	0.0003	0.0000	0.0004	0.0000	0.0000	0.0000
Urban and rural areas in the eastern region	0.0016	0.0000	0.0001	0.0000	0.0000	0.0002	0.0003	0.0000	0.0000	0.0000	0.0001	0.0001	0.0004	0.0004	0.0008	0.0000	0.0001	0.0000	0.0001
T_{Wrc}	0.0026	0.0003	0.0001	0.0015	0.0026	0.0027	0.0013	0.0004	0.0003	0.0004	0.0006	0.0003	0.0009	0.0042	0.0016	0.0013	0.0000	0.0000	0.0002
Rural interior	0.0023	0.0000	0.0001	0.0012	0.0011	0.0010	0.0013	0.0002	0.0001	0.0002	0.0002	0.0003	0.0007	0.0020	0.0011	0.0005	0.0000	0.0000	0.0000
Rural interior of western region	0.0000	0.0000	0.0001	0.0009	0.0001	0.0005	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001	0.0004	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
Rural interior of eastern region	0.0023	0.0000	0.0000	0.0003	0.0010	0.0005	0.0012	0.0001	0.0000	0.0002	0.0001	0.0002	0.0003	0.0019	0.0010	0.0005	0.0000	0.0000	0.0000
Urban interior	0.0003	0.0002	0.0000	0.0003	0.0015	0.0017	0.0001	0.0002	0.0002	0.0002	0.0004	0.0000	0.0002	0.0022	0.0006	0.0008	0.0000	0.0000	0.0001
Urban interior of western region	0.0001	0.0001	0.0000	0.0000	0.0005	0.0011	0.0000	0.0002	0.0000	0.0000	0.0004	0.0000	0.0001	0.0001	0.0006	0.0003	0.0000	0.0000	0.0001
Urban interior of eastern region	0.0002	0.0001	0.0000	0.0003	0.0010	0.0007	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000	0.0001	0.0021	0.0000	0.0005	0.0000	0.0000	0.0000
The proportion of T_{Br}(%)	0.90	3.32	49.41	30.12	20.92	32.83	2.13	4.63	7.79	59.46	6.41	0.06	1.55	8.86	1.16	0.00	0.00	25.91	18.53
The proportion of T_{Wr}(%)	99.10	96.68	50.59	69.88	79.08	67.17	97.87	95.37	92.21	40.54	93.59	99.94	98.45	91.14	98.84	100.00	100.00	74.09	81.47
The proportion of T_{WrBc}(%)	46.32	42.56	20.82	23.57	0.23	8.56	16.93	50.32	19.23	9.62	31.67	55.61	45.06	12.85	33.81	22.77	73.43	9.86	29.60
The proportion of T_{Wrc}(%)	52.78	54.12	29.77	46.31	78.85	58.61	80.94	45.05	72.98	30.92	61.92	44.33	53.39	78.29	65.03	77.23	26.57	64.23	51.86

①*This indicator is only the internal component of calculating the T-value of the inequality between groups. The value is positive or negative, which is different from the T value after summation. Referring to Huang Guoping (2012) (26), the value is rounded off, and the actual value is not zero, so the calculated contribution is not zero. (The table below is the same).*

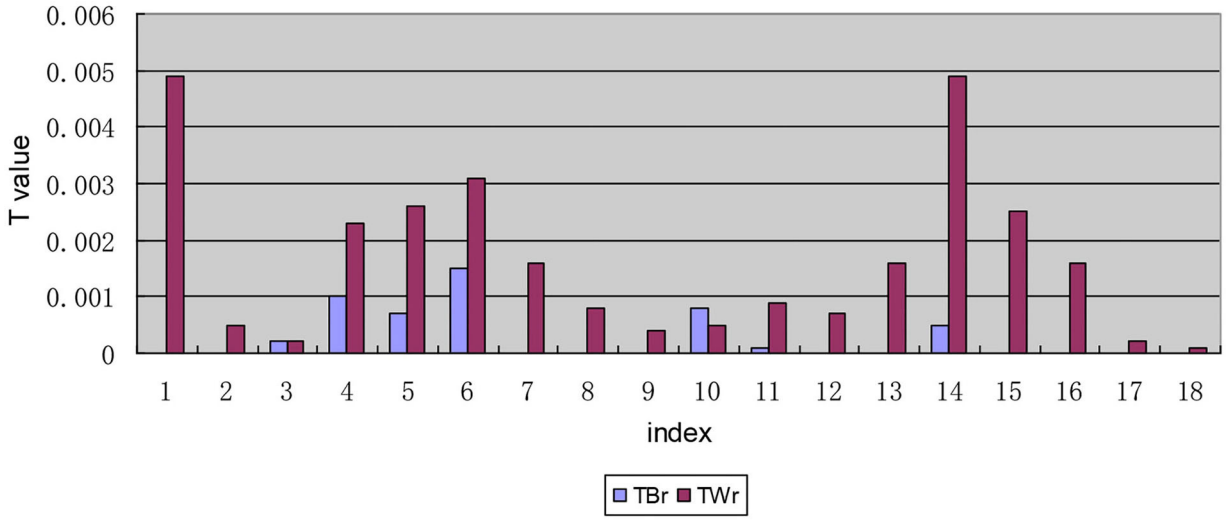

FIGURE 4 | Decomposition of *T*-values of each indicator along the regional dimensional.

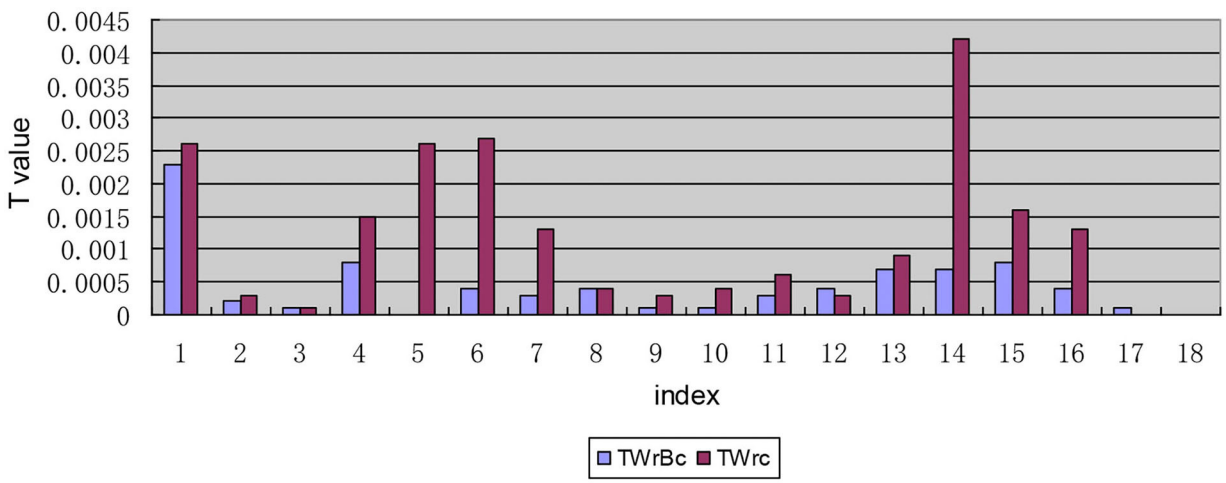

FIGURE 5 | Intra-regional inequality between each indicator decomposition based on the urban and rural dimension.

areas within regions, with T_{Wrc} values >0.0020. Moreover, the inequality within urban and rural areas within regions in these four indicators is larger than the inequality between urban and rural areas within regions (see **Figure 5**).

Urban-Rural Dimension: First Bivariate Theil-T Index Hierarchical Decomposition Calculation

By substituting relevant data into formula 2, the bidimensional hierarchical calculation results shown in **Table 4** can be obtained. Compared with the decomposition of the bivariate Theil-T index with priority to the regional dimension, the internal composition of the bivariate Theil-T index with priority to the urban and rural dimension has changed.

Regional Dimension Decomposition Results of Total T-Values

The results of the total *T*-values obtained by the decomposition of the urban and rural dimension are the same as those obtained by the decomposition of the regional dimension.

Decomposition Results of T-Values of Each Indicator Along the Urban-Rural Dimension

After the first-order decomposition of each indicator along the urban-rural dimension, the comparison of *T*-values between urban-rural areas and within urban-rural areas shows that the *T*-values of I1, I4, I5, I6, and I14 of the equalization of drug and welfare response levels for Chinese patients with chronic diseases are significantly different from the values for other indicators. On the whole, China needs to increase the accessibility and fairness of drug distribution in terms of

TABLE 4 | Theil index decomposition results of drug welfare induction level of patients with chronic diseases in urban and rural areas.

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16	I17	I18	Total
T	0.0050	0.0005	0.0004	0.0033	0.0033	0.0046	0.0016	0.0009	0.0004	0.0013	0.0010	0.0007	0.0016	0.0054	0.0025	0.0016	0.0002	0.0001	0.0003
T_{Bc}	0.0021	0.0000	0.0000	0.0003	0.0000	0.0004	0.0002	0.0001	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0006	0.0002	0.0000	0.0000	0.0000
Weighted logarithm (urban)	0.0225	−0.0028	0.0015	0.0087	0.0002	0.0089	0.0067	−0.0046	−0.0004	0.0042	−0.0030	−0.0032	0.0004	0.0001	0.0112	−0.0064	−0.0025	−0.0012	0.0017
Weighted logarithm (rural)	−0.0204	0.0029	−0.0015	−0.0084	−0.0002	−0.0086	−0.0065	0.0047	0.0004	−0.0041	0.0030	0.0032	−0.0004	−0.0001	−0.0106	0.0066	0.0025	0.0012	−0.0017
T_{Wc}	0.0028	0.0004	0.0004	0.0030	0.0033	0.0042	0.0014	0.0008	0.0004	0.0012	0.0010	0.0007	0.0016	0.0054	0.0019	0.0014	0.0001	0.0001	0.0003
T_{WcBr}	0.0002	0.0002	0.0003	0.0015	0.0007	0.0016	0.0001	0.0004	0.0001	0.0008	0.0003	0.0004	0.0008	0.0012	0.0003	0.0002	0.0001	0.0000	0.0001
Interarea within the urban	0.0002	0.0001	0.0000	0.0001	0.0004	0.0008	0.0001	0.0003	0.0001	0.0003	0.0003	0.0002	0.0002	0.0012	0.0001	0.0001	0.0000	0.0000	0.0001
Interarea within the rural	0.0000	0.0000	0.0002	0.0014	0.0003	0.0007	0.0000	0.0001	0.0000	0.0005	0.0000	0.0002	0.0005	0.0000	0.0003	0.0001	0.0000	0.0000	0.0000
T_{Wcr}	0.0026	0.0003	0.0001	0.0015	0.0026	0.0027	0.0013	0.0004	0.0003	0.0004	0.0006	0.0003	0.0009	0.0042	0.0016	0.0013	0.0000	0.0000	0.0002
Eastern interior	0.0025	0.0002	0.0000	0.0006	0.0020	0.0011	0.0013	0.0001	0.0002	0.0003	0.0001	0.0002	0.0004	0.0040	0.0010	0.0010	0.0000	0.0000	0.0000
Eastern interior of urban areas	0.0002	0.0001	0.0000	0.0003	0.0010	0.0007	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000	0.0001	0.0021	0.0000	0.0005	0.0000	0.0000	0.0000
Eastern interior of rural areas	0.0023	0.0000	0.0000	0.0003	0.0010	0.0005	0.0012	0.0001	0.0000	0.0002	0.0001	0.0002	0.0003	0.0019	0.0010	0.0005	0.0000	0.0000	0.0000
Western interior	0.0001	0.0001	0.0001	0.0009	0.0006	0.0016	0.0000	0.0002	0.0002	0.0001	0.0005	0.0001	0.0005	0.0002	0.0006	0.0003	0.0000	0.0000	0.0001
Western interior of urban areas	0.0001	0.0001	0.0000	0.0000	0.0005	0.0011	0.0000	0.0002	0.0000	0.0000	0.0004	0.0000	0.0001	0.0001	0.0006	0.0003	0.0000	0.0000	0.0001
Western interior of rural areas	0.0000	0.0000	0.0001	0.0009	0.0001	0.0005	0.0000	0.0000	0.0001	0.0000	0.0001	0.0001	0.0004	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000
The proportion of T_{Bc}(%)	43.14	8.02	2.54	10.14	0.00	7.72	12.33	11.67	0.16	6.11	4.22	6.41	0.04	0.00	22.03	12.01	17.50	8.88	4.26
The proportion of T_{Wc}(%)	56.86	91.98	97.46	89.86	100.00	92.28	87.67	88.33	99.84	93.89	95.78	93.59	99.96	100.00	77.97	87.99	82.50	91.12	95.74
The proportion of T_{WcBc}(%)	4.08	37.86	67.69	43.55	21.15	33.68	6.73	43.28	26.85	62.97	33.87	49.26	46.57	21.71	12.94	10.76	55.93	26.89	43.88
The proportion of T_{Wcr}(%)	52.78	54.12	29.77	46.31	78.85	58.61	80.94	45.05	72.98	30.92	61.92	44.33	53.39	78.29	65.03	77.23	26.57	64.23	51.86

improving the level of drug welfare of patients with chronic diseases, especially in terms of the accessibility of medicines. Furthermore, in addition to the two indicators of I17 and I18, the inequality within urban and rural areas in the remaining indicators is larger than that between urban and rural areas. A visual comparison of the inequality between urban and rural areas and the inequality within urban and rural areas is shown in **Figure 6**.

Internal Composition of the Inequality Between Urban and Rural Areas

In the internal composition of the inequality between urban and rural areas, **Table 4** lists the weighted log values of the deviation of the induction level from the average value of all indicators in the process of calculating the *T*-value of the inequality between urban and rural areas. In the composition of the T_{Bc} value, the urban component value of indicators I1, I3-I7, I10, and I13-15 is positive, while the rural component value is negative, indicating that these indicators are low in the rural area. The urban component value of indicators I2, I8, I9, I11, I12, and I16-I18 is negative, while the rural component value is positive. Therefore, these indicators are at a low level in cities.

The Internal Composition of the Inequality Within Urban and Rural Areas

In the composition of the inequality within urban and rural areas, the intra-regional inequality within urban and rural areas found for indicators I1, I5, I6, and I14 are significantly higher than those the interregional inequality within urban and rural areas (see **Figure 7**). Further analysis of the interregional inequality within urban and rural areas shows that the inequality between rural areas for the five indicators of I3, I4, I10, I13, and I15 is larger than that between urban areas (see **Figure 8**).

Meanwhile, It can be seen from the composition of the intra-regional inequality within urban and rural areas (**Figure 9**) that the indicators "I1: satisfaction with the number of medical and health service institutions within 15 min," "I7: proportion of drug expenditure in household disposable income," and "I15: affordable level of out-of-pocket drug expenses" show a large inequality in rural areas in eastern China. For indicators "I4: the inequality between rural areas in western China is large when the required drug is available in online drug stores," "I5: unavailability of cheap drug needed," and "I14: satisfaction with the level of secondary reimbursement of drug costs," the rural-eastern internal inequality is similar to the urban-eastern internal inequality, and the inequality is larger than that for other indicators. Indicator "I6: The expensive drug needed is not affordable" shows a large inequality in the urban areas in the western region. The reasons for the above phenomenon are mainly found in two aspects: on one hand, the disparity of economic development level among provinces in the region is still large; on the other hand, local governments pay different levels of attention to drug welfare and support it in different ways. While the state is committed to solving the inequality of drug welfare between urban and rural areas, it pays insufficient attention to the intra-regional inequality within urban and rural areas.

DISCUSSION

In this study, we construct an indicator system to measure the drug welfare induction level of patients with chronic diseases in China. We use the bivariate Theil index for hierarchical decomposition to empirically analyze the samples of four provinces under investigation and find out the differential structure of the drug welfare induction level of patients with chronic diseases from the regional dimension and the urban-rural dimension.

In the decomposition results of both regional dimension priority and urban-rural dimension priority, the total T value of the drug welfare induction level is 0.0003, which is close to 0, indicating the overall induction level is relatively equal. This shows that the differences of chronic disease drug management and health services in China are not great as a whole. There is not much difference in the medication situation of patients, which is similar to the conclusions of previous studies: The vast majority of CNCD patients do not receive proper care, and more than 70% of CNCD patients are not well-controlled (40). From 2010 to 2014, the gap of self-rated health between different income groups in China had been narrowed and health equity had been improved (41).

Bivariate Theil-T Index With Regional Dimension Priority

The hierarchical decomposition of the Theil index with priority in the regional dimension shows that the intra-regional (eastern region interior or western region interior) gap of the drug welfare induction level of patients with chronic diseases in China is larger than the inter-regional (between eastern and western regions) gap. This is because China's current poverty alleviation policies for health in the west have gradually narrowed the gap between regions. For example, the government has increased the proportion of subsidies to the central and western regions and remote and poor areas when arranging subsidy funds for public health and resident medical insurance; it also has implemented special subsidies for poor areas and focused on improving the medical and health service capabilities of the central and western regions. Unlike previous conclusions, previous studies have shown that there are significant regional differences in the distribution of health resources in China (42). The *T*-value of the index I1 is $>$ 0.0040 and 0.0020 after the first decomposition and the second decomposition, respectively, indicating that the level of induction of chronic disease patients represented by this index is relatively low. In other words, the degree of equalization of access to medical and health institutions is not high. It is worth noting that in the primary and secondary decomposition results of the regional dimension priority, the *T-values* of indicators I6 and I14 are larger than that of others, indicating that patients' induction of the affordability of high-priced drugs and the fairness of secondary reimbursement of drug costs is quite unbalanced. Previous studies have shown that in terms of per capita consumption capacity, the price of new anticancer drugs is unaffordable in China (43).

In terms of the internal composition of the inter-regional gap, patients with chronic diseases in the eastern region have a

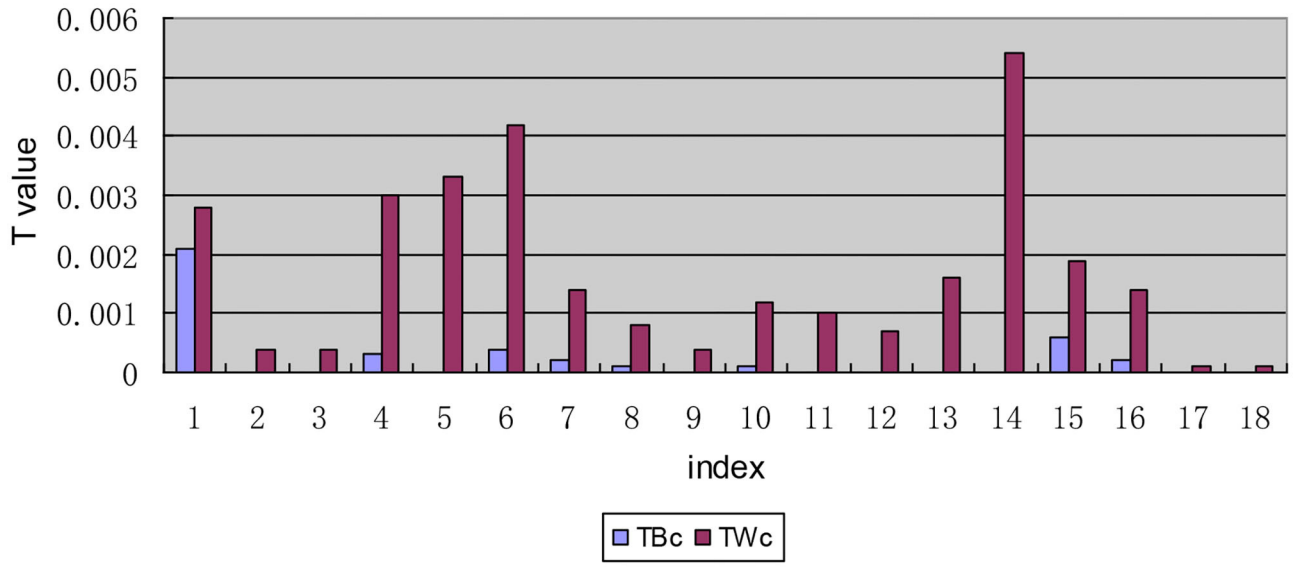

FIGURE 6 | Decomposition of *T*-values of each indicator along the urban and rural dimension.

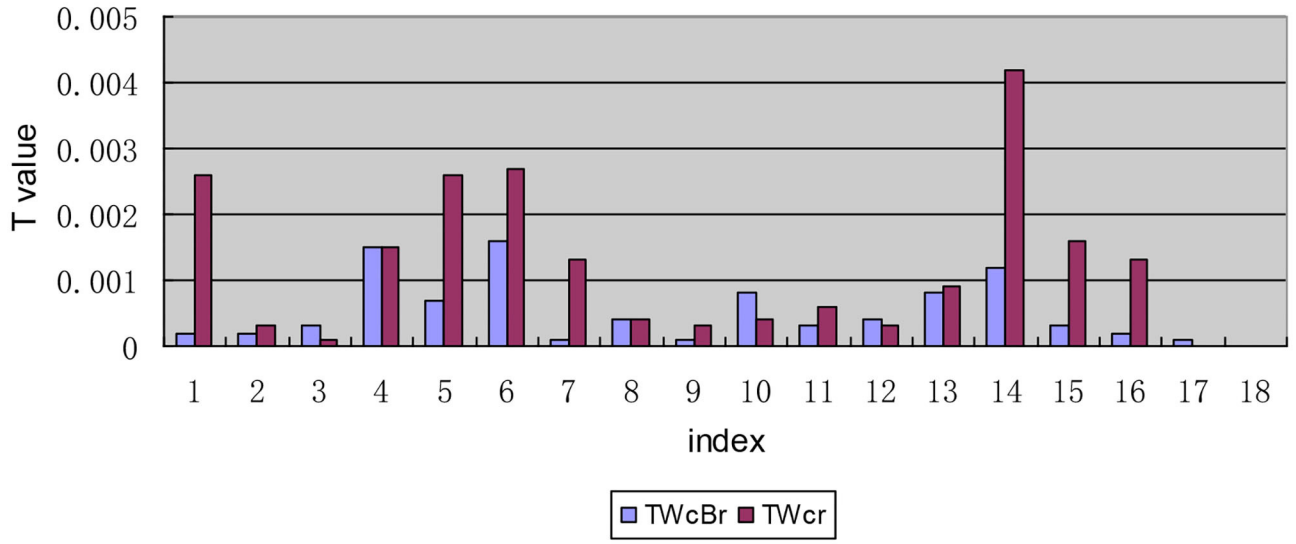

FIGURE 7 | Decomposition diagram of the inequality in each indicator between urban and rural areas by region.

higher level of drug welfare induction, which is consistent with national conditions and related research results (44). The eastern region is economically developed, and the medical insurance fund guarantee is fundamentally stronger than that of the western region. Even if the western region has the support of Health Poverty Alleviation Policy, there is an imbalance in the drug welfare of patients with chronic diseases between the east and west of China, and there is a certain gap.

The price of medicine has always been a major issue related to the national economy and people's livelihood. In recent years, the Chinese government has made tremendous efforts to reduce drug prices and achieved certain results. For example, a series of comprehensive policies have been implemented, including "zero tariffs on imported anti-cancer drugs," "consistency evaluation and quality evaluation of generic drugs," "4+7' centralized drug procurement," and "zero-profit drug policy." These measures reduce the intermediate links of drug circulation, saving a lot of costs in promotion, distribution and other links, and reduce drug prices to the greatest extent. These drug policies have something in common with other countries: the US federal and state policies on generic drugs have reduced consumer spending; the combined drug procurement program of federal agencies will reduce the average cost sharing of Medicare beneficiaries (45, 46). However, the above-mentioned policies also bring some hidden

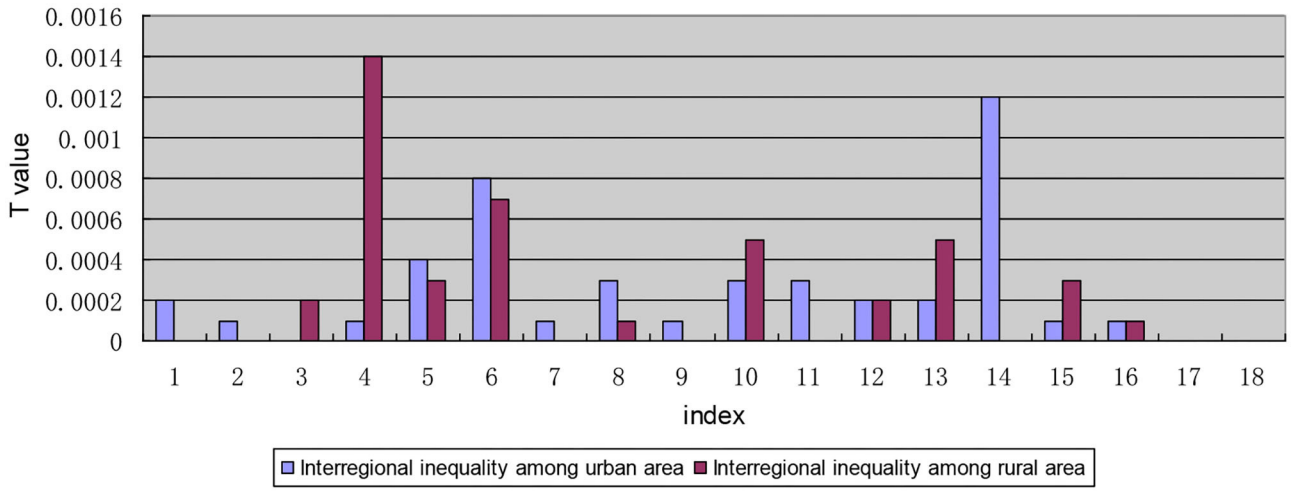

FIGURE 8 | Internal composition of the interregional inequality for each indicator within urban and rural areas.

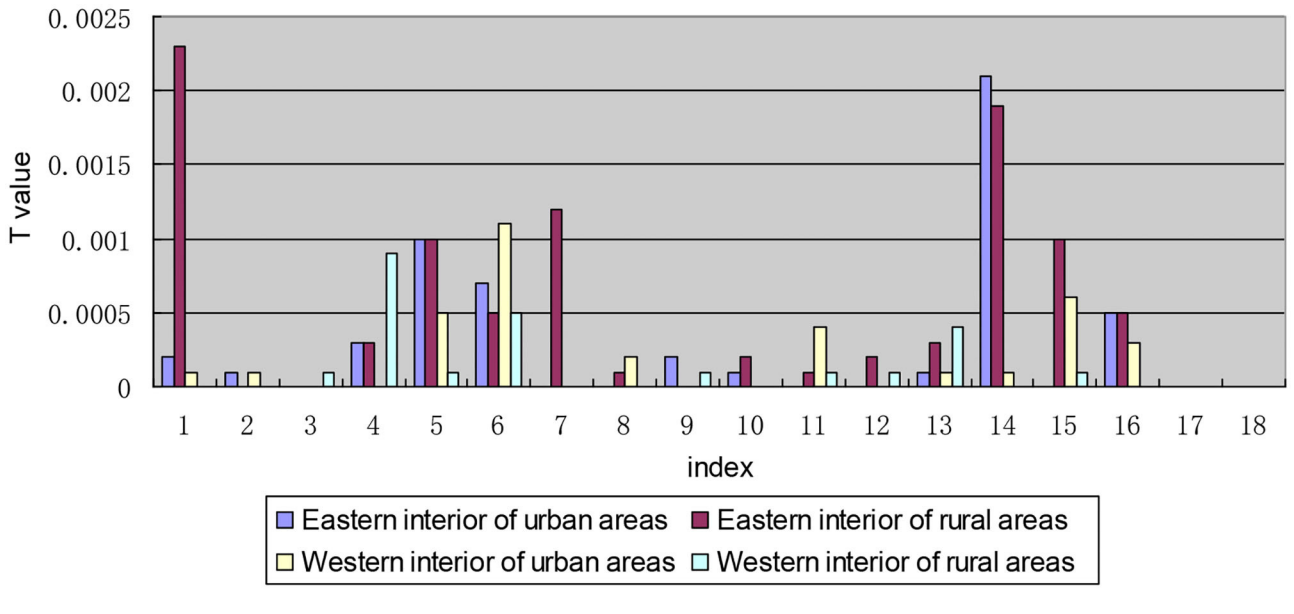

FIGURE 9 | Internal composition of the intra-regional inequality within urban and rural areas.

worries, such as the risk that the burden of patients' medical expenses and the burden of medical insurance fund expenditures will not decrease but increase (47). Through field investigations and empirical analysis, it is found that the current situation of unaffordable high-priced drugs is still grim in both urban and rural areas in China.

Bivariate Theil-T Index With Urban-Rural Dimension Priority

The hierarchical decomposition of Theil index with priority in the urban-rural dimension shows that the inequality within urban and rural areas in patients' drug welfare induction is much larger than that between urban and rural areas. The contribution rate of the gap within urban and rural areas accounts for 95.74%, which is the main aspect of the inequality of drug welfare for patients with chronic diseases. Early research found that compared with eastern and central regions, the medical and health burdens of farmers in western China (11 provinces and regions) were gradual (48). In particular, the degree of medical equalization in the eastern rural areas is relatively low, which is mainly reflected in the accessibility of medical institutions, the affordability of self-paid drugs, and the proportion of drug expenditures to household disposable income.

The first-order decomposition results show that the gap within urban and rural areas is greater than the gap between urban

and rural areas. Although the country is committed to solving the problem of drug inequality between urban and rural areas, it has not paid enough attention to inequality within urban and rural areas. By addressing health inequality and creating a healthy social environment, China will be able to better cope with the heavy burden of chronic diseases (49). The accessibility of medicines represented by indicators I1, I4, I5, and I6 and the fairness of medicines represented by index I14 have a low degree of equalization. It can be seen that the problem of accessibility of medicines is the main aspect of the inequality of drug welfare. Timely and adequate supply of medicines is a difficulty faced by chronically ill patients in rural areas in China. However, under the severe burden of disease, "patients are poor because of diseases, and patients go back into poverty because of diseases." The composition of the inequality within urban and rural areas shows that the intra-regional inequality in drug welfare for patients with chronic diseases is greater than interregional inequality regardless of whether it is within cities or rural areas. The internal inequality in the west is greater than that in the east, which are mainly embodied in the accessibility of medicines. This is also due to the large gap in the economic development level of the provinces within the region. The low drug welfare in western China is mainly manifested in the poor accessibility of online drugs, which is related to the backward rural economy, lower Internet penetration rate, older chronic disease patients, lower education level, and less popularity of network usage. And it is more difficult to distribute drugs in the western region than that in the eastern region.

Policy Implications

Based on the above analysis, we seriously recommend that drug policy makers consider our results and formulate relevant intervention measures to improve the level of equalization of drug welfare for patients with chronic diseases.

First of all, in the face of poor affordability of high-priced drugs for chronic disease patients (I6), and whether in urban or rural areas, the intra-regional inequality is significantly larger than the inter-regional inequality, strong medical reform measures should be taken to strengthen the price regulation of commonly used drugs and high-priced drugs. In fact, there are inequalities in drug welfare in all regions of the country, and as far as western provinces are concerned, the driving force of medical insurance policies on the drug welfare of local patients with chronic diseases is also different. The National Healthcare Security Administration, which is directly under the State Council, was established in 2018, avoiding the problem of "decentralized functions" in the past. It enhances the coordination and leadership of medical reform, enabling medical insurance to act as a payer to leverage the transformation of medical service models and forces the reform of the pharmaceutical industry system. A series of policies such as medical insurance fund supervision, mass purchase, medical insurance catalog adjustment, DRG (Diagnosis Related Groups) payment, etc. ensure patients' high-priced drug use, great reduction of the economic burden of patients, improvement of public health, and creation of economic value (50).

Second, in order to ensure the supply of cheap drugs (I5) and the quality and level of medications for patients with chronic diseases, the production and supply guarantee mechanism for cheap drugs should be improved to promote the equalization of cheap drugs in urban and rural areas. Studies have shown that although the industries in developing countries are booming, the poor still cannot afford drugs (51), so the government should ensure the supply of cheap drugs, such as generic drugs (50). On the one hand, the shortage of cheap drugs is due to the low-price drug bidding system, which causes all links of the supply chain to lose production and sales momentum due to lack of profit; On the other hand, the raw materials are stockpiled and scarce, companies that successfully won the bid can only reduce costs, leading to a decline in drug quality. The shortage of cheap medicines at the grassroots level has a major impact on chronically ill patients and doctors (52). Therefore, it is necessary to establish a safety early warning and emergency management mechanism for drug supply.

Third, the government should establish a public health insurance budget system to promote the equalization of secondary drug reimbursements in urban and rural areas (53). Through the above empirical research, it is found that the level of secondary reimbursement of drug expenses for patients in China is still unequal. It is suggested that the existing decentralized basic medical security system be integrated into the province-based single payment system through the reorganization of the financing system, payment structure, and operation mode (54). The government can also promote Urban and Rural Residents' Serious Illness Insurance Livelihood Project, and magnify the superimposed effects and security guarantee effects of various security systems to eliminate the phenomenon of "Poverty due to illness." In addition, in order to effectively improve the drug welfare of patients with chronic diseases and reduce the burden of outpatient drug costs for patients with hypertension, diabetes, etc., the National Medical Insurance Bureau should establish a complete outpatient medical expenses mutual assistance mechanism and include outpatient medical expenses into the payment scope of the basic medical insurance coordinating fund.

Fourth, the government should strengthen the standardized management of online pharmacies (55) to improve the efficiency of real-time supervision and to enhance patients' trust in Internet drug platforms. Previous studies have shown that purchasing drugs from online pharmacies can improve the accessibility of drugs. However, due to the imperfect supervision system, the illegal sales of prescription drugs have been intensified. Therefore, it is necessary to strictly regulate online pharmacy sales practices (56). At the same time, this study finds that patients in rural areas in western China rarely buy drugs online, which is also related to the current Internet drug sales restrictions in China. Many drugs for the treatment of chronic diseases, such as cardiovascular and cerebrovascular drugs, are basically prescription drugs, while the drugs sold in online pharmacies can only be non-prescription drugs. At the same time, the medical insurance system cannot adapt to medical e-commerce payment, obliterating the convenience and price advantage of online drugs. The "Internet+" model should innovate according to the existing international mature model (57). It is strongly recommended that electronic prescription review methods be promoted in a timely manner and restrictions on online sales

of prescription drugs be released on the basis of ensuring drug safety. In addition, the medical e-commerce should be covered by medical insurance system.

Limitations and Future Research

This study has some limitations. First, the patient's profile and environmental factors may vary geographically. Therefore, the environment of these four provinces may not represent all urban and rural areas in China. Second, the sensitivity level of drug welfare is easily affected by other factors, such as the regional economic system and the personal qualities of patients. Therefore, longitudinal studies with large sample sizes are expected to further explore the determinants that affect the induction level equalization.

CONCLUSION

As the population of chronic diseases in China continues to expand, our research results indicate that the government should focus on increasing the level of drug welfare for chronic disease patients in the western rural areas in the future. The policy should be tilted toward the disadvantaged provinces within the region to promote the equalization of the level of drug welfare for patients with chronic diseases in China.

STRENGTHS AND LIMITATIONS OF THIS STUDY

There was little previous research on the equalization of drug welfare induction level of Chinese patients with chronic diseases.

We set up the index system of drug welfare level by using the questionnaire, and studied it from four aspects of Drug Accessibility Effect Induction level, Drug Price Effect Induction leve, Drug Fairness Effect Induction level, and Drug Health Effect Induction level.

We Creatively used the bivariate Theil-T index method to measure the level of drug welfare induction.

Limitations include the subjectivity of the indicator system and the representativeness of the sample.

DATA AVAILABILITY STATEMENT

The datasets used or analyzed in the current study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

Ethical approval (case reference number: KY2017039) was obtained from the Ethics Committee of Nanjing Hospital of Chinese Medicine affiliated with Nanjing University of Chinese Medicine in China, which undertook the study. Informed consent was obtained in written form. All subjects gave their informed consent for inclusion before they participated in the study.

AUTHOR CONTRIBUTIONS

ST and RZ: designing the manuscript and structure and writing the manuscript. YS: data processing and collected the references. YG: indicator calculation and result analysis. YC: checked the data and edited the language. All authors contributed to the interpretation of the data and approved the final version for submission.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2020.581533/full#supplementary-material

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Associations of Socioeconomic Status and Physical Activity With Obesity Measures in Rural Chinese Adults

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Background: Although independent association of socioeconomic status (SES) or physical activity (PA) with obesity has been well-documented in urban settings, their independent and joint associations on obesity measures are limited in rural regions.

Methods: Almost 38,000 (n = 37,922) individuals were included from the Henan Rural Cohort Study. The International Physical Activity Questionnaire (IPAQ) was used to evaluate PA. Obesity was reflected by body mass index (BMI), waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), body fat percentage (BFP), and visceral fat index (VFI). The independent and interactive effects of SES and PA on obesity were analyzed by logistic regression models and generalized linear regression models, respectively.

Results: Compared with high education level, the OR (95%CI) of obesity defined by BMI with low education level was 1.466 (1.337, 1.608), 1.064 (0.924, 1.225), and 1.853 (1.625, 2.114) in total population, men and women, respectively. Besides, the OR (95%CI) of obesity defined by BMI associated with per capita monthly income were 1.089 (1.015, 1.170), 1.192 (1.055, 1.347), 1.038 (0.951, 1.133) in total population, men and women, respectively. Similar results had been observed in other obesity measures. Negative interactive association of low education level and PA on obesity measures were observed only in women (all $P < 0.05$).

Conclusions: This study suggests that women are more susceptible to obesity concerning low SES and that adequate PA may be a potential target for mitigating the negative effect of low SES on obesity in women.

Clinical Trial Registration: The Henan Rural Cohort Study has been registered at Chinese Clinical Trial Register (Registration number: ChiCTR-OOC-15006699) http://www.chictr.org.cn/showproj.aspx?proj=11375.

Keywords: physical activity (exercise), obesity, rural population, gender difference, socioeconomic status

INTRODUCTION

Obesity is a growing and disturbing global public health crisis (1). According to the Global Burden of Disease statistics in 2017, more than four million people died each year as a result of being overweight or obese (2). It turns out that excess weight is the main risk factor for various diseases, especially stroke and coronary heart disease (3–5). Body mass index (BMI) has been widely used for defining obesity. However, BMI alone does not fully characterize adiposity, and other anthropometric measures have been proposed to define obesity, such as waist circumference (WC) (6), waist-to-hip ratio (WHR) (7), waist-to-height ratio (WHtR) (8), body fat percentage (BFP) (9), and visceral fat index (VFI) (10), etc. They define obesity according to different anthropometric emphasis with different predictive capabilities for diseases. Besides, the prevalence of obesity may vary greatly with different measures used to define obesity. However, it is still controversial which measure is most appropriate to define obesity, we therefore used these six objectively measured anthropometric methods to more accurately monitor obesity in the current study.

It is well-known that the socio-economic environment has a significant impact on the prevalence of a high number of diseases, including obesity (11, 12) as it influences people's attitudes, experiences, and access to several health risk factors (13, 14). Based on several systematic reviews (15, 16) of socioeconomic inequalities in obesity, it was found that the relationship between SES and obesity varies across countries with different levels of development. In developed countries, socioeconomically disadvantaged groups tend to have a higher prevalence of obesity, i.e., people with lower income and/or lower levels of education tend to be more likely to be obese. In developing countries, the SES-obesity relationship was found to be more complex: in low-income developing countries, those living in more affluent circumstances are more likely to experience overweight and obesity for both men and women, whereas in middle-income countries, the relationship between SES and obesity is largely mixed for men and predominantly negative for women (15). Notably, gender appears to play an important role in the SES-obesity relationship, and it was said that ignoring gender differences when examining the SES-obesity association may lead to targeting of wrong populations for reducing obesity prevalence and its resultant socioeconomic gradients (17). Additionally, researches on the SES-obesity association were mainly concentrated in developed countries and developing urban cities, with very limited research in rural areas of developing countries. Considering the serious epidemic of obesity and overweight in developing countries, especially in rural settings (18), the SES-obesity associations in these settings were also meriting focus.

It had been well-documented that regular physical activity (PA) has great benefits for keeping fit (19). According to Xiao et al., compared to physically inactive male respondents, physically active ones had about one quarter lower risk of being obese (20). Furthermore, it had been shown that in the SES-obesity relationships, PA could play a significant role (21, 22). For instance, Merino et al. suggested that promoting PA would contribute to preventing obesity for low SES-individuals (21). However, the association between SES and obesity whether affected by PA and how affected by PA was not available in rural regions.

Therefore, the purpose of this study was to investigate the independent and potential joint associations of SES and PA on different obesity measures among participants of different genders from the baseline survey of the Henan Rural Cohort Study.

Abbreviations: BFP, body fat percentage; BMI, body mass index; CI, confidence interval; MET, metabolic equivalent; PA, physical activity; SD, standard deviation; SES, socioeconomic status; VFI, visceral fat index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

MATERIALS AND METHODS

Study Population

The Henan Rural Cohort Study was conducted in Henan, China, using a multistage stratified cluster sampling method to recruit a total of 39,259 individuals as a baseline cohort from five rural areas (Suiping, Yuzhou, Xinxiang, Tongxu, and Yima) between 2015 and 2017 (23). Almost 38,000 (n = 37,922) individuals aged 18–79 years were included for the further analysis, after excluding individuals with missing data on per capita monthly income, PA, height, weight, waist or hip circumference, body fat percentage (BFP), and visceral fat index (VFI). This study was conducted under the Declaration of Helsinki. Zhengzhou University Life Science Ethics Committee had approved this survey and all participants had signed written informed consent.

Assessment of Obesity

Anthropometric measures of obesity include waist and hip circumference, height, weight, BFP, and VFI. Weight, BFP, and VFI data were measured using a bioelectrical impendence analysis device (OMRON V. BODY HBF-371) following its operating instructions. Body weight was measured with light clothes to an accuracy of 0.1 kg. Height was measured by taking off shoes and leaning against a calibrated wall. Waist and hip circumferences were measured 1.0 cm above the navel and at the highest hip level, respectively. Height and waist and hip circumference were measured at least twice, each accurately to 0.1 cm, with the difference between the two measurements <0.5 cm and averaged for statistical analysis. The details of the anthropometric measures have been described elsewhere (18).

BMI is calculated as weight (kg) divided by height squared (m^2), WHR is calculated as WC (cm) divided by hip circumference (cm), and WHtR is calculated as WC (cm) divided by height (cm). Individuals with a BMI $\geq$ 28 kg/m^2 were defined as obese individuals, following the Working Group on Obesity in China (24). The cut-off values for the other five obesity measures were set based on previous criterion as follows: WC, men/women $\geq$ 90/80cm (6); WHR, men/women $\geq$ 0.90/0.85 (7); WHtR $\geq$ 0.5 (8); BFP, men/women $\geq$ 25%/30% (9); VFI $\geq$ 10 (25).

Assessment of SES

Education level and per capita monthly income were used as proxies of SES, which were consistent with previous studies (20, 26). Education level was derived from the item "educational level" in the questionnaire. Options include illiteracy, primary school, junior high school, senior high school/technical secondary school, university/ junior college, and postgraduate. They were finally divided into three groups: low (illiteracy or primary school), medium (junior high school), and high (senior high school or above). Per capita monthly income was a continuous indicator obtained by dividing the average annual income by the number of household members. Due to the discrete nature of the data, a logarithmic transformation was used for statistical analysis.

Assessment of PA

The levels of PA were assessed by the International Physical Activity Questionnaire (IPAQ) (27, 28). Participants were asked about the amount of time spent on vigorous activity, moderate activity, and walking over the past week, and the total metabolic equivalent (MET) value was estimated by combining the different types of PA during the week with the corresponding coefficients. The detailed procedure had been described in previous studies (29). Briefly, 1 MET was defined as the amount of energy expended by an individual while sitting quietly. The coefficients of compendium average MET were eight for vigorous activity; four for moderate activity; and 3.3 for walking. PA was classified into three levels: low, moderate, and high. Classification of PA as high shall meet one of the following two criteria: (1) Vigorous activity at least 3 days/week, Mets at least 1,500 MET-min/week. (2) Any combination of the three exercise types (vigorous activity, moderate activity, or walking) for at least 5 days/week and accumulating Mets of at least 3,000 MET-min/week; A classification of PA as moderate shall meet one of the following four criteria: (1) At least 20 min of vigorous activity 3 days a week. (2) Moderate activity for at least 30 min 5 days a week. (3) Walking for at least 30 min per day 5 or more days a week. (4) Accumulated Mets of at least 600 MET-min/week.

Assessment of Covariates

In addition to SES indicators and PA, we have collected for other variables associated with obesity: region (30), age, gender, marital status, smoking, alcohol consumption, adequate fruit and vegetable intake, and high-fat diet (18, 25). All variables were collected by trained interviewers through face-to-face interviews. Marital status was categorized into married/cohabitation, divorced/widowed/separated and unmarried groups. Smoking and drinking status were categorized into current, former, and never groups. Dietary habits included high ($\geq$500 g/day) and low (<500 g/day) fruit and vegetable intake groups, and high ($\geq$75 g/day) and low-fat diet (<75 g/day) groups (31). The dietary data were collected via a food frequency questionnaire (FFQ) covering the intake of food groups during the previous 12 months. Based on five consumption frequencies (never, day, week, month, year), participants were asked about the amount of food consumed (kg, g). The reliability and validity of FFQ have been conducted and published elsewhere (32). Briefly speaking, the reliability of the FFQ was established by comparing two administrations of the FFQ over a 4-week period while relative validity was established against a 24 h diet recalls (24DR), and the results recommended that our FFQ is appropriate for ranking participants according to food group intake of a rural population.

Statistical Analysis

Categorical variables and continuous variables were expressed as number (percentage) and median (interquartile range), respectively. The differences in continuous and categorical variables between different genders were analyzed by the Mann-Whitney *U* test and Chi-square test, respectively. We calculated Pearson correlation coefficients among SES indicators, PA and obesity measures, and correlation maps were used to show the direction (negative or positive) and magnitude (strength) of correlation among SES indicators, PA and obesity measures. The independent associations between SES indicators, PA, and obesity measures (dichotomous form) were assessed by using logistic regression models. Interaction associations of SES indicators and PA on obesity measures were conducted by generalized linear regression models and presented by Interaction plots which exhibited how the estimated associations of SES indicators on obesity measures were affected by altered PA intensity. Backward stepwise approaches were used to select covariates for the multivariate analysis, and all explanatory variables with a *P*-value <0.05 were included, including region, age, marital status, smoking status, drinking status, fruit and vegetable intake, high fat diet, education level, per capita monthly income, and PA. Besides, a sensitivity analysis was conducted on the BMI cut-off values of 30 kg/m^2 (33) to assess the robustness of the main findings. R software version 3.5.1 and SPSS version 21.0 were used for data processing and analysis. All statistical significance was set a $P < 0.05$ at two tails.

RESULTS

Basic Characteristics of the Study Population

Table 1 showed the demographic characteristics of the 37,922 participants aged 18–79 years old. The median (interquartile range) age of the total population was 56 (17) years, with men having a higher median (interquartile range) age than women (59 (17) vs. 55 (16), $P < 0.001$). Other selected variables included region, age, education level, smoking status, drinking status, adequate vegetable and fruit intake, high fat diet, PA, as well as obesity measures, which were distributed differently by gender (all $P < 0.001$).

Independent Associations Between SES Indicators, PA and Obesity Measures

Figure 1 and **Supplementary Table 1** showed the independent associations between SES indicators or PA and obesity measures. Logistic regression analyses were performed using a fully adjusted model that adjusted for region, age, marital status, smoking status, drinking status, fruit and vegetable intake, high fat diet, SES indicators or PA. The results showed that the associations

TABLE 1 | Characteristics of the study population.

Variables	Overall	Men	Women	*P*
	(*N* = 37,922)	(*N* = 14,877)	(*N* = 23,045)	
Region (*n*, %)				<0.001[a]
Yuzhou	8,995 (23.7)	3,132 (21.1)	5,863 (25.4)	
Suiping	15,716 (41.4)	6,477 (43.5)	9,239 (40.1)	
Tongxu	2,464 (6.5)	994 (6.7)	1,470 (6.4)	
Xinxiang	9,796 (25.8)	3,972 (26.7)	5,824 (25.3)	
Yima	951 (2.5)	302 (2.0)	649 (2.8)	
Age [years, median (interquartile range)]	56 (17)	59 (17)	55 (16)	<0.001[b]
Marital status (*n*, %)				0.502[a]
Married/cohabitation	34,103 (89.9)	13,398 (90.1)	20,705 (89.8)	
Unmarried/divorced/widowed	3,819 (10.1)	1,479 (9.9)	2,340 (10.2)	
Education level (*n*, %)				<0.001[a]
Low	16,941 (44.7)	4,992 (33.6)	11,949 (51.9)	
Medium	15,211 (40.1)	6,917 (46.5)	8,294 (36.0)	
High	5,770 (15.2)	2,968 (20.0)	2,802 (12.2)	
Log-transformed per capita monthly income [median (interquartile range)]	3.9 (0.5)	3.9 (0.5)	3.9 (0.5)	0.807[b]
Smoking status (*n*, %)				<0.001[a]
Never	27,652 (72.9)	4,693 (31.5)	22,959 (99.6)	
Ever	3,065 (8.1)	3,044 (20.5)	21 (0.1)	
Current	7,205 (19.)	7,140 (48.)	65 (0.3)	
Drinking status (*n*, %)				<0.001[a]
Never	29,324 (77.3)	6,943 (46.7)	22,381 (97.1)	
Ever	1,743 (4.6)	1,682 (11.3)	61 (0.3)	
Current	6,855 (18.1)	6,252 (42.0)	603 (2.6)	
High fat diet (yes, *n*, %)	7,252 (19.1)	3,731 (25.1)	3,521 (15.3)	<0.001[a]
Adequate vegetable and fruit intake (yes, *n*, %)	21,896 (57.7)	6,455 (43.4)	9,571 (41.5)	<0.001[a]
PA-MET [hour/day, median (interquartile range)]	17.0 (9.9)	17.0 (15.1)	17.5 (9.8)	<0.001[b]
Physical activity (*n*, %)				
Low	11,636 (30.7)	4,998 (33.6)	6,638 (28.8)	<0.001[a]
Moderate	14,652 (38.6)	4,263 (28.7)	10,389 (45.1)	
High	11,634 (30.7)	5,616 (37.7)	6,018 (26.1)	
Obesity (*n*, %)				
BMI	6,693 (17.6)	2,337 (15.7)	4,356 (18.9)	<0.001[a]
WC	19,547 (51.5)	5,152 (34.6)	14,395 (62.5)	<0.001[a]
WHR	23,731 (62.6)	8,226 (55.3)	15,505 (67.3)	<0.001[a]
WHtR	25,809 (68.1)	9,166 (61.6)	16,643 (72.2)	<0.001[a]
BFP	25,672 (67.7)	7,066 (47.5)	18,606 (80.7)	<0.001[a]
VFI	16,751 (44.2)	9,403 (63.2)	7,348 (31.9)	<0.001[a]

SD, standard deviation; MET, metabolic equivalent; BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; BFP, body fat percentage; VFI, visceral fat index. [a]Chi-square test was used to test the distributions of categorical variables between genders. [b]Mann-Whitney U Test was used to compare the difference of continuous variables between genders.

of PA with obesity measures were the same both in the total population and across gender, the higher the level of PA, the lower the odds of obesity measures. However, the associations of SES indicators with obesity measures vary across different populations. In terms of education level, compared with high education level, the OR (95%CI) of obesity defined by BMI in total population, men and women with low education level were 1.466 (1.337, 1.608), 1.064 (0.924, 1.225), and 1.853(1.625, 2.114), respectively. Besides, the OR (95%CI) of obesity defined by BMI associated with per capita monthly income were 1.089 (1.015, 1.170), 1.192 (1.055, 1.347), 1.038(0.951, 1.133) in total population, men and women, respectively. Similar results had been observed in other obesity measures. **Supplementary Figure 1** displayed the correlation between SES

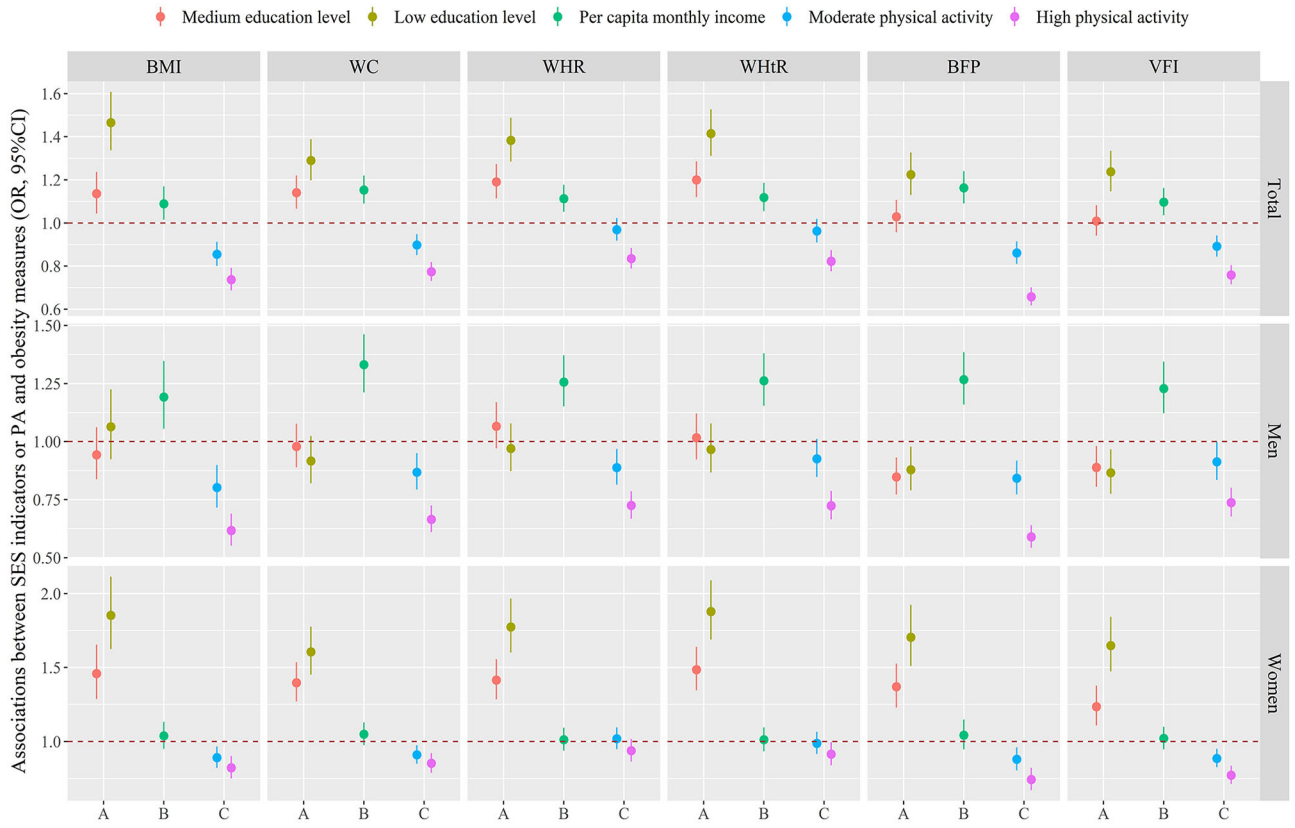

FIGURE 1 | Associations between education level (A) or per capita monthly income (B) or PA (C) and obesity measures. Logistic regression analyses were performed using a fully adjusted model that adjusted for region, age, marital status, smoking status, drinking status, fruit and vegetable intake, high fat diet, SES indicators or PA. The dots and lines were exhibited the estimated regression coefficient and corresponding 95% confidence intervals, respectively. SES, socioeconomic status; PA, physical activity; BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; BFP, body fat percentage; VFI, visceral fat index.

indicators, PA, and obesity measures. PA showed a negative correlation with obesity measures in both the total population and different genders. Education level and per capita monthly income were positively correlated with obesity measures in men, whilst negatively correlated with obesity measures in women.

Combined Associations of SES Indicators and PA With Obesity Measures

Figure 2 showed regression associations of SES indicators on obesity measures (dichotomous form) classified by BMI, WC, WHR, WHtR, BFP, or VFI as a function of PA by using generalized linear models in a fully adjusted model, which adjusted for region, age, marital status, smoking status, drinking status, fruit and vegetable intake, high fat diet, education level or per capita monthly income. We did not observe any interaction association between per capita monthly income and PA on obesity measures, neither in the total population nor in different genders. However, there were significant negative interactive associations between low or medium education level and PA on obesity measures both in total population and in women (all $P < 0.05$), which implies that in women, the positive association between low or medium education level and obesity weakens with increasing PA intensity.

Sensitivity Analysis

The results of the sensitivity analysis were shown in **Supplementary Table 2**. The estimated associations between SES indicators or PA and obesity measures defined by BMI remained fairly robust after using different cut-off values of BMI.

DISCUSSION

In this study, the results suggested that: first, a negative association between PA and obesity was observed in both men and women. Second, there were gender differences in the independent and joint associations between SES indicators and obesity measures. The significant inverse association between education level and obesity measures was found only in women, whereas the significant positive association between monthly per capita income and obesity measures was found only in men. Third, we found a negative interaction association between PA and low education level on obesity measures in women.

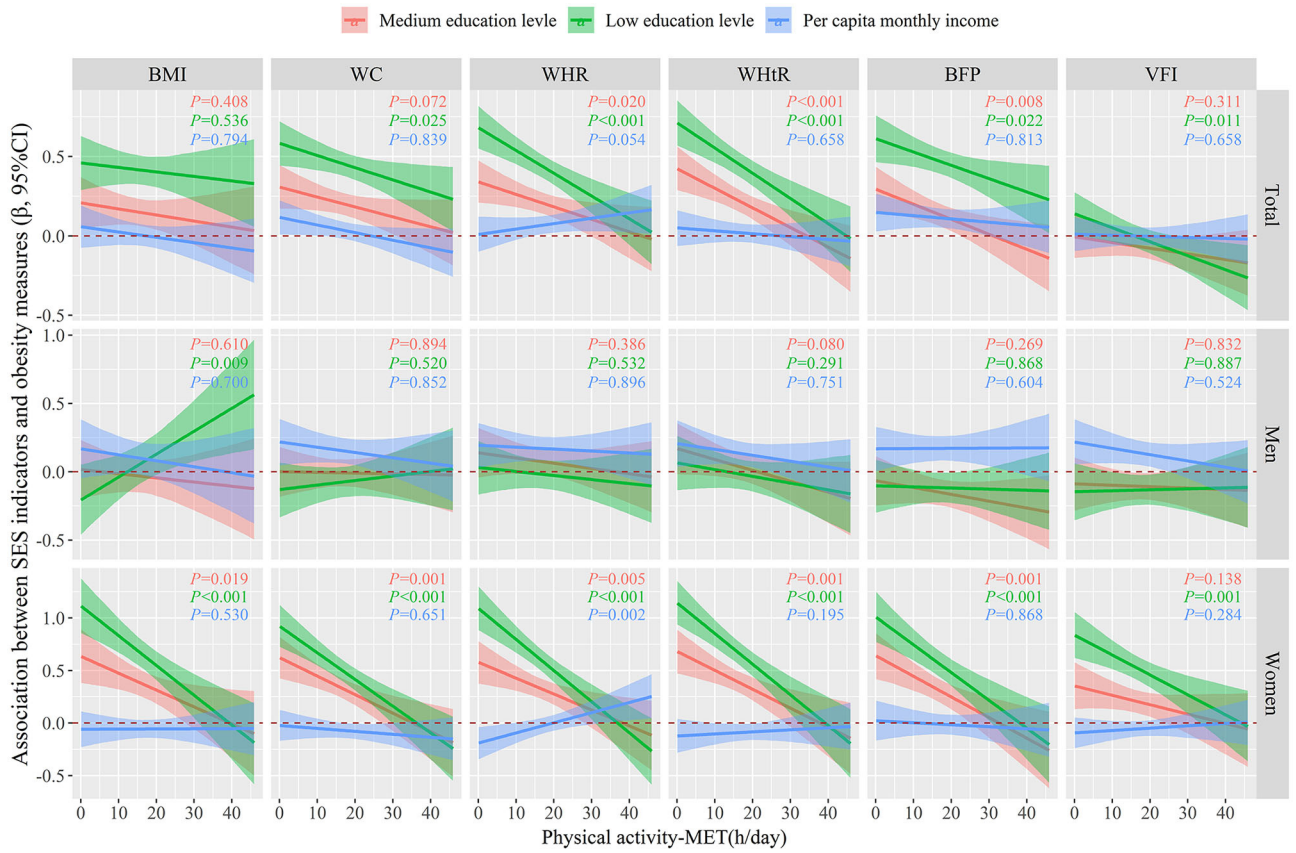

FIGURE 2 | Regression associations between SES indicators and obesity measures (dichotomous) as a function of PA were evaluated by using generalized linear models, after adjusting for age, marital status, smoking status, drinking status, fruit and vegetable intake, high fat diet, education level or per capita monthly income. The lines and areas represented the estimated regression coefficient and 95% confidence intervals, respectively. SES, socioeconomic status; PA, physical activity; BMI, body mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio; BFP, body fat percentage; VFI, visceral fat index.

PA can maintain a healthy weight and reduce the risk of many health problems, including obesity (34–36). A broad range of strategies are recommended to reduce the prevalence of obesity, and PA remains the most common treatment. PA offsets by increased energy consumption and positive energy balance to reduce diet-induced weight gain (37). Additionally, PA has a far-reaching impact on the normal function of the immune and endocrine system (38, 39), as well as the reduction of inflammation and oxidative stress (40, 41), which may help protect individuals from the development of obesity (42, 43). However, according to our previous study in 2019 (29), physical inactivity, and sedentary behavior (sitting for >7.5 h per day) were high in rural areas. The age-standardized prevalence of light PA was 32.74%, higher than the global PA level (44). Besides, the level of sedentary behavior was 26.88%, which was higher compared with a previous study of a 20-country comparison of sitting (45). A major difference between urban and rural environments is that for some rural residents, there may be additional barriers to regular active PA, including isolation, climate, safety fears, cost, lack of transportation, and lack of PA spaces (46). Taking steps to enhance features such as playgrounds, parks, and recreation facilities in rural environments and to reduce barriers to active PA may be good ways to promote active living and address the issue of obesity in rural areas.

It is well-known that SES has an impact on human health status. Extensive research has been carried out to explore the relationship between SES and obesity. However, the results are inconclusive. We found that higher education level was associated with lower odds of obesity in women, which is consistent with some studies in the Philippines (47), Thailand (48), Tehran (49), and urban areas such as Zhejiang (20), Tianjin (26), Guangdong (50), and 33 communities of Northeast China (51). Besides, it was observed in the present study that, men with higher income had higher odds of obesity, which is in agreement with studies in Thailand (48), Mexican (52), and other studies in China (20, 51), but differs from studies in Molise adults (53) and Brazil adults (54). A recent review (16) concluded that in low-income countries, overweight and obesity are more common in more socioeconomically affluent groups and that this pattern flattens and then reverses as country-level income increases. The complex pattern of the SES-obesity relationship highlights the profound influence of social context on obesity, as the social

environment can affect people's health in many ways (55), like economic and social development, employment levels, changes in dietary patterns, levels of food safety, resources that support PA, access to health services, and people's beliefs, awareness, and behaviors about healthy eating and lifestyle.

We found gender differences in the SES-obesity relationship, with a negative association between education level and obesity in women, but no such relationship was found in men. Research suggests that there is a social stratification of women's body size (56). Body size ideals and perceptions of social pressure to be slim vary by socioeconomic class. Socially advantaged women are more dissatisfied with their bodies than socially disadvantaged women (57). The desire to be slim will eventually be transformed into powerful motivation to keep a fit figure. Besides, well-educated women have an advantage in understanding the health benefits of a healthy weight, a reasonable diet, and adequate PA (58, 59). Additionally, according to Gore et al., girls with lower education levels had the highest levels of depressive symptoms and stress levels (60), which may lead to pro-inflammatory effects or reduce the integrity of the intestinal barrier, in which case obesity may be induced (61). But to men, high SES not only increases the chance of obtaining excess food, but also increases the chance of avoiding manual labor (62), and larger size generally regarded as more likely to have physical strength and superiority, so the community culture of male obesity is relatively tolerant (58).

Based on our result, we found a negative interaction association between PA and low education level on obesity measures in women, which is consistent with some existing literature (21, 22). For instance, a study conducted in Spain used path analysis to disentangle the direct and indirect effects of SES on obesity, in which PA served as a mediator variable, and found that PA had a significant mediating effect on the SES-obesity relationship and concluded that promoting PA was helpful to prevent obesity (21). The possible mechanisms underlying the combined association of SES indicators and PA on obesity measures deserve exploration. There are several potential explanations. The socio-economic and physical environment could affect people's health both tangibly and intangibly (63, 64), as Adler found that social inequalities such as unequal income distribution increase people's exposure to stressful events (63). Physical environment characteristics, on the other hand, could affect people's opportunities to engage in PA, specifically the availability of parks and recreation facilities, and a pedestrian environment that promotes PA, such as walking and exercise (64), which is, however, very limited in rural areas. With increased exposure to stress and decreased access to PA, obesity is more likely to occur. Another explanation is that, according to Carroll-Scott et al., a disadvantageous SES is itself a stressful state (65), and PA can alleviate oxidative stress or inflammatory response (40, 41, 61), thus to a certain extent offset the adverse effects of SES on obesity.

Our results also found gender differences in the combined association of PA and SES indicators on obesity measures. The possible explanations are as follows. First, several studies have found that low SES has a greater negative impact on good health for women than for men (66). Our results are in line with this finding, with men being largely unaffected in terms of the burden of obesity at low education level, while women show a significant inverse relationship. Furthermore, men with low SES were more likely to engage in high levels of PA (62), making it less likely that low SES and PA would have a meaningful interaction effect on obesity. Secondly, women are less educated than men, with 51.3% of women vs. 33.6% of men classified in the low education group as shown in **Table 1**. Less-educated women are less likely to work, and roles such as childrearing and maintaining the household are usually fulfilled by them (66), thus they are more likely to be socially isolated compared to men (67). However, mutual support among socially connected people is of great significance as it can lead to positive changes such as reduced caloric intake and increased PA (68). As educational attainment has been established, PA can be an alternative way to reduce the obesity associated with low levels of education, especially among women.

The present study has several strengths: the exploration of the SES-PA-obesity relationship was conducted in a relatively large rural population, which helps to fill a gap in the literature on the SES-PA-obesity relationship in rural areas. Besides, adjusting for multiple covariates helps to control for potential confounders, and defining obesity using several different objectively measured anthropometric measures contributes to more accurate monitoring of obesity. In terms of limitations, first, due to the nature of the cross-sectional design, the present study was unable to determine a causal relationship between SES or PA and obesity measurements. Second, the information on lifestyle factors was obtained based on self-reports, so recall bias cannot be excluded. Finally, although some important confounding covariates were controlled for, some unmeasured factors (e.g., genetic and physiological factors) were not taken into account, which may have influenced the results.

CONCLUSION

In summary, the burden of obesity is likely to be higher among women with low levels of education and men with high per capita monthly income in the Chinese rural population. Promoting PA may counteract the negative impact of low SES on obesity in women. From a policy perspective, gender differences need to be considered when taking measures to reduce the prevalence of obesity and reduce the SES gradient, and further prospective studies through geographically robust study designs are 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 Ethics approval was obtained from the Zhengzhou University Life Science Ethics Committee [Ethics approval code:

[2015] MEC (S128)]. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MP: investigation, data curation, methodology, formal analysis, visualization, and writing-original draft. JH: investigation, data curation, writing-review, and editing. JG, RL, ZM, and WH: investigation, writing-review, and editing. XL: investigation, validation, writing-review, and editing. RC: investigation, methodology, writing-review, and editing. SY and XW: writing-review and editing. XW: data curation, writing-review, and editing. JH: conceptualization, methodology, investigation, validation, supervision, writing-reviewing, and editing. CW: conceptualization, methodology, investigation, validation, supervision, funding acquisition, project administration, and writing-original draft. All authors contributed to the article and approved the submitted version.

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Factors Associated With Low Physical Activity in Two Latin American Populations at Risk of Developing Type 2 Diabetes: An Exploratory Analysis

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Low level of physical activity is a risk factor for chronic non-communicable diseases. Specifically, people at risk of Type 2 Diabetes (T2D) have shown to benefit from being physically active. The objective of this study was to explore what factors were associated with low physical activity in people at high risk of T2D living in Bogota and Barranquilla, Colombia.

Methodology: Cross-sectional study using baseline data from a quasi-experimental clinical trial (PREDICOL Project). The study included 1,135 participants of Bogota and Barranquilla that presented a high risk of developing T2D according to the Finnish Diabetes Risk Score (>12 points) and who underwent an oral glucose tolerance test. The main outcome variable was the level of physical activity assessed by the International Physical Activity Questionnaire. Unadjusted and adjusted logistic regression analysis were used to calculate odds ratios (OR) and the corresponding 95% confidence intervals (CI).

Results: In total, 72.5% of the study participants had low level of physical activity. Participants in the age group between 45 and 54 years showed 74% greater odds of having low physical activity compared with the youngest age group (OR 1.74, 95% CI 1.1 −2.8). People living in Barranquilla were eight times more likely to have low physical activity compared with those in Bogotá D.C. (OR 8.1, 95% CI 5.7 to 11.4).

Conclusion: A large proportion of the population at risk of developing D2T in two large cities of Colombia have a sedentary lifestyle. Interventions should be designed and implemented in order to increase physical activity in these populations.

Keywords: physical activity, risk factors, population, pre-diabetic state, Latin America

INTRODUCTION

Globally, the prevalence of low physical activity varies from 16.3% in Oceania to 39.1% in Latin America (1). The Pan-American Health Organization estimated that three-quarters of the adult population is sedentary (2). Previous studies have suggested that the differences in the prevalence of low physical activity in the Americas are due to different methods of measurement (3–5). The prevalence of low physical activity in Colombia varies between 24, 4–79% (3, 5, 6). Furthermore, people between 30 to 49 years-old present double the probability of low activity physical, to live in low socioeconomic, and perceive themselves with a perception of regular or poor health (3).

There is consistent scientific evidence on the benefits of physical activity on overall health (3, 7–9). Specifically, previous studies have shown that people with low levels of physical activity have an increased risk of chronic non-communicable diseases (CNCD) (10–12). Also, low physical activity has been associated with lower survival in these patients T2D in low and middle-income countries (10, 11). Finally, low levels of physical activity is estimated to be strongly associated with insulin resistance and cardiovascular risk factors (13, 14).

Previous studies in Colombia revealed that people at risk of T2D had a higher prevalence of sedentary lifestyle compared with people with normal glucose tolerance (1, 9, 15). Similar results have been reported in studies targeting lifestyle behavior in people at high risk of T2D (16, 17) reporting lower levels if physical activity in populations with either impaired glucose tolerance (IGT) or impaired fasting glucose (IFG) compared with individuals with a healthy glucose metabolism.

Several determinants have been related to physical inactivity in the population. Low socioeconomic status have shown to be associated with low physical activity levels (1, 3, 7). Furthermore, several factors such as lack of time, resources, and being a woman have been linked with physical inactivity in Latin America (3, 4, 7, 18). Also extended periods of watching TV, having reduced the number of hobbies as well as not spending enough time outdoors besides, being overweight and obese have been identified as predictors of low physical activity (4, 10). Moreover, the type of built environment in cities is also an important factor contributing to physical activity levels in the population. Factors such as a neighborhood, the availability of space in an urban area, environmental planning, perceived safety, and road safety influence the practice of physical activity (4, 11, 14, 18).

However, information on determinants of low physical activity in people at risk of T2D in Colombia is poor. The objective of this study was to explore what factors were associated with low physical activity in people at high risk of T2D in Bogota and Barranquilla.

Abbreviations: D2T, Type 2 Diabetes; WHO, World Health Organization; NCD, chronic non-communicable diseases; OGTT, glucose tolerance test.

MATERIALS AND METHODS

Study Design and Population

This is a cross-sectional study using baseline data from PREDICOL, a clinical trial designed to evaluate a community health program for the prevention of T2D and other cardiometabolic risk factors in the adult population of two districts in Bogotá (the capital city of Colombia) and Barranquilla (the main Atlantic port city) (PREDICOL Project; ClinicalTrials.gov identifier NCT03049839).

The study participants were recruited from 1350 households of lower socio-economic population strata in Bogota and Barranquilla. All persons older than 30 years-of-age in each household were asked to fill in the Finnish Diabetes Risk Score (FINDRISC) (19, 20). Each respondent with a FINDRISC >12 was invited to an oral glucose tolerance test (OGTT; n = 2,118). The threshold of FINDRISC> 12 was chosen according to the recent guidelines for screening for people at high risk of T2D released by the Colombian Ministry of Health and Social Protection (21). Finally, the results of the OGTT were obtained from 1,176 household members. Pregnant women and people with T2D were excluded in this study as well as people with missing data on the variables to be used in this analysis. The final study sample included 1,135 participants.

Physical Activity Assessment

Physical activity was assessed using the short version of the International Physical Activity Questionnaire (IPAQ-SV) which has been validated in many countries including in Latin America (22–25). This version consists of seven questions assessing the frequency, intensity, and duration of physical activity during the last 7 days. The questionnaire also includes the time during which the person remains seated. The data obtained allows to calculate metabolic equivalents of task (METs) per minutes during a regular week. The selected MET values were derived from work undertaken during the IPAQ Reliability Study undertaken in 2000–2001 (24). Using the Ainsworth et al. Compendium an average MET score was derived for each type of activity (26). For example, all types of walking were included and an average MET value for walking was created. The same procedure was undertaken for moderate-intensity activities and vigorous-intensity activities. The following values continue to be used for the analysis of IPAQ data: Walking = 3.3 METs, Moderate PA = 4.0 METs and Vigorous PA = 8.0 METs. Using these values, four continuous scores were defined: Walking MET-minutes/week = 3.3 * walking minutes * walking days; Moderate MET-minutes/week = 4.0 * moderate-intensity activity minutes * moderate days; Vigorous MET-minutes/week = 8.0 * vigorous-intensity activity minutes * vigorous-intensity days. And (iv) total physical activity MET-minutes/week = sum of Walking + Moderate + Vigorous MET minutes/week scores. The participants were then categorized into low physical activity ($\leq$ 479 METs-min/week), moderate physical activity (480–1,499 METs-min/week) and high physical activity ($\geq$ 1,500 METs-min/week), accordingly. Also, participants were asked whether they perform routinely at least 30 min per day of physical activity at work and/or leisure time.

Physical activity was also self-reported in the FINDRISC questionnaire. The FINDRISC score was developed by the researchers of the Diabetes prevention study in Finland (DPS) (19, 20). It has been adapted and validated to predict diabetes in the Latin America region. The pertinent question asks whether the subject practices regularly at least 30 min of daily physical activity at work or during leisure time. The questionnaire also assessed daily fruit and vegetable consumption, current use of hypertension medication, family history of T2D and whether the subject has had a past history of hyperglycemia.

Measurements

Height and weight were measured without shoes and with light clothing. BMI was calculated as weight (kg) divided by height^2 (m^2). Waist circumference (to the nearest cm) was measured at the approximate midpoint between the lower margin of the last palpable rib and the top of the iliac crest. Blood pressure (2 mmHg precision) was be recorded twice while the study participants remained in a seated position. The mean value of the two measurements was used for this analysis. All participants underwent an OGTT that was carried out according to the World Health Organization (WHO) recommendations (27). The test started after at least 8 h fasting, and the 2-h blood samples was obtained after oral ingestion of water solution with 75 g anhydrous glucose. The glucose tolerance status was classified according to the criteria of the World Health organization (28, 29). Individuals who had fasting plasma glucose (FPG) level $\geq$126 mg/dl or 2 h plasma glucose (2hPG) $\geq$200 mg/dl were classified as having T2D. Those with 2hPG$\geq$140 mg/dl but <200 mg/dl, and FPG <126 mg/dl were classified as having impaired glucose tolerance (IGT). Impaired fasting glucose (IFG) was defined as FPG $\geq$110 but <126 mg/dl, and 2hPG <140 mg/dl. In all cases, a supervisor field was trained to check all the information collected, this didn't allow missing information in the dataset.

Ethical Issues

The study was approved by the ethics committee of the Universidad del Norte through the 141-evaluation act. April 28th, 2016. All participants signed the consent form and could withdraw from the study at any moment. The study followed the norms of good clinical practice and the Helsinki guidelines.

Statistical Analysis

Data processing and analysis were performed in the statistical software SPSS version 25 (SPSS; Chicago, IL, USA). Distributions of physical activity frequencies are presented in absolute numbers and percentages. Chi-square tests were used to evaluate the differences in proportions between the subgroups. Continuous variables are summarized in medians and interquartile ranges, after checking the normality through the Kolmogorov–Smirnov test. To examine the relationship between the level of physical activity and some baseline characteristics of the participants, non-parametric estimates for ordinal variables were used (Spearman and Kendall tests). Collinearity diagnostics were performed to assess the assumptions of the model. To evaluate the factors associated with low physical activity, binary logistic regression models were used. Total physical activity was dichotomized into (i) sufficient physical activity (moderate or high physical activity and (ii) low physical activity (none or low physical activity). First, unadjusted logistic regression models were performed to identify covariates that were associated with low physical activity. Then, a backward logistic regression model was used including all variables that had a statistically significant association with low physical activity in the unadjusted logistic regression analysis. Variables were removed from the model according to Wald probability statistics. Odds ratios (OR) and 95% confidence intervals (95% CI) were calculated. A p-value of <0.05 was considered statistically significant.

RESULTS

Data from 1,135 participants were included (**Table 1**). Three out of four participants were female. The prevalence of having high levels of physical activity was higher in both men and women living in Bogota than in Barranquilla. Whereas, 16.8% of men and 13% of women were physical active in Bogota, the corresponding prevalence was 8.4% (men) and 1.6% (women) in Barranquilla. More than half of the participants had only elementary school or no education. In men, there were no statistically significant differences in educational levels, smoking status, BMI, fruit intake, receiving hypertension treatment or glucose metabolism disorders according to the physical activity categories. However, a higher proportion of men 55 years-of-age and older engaged in high physical activity compared with the younger age-groups (p-value 0.017). In women, those with lower education had a higher percentage practicing high physical activity compared with women with higher education (p-value 0.028). No statistically significant differences were observed in the distribution of smoking, age groups, BMI, daily fruit intake, hypertension treatment and glucose metabolism disorders.

No statistically significant differences were observed between sitting time, BMI, fasting glucose, 2-h glucose, diastolic blood pressure and the prevalence of low, moderate, and high physical activity (**Table 2**). However, systolic blood pressure was statistically significantly and inversely correlated with physical activity ($r = -0.069$ and $\overline{C}$=-0.065). Whereas, 40% of the study participants with high physical activity had systolic blood pressure levels of >140 mmHg, the corresponding prevalence of high systolic blood pressure was only 28% in the moderate physical activity group and 24.4% in the low physical activity group ($p < 0.05$). No statistically significant differences were found between sitting time and low, moderate and high physical activity ($r = -0.013$, $\overline{C}$=-0.012; $p > 0.05$).

Low physical activity assessed by the IPAQ-SV as the reference point (gold standard). A negative answer to the question on physical activity in the FINDRISC had a very high sensitivity (93%; 95% CI 91–95%) but a very low specificity (15%; 95% CI 11–20%) compared with low physical activity assessed by the IPAQ-SV (data not shown). The positive predictive value was 77% (95% CI 76–78%) and the negative predictive value was 42% (95% CI 34–51%). The concordance between the two scores was also very poor (kappa 0.11). Nevertheless, people who reported

TABLE 1 | Baseline characteristics of the participants of PREDICOL according to their physical activity levels at baseline and sex.

Variable	Men			*p*-value[a]	Women			*p*-value[a]
	Physical activity				Physical activity			
	Low	Moderate	High		Low	Moderate	High	
	193 (72.0)	42 (15.7)	33 (12.3)		661 (76.2)	144 (16.6)	62 (7.2)	
City								
Barranquilla	124 (86.7)	7 (4.9)	12 (8.4)	< 0.001	414 (93.2)	23 (5.2)	7 (1.6)	< 0.001
Bogota D.C.	69 (55.2)	35 (28.0)	21 (16.8)		247 (58.4)	121 (28.6)	55 (13.0)	
Education level								
No schooling	47 (68.1)	12 (17.4)	10 (14.5)	0.941	151 (69.3)	45 (20.6)	22 (10.1)	0.028
Elementary school	79 (71.8)	17 (15.5)	14 (12.7)		278 (76.2)	59 (16.2)	28 (7.7)	
Junior high school	44 (77.2)	7 (12.3)	6 (10.5)		157 (82.6)	23 (12.1)	10 (5.3)	
Superior	23 (71.9)	6 (18.8)	3 (9.4)		74 (79.6)	17 (18.3)	2 (2.2)	
Current smokers								
Yes	24 (68.6)	4 (11.4)	7 (20.0)	0.295	34 (64.2)	14 (26.4)	5 (9.4)	0.091
Age groups (years)								
< 45	27 (77.1)	5 (14.3)	3 (8.6)	0.017	145 (75.9)	36 (18.8)	10 (5.2)	0.069
45-54	49 (83.1)	7 (11.9)	3 (5.1)		189 (82.2)	27 (11.7)	14 (6.1)	
55-64	61 (75.3)	7 (8.6)	13 (16.0)		191 (74.3)	41 (16.0)	25 (9.7)	
> 64	56 (60.2)	23 (24.7)	14 (15.1)		136 (72.0)	40 (21.2)	13 (6.9)	
BMI (kg/m^2)								
Normal	27 (69.2)	5 (12.8)	7 (17.9)	0.519	78 (77.2)	16 (15.8)	7 (6.9)	0.672
Overweight	91 (70.0)	21 (16.2)	18 (13.8)		250 (74.2)	64 (19.0)	23 (6.8)	
Obesity	75 (75.8)	16 (16.2)	8 (8.1)		333 (77.6)	64 (14.9)	32 (7.5)	
Daily fruit intake								
No	174 (72.2)	39 (16.2)	28 (11.6)	0.510	558 (76.3)	126 (17.2)	47 (6.4)	0.105
Yes	19 (70.4)	3 (11.1)	5 (18.5)		103 (75.7)	18 (13.2)	15 (11.0)	
Physical activity								
< 30 min physical activity/d	178 (73.9)	37 (15.4)	26 (10.8)	0.055	617 (77.9)	121 (15.3)	54 (6.8)	0.001
≥30 min physical activity/d	15 (55.6)	5 (18.5)	7 (25.9)		44 (58.7)	23 (30.7)	8 (10.7)	
Treatment Hypertension								
No	116 (75.3)	21 (13.6)	17 (11.0)	0.371	415 (76.3)	92 (16.9)	37 (6.8)	0.848
Yes	77 (67.5)	21 (18.4)	16 (14.0)		246 (76.2)	52 (16.1)	25 (7.7)	
Oral glucose tolerance test (OGTT)								
NT	132 (71.7)	32 (17.4)	20 (10.9)	0.697	502 (75.3)	116 (17.4)	49 (7.3)	0.520
IFG	6 (66.7)	1 (11.1)	2 (22.2)		19 (70.4)	4 (14.8)	4 (14.8)	
IGT	39 (76.5)	6 (11.8)	6 (11.8)		78 (82.1)	12 (12.6)	5 (5.3)	
T2D	16 (66.7)	3 (12.5)	5 (20.8)		62 (79.5)	12 (15.4)	4 (5.1)	

[a] *Test of homogeneity (X^2); n (%). BMI, body mass index; NT, Normotolerence; IFG, impaired fasting glucose; IGT, impaired glucose tolerance; T2D, type 2 diabetes.*

<30 min of daily physical activity during work and/or leisure time in the FINDRISC had more than twice the probability of showing a low physical activity in the IPAQ-SV (OR 2.4; 95% CI 1.6-3.7).

Table 3 shows the unadjusted and adjusted odds ratios of the determinants of low physical activity in the participants of PREDICOL at baseline. Age group and city of residence was all statistically significantly associated with low physical activity levels in the adjusted logistic regression analysis. Participants in the age group between 45 and 54 years showed 74% greater odds of having low physical activity compared with the youngest age group (OR 1.74, 95% CI 1.1 −2.8). People living in Barranquilla were eight times more likely to have low physical activity compared with those in Bogotá D.C. (OR 8.1, 95% CI 5.7 to 11.4).

DISCUSSION

Our data revealed that study participants in Barranquilla were more likely to have low levels of physical activity compared with people at risk of T2D in Bogota. Furthermore, age between 45 and 54 years-old was associated with increased probability of low physical activity compared with younger people (age 30–45 y). No differences were found in sitting time, diastolic blood pressure, BMI or blood glucose levels according to physical activity levels.

TABLE 2 | Characteristics of study participants of PREDICOL according to their level of physical activity.

Variable	Classification physical activity			Rank correlation	
	Low ($n = 854$)	Moderate ($n = 186$)	High ($n = 95$)	*r*	$\overline{C}$
Sitting time (minutes/week)					
≤ 420	525 (61.5)	115 (61.8)	64 (67.4)	−0.013	−0.012
421–840	148 (17.3)	23 (12.4)	14 (14.7)		
> 840	181 (21.2)	48 (25.8)	17 (17.9)		
BMI (kg/m^2)					
≤ 24.9	105 (12.3)	21 (11.3)	14 (14.7)	−0.038	−0.036
25–29.9	341 (39.9)	85 (45.7)	41 (43.2)		
> 29.9	408 (47.8)	80 (43.0)	40 (42.1)		
Fasting glucose (mg/dl)					
≤ 109	741 (86.8)	163 (87.6)	80 (84.2)	0.006	0.005
110–125	66 (7.7)	14 (7.5)	10 (10.5)		
> 125	47 (5.5)	9 (4.8)	5 (5.3)		
2-h glucose levels (mg/dL)					
≤ 139	687 (80.4)	157 (84.4)	78 (82.1)	−0.031	−0.030
140–199	121 (14.2)	20 (10.8)	11 (11.6)		
> 199	46 (5.4)	9 (4.8)	6 (6.3)		
Systolic blood pressure (mmHg)					
≤ 135	577 (67.6)	123 (66.1)	51 (53.7)	−0.069*	−0.065*
136–140	69 (8.1)	11 (5.9)	6 (6.3)		
> 140	208 (24.4)	52 (28.0)	38 (40.0)		
Diastolic blood pressure (mmHg)					
≤ 84	495 (58.0)	102 (54.8)	43 (45.3)	−0.054	−0.051
85–89	136 (15.9)	34 (18.3)	21 (22.1)		
> 89	223 (26.1)	50 (26.9)	31 (32.6)		

*n (%); *Correlation is statistically significant at the 0.05 level; r, Spearman rank correlation. $\overline{C}$, Kendall rank correlation.*

TABLE 3 | Risk factors associated with low physical activity at baseline of the PREDICOL.

Variable	Low physical activity	
	OR (95% CI)	OR (95% CI)$^{\int}$
Age groups (years)		
< 45	Ref.	Ref.
45-54	1.46 (0.95–2.25)	1.74 (1.1–2.8)
55-64	0.92 (0.62–1.36)	1.2 (0.81–1.92)
> 64	0.67 (0.45–0.99)	1.0 (0.67–1.62)
Sex		
Male	Ref.	Ref.
Female	1.25 (0.92–1.7)	1.33 (0.94–1.9)
City		
Bogotá D.C.	Ref.	Ref.
Barranquilla	8.1 (5.7–11.3)	8.1 (5.7–11.4)
Education level		
No schooling	Ref.	
Elementary school	1.36 (0.98–1.88)	
Junior high school	1.96 (1.31–2.95)	
Superior	1.55 (0.95–2.54)	
Body Mass Index (kg/m^2)		
< 25 (kg/m^2)	Ref.	
≥ 25 (kg/m^2)	1.01 (0.67–1.52)	
Current smokers		
No	Ref.	
Yes	0.61 (0.38–0.97)	

$^{\int}$ *The adjusted model included age group, sex and city; OR, Odds Ratio; Ref, reference group.*

The fact that three out of four participants at higher risk of developing T2D had low levels of physical activity is of concern. General population studies have shown that the prevalence of physical inactivity is higher in low and middle-income countries compared to high-income countries (1). In the ELAN study carried out in eight Latin American countries, the overall prevalence of physical inactivity was 41%, ranging between 27% in Chile to 47% in Costa Rica and Venezuela. The prevalence was higher in women and people with more education (30). Moreover, a study of adolescents from Latin America and the Caribbean showed that around 15% were physically active (moderate to vigorous for at least 1 h/day) (24). It should be noted that the prevalence of physical inactivity found in Bogotá is similar to that reported in western high-income countries, while Barranquilla was similar to that reported for Kuwait (1). These differences are probably related to urban design, climatic conditions, and behavioral aspects (1). In Colombia, a previous study conducted in Barranquilla (DEMOJUAN) also revealed a high prevalence of physical inactivity (around 80%) (15). Furthermore, they also observed a higher proportion of sedentary lifestyles in those individuals at high risk of type 2 diabetes (1, 9). Likewise, it has been reported that men carry out more moderate and intense physical activity than women. A study carried out in Bogotá found an OR 1.62 (95% CI: 1.31 to 2.01) in men compared to women for these levels of physical activity (30). It is important to indicate that the time that an individual is sitting does not necessarily correlate with the level of physical activity performed. A study from the Medical University of Lodz showed that the time that students remained seated was an average of 46 h per week, but 65% were in the high category of physical activity and <2% were in a low category, using the long version of the IPAQ (9). In the PREDICOL study we found that most of the studied population does not follow a healthy lifestyle (physical inactivity, low intake of fruits and vegetables and high prevalence of overweight and obesity). Similar results have been reported in diabetes prevention studies conducted in Spain, Poland, Greece and Finland (16, 17). Comparing the National Surveys on food intake and nutrition (ENSIN) conducted in Colombia in 2010 and 2015 there was a significant decrease in physical activity (at least 150 min/week) from 53.5 to 51.1% (31).

The adjusted prevalence of people in a study who carried out regular physical activity in Bogotá was 36.8%, this figure was similar to our findings in the same city (30). The causes can be multiple, including different facilities and local incentives. Bogotá, for example, has been implementing an intense PA policy by building large recreational parks and playgrounds, as well as an extensive network of urban bike trails.

There are also different climatic conditions with Barranquilla having a very hot and humid climate while Bogotá is located in a plateau with temperate climate all year round. In a longitudinal data study of individuals ages 18 to 55 in the 1991–2006 China Health and Nutrition Surveys, there was a 32% decrease in average weekly physical activity. This was strongly associated with urbanization factors such as greater availability of higher education institutions, housing infrastructure, sanitation improvements, and the economic well-being of the community in which people operate (32). In our case, Barranquilla has been experiencing intense economic and cultural development for the last decades and is now the most important city in the Caribbean coast. Similarly, it is important to note that Colombia is a heterogeneous country, where habits are markedly different in each territory. Bogotá and Barraquilla belong to the group of the 5 largest cities in Colombia and our study was carried out in urban environments, so the conclusions of this research could not be extrapolated to smaller populations or rural areas; making this a potential source of research for future projects. Additionally, the use of urban space built for pedestrians (sidewalks, parks) has been one of the main priorities in the last decades in Bogotá, but less so in Barranquilla.

Our study has some limitations. The use of questionnaires do not provide as precise data on physical activity as could be provided by direct measurements such as the use of pedometers. Most of the participants were below the high school level, so the final results cannot be extrapolated to all communities. The cross-sectional design of this analysis may limit inferences on the causal relationship of risk factors with low levels of physical activity. There may be important variations in physical activity levels according to household levels and thus, an overall effect could mask lower level variations at the level of household. All study participants of the two cities included in the study belong to the lowest two out of six socio-economic levels. In addition, there may be differences in physical activity levels according to living setting (such as urban or rural areas) as well we could not account for. Thus, our results do not allow to generalize to populations of higher household, respectively, socio-economic levels or different living settings. Therefore, the findings of our study should be considered for exploratory purposes only.

CONCLUSION

A large proportion of the population at risk of developing T2D in two large cities of Colombia have a sedentary lifestyle. Moreover, the proportion of people at risk of T2D with low physical activity levels was higher in the districts of Barranquilla. Thus, our study provides more scientific evidence to support the need for lifestyle intervention programs targeting an increase of physical activity in people at high risk of T2D. The use of devices to measure physical activity directly such as pedometers and GPS tracking may provide more accurate data to correlate with environmental and lifestyle variables.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because The PREDICOL Project is a Project that is currently in progress, therefore the database according to the regulations may not be published until the end of the study, for any requirement you can contact the authors. Requests to access the datasets should be directed to tacosta@gmail.com.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by ethics committee of the Universidad del Norte, Barranquilla, Colombia. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

PA, TA, RT, KF, NB, and JA contributed conception and design of the study. SR, TA, PA, LA, MP, and LC supervised data collection. LA organized the dataset. KF, TA, LA, PA, VF-G, and LA performed the statistical analysis. TA, RT, KF, VF-G, and LA wrote the first draft of the manuscript with support from PA and NB. All authors contributed to manuscript revision, read and approved the submitted version.

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Impact of COVID-19 Lockdown on Physical Activity Among the Chinese Youths: The COVID-19 Impact on Lifestyle Change Survey (COINLICS)

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Background: The study sought to assess the changes in physical activity (PA) and sedentary time among Chinese youths at different stages after the COVID-19 outbreak.

Methods: It was based on a retrospective online survey conducted in May 2020. More than 10,000 youths voluntarily recalled their PA-related information at three stages: before COVID-19 (January), during lockdown (February), and after lockdown (May). χ^2 tests were conducted to evaluate the significance of the differences in participants' characteristics between sexes, and Wilcoxon Rank Sum tests were performed to examine the significance of differences in changes in PA and sedentary behavior levels between sexes.

Results: A total of 8,115 participants were included, with a mean age of 20. The percentage of no PA per week increased significantly and then slightly fell, and that of ≥150 min/week substantially decreased and then rebounded partially (all $p < 0.001$) (for instance, the percentage of ≥150 min/week of PA total decreased from 38.6 to 19.4%, then rebounded back to 25.3%). Means hours per day spent in sedentary behaviors had significantly increased during lockdown comparing to pre-COVID-19 (all $p < 0.001$). There were more participants reported reduced PA level than those indicated increased, and more participating youths had their sedentary behavior level increased than those who had it decreased.

Conclusions: The study found COVID-19 had both immediate and longer-term impacts on self-reported physical activities and sedentary behaviors among Chinese youths. Relevant efforts should be strengthened to get youths physically moving again.

Keywords: COVID-19, physical activity, sedentary behavior, youth, China

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INTRODUCTION

The modern post-industrial life to date has featured physical inactivity and sedentary behavior, which has been a global pandemic resulting in huge costs for human beings (1). Physical inactivity and sedentary behavior have been associated with a large number of mental and physical chronic diseases, including but not limited to depression, heart diseases, stroke, diabetes, and cancers (2–4).

A lot of efforts have been made to address the physical inactivity and sedentary behavior for years. However, this issue appears to persist (5, 6), as physical activity (PA) patterns did not improve and time spent on sedentary behavior has significantly increased over time (6). At the current pace, the 2025 global PA target (reducing 10% of insufficient PA) set by the World Health Organization member states would not be met (5).

However, the current situation may have been worsened by the stay-at-home order, issued by many governments around the world aiming at containing the spread of the coronavirus disease 2019 (COVID-19) pandemic, which has brought a significant impact on human lives. Millions of people are thus affected globally. Although some comments and reviews have indicated that PA will be essential for mental and physical health during the lockdown period (7–10), a few studies examining impacts of COVID-19 pandemic on PA and sedentary behavior have revealed that PA had substantially decreased while sedentary time had significantly increased during the lockdown in children and adolescents (11–13). However, it appears that such evidence is missing in youth, who is particularly vulnerable to lifestyle changes (14). Moreover, another important question we should answer is about the longer-term impact of COVID-19 pandemic on PA and sedentary behavior patterns; e.g., could the PA level, if affected by lockdown measures, return to normal after lockdown is lifted (9)? If the immediate impacts last and become new social norms, the impacts of COVID-19 on PA and sedentary behavior reduction could be catastrophic, and further aggressive efforts then need to be taken.

Therefore, the aim of this study was to assess the immediate and longer-term changes in PA and sedentary behavior in youths by using a large sample from all provinces of China. Our timely results would draw special attention from a wide array of stakeholders, from clinical practitioners to policy-makers, to the changed PA and sedentary behaviors among youths, so that these influences could be considered and hopefully remedied through clinical practice and policy interventions during this unusual period.

METHODS

Data Collection

This study was based on the COVID-19 Impact on Lifestyle Change Survey (COINLICS), a retrospective online survey using a self-administered questionnaire distributed via social media platforms in May 2020. Recalled information was collected from three stages: before COVID-19 (January 2020), lockdown (February 2020), and 3 months after lockdown lifted (May 2020). The inclusion criteria were: (1) at post-mandatory education level (high school students, junior college students, undergraduate and postgraduate students); (2) residents of China and speak Chinese; (3) own a smartphone with internet access.

A web-based questionnaire was initially distributed among three Tencent QQ groups and three WeChat groups of educators at three education levels (high school, college, and graduate school). At least two educators from each province had shared the online questionnaire with their students through Tencent QQ and WeChat groups and/or moments. Those who completed the questionnaire were also encouraged to forward it to others. Informed consent of all participants was collected on the online questionnaire. Only those who agreed to participate and clicked the "agree" button could continue the questionnaire. Three commonsensical questions were used in the questionnaire to check the validity of the questionnaire (e.g., where is the capital of China). If any of the three questions were answered incorrectly, the questionnaire was considered as invalid. The questionnaire was required to be completed online anonymously. It usually took 10–20 min to complete the questionnaire. The study was approved by Sichuan University Medical Ethical Review Board (KS2020414).

A total of 10,082 participants were recruited from all Chinese provinces using snowball sampling from May 9 to May 24, 2020. In the study, 1,967 of them were excluded due to the exclusion criteria we applied (i.e., PA time + sedentary behavior time + sleep time $\leq$24 h/days), so the final sample size was 8,115. Since all questions were required, there was no missing data.

Measurement

International Physical Activity Questionnaire (IPAQ)—long form was used to measure the physical activities and sedentary activities (15). Since all participants were full-time students, the occupational PA domain was removed. For each domain of PA (i.e., transportation, housework, and leisure-time), a score was summed up separately. Specifically, the number of minutes of moderate activity (including walking and riding) and two times of the number of minutes of vigorous activity were added up in each domain (16). Then, a total PA score was calculated by adding the scores of all domains. Moderate activities are defined as those performed for at least 10 min that produce a moderate increase in respiration and heart rate, and cause sweating, while vigorous activities are those producing a greater increase in respiration, heart rate, and sweating. According to the guidelines of the US Department of Health and Human Services (17), sufficient PA was defined as $\geq$150 min/week. The PA was categorized into three levels: none, 1–149 min/weeks, and $\geq$150 min/weeks (18). Changs in PA levels were grouped into: increased, constant, and decreased, while increased indicates moving from lower levels to higher levels, decreased represents moving from higher levels to lower levels, and constant means staying in the same levels. The same rule applied to changes in sedentary behavior levels.

Information regarding sedentary behavior was collected by the IPAQ, too. Average time spent in sedentary behaviors (e.g., watching TV) during the three stages was recorded for workdays and weekends separately.

In addition to the IPAQ-long form, the variables that were also collected were: sex, age, ethnicity, urbanicity, region, household income, major and current education level.

Statistical Analysis

Descriptive statistics were calculated as mean and standard deviation (SD) for continuous variables and percentages for categorical variables. χ^2 tests were conducted to evaluate the significance of differences in participants' characteristics between sexes, and Wilcoxon Rank Sum tests were performed to examine the significance of differences in changes in PA

and sedentary behavior levels (under lockdown vs. pre-COVID-19 and lockdown lifted vs. pre-COVID-19) between sexes. In addition, Cuzick's tests for trend were carried out to determine the associations between PA and sedentary behavior levels and the different stages of COVID-19. Furthermore, to understand the association between participants' characteristics and changes in PA total levels (decreased vs. constant), multivariable logistic regressions were conducted. All statistical analyses were performed using R 3.6.2 and statistical significance was declared if $p < 0.05$ (19).

RESULTS

In the study, a total of 8,115 participants were included, with an average age of 20 (ranging from 15 to 33). As shown in **Table 1**, there were more females than males (5,688 vs. 2,427). Han people dominated our sample (over 95% were Han ethnicity). A slightly more non-urban sample than urban sample was collected. The most majority were from western China. Males were more likely to be majoring in science or engineering (50.8%), while females tended to be majoring in medical science (39.4%) and social science (43.1%) ($p < 0.001$). In terms of the current education level, undergraduate students were the majority (76.7% in males and 72.6% in females).

As shown in **Figure 1**, PA pattern was significantly associated with stages of COVID-19 in four domains (PA total, PA leisure time, PA household, and PA transportation) for both males and females. Specifically, the percentage of none PA per week increased significantly and then slightly fell, and that of ≥150 min/weeks substantially decreased and then rose partially (all $p < 0.001$, see **Supplementary Table 1**). For example, the percentage of reporting ≥150 min/weeks in males was 38.6% in Pre-COVID-19, then dropped almost half during lockdown (19.4%), before it recovered slightly (25.3%) after lockdown lifted ($p < 0.001$).

Figure 2 shows time spent in sedentary behaviors before COVID-19, during lockdown, and after 3 months of lockdown lifted for both males and females. On both weekends and workdays, means of hours per day spent in sedentary behaviors had significantly increased during lockdown comparing to pre-COVID-19. Nevertheless, it did not fall back in May 2020 and even slightly increased (all $p < 0.001$, see **Supplementary Table 1**). For example, the average time spent in sedentary behaviors on a workday in women was 4.3 h, then increased to 5.1 h, before it finally jumped to 5.5 ($p < 0.001$).

Table 2 presents the changes in PA and sedentary behavior levels during lockdown vs. pre-COVID-19, and changes in PA and sedentary behavior after lockdown lifted vs. pre-COVID-19. While most of the participants remained constant in terms of PA level and sedentary behavior level between during lockdown and pre-COVID-19 and between lockdown lifted and pre-COVID-19, there were more participants reported reduced PA level than those indicated increased PA level (for all PA domains and PA total), and more participating youths had their sedentary behavior level increased than those who had it decreased. For instance, 24.7% of males reported decreased PA total level between during lockdown and pre-COVID-19, but the percentage of reported increased PA total level was as low as 3.5%. The changes in PA total after lockdown lifted vs. pre-COVID-19, and changes in sedentary time for weekend and workday during lockdown vs. pre-COVID-19 and after lockdown lifted vs. pre-COVID-19 were significantly different between males and females ($p < 0.05$).

Our multivariable logistic regression (see **Supplementary Table 2**) shows that older participants (OR, 1.06; 95% CI, 1.02–1.09), those with higher household income (e.g., OR, 1.46; 95% CI, 1.23–1.73 for ≥12,000–20,000 group), and undergraduates (OR, 1.53; 95% CI, 1.25–1.87) comparing to high school students were more likely to report decreased PA level under lockdown; non-urban participants (OR, 0.80; 95% CI, 0.72–0.90) were less likely to have decreased PA level under lockdown. After lockdown lifted, higher household income groups (OR, 1.37; 95% CI, 1.16–1.63 for ≥12,000–20,000 group; OR, 1.26; 95% CI, 1.03–1.54 for ≥60,000–10,0000 group; OR, 1.54; 95% CI, 1.24–1.93 for ≥100,000–200,000 group) were more likely to report decreased PA level.

TABLE 1 | Baseline characteristics of participating youths ($n = 8,115$).

Variable	Male ($n = 2,427$)	Female ($n = 5,688$)	Total ($n = 8,115$)	*p*-value
Ethnicity *n* (%)[a]				0.309
Han	2,319 (95.6)	5,403 (95.0)	7,722 (95.2)	
Minority	108 (4.4)	285 (5.0)	393 (4.8)	
Urbanicity *n* (%)[a]				0.040
Urban	1,024 (42.2)	2,261 (39.8)	3,285 (40.5)	
Non-urban	1,403 (57.8)	3,427 (60.2)	4,830 (59.5)	
Region *n* (%)[a]				0.252
Northeast	10 (0.4)	22 (0.4)	32 (0.4)	
East	220 (9.1)	559 (9.8)	779 (9.6)	
West	2,090 (86.1)	4,909 (86.3)	6,999 (86.2)	
Central	93 (3.8)	176 (3.1)	269 (3.3)	
Hubei	14 (0.6)	22 (0.4)	36 (0.4)	
Household income (RMB/year) *n* (%)[a]				<0.001
<12,000	475 (19.6)	1,040 (18.3)	1,515 (18.7)	
≥12,000–20,000	541 (22.3)	1,660 (29.2)	2,201 (27.1)	
≥20,000–60,000	643 (26.5)	1,537 (27.0)	2,180 (26.9)	
≥60,000–10,0000	386 (15.9)	755 (13.3)	1,141 (14.1)	
≥100,000–200,000	259 (10.7)	511 (9.0)	770 (9.5)	
≥200,000	123 (5.1)	185 (3.3)	308 (3.8)	
Major *n* (%)[a]				<0.001
Medical Science	555 (22.9)	2,241 (39.4)	2,796 (34.5)	
Science or Engineering	1,232 (50.8)	996 (17.5)	2,228 (27.5)	
Social Science	640 (26.4)	2,451 (43.1)	3,091 (38.1)	
Current education *n* (%)[a]				<0.001
High school	508 (20.9)	1,380 (24.3)	1,888 (23.3)	
Undergraduates	1,861 (76.7)	4,132 (72.6)	5,993 (73.9)	
Graduates	58 (2.4)	176 (3.1)	234 (2.9)	

[a] *Percentage within sex.*

χ^2 *tests were conducted to evaluate the significance of differences in participants' characteristics between sexes.*

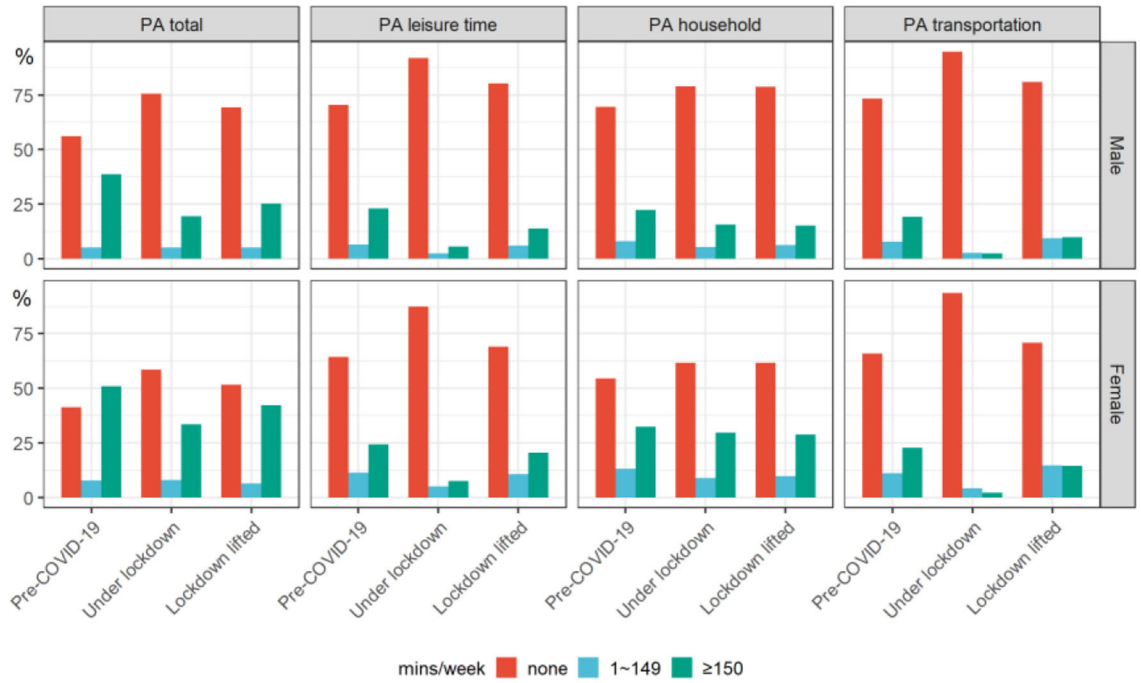

FIGURE 1 | Physical activity in different stages of COVID-19 (pre-COVID-19, under lockdown, and 3 months after lockdown lifted) by sex among participating youths. Physical activity (none, 1–149 min/weeks, and ≥150 min/weeks) was significantly associated with stages of COVID-19 in four domains (PA total, PA leisure time, PA household, and PA transportation) for both male and female ($p < 0.001$). See **Supplementary Table 1** for more details. PA, physical activity.

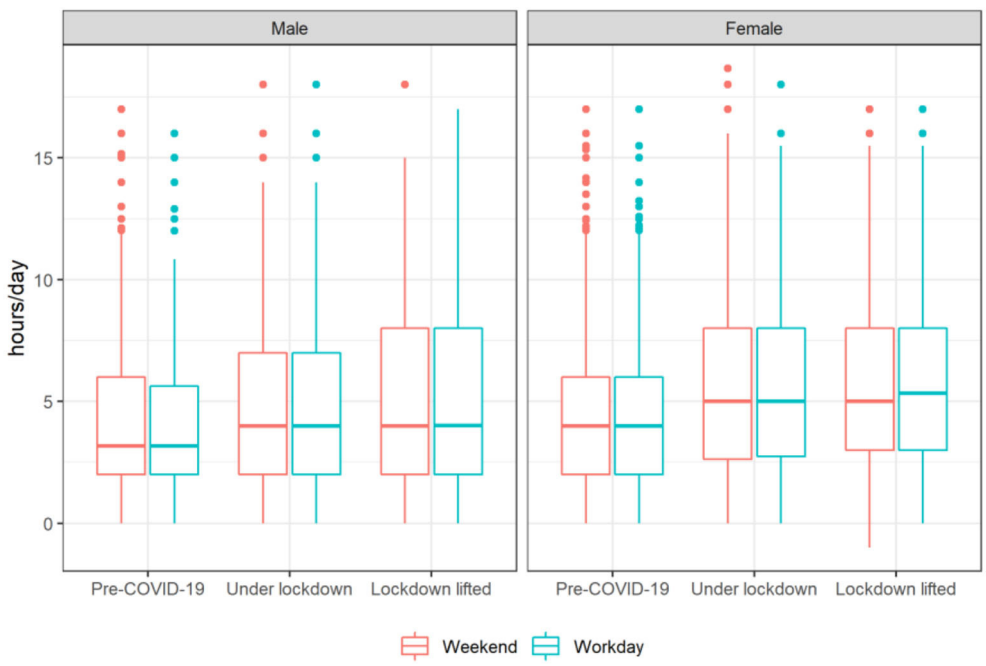

FIGURE 2 | Time spent in sedentary behaviors in different stages of COVID-19 (pre-COVID-19, under lockdown, and 3 months after lockdown lifted) by sex among participating youths. Time spent in sedentary behaviors in different stages of COVID-19 was different on weekend and workday for both male and female ($p < 0.001$). See **Supplementary Table 1** for more details.

TABLE 2 | Changes in physical activity and sedentary behavior levels during lockdown vs. pre-COVID-19, and changes in PA and sedentary behavior after lockdown lifted vs. pre-COVID-19 among participating youths.

	Under lockdown—Pre-COVID-19			*p*-value	Lockdown lifted – Pre-COVID-19			*p*-value
	Male ($n = 2427$, row percentage)	Female ($n = 5688$, row percentage)	Total ($n = 8115$, column percentage)		Male ($n = 2427$, row percentage)	Female ($n = 5688$, row percentage)	Total ($n = 8115$, column percentage)	
PA total %				0.449				0.002
Increased	16.1	83.9	3.5		20.7	79.3	7.6	
Constant	30.9	69.1	71.8		30.6	69.4	72.7	
Decreased	29.1	70.9	24.7		30.8	69.2	19.7	
PA leisure time %				0.139				<0.001
Increased	14.2	85.8	2.6		16.9	83.1	10.2	
Constant	31.7	68.3	70.9		32.1	67.9	72.2	
Decreased	26.6	73.4	26.5		28.6	71.4	17.5	
PA household %				<0.001				<0.010
Increased	17.7	82.3	8.3		18.3	81.7	9.9	
Constant	31.4	68.6	77.1		32.0	68.0	73.2	
Decreased	28.8	71.2	14.7		27.5	72.5	16.9	
PA transportation %				<0.001				0.126
Increased	26.8	73.2	1.6		18.6	81.4	9.7	
Constant	32.2	67.8	69.3		32.3	67.7	71.2	
Decreased	24.5	75.5	29.2		26.9	73.1	19.2	
Sedentary time weekend %				0.036				0.012
Increased	27.8	72.2	8.5		28.0	72.0	9.5	
Constant	29.9	70.1	87.8		29.8	70.2	86.1	
Decreased	35.1	64.9	3.8		36.3	63.7	4.4	
Sedentary time workday %				<0.001				<0.001
Increased	26.3	73.7	8.2		26.7	73.3	9.6	
Constant	29.9	70.1	87.6		29.8	70.2	85.5	
Decreased	37.9	62.1	4.2		38.4	61.6	4.9	

PA, physical activity.

The categories "increased," "constant," and "decreased" reflect the changes of PA levels (none, 1–149 min/weeks, and ≥150 min/weeks). For instance, if one moved from ≥150 min/weeks to 1–149 min/week, then deemed as "decreased." The same applies to sedentary time levels (<2 h/days and ≥2 h/days).

χ^2 tests were performed to examine the significance of differences in changes in PA and sedentary behavior levels between sexes.

DISCUSSION

China, as the first country to be impacted by COVID-19 and also first to implement and lift lockdown measures, provides valuable evidence and references to other countries. This study, by using a large sample of Chinese, revealed that COVID-19 brought significant and unfavorable impact on youths' self-reported physical activities and sedentary behaviors, and such impacts were maintained for at least 3 months. Specifically, PA had substantially decreased yet sedentary time had significantly increased during the lockdown. After lockdown lifted, PA had rebounded slightly but sedentary time remained.

Our study showed that before COVID-19 the percentage of participants who reported sufficient physical activity (≥150 min/weeks) was low (38.6% in males and 50.9% in females), and the sedentary time was ∼4 h. This is in line with existing literature (20). A small number of studies have examined the impacts of COVID-19 on PA and sedentary behavior. They consistently found that the COVID-19 had resulted in substantial and negative changes to physical activities and sedentary behaviors among children and adolescents (11–13, 21) and in adults (22–25). Our findings add to the existent literature that this trend was also found in youth and that the impact brought by COVID-19 was not only immediate also lasted. Based on the current trend, we believe that it will continue to sustain.

Although PA had rebounded slightly after lifting the lockdown, it appeared that lockdown lifting did not decrease sedentary time. As the youth become more cautious of infections of COVID-19 (26), outdoor activities might not be widely adopted despite the encouragement of governments and the resumption of school. They might tend to continue to minimize unnecessary activities as long as the perceived COVID-19 risk exists. Under such circumstances, special attention should be given to indoor PA interventions. Nevertheless, a previous study estimated that if the current patterns persist and become a new social norm, more efforts would be needed to reverse this alarming trend (9). This is especially true for sedentary behavior, which is difficult to change by health interventions (27). It is evidenced by our findings, that lockdown lift only slightly

increased PA time but did not have an impact on sedentary behavior time.

To our knowledge, no studies had investigated the lasting impacts of pandemics on PA and sedentary behavior. However, a previous study examined the PA and sedentary behavior among children and adolescents affected by the 2011 earthquake and tsunami in Japan and found that PA had significantly decreased even after 3 years of the earthquake (28). This may be partially in line with our findings and suggests that particular monumental events could have lasting impacts on people's behaviors. Therefore, future studies may need to corroborate this and explore ways to mitigate such impacts.

The study has several limitations. First, recall bias might be introduced. To minimize such bias, questions on PA and sedentary behavior in different stages of COVID-19 were placed next to each other for participating youths to better compare. Since the study focused more on changes in PA and sedentary behavior instead of absolute values on certain time points, their answers were likely to be valid and reliable. Second, the use of the snowball sampling method through social media platforms does not allow us to generalize the findings to the entire youth group in China, not to mention their counterparts in other countries. However, it could be the most feasible way to reach as many as possible youths under such unusual circumstances. Third, participants might disengage from the survey before they complete, but such data was not recorded. So we would not know such impacts to our findings.

Despite these limitations, this study is unique in exploring the immediate and longer-term impacts of COVID-19 on PA and sedentary behavior among Chinese youths. It is the first scientific attempt in its kind to examine such impacts, and information from this timely and large-scale survey could inform multiple stakeholders in decision-making (29). Based on results from **Supplementary Table 2**, special attention may be given to students majoring in Science or Engineering and those who reported higher household income, as they were more likely to indicate decreased PA level after COVID-19.

CONCLUSION

The study found that COVID-19 had both immediate and longer-term impacts on physical activities and sedentary behaviors among Chinese youths. Although physical activities had rebounded back slightly after 3 months of lockdown lift, it appeared that lockdown lift did not improve the situation of time spent in sedentary behaviors. Relevant efforts should be supported and strengthened to get youths physically moving again.

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 Sichuan University Medical Ethical Review Board. The ethics committee waived the requirement of written informed consent for participation.

AUTHOR CONTRIBUTIONS

JZ: conceptualization and writing—original draft preparation. JZ and SY: methodology, investigation, and visualization. BG and XX: software. BG: validation. XX: formal analysis. RP and SY: resources. XX: Data curation. XX, BG, RP, XP, SY, and PJ: writing—review & editing. PJ: supervision and project administration. JZ: funding acquisition. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2021.592795/full#supplementary-material

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Levels of Physical Activity in the Adult Population of La Guajira, Colombia: A Focus on Ethnicity

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The objective of this study is to analyze the physical activity levels among the ethnic groups in La Guajira, Colombia, according to the different ethnic groups and their sociodemographic factors. With regards to ethnic groups, two groups were studied, ethnic (Indigenous and Afro-Colombian) and non-ethnic (White or Mestizo). In order to obtain the relevant data a non-probability sample of 251 people of ≥18 years of age were asked to complete the short version of the International Physical Activity Questionnaire (IPAQ). In this analysis, physical activity (METs.min^{-1}) levels were considered as the dependent variable, while the independent variables were linked to the sociodemographic factors: sex, age, social class, civil status, educational level, and municipality of residence. The individuals were then categorized based on their physical activity levels and their compliance with the World Health Organization's (WHO) physical activity recommendations. Next, using the sociodemographic variables, regression models were made to determine the likelihood of the participants meeting these physical activity targets; these models found that 78.1% of the studied participants met the targets. According to the results of the bivariate analysis, participants of ≥47 years of age, and those with only a primary education presented a lower probability of complying with the physical activity recommendations, while those who lived in large municipalities (Riohacha) displayed a larger probability of compliance [OR = 2.16; 95% CI: (1.18–3.96)]. Furthermore, the multivariate analysis showed that Indigenous and Afro-Colombian people in a low social class are more likely to comply with the physical activity recommendations [ORad = 4.88; 95% CI: (1.31–18.1)], while residing in a smaller municipality (Manaure) is associated with a lower probability of compliance [ORad = 0.39; 95% CI: (0.16–0.91)]. In addition, the educated participants were shown to be active and to comply with the physical activity recommendations is to a high degree, even when compared with national and global results. In the ethnic group however, low social class stood out as the sociodemographic factor most associated with high physical activity, while Afro-Colombians were shown to be more active than the Indigenous people. The results of this study offer evidence that can either form a base for future research.

Keywords: physical activity, sedentary behavior, indigenous people, ethnic groups, demography

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INTRODUCTION

Physical activity is defined as the point between the highest expenditure of energy in any action that an individual performs, and the expenditure of energy when they are in a state of rest (1). Public health promotion strategies always recommend physical activity for the improvement of health, as well as for the primary and secondary prevention of chronic non-communicable diseases (2). However, despite this, one-third of the world's population is categorized as inactive or sedentary. This has lead to one of the largest public health crises in the world with a deterioration of lifestyle, and an increase in the prevalence of obesity, cardiovascular disease, and diabetes (3). Therefore, many countries have implemented regulations and legislation that promotes physical activity and encourage a healthy lifestyle (4).

While the health benefits of physical activity are recognized however, it is the frequency and intensity with which it is practiced that determines the amount needed to promote good health (4). In order to estimate the varying levels of physical activity among different populations, the WHO proposed the use of the metabolic equivalent of task (MET) as a unit for the measurement of the intensity of physical activity. The MET unit is defined as the energetic cost involved in an act, for example sitting and being calm is equivalent to 1 Kcal/kg/h, while a moderately active person would use three to six times more energy (3–6 METs), and a person engaged in vigorous activity uses more than six times that amount (>6 METs) (5). This unit of measurement has allowed for the homogenization of studies on the measurement of physical activity in across different populations (6–10).

Based on the findings from various international studies on physical activity among ethnic minorities -related to Indigenous communities, those of African descent, Romani groups, immigrants, race and religious groups–, minority ethnic groups are considered less active than the majority of the population, while the factors that influence their behavior are also different. In the North American continent, different dynamics have been observed among different ethnicities, for example, physical activity works as more of a protective factor, in terms of its protective qualities against cardiovascular diseases, among Indigenous people with higher activity levels than among the White population (11, 12). Furthermore, other indigenous groups, such as African-Americans, were shown to be more sedentary than others (13). A systematic review indicated that physical activity among ethnic minority groups in Europe meanwhile, is influenced by a wide variety of factors, including sex, religion, cultural requirements, and knowledge, and that these recurrent sociodemographic factors are part of the social/cultural environment as well as being part of various psychosocial factors (14). In countries like Australia, the dynamics of the Indigenous population's physical activity are explained from a socioecological perspective, where the surrounding environmental factors cannot be separated from social relationships, occupation, nutrition, or municipality of residence (15). In Canada, the sociocultural factors that determine the physical activity among Indigenous youth (16) are considered to be the cultural physical activities related to traditional games and cultural expressions that allow for participation within the community (17). On the Polynesian islands, sociocultural factors are explained from a collective perspective in which social organization favors collective activities over individual activities; a choice that is also reflected in the behaviors around physical activity and nutrition (18). In general, from an ethnicity perspective, studies point to differences in physical activity that could be explained by social determinants of health, such as social behavior (community surroundings, health care), or by influential sectors in the community (education, public health, forms of transport) (19). In the same way, although physical activity constitutes a protective on factor against cardiovascular disease, this does not carry over to other non-chronic diseases, such as type 2 diabetes; something which could be due to genetic differences in the physiology of some ethnic groups, such as in South Asians (12).

In Latin America and the Caribbean, both Indigenous people and those with African descent are categorized as ethnic minorities (20). Ethnicity is defined as a human group that shares and recognizes its own specific cultural characteristics, which determine its identity (ethos) and thus differentiates it from other groups (21). The scarce number of studies that exist on physical activity among these Indigenous communities in Latin America, show that their physical activity levels are relatively low or similar to the non-indigenous people. These results could possibly be explained by the transition that Indigenous populations are experiencing with their integration into the market, as these also interact with other historical, cultural, social, economic, environmental, and demographic factors; as has been the case in Chile and Ecuador. The study carried out in Chile identified small differences in the intensity of different indigenous groups' (Pehuenche and Atacameña) physical activity levels, while in Ecuador (the indigenous Shuar population), the study showed relatively low levels of physical activity. In both of these cases however, the physical activity levels could be explained by the assimilation of these communities into salaried jobs, an increase in subsistence activities and the market economy (22, 23).

Colombia particularly, is characterized by being a multi-ethnic and multilingual country that shows displays an important recognition of its minority groups (21). The findings by the National Health and Nutrition Survey (24), showed that 21.5% of the general population carry out physical activities in their leisure time. With regards to the ethnic group, the Indigenous population showed a significantly higher compliance with the physical activity recommendations (63%) than the Afro-Colombians and non-ethnic group (24). However, in Colombia, despite the development of regional plans and programs promoted by the government to stimulate physical activity as a means of social welfare, there is still no disaggregated information on the physical activity levels among regional ethnic groups. This is the case even in La Guajira, where a total concentration of 97.5% of Colombia's indigenous Wayuu population reside (25). The objective of this study is to analyze the physical activity levels among the ethnic groups in La Guajira, Colombia, according to the different ethnic groups and their sociodemographic factors.

MATERIALS AND METHODS

Type of Study

A cross-sectional population study was conducted on the physical activity levels among the adult Colombian of La Guajira.

Population and Sample

According to Colombia's Agustín Codazzi Geographic Institute, La Guajira is one of the political-administrative division's 32 departments (26). The department of La Guajira has a total population of 825,364 of which 53% are considered adults, and it is divided into 15 municipalities According to census records from 2018, the region's population is predominantly composed of ethnic groups, with 44.9% being indigenous Wayuu and 7.3% being Afro-Colombian, Palenquera and Raizal. Furthermore, the census shows that the highest concentration of Indigenous and Afro-Colombian populations are in the municipalities of Manaure, Maicao, Uribia, Riohacha, Barrancas, and Dibulla (21, 25).

For this study, a non-probability sample of 251 individuals resided across three municipalities, that contained approximately 21% of the adults in La Guajira, was taken (25). These municipalities were Manaure in Upper Guajira: ($n = 74$), Riohacha in Middle Guajira: ($n = 151$), and Barrancas in Lower Guajira: ($n = 26$). The criteria for the selection of municipalities were based on accessibility to the municipality, as these are not conflict zones or areas of public disorder.

Territorially speaking, these municipalities are characterized by their contrasting size, number of inhabitants, and total Indigenous population. Riohacha has 3,104 Km^2 of land and has a concentration of 27.4% of the whole of La Guajira's population, 20% of which are Indigenous people. The next in size is Manaure, with 1,606 Km^2, and a concentration of 11.1% of La Guajira's population, of which 62% are Indigenous people. Finally, Barrancas is the smallest municipality with only 670 Km^2 to its name, and a concentration of 3.6% of La Guajira's total population, of which 26% are Indigenous people (27). For the benefit of the reader and to facilitate understanding, the municipalities will be referred to according to their territorial characteristics: Riohacha (large municipality), Manaure (medium municipality), and Barrancas (small municipality).

Inclusion criteria: individuals of ≥18 years of age, who understand Spanish and reside in urban areas (due to conflicts and areas of public disorder in rural areas). Pregnant women were excluded from this study.

Study Variables

The response variable refers to the level of physical activity, as per the recommendations established by the WHO (5): light-level (≤600 METs.min^{-1} per week), moderate-level (601–3,000 METs.min^{-1} per week) and, vigorous-level (>3,000 METs.min^{-1} per week). The dependent variable was obtained from the answers from the participants' of the short version of the IPAQ (28). The responses obtained were transformed into METs (29) by means of the estimated numerical values standardized by Crespo-Salgado et al. (METs × minutes × days of the week) (30). Then, using this information, the participants were categorized as inactive or mildly physically active, moderately physically active and vigorously physically active.

The independent variables were related to personal and sociodemographic characteristics, and ethnic group. The personal and sociodemographic variables were: Sex (woman, man); age (age groups 18–26; 27–36; 37–46, 47–56; 57–66; ≥67 years); civil status (single, married, common-law marriage or registered partnership, separated); social class [categorized according to the strata of residential properties that receive public services, with 6 being the wealthiest stratum and 1 being the poorest (31)]; educational level (doctorate, master's degree, bachelor's degree, technical qualifications, high school, middle school, and primary school); and municipality of residence (territorial size), referring to the municipality where the respondent resided at the time of the interview, specifically Riohacha (large municipality), Manaure (medium municipality), and Barrancas (small municipality). The group considered as the ethnic group, was formed directly from the variables determined by the Colombian government's National Administrative Department of Statistics (DANE) and in this way respected their classification (asking: Which ethnic group do you self-identify as? Afro-Colombian, Indigenous, White, Mestizo). The White and Mestizo population is classed as non-ethnic (25).

Instruments Used in the Collection of Information

A two-part questionnaire was put together with a total of 14 questions. The first part consisted of seven Likert scale questions formed using questions drawn from national and regional questionnaires on socioeconomic aspects (31, 32). The second part consisted of the short version of the IPAQ (validated) which presents seven questions related to the practice of daily physical exercise (28, 33).

The questionnaire was distributed to the participants during an interview by three nutrition experts who specialize in physical activity and have local knowledge of the municipalities. This last requirement was essential to facilitate access to the interviewed individuals, and to ensure that the interviewers were in places without armed conflict. The group of field professionals selected the participants in each municipality through a consensus. The interviews were conducted between March and June 2018 and lasted approximately 20 min each.

Analysis and Interpretation of Data

For the interpretation of data, the sociodemographic variables were re-categorized: 1. Age (individuals of 47–56, 57–66, 67–76, and ≥77 years of age were grouped into one category of ≥47 years of age); 2. civil status (single and separated individuals were grouped into one category); 3. social class [medium (strata 5 + 4 + 3 = ≥3), low (stratum 2), and very-low (stratum 1); and 4. educational level (individuals with higher educational levels were grouped into university + postgraduate].

To assess the factors associated with the level of physical activity, the recommendations established by the WHO were taken as the gold standard (5). For the interpretation of the results, the physical activity recommendations were grouped

according to compliance "YES" or non-compliance "NO." The people who fulfilled the recommendations were classified as those who were active, participating in >600 METs.min^{-1} per week, while the non-compliant group consisted of those who were inactive, participating in ≤600 METs.min^{-1} of physical activity per week.

In addition, in order to evaluate the population participants' physical activity levels among both those who are considered socially vulnerable minorities (e.g., Indigenous people) and those considered as the majority population (e.g., Whites) (34), the studied population was re-categorized into: ethnic groups (Indigenous people + Afro-Colombians) and non-ethnic groups (White + Mestizo). In order to correctly interpret the results, both the completion of the physical activity recommendations (>600 METs.min^{-1} per week) and the sociodemographic characteristics were taken into consideration for both groups.

The descriptive analysis used the sociodemographic variables to measure the frequency with which physical activity was undertaken (absolute and relative) in each category, across the total sample. The chi-square test with a statistical significance level of $p < 0.05$ was performed alongside the Odds Ratio (OR) method, in order to observe the differences between the studied groups according to their compliance with the physical activity recommendations. Binary logistic regression techniques (ORcrude) and 95% confidence intervals (CI) were calculated, oriented toward the probability of compliance with the physical activity recommendation, and then this was stratified according to the ethnic and non-ethnic groups for each sociodemographic variable studied. In addition, an adjusted multivariate analysis (ORa) for potential confounding factors was performed on: Sex, age, marital status, socioeconomic level, educational level, and municipality of residence. The analyses were performed with the statistical package IBM-SPSS Statistics for Windows, version 26.0.

Ethical Aspects

The informed consent and ethical permission are both included in the questionnaire, as per the Colombian regulations and the Helsinki declaration that regulate any research carried out in the health field (35, 36).

RESULTS

Table 1 shows the distribution of the sociodemographic characteristics among the studied population. The results show that 57% of the participants are women, 79.3% are under the age of 46, 33.1% identify as single, 23.9% have a primary education, and 60.2% live in the capital of the department (Riohacha). With regards to social class, 90% are of a low social class, in social strata 1 and 2 (19.1 and 70.5%, respectively), and there is an absence of people in the highest social strata (5 and 6). Furthermore, 69.7% belong in the ethnic group, specifically Afro-Colombians (39%) and Indigenous people (30.7%).

Table 2 shows the physical activity levels according to the studied population's sociodemographic factors. The results indicate that 47% have a moderate physical activity level and 31.1% have a vigorous level, with the best levels found in men and Afro-Colombians (when compared to others within the ethnic group). The most prevalent moderate physical activity level is found in 54.4% of those between the ages of 27–38, 63% among those who are married, 56.1% of those with a secondary education, and 71.5% of those in social stratum 1.

Table 3 shows the level of compliance with physical activity recommendations and its association with sociodemographic characteristics. It points to the fact that 78.1% of the studied population complies with the physical activity recommendations and that age ($X^2 = 4.45$; $p = 0.035$), educational level ($X^2 = 12.42$; $p < 0.001$), municipality of residence ($X^2 = 6.35$; $p = 0.012$),

TABLE 1 | Distribution of the sociodemographic characteristics of the study population of La-Guajira, Colombia.

Variables	*n*	%
SEX		
Woman	143	57
Man	108	43
AGE (YEARS)		
18–26	57	22.7
27–36	79	31.5
37–46	63	25.1
47–56	31	12.3
57–66	17	6.80
≥67	4	1.60
MARITAL STATUS		
Single	83	33.1
Married	55	21.9
Separated	19	7.50
Common-law Marriage	94	37.5
SOCIAL CLASS (STRATA)		
6	0	0
5	1	0.40
4	3	1.20
3	22	8.80
2	177	70.5
1	48	19.1
LEVEL OF EDUCATION		
Master - Doctorate Degree	23	9.20
Bachelor's Degree	20	7.90
Technical Qualifications	66	26.3
Middle - High School	82	32.7
Primary School	57	23.9
MUNICIPALITY OF RESIDENCE (TERRITORIAL SIZE)		
Riohacha (large)	151	60.2
Manaure (medium)	74	29.5
Barrancas (small)	26	10.4
ETHNIC GROUP		
Indigenous People	77	30.7
Afro-Colombians	98	39.0
Non-ethnic Group	76	30.3
Total	**251**	**100**

TABLE 2 | Levels of physical activity according to the sociodemographic factors of the population of La-Guajira, Colombia.

Variables	Level of physical activity					
	Light[a]		Moderate[b]		Vigorous[c]	
	METs.min^{-1}·week	*n* (%)	METs.min^{-1}.week	*n* (%)	METs.min^{-1}.week	*n* (%)
SEX						
Woman	350.9 ± 143.5	38 (26.6)	1,604.8 ± 679.4	66 (46.1)	4,462.3 ± 1,472.9	39 (27.3)
Men	365.4 ± 131.9	17 (15.7)	1,725.8 ± 614.6	52 (48.1)	4,699.1 ± 1,792.8	39 (36.2)
AGE (YEARS)						
18–26	422.7 ± 129.1	10 (17.5)	1,555.6 ± 724.6	25 (43.9)	4,408.2 ± 1,262.9	22 (38.6)
27–36	308 ± 160.2	15 (19.0)	1,538.1 ± 672.4	43 (54.4)	4,590.1 ± 1,800	21 (26.6)
37–46	383.8 ± 119.3	13 (20.6)	1,888.2 ± 580.81	30 (47.6)	4,707.5 ± 1,735.6	20 (31.7)
47–56	362.7 ± 126.68	14 (45.1)	1,702.9 ± 567.7	13 (41.9)	4,176.5 ± 1,046.2	4 (12.9)
57–66	225 ± 46.8	3 (16.7)	1,692.3 ± 569.6	7 (38.9)	5,306.1 ± 2,320.6	8 (44.4)
≥67	0	0	0	0	3,539.3 ± 169.2	3 (100)
MARITAL STATUS						
Single	374.6 ± 153.25	19 (24.7)	1,704.5 ± 721.5	42 (54.5)	4,065.3 ± 1,296.8	16 (20.8)
Married	373.4 ± 123.3	10 (21.8)	1,537.6 ± 599.4	29 (63)	4,531.1 ± 1,844.8	7 (15.2)
Separated	346.5 ± 188.8	2 (5.60)	1,884.7 ± 595.3	12 (33.3)	4,202.8 ± 849.6	22 (61.1)
Common-law Marriage	333.522 ± 133.8	24 (26.1)	1,652.2 ± 621.2	35 (38)	5,093.2 ± 2,006.1	33 (35.9)
SOCIAL CLASS (STRATA)						
5	462	1 (100)	0	0	0	0
4	288 ± 12.7	2 (66.7)	2,148	1 (33.3)	0	0
3	293.1 ± 134	7 (25.0)	1,839.5 ± 672.1	10 (35.7)	3,739 ± 820.1	11 (39.3)
2	363.7 ± 141.4	38 (21.5)	1,626.9 ± 641.2	77 (43.5)	4,804.7 ± 1725.5	62 (35.0)
1	383 ± 148	7 (16.6)	1,661.4 ± 688.3	30 (71.5)	3,656 ± 733.1	5 (11.9)
LEVEL OF EDUCATION						
Master - Doctorate Degree	413 ± 86.4	4 (17.4)	2,206.8 ± 748.5	11 (47.8)	4,264.9 ± 1,015.3	8 (34.8)
Bachelor's Degree	299 ± 189.4	6 (30.0)	1,727.3 ± 761.6	7 (35.0)	4,457.1 ± 1,445.6	7 (35.0)
Technical Qualifications	356.1 ± 147.9	9 (13.7)	1,526.1 ± 688.8	35 (53.0)	4,169.8 ± 1,418	22 (33.3)
Middle - High School	355.4 ± 136.8	13 (15.9)	1,597 ± 540.8	46 (56.1)	4,917.7 ± 1,864.1	23 (28.0)
Primary School	361.7 ± 134.8	23 (38.3)	1,706 ± 630.3	19 (31.6)	4,840.9 ± 1,859.6	18 (30.0)
MUNICIPALITY OF RESIDENCE (TERRITORIAL SIZE)						
Riohacha (large)	336.7 ± 125.8	25 (16.6)	1,777.3 ± 621.6	74 (49.0)	4,545.9 ± 1,606.6	52 (34.4)
Manaure (medium)	412.1 ± 136.9	21 (28.4)	1,552.2 ± 667.3	30 (40.5)	4,722.3 ± 1,796.7	23 (31.1)
Barrancas (small)	279.8 ± 137.9	9 (34.7)	1,255.1 ± 614.9	14 (53.8)	4,099.3 ± 946.8	3 (11.5)
ETHNIC Group						
Indigenous	353 ± 133.5	24 (31.1)	1,688.7 ± 648	32 (41.6)	4,824.5 ± 1,864.8	21 (27.3)
Afro-Colombians	337.7 ± 157.4	19 (19.4)	1,696.5 ± 638.8	48 (49.0)	4,596.3 ± 1,590.8	31 (31.6)
Non-ethnic Group	391.8 ± 119.3	12 (15.8)	1,584 ± 681.5	38 (50.0)	4,365.3 ± 1,519.7	26 (34.2)
Total	356.1	55 (21.9)	1,658.1	118 (47)	4,580.7	78 (31.1)

[a] *Light level (≤600 METs.min^{-1} per week).*
[b] *Moderate level (601–3,000 METs.min^{-1} per week).*
[c] *Vigorous level (>3,000 METs.min^{-1} per week).*

and ethnicity all impact the levels of that compliance. Through this, it can be observed that the participants of ≥47 years of age [OR = 0.49; 95% CI: (0.25–0.96); $p < 0.05$] and those that have a primary level education [OR = 0.32; 95% CI: (0.17–0.62); $p < 0.05$], have a lower probability of complying with the physical activity recommendations, that is to say, they are less active. Furthermore, the results show that those living in Riohacha (large municipality), as opposed to those living in Manaure (small municipality) and Barrancas (medium municipality), have higher activity levels and a higher probability of complying with the recommendations [OR = 2.16; 95% CI: (1.18–3.96); $p < 0.05$]. Finally, with regards to ethnicity, it is observed that the studied Indigenous community, as opposed to the Afro-Colombians and non-ethnic groups, are less active and have a lower probability of complying with the recommendations [OR = 0.48; 95% CI: (0.26–0.89); $p < 0.05$].

Table 4 is disaggregated into ethnic (Indigenous and Afro-Colombian) and non-ethnic groups, and shows the association

TABLE 3 | Compliance with the physical activity recommendations and its association with the sociodemographic characteristics of the population of La-Guajira, Colombia.

Variables	Compliance With physical activity Recommendations *n* (%)		OR (CI 95%) Compliance (YES)
	NO (Inactive[a])	YES (Active[b])	
SEX			
Woman	38 (26.6)	105 (73.4)	0.53 (0.28–1)
Man	17 (15.8)	91 (84.2)	1.89 (1–3.59)
AGE (YEARS)			
18–26	10 (17.5)	47 (82.5)	1.41 (0.66–3.03)
27–36	15 (19.0)	64 (81.0)	1.29 (0.67–2.51)
37–46	13 (20.6)	50 (79.4)	1.11 (0.55–2.23)
≥47	17 (32.7)	35 (67.3)	0.49 (0.25–0.96)*
MARITAL STATUS			
Single + separated	21 (20.6)	81 (79.4)	1.14 (0.61–2.11)
Married	10 (18.2)	45 (81.8)	1.34 (0.63–2.87)
Common-law marriage	24 (25.5)	70 (74.5)	0.71 (0.39–1.32)
SOCIAL CLASS (STRATA)			
Medium-high (strata ≥ 3)	10 (38.5)	16 (61.5)	0.49 (0.19–1.20)
Low (strata 2)	38 (21.5)	139 (78.5)	0.91 (0.47–1.78)
Very low (strata 1)	7 (14.6)	41 (85.4)	1.87 (0.79–4.43)
LEVEL OF EDUCATION			
University + Postgraduate	10 (23.3)	33 (76.7)	0.91 (0.42–1.99)
Technical Qualifications	9 (13.6)	57(86.4)	2.09 (0.96–4.56)
Middle - High School	13 (15.9)	69 (84.1)	1.75 (0.88–3.49)
Primary School	23 (38.3)	37 (61.7)	0.32 (0.17–0.62)*
MUNICIPALITY OF RESIDENCE (TERRITORIAL SIZE)			
Riohacha (large)	25 (16.6)	126 (86.4)	2.16 (1.18–3.96)*
Manaure (medium)	21 (28.4)	53 (71.6)	0.6 (0.32–1.13)
Barrancas (small)	9 (34.6)	17 (65.4)	0.48 (0.2–1.16)
ETHNIC GROUP			
Indigenous People	24 (31.2)	53 (68.8)	0.48 (0.26–0.89)*
Afro-Colombians	19 (19.4)	79 (80.6)	1.28 (0.68–2.39)
Non-ethnic Group	12 (15.8)	64 (84.2)	1.73 (0.86–3.52)
Total	55 (21.9)	196 (78.1)	

[a] *Inactive: ≤ 600 METs.min^{-1} per week [according to the WHO (5)].*
[b] *Active: > 600 METs.min^{-1} Per week [according to the WHO (5)].*
**Significant differences ($p < 0.05$).*
OR, Odds Ratio.

between compliance with the physical activity recommendations and the sociodemographic variables. The results indicate that compliance with the physical activity recommendations is associated to belonging to a low social class, particularly belonging to stratum 2 [ORa = 4.88; 95% CI: (1.31–18.1); $p < 0.05$]. The lower probability of compliance with the recommendations on the other hand, is associated with residing in Manaure [ORa = 0.39; 95% CI: (0.16–0.91); $p < 0.05$]. With regards to the non-ethnic group, a lower probability for compliance with the recommendations is shown by those who reside in Manaure [ORa = 0.05; 95% CI: (0–0.91); $p < 0.05$] and Barrancas [ORa = 0.005; 95% CI: (0–0.16); $p < 0.05$], when compared to those residing in Riohacha.

DISCUSSION

This cross-sectional study carried out on a sample of the adult Colombian population, of three different municipalities of a large, medium and small size in La Guajira, with and who's populations that included Indigenous people and Afro-Colombians (ethnic group) as well as White and Mestizos (non-ethnic group), shows that Indigenous people are less active than the Afro-Colombians. In addition, it shows that among the studied ethnic group belonging to a lower social class is associated with higher physical activity levels and that among both groups, residing in a municipality of a small size is associated with having a low physical activity level.

TABLE 4 | Association between compliance with the recommendations of physical activity among the ethnic population of La Guajira and its sociodemographic characteristics, Colombia.

Variables	Compliance With recommendations			
	Ethnic group[a]		Non-ethnic group[b]	
	OR (c)[c] (95% CI)	OR (a)[d] (95% CI)	OR (c)[c] (95% CI)	OR (a)[d] (95% CI)
SEX				
Woman	1 Ref.	1 Ref.	1 Ref.	1 Ref.
Man	1.54 (0.76–3.14)	1.13 (0.51–2.50)	1.55 (0.41–5.82)	3.14 (0.38–26.2)
AGE (YEARS)				
18–26	1 Ref.	1 Ref.	1 Ref.	1 Ref.
27–36	0.82 (0.29–2.29)	1.10 (0.34–3.60)	1.67 (0.24–11.13)	6.78 (0.2–251.6)
37–46	0.75 (0.26–2.17)	1.19 (0.34–4.20)	1.33 (0.2–9.02)	0.33 (0–14.3)
≥47	0.50 (0.17– 1.47)	1.10 (0.31–3.90)	0.33 (0.07–1.7)	0.03 (0–1.20)
MARITAL STATUS				
Single + separated	1 Ref.	1 Ref.	1 Ref.	1 Ref.
Married	1.29 (0.45–3.70)	1.67 (0.5–5.50)	1.02 (0.26–4.02)	32.9 (1.04–1040.7)
Common-law marriage	0.63 (0.3–1.35)	0.76 (0.32–1.81)	4.34 (0.49–38.3)	22.7 (0.54–959.7)
SOCIAL CLASS (STRATA)				
Medium-high (strata ≥ 3)	1 Ref.	1 Ref.	1 Ref.	1 Ref.
Low (strata 2)	2.38 (0.81–6.96)	4.88 (1.31–18.1)*	2.92 (0.57–14.9)	1.43 (0.09–21.5)
Very low (strata 1)	4.86 (1.13–20.84)*	4.61 (0.94–22.5)	2.28 (0.36–14.7)	1.42 (0.04–52.1)
LEVEL OF EDUCATION				
University + Postgraduate	1 Ref.	1 Ref.	1 Ref.	1 Ref.
Technical Qualifications	2.35 (0.71–7.81)	2.37 (0.63–8.91)	1.59 (0.23–11.2)	6.63 (0.28–158.7)
Middle - High School	2.01 (0.66–6.19)	1.87 (0.55–6.37)	1.25 (0.22–7.26)	17.30 (0.49–610.89)
Primary School	0.56 (0.19–1.64)	0.41 (0.11–1.57)	0.52 (0.1–2.85)	1.61 (0.07–34.6)
MUNICIPALITY OF RESIDENCE (TERRITORIAL SIZE)				
Riohacha (large)	1 Ref.	1 Ref.	1 Ref.	1 Ref.
Manaure (medium)	0.49 (0.22–1.03)	0.39 (0.16–0.91)*	0.39 (0.08–1.99)	0.05 (0–0.91)*
Barrancas (small)	0.69 (0.20–2.38)	0.35 (0.08–1.50)	0.09 (0.02–0.51)*	0.005 (0–0.16)*

[a] *Ethnic group: Indigenous people and Afro-Colombians.*
[b] *Non-ethnic group: White and Mestizo.*
[c] *ORc crude and 95% CI obtained through Binary Logistic Regression.*
[d] *ORa adjusted for all the independent variables included in the model (sex, age, marital status, social class, educational level, and municipality of residence).*
Ref., Reference value and condition.
**Indicates a significant difference from the reference condition (95% IC).*

The physical activity levels among La Guajira's studied population could be considered excellent when compared to other regions of the world as well as when compared on a national level. The study shows that about half of the individuals (47%) engaged in moderate levels of physical activity and 31% engaged to a vigorous level. The percentage of individuals engaged in physical activity to a vigorous level in La Guajira was similar to that shown by the data on individuals at a global level (31.4%), but higher than those in North America (24.6%) and Europe (25.4%). There is also a higher prevalence of men than women showing a vigorous physical activity level; something that is common in this type of study (37). In this study, 78.1% of La Guajira's participants showed an active condition that was above the globally established 68.9% (37) and higher than other countries in the Americas such as the United States (10%) (38) and the Dominican Republic (59.2%), which are among the lowest. In contrast, the high levels of physical activity shown in the study population is similar to those reported by Chile 80.2% (8), Ecuador (77.4%), and Brazil (72.2%) (39). Furthermore, compared to the general Colombian population, the studied population in La Guajira showed higher physical activity levels than those reported in urban areas (51.1%), and even higher than those reported in Colombia's Atlantic region (45.9%) (24). According to the results of the 2015 National Nutrition Survey (24), this higher rate of engagement with physical activity is observed in both men and women, and is higher in La Guajira's population than the general Colombian population by 61.1 and 42.7%, respectively.

Correlating with the findings from this study, scientific literature shows that "age" is a global determining factor in the levels of engagement with physical activity, where physical activity decreases with age (37). A study in Chile showed

increased physical activity among 86.6% of young people between the ages of 18–24, while a decreasing physical activity was observed in 62.8% of those over the age of 65 (8). In the same way, a study carried out in the United States showed that 63.9% of individuals between the ages of 20–29 were more compliant with physical activity recommendations while 46.9% of those over the age of 70 saw a decrease in their compliance with the recommendations (38). In addition, educational level was also shown, as in our research, to be another factor related to physical activity levels; the aforementioned studies showed that those who had undertaken basic primary education had a lower physical activity level when compared to those who had a moderate education [those with a secondary education showed and those with a higher education (8)].

In the present study, a higher engagement with physical activity was observed in the lower social class (stratum 2) than the higher social classes within the ethnic group. With this in mind, economic factors, and even cultural factors must be mentioned as having a possible role in influencing engagement with physical activity. For example, among the Polynesian islands' Indigenous population, it was observed that engagement with physical activity was not related to socioeconomic status but to more cultural factors, such as obesity and eating habits (18). Meanwhile, and in contrast to the present study, research carried out in Chile showed that there was a prevalence of lower physical activity levels among adults with a lower income (22.9%) when compared to those with a moderate income (18.4%) (8). While, another Latin American study, highlighted that it is the regions where the highest concentration of Indigenous people are, that have less access to information, sport, public services and recreation facilities (20). Thus, though economic and cultural factors play a role in people's engagement with physical activity, it seems that there is no pattern of association between physical activity and socioeconomic levels.

Global tendencies indicate that the prevalence of lower physical activity levels is higher in countries with a higher income (37–39). These results are similar to those found by this study, as when disaggregating the results of the ethnic and non-ethnic groups during the logistic regression analysis, it was observed that within the ethnic group, the lower social classes (stratum 2) complied more with the physical activity recommendations than those in a higher social class (stratum $\geq$ 3). A possible explanation to this phenomenon is the jobs that these individuals may have; manual jobs may have higher occupational physical activity demands when compared to non-manual jobs, with leisure time increasing in the same way it does for the groups with a higher income (40, 41).

There are some reports on physical activity among Indigenous populations that have been carried out under a demographic perspective that includes ethnicity. For example, a study in Canada compared the vigorous physical activity among Whites to the physical activity levels among different ethnicities (Aborigines, Blacks, Latin Americans, West Asians or Arabs, and South Asians). Through this, they observed that Aboriginal people were more likely to be physically active, while those from East or Southeast Asia were less likely to comply with the physical activity recommendations, thereby showing changes in physical activity according to ethnicity (11). These results are contrary to what was observed in this study, since although ethnicity showed an association to compliance with the physical activity recommendations, it was found that Indigenous people were less likely to be physically active when compared to the non-ethnic groups, as well as when compared to other ethnic groups. Furthermore, and again in contrast to this study, studies carried out in Australia found that the level of compliance with the recommendations among Aboriginals (63.15%) and non-Aboriginals (65.4%) did not present significant differences. In fact, they found that the studied characteristics associated with physical activity, such as healthy lifestyle habits, surrounding infrastructure (such as access to shops/services, public transportation, recreation facilities, etc.) and social relations, were generally very similar for both groups (42). Similarly to the Australian study, in Chile it was reported that there were no statistically significant differences in moderate-vigorous physical activity levels between the indigenous Mapuche people and those of European descent (43).

The current study with its focus on ethnicity, could be used as a reference for future research as it is one of our region's pioneering studies in this area. Among the limitations of the present study however, it must be noted that due to the use of a non-probabilistic sample, the interpretation of the results cannot cover the entirety of La Guajira's population. Furthermore, the presence of public disorder and conflicts in the region are also a barrier for the carrying out of randomized studies. However, in order to minimize possible errors, the municipalities with the greatest ease of access were randomly selected according to whether they belonged to Upper, Middle or Lower Guajira (44). Another limiting factor was the difference in sample size collected between the studied municipalities which was due to elements such as density of the population and the initiative with which individuals participated, which was greater in Riohacha. This discrepancy was minimized by the adjustment of any confusing factors through the employment of all the independent variables. Another of the study's limitations was the implicit subjectivity involved in the application for a survey (IPAQ self-report) to obtain the necessary quantitative data on physical activity levels in the area. This was controlled however by using "age," due to its inverse relationship with physical activity—in that the higher the age, the lower the physical activity level—as a fundamental sociodemographic characteristic (37). In addition, it must be noted that the use of the standardized questionnaire continues to be the tool of greatest use for studies on populations (33).

The results also showed that the studied population in La Guajira complieds with the recommended physical activity, which could be a contributing factor to the prevention of pathologies associated to cardiovascular diseases and type 2 diabetes (2, 40, 43). Further to this, proposed population strategies, that include the creation of bio-health spaces with mechanical elements that facilitate physical activity, have been made with the aim to encourage an increase in physical activity (45). However, these strategies are not options for all the ethnic groups and are instead specifically designed for the Indigenous. In fact, Manaure's Territorial Health Plan encompasses the very problems that the municipality has of not having enough space

to carry out activities aimed at those residing in urban areas, and neither does it have programs to save the customs and games of the indigenous Wayuu community, or give effective plans for the use of leisure time. Although the plan gives evidence that shows the necessities of these Indigenous people, it does not incorporate in its politics the use of physical activities as a cross-component for the promotion of health, in a way that would guarantee the strengthening of their culture and customs around the carrying out of traditional games, recreation and physical activities (46). With this in mind, the authors reflect on the implications of this study on public policies. Local institutions should continue to invest in stimulus programs that encourage increased physical activity with a specific approach for ethnic groups. In addition, studies on policy analysis in the region could be carried out to help understand the strategies associated with the promotion of physical activity and its impact on the population.

It is concluded that the studied Colombian population of La Guajira is active and their compliance with the physical activity recommendations is high, even when compared to national and global results. It is further noted that within the ethnic group, the Afro-Colombians are more active than the Indigenous community. In addition, among the sociodemographic factors, age, education, municipality of residence and ethnicity are the main sociodemographic factors that explain impact the physical activity levels among the studied population and the level to which they comply with the recommendations. The results show that being older, with a low level of education, and self-identifying as Indigenous, is associated with low physical activity and non-compliance with the physical activity recommendations, while residing in a large territorial municipality is associated with a higher level of physical activity. When disaggregating the results in the ethnic group, it was concluded that belonging to a low social class is associated with compliance with the physical activity recommendations among both Indigenous people and Afro-Colombians.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

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

AUTHOR CONTRIBUTIONS

YP and RO-M: conceptualization and methodology. JM-F: software. JM-F, YP, and RO-M: validation. YP and JN-R: formal analysis. YP: investigation, resources, writing – original draft preparation, project administration, and funding acquisition. YP and JM-F: data curation. RO-M: writing – review, editing, and supervision. All authors contributed to the article and approved the submitted version.

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Perceived Neighborhood Crime Safety Moderates the Association Between Racial Discrimination Stress and Chronic Health Conditions Among Hispanic/Latino Adults

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Background: Little is known about the link between perceived neighborhood walkability and prevalence of chronic disease. Even less is known regarding this association among Hispanic/Latino adults, despite exhibiting high rates of chronic diseases. Stress due to racial discrimination is a harmful social determinant of health in Hispanics/Latinos. Having both low perceived neighborhood walkability and high racial discrimination stress may exacerbate the chronic disease status of Hispanics/Latinos. Among a U.S. national sample of Hispanic/Latino adults, this cross-sectional study aims to examine (1) the associations among overall perceived neighborhood walkability, racial discrimination stress, and having a chronic health condition; and (2) whether overall perceived neighborhood walkability moderates the hypothesized association between racial discrimination stress and having a chronic health condition.

Methods: In January 2018, 798 Hispanic/Latino adults (*M* age = 39.7 years, SD = 15.1; 58.6% female; 70.0% U.S. born; 52.0% Mexican/Mexican American) responded to a survey via Qualtrics Panels. Surveys included the Neighborhood Environment Walkability Scale-Abbreviated, Hispanic Stress Inventory-2, and self-reported presence/absence of chronic health conditions (e.g., hypertension, heart disease). A logistic regression was conducted testing for the moderation of the main effect of racial discrimination stress on the presence of a chronic health condition by overall perceived neighborhood walkability.

Results: After controlling for age, body mass index, and income, racial discrimination stress was inversely associated with overall perceived neighborhood walkability ($b = -0.18$, $p < 0.001$) and positively associated with having a chronic health condition (OR = 1.02; 95% CI [1.00, 1.03]). While overall perceived neighborhood walkability was not associated with having a chronic health condition, perceived crime safety was inversely associated with having a chronic health condition (OR = 0.94; 95% CI [0.89, 0.99]). Perceived crime safety moderated the positive association between discrimination stress and having a chronic health condition, such that the association was only significant among those who perceived their neighborhood to be less safe ($\beta = -0.004$, 95% CI [−0.01, −0.00]).

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Conclusions: Overall perceived neighborhood walkability was inversely associated with racial discrimination stress, but not associated with having a chronic health condition. Perceived neighborhood crime safety, but not infrastructure or aesthetics, matters when it comes to the link between racial discrimination stress and having a chronic health condition among Hispanics/Latinos.

Keywords: Hispanic Americans, chronic disease, neighborhood, discrimination, stress

INTRODUCTION

In the United States, chronic diseases including cancer, coronary heart disease, and type 2 diabetes are the leading causes of death among Hispanics/Latinos (1, 2). Type 2 diabetes is also more prevalent among Hispanics/Latinos (17%) compared with non-Hispanic Whites (8%) (3). Additionally, Hispanics/Latinos are more likely to develop type 2 diabetes at an earlier age and have more severe diabetes-related complications than the U.S. adult population overall (3).

Neighborhood walkability, which is how conducive the area around one's home is to walking, has been linked to prevalence of chronic disease (4–8). Most work on neighborhood walkability has employed objective measures such as land use, population density, crime rates, and/or proximity to parks (9). A 10-year longitudinal study employing objective measures found that, as neighborhoods became more walkable over time, community-wide diabetes prevalence and cardiovascular disease risk (e.g., high blood pressure and cholesterol) declined (8). Others have reported similar associations using objective measures of neighborhood walkability (4–6). The facilitation of physical activity is one behavioral mechanism identified as connecting greater objectively-measured walkability with lower prevalence of chronic disease (4, 9–12). In comparison, perceived neighborhood walkability is defined as the summation of a person's subjective evaluations of the environment around their home such as their perceptions of aesthetics, built environment features (e.g., presence of crosswalks), and/or safety from crime and traffic (9). A large, multi-country study found certain domains within perceived neighborhood walkability were associated with body mass index (BMI) (7). Most notably, greatest perceived safety from traffic and crime, and nearness to destinations (e.g., stores) were strongly associated with lower BMI (7). The association between perceived neighborhood walkability and chronic diseases is unknown. However, some evidence has suggested that one's perception of neighborhood walkability may have more influence on one's physical activity engagement than objective measures of neighborhood walkability (13, 14).

Furthermore, of the extant literature on the topic, Hispanic/Latino adults make up a small percentage of the overall participants investigated, despite having some of the highest rates of chronic diseases (6, 8, 11). When Hispanics/Latinos are included in studies of neighborhood walkability, they are often compared to their non-Hispanic White peers, hindering our ability to capture within ethnic group variability in experiences, behaviors and health outcomes (15). These data are necessary to inform culturally tailored, community-based interventions to better address disparities in chronic diseases among Hispanic/Latino adults in the United States (16, 17).

A particularly salient social determinant of health among people of color in the United States is racial discrimination (18–20). The Psychosocial Stress Model explains that the stress associated with institutional racism and individual-level experiences with racism lead to health disparities, such as those documented among Hispanic/Latino adults (3, 18, 21). Institutional racial discrimination refers to systems or structural differences that manifest in inequitable distributions of resources and opportunities for people of color. Individual-level experiences of racial discrimination are defined as one's experiences of being treated more poorly than others because of one's race or ethnicity. Empirical evidence suggests that heightened stress due to experiences of racial discrimination is linked to higher rates of chronic diseases by way of several pathways, such as heightened cortisol production, accelerated cellular aging, and poorer health behaviors, including physical activity avoidance, smoking, and greater alcohol consumption (20, 22–24). Meta-analysis results suggest that the inverse association between experiences of racial discrimination and general health may be particularly robust for Hispanic/Latino adults (25). Since experiences of discrimination often take place in public settings (26), including one's neighborhood, it is plausible that perceived neighborhood walkability and racial discrimination stress interact to increase risk for poor health behaviors and associated chronic disease risk. Additionally, neighborhood walkability can be described as an example of institutional racism, such that Hispanics/Latinos disproportionately live in low socioeconomic areas, which is associated with lower objective and perceived neighborhood walkability (27, 28). Theoretical models and empirical literature tend to suggest one's environment is a moderator in the association between psychosocial factors and health/health behaviors (18, 29, 30). However, the association between perceived neighborhood walkability and racial discrimination stress and how they interact in their associations with chronic diseases among Hispanics/Latinos in the United States are unknown.

Among a national sample of U.S. Hispanic/Latino adults, this study aims to (1) test the associations among overall perceived neighborhood walkability, racial discrimination stress, and having a chronic health condition; and (2) examine whether overall perceived neighborhood walkability moderates the association between racial discrimination stress and having a chronic health condition.

Informed by the aforementioned literature, hypotheses to the study aims are outlined as follows. Regarding aim 1, it is hypothesized that there will be a significant inverse association between racial discrimination stress and overall perceived neighborhood walkability (26, 28, 31); a significant positive association between racial discrimination stress and having a chronic health condition (18, 20, 22–25); and a significant inverse association between overall perceived neighborhood walkability and having a chronic health condition (7, 11). Regarding aim 2, it is hypothesized that overall perceived neighborhood walkability will significantly moderate the association between racial discrimination stress and having a chronic health condition (18, 29, 30), such that higher overall perceived neighborhood walkability will reduce the strength of the association between racial discrimination stress and having a chronic health condition, adjusting for age, BMI, annual household income, acculturation, U.S. region of residence, and health insurance status (32–41).

The findings of this study advance the literature by elucidating the associations among social and environmental factors and the presence of a chronic health condition among Hispanic/Latino adults, a sizable sub-set of the U.S. population at heightened risk for chronic diseases (3, 21). A better understanding of these associations could inform culturally tailored, community-based strategies to better promote healthy behaviors and prevent chronic diseases among Hispanics/Latinos in the United States (16, 17, 42).

MATERIALS AND METHODS

Data Collection

In January 2018, Qualtrics Panels was used to recruit Hispanic/Latino adults to complete a 197-question electronic survey in English or Spanish, which assessed their demographic information, health behaviors, physical and mental health conditions, and perceptions of their social and physical environments. Measures in the survey that were not already validated in Spanish were translated forward and backward to Spanish from English by two bi-lingual research assistants. Eligible respondents were 18 years or older, identified as Hispanic or Latino, resided in the United States, and were fluent in English or Spanish. Qualtrics Panels partners with over 20 online panel providers, namely market research panels, to supply a nationwide sample of potential participants who fit the eligibility requirements of this cross-sectional study (43).

Potential research participants were contacted by Qualtrics Panels via an email invitation. To avoid self-selection bias, the specific details of the study were not included in the email invitation. Those who expressed interest in participating were sent study details and underwent informed consent protocols in line with the committee responsible for human experimentation (institutional and national) and with the World Medical Association's Declaration of Helsinki. Specifically, prior to taking the survey, all participants provided their consent by selecting a radial button that read, "I have read the contents of this consent form. I give my consent to participate in this study," which appeared at the bottom of the electronic informed consent form. Written documentation of consent was waived. Participants who completed the survey, received a pre-determined amount of points (stated in the email invitation to participate in the study). The amount of points was determined by the length of the survey, participant's specific panelist profile, and target acquisition difficulty. The points earned for completion of the survey can be redeemed for cash, airline miles, gift cards, points on online games, sweepstakes entrances and vouchers. This research protocol was approved by the Institutional Review Board at the University of Oregon. The dataset analyzed for this study can be found in the Harvard Dataverse, (44).

Measures

Demographic characteristics of the respondents were assessed using the Demographic and Health Information Data Questionnaire (45, 46). Demographic characteristics reported in this study include respondents' age, height, weight, gender, ethnic origin, whether English was their first language, nativity, acculturation, highest level of education, employment status, U.S. region of residence, relationship status, health insurance status, and annual household income. Response options for all demographic characteristics appear in **Table 1**. BMI was calculated using the following equation: 703 $\times$ weight (lbs) /[height (in)] $\wedge$ 2 (47). Seven respondents were excluded from the analyses because of seemingly implausible BMI values ($<$12 or $>$65). Annual household income was assessed by asking respondents to select the total combined income that is made yearly by all working members of their household from 11 U.S. dollar ranges. Response options were collapsed into: $<$\$10,000–\$29,000, \$30,000–\$69,999, and \$70,000–\$100,000+. Acculturation was assessed with The Abbreviated Multidimensional Acculturation Scale, which includes 6 U.S. cultural identity items (e.g., "I think of myself as being U.S. American"), nine English language competence items (e.g., "How well do you speak English on the phone?"), and six U.S. cultural competence items (e.g., "How well do you know popular American television shows?") (48). U.S. cultural identity items were assessed on a Four-point-Likert scale with response options ranging from 1 ("strongly disagree") to 4 ("strongly agree"). English language competence and U.S. cultural competence were assessed on a Four-point-Likert scale with response options ranging from 1 ("not at all") to 4 ("extremely well"). The Abbreviated Multidimensional Acculturation Scale has been shown to produce reliable and valid responses among Hispanics/Latinos (48). A mean was calculated to create a total U.S. acculturation score from all of the items within the U.S. cultural identity, English language competence, and U.S. cultural competence sub-scales. A higher mean score denotes a greater degree of acculturation to the United States.

The independent variable, racial discrimination stress, was measured by the total score of the Discrimination Stress sub-scale (11 items; e.g., "I was discriminated against because of my customs and cultural celebrations") from the Hispanic Stress Inventory-2. The Discrimination Stress sub-scale assesses psychosocial stress from discriminatory experiences related to being Hispanic. For each item, respondents were asked if they

TABLE 1 | Descriptive characteristics of the study sample and key study variables.

Variable	*N*	Missing	Mean (S.D.)[a]	Skewness (S.E.)[b]	Kurtosis (S.E.)	Min., Max.
Age	797	1	39.65 15.05	0.307 0.087	−0.955 0.173	18, 81
Body mass index	774	24	28.3 7.266	1.06 0.088	1.72 0.176	13.70, 64.19
Acculturation	791	7	71.46 10.59	−1.18 0.087	1.83 0.174	21, 84
Perceived neighborhood walkability	794	4	46.88 7.25	−0.184 0.087	0.014 0.173	21, 64
Racial discrimination stress	789	9	14.237 12.67	0.937 0.087	0.35 0.174	0, 55

Variable	*N* (Valid %)
Gender	
Woman	467 (58.6)
Man	320 (40.2)
Transgender	8 (1.0)
Other	2 (0.3)
Missing	1
Ethnic origin	
Mexican or Mexican American	415 (52.0)
Puerto Rican	136 (17.0)
Cuban	68 (8.5)
Spanish	44 (5.5)
Dominican	27 (3.4)
Another Hispanic or Latino origin (e.g., Columbian, Venezuelan, Peruvian)	108 (13.5)
Missing	0
English is first language	
Yes	522 (65.4)
No	276 (34.6)
Missing	0
Nativity	
U.S. born	556 (70.0)
Born outside of the United States	238 (30.0)
Missing	4
Highest level of education completed	
Less than high school	22 (2.8)
High school or GED	217 (27.6)
Trade/Technical school	60 (7.6)
2-year college	162 (20.6)
4-year college/university	237 (30.2)
Professional/Graduate	88 (11.2)
Missing	12
Employment status	
Work full-time	395 (49.7)
Work part-time	114 (14.3)
Unemployed but looking for a job	97 (12.2)
Do not work (e.g., stay-at home parent, retired, on disability, etc.)	189 (23.8)
Missing	3
Relationship status	
I am married or in a civil union	364 (45.6)
I am single, I do not have a spouse or partner	284 (35.6)
I am not married, but in a relationship	132 (16.5)
I am widowed	18 (2.3)
Missing	0
U.S. region of residence	
South	316 (39.6)
West	182 (22.8)
Northeast	155 (19.4)
Midwest	145 (18.2)
Missing	0
Health insurance status	
Private insurance (e.g., HMO, PPO)	392 (49.1)
Public insurance (e.g., Medicare, Medicaid)	304 (38.1)
Uninsured	102 (12.8)
Missing	0
Annual household income	
<$10,000–29,000	231 (29.0)
$30,000–69,999	300 (37.6)
$70,000–100,000+	266 (33.4)
Missing	1
Current chronic health conditions reported	
High cholesterol	175 (21.9)[c]
Heart disease	27 (3.4)
Cancer	15 (1.9)
Hypertension	181 (22.7)
Type 2 diabetes	122 (15.3)
None	54 (6.8)
Missing	0
Presence of a chronic health condition	
At least one current chronic health condition	362 (45.4)
No current chronic health conditions	436 (54.6)
Missing	0

[a]S.D.: standard deviation; [b]S.E.: standard error; [c]Respondents could report having more than one chronic health condition, thus, percentages reflect the proportion of the sample that endorsed having each of the listed chronic health conditions.

have experienced the reported stressor (Yes/No), and if they had experienced the stressor, they were asked to rate how stressful the event was on a five-point-Likert scale ranging from 1 ("not at all worried/tense") to 5 ("extremely worried/tense"). Possible scores ranged from zero to 55 and higher scores indicate greater racial discrimination stress. The Hispanic Stress Inventory-2 sub-scales have been shown to produce reliable and valid responses in Spanish and English among a diverse sample of Hispanic/Latino adults in the United States (49, 50). In this sample, the Discrimination Stress sub-scale had good reliability ($\alpha = .933$).

The dependent variable, presence of a chronic health condition, was assessed by one question from the Demographic and Health Information Data Questionnaire (45, 46). Respondents were asked to indicate all of the health conditions they currently have from the following: high cholesterol, overweight/obesity, heart disease, cancer (specify the type), high blood pressure, type 2 diabetes, other (specify), or to select "I do not have any of these health conditions."

The hypothesized moderator, overall perceived neighborhood walkability, was measured using a total sum score of four sub-scale scores from the Neighborhood Environment Walkability Scale- Abbreviated (NEWS-A) including: infrastructure for walking/cycling (six items; e.g., "There are sidewalks on most of the streets in my neighborhood"), aesthetics (four items; e.g., "There are trees along the streets in my neighborhood"), traffic safety (three items; e.g., "The speed of traffic on most *nearby* streets is usually slow (30 mph or less)"), and crime safety (three items; e.g., "The crime rate in my neighborhood makes it unsafe to go on walks during the day") (51). Respondents chose from four-point Likert scale response options ranging from 1 ("strongly disagree") to 4 ("strongly agree") for each item. Five items were reverse coded to align with the direction of the other items. Possible scores ranged from 16 to 64 and higher scores indicate greater overall perceived neighborhood walkability. The scale has demonstrated validity and reliability in English and Spanish (52, 53). In this sample, the overall NEWS-A had adequate reliability ($\alpha = 0.761$).

Analyses

Descriptive statistics were conducted to review missing cases and response distributions for scale variables with a skew or kurtosis outside of ±2 (54). Preliminary analyses also included a Pearson correlation in order to examine potential multicollinearity ($r > \pm 0.80$) between key study variables and independent-samples *t*-tests to assess unadjusted associations between key study variables and the dependent variable (55).

Regarding the dependent variable, having "overweight/obesity" was removed as one of the chronic conditions. Instead, BMI was included as a covariate in the regression models because of its association with chronic disease risk (39). Respondents endorsed having up to four of the six included chronic health conditions. Of those who endorsed having at least one of the health conditions, 60.22% reported having only one of the conditions followed by 23.48% with two. Given this distribution, responses were dichotomized into whether the respondent endorsed currently having either any or none of the health conditions. Prior research also supports treating presence of a chronic health condition as a binary term (36, 56), given meaningful differences between the two groups in health service use (e.g., emergency room visits) and general medical expenditures (36).

To address study aim 1, one multiple linear regression model and two binary logistic regression models were conducted. Age, annual household income, BMI, acculturation, U.S. region of residence, and health insurance status were initially included in these models as covariates because of their associations with having a chronic health condition (32–41). In pursuit of parsimonious models, covariates were removed that had non-significant ($p \geq 0.05$) regression coefficients in all of the regression models conducted for study aims 1 and 2, and also had no notable effects on the models' variance explained or results when they were removed (57). First, the association between overall perceived neighborhood walkability and racial discrimination stress, adjusting for the covariates, was assessed in a multiple linear regression model. Second, the main effects of racial discrimination stress on presence of a chronic health condition, adjusting for the covariates, was investigated using binary logistic regression. Third, the main effects of overall perceived neighborhood walkability on the presence of a chronic health condition, adjusting for the covariates, was conducted using binary logistic regression. The binomial assumption was assumed because there was no reason to believe there was dependence among observations or that the sample was non-random (58).

For study aim 2, overall perceived neighborhood walkability and racial discrimination stress were grand-mean centered and an interaction term was created. A binary logistic model was conducted that included: the covariates, centered overall perceived neighborhood walkability, centered racial discrimination stress, and the interaction term. All statistical analyses were conducted in IBM SPSS Statistics for Windows, Version 26 (59). The moderation plot was conducted in R, Version 3.6.1 using the interactions package (60, 61).

Exploratory Analyses

For *post hoc* exploratory purposes, aims 1 and 2 were re-examined using the individual sub-scales of the NEWS-A. Infrastructure for walking/cycling ($\alpha = 0.764$), aesthetics ($\alpha = 0.799$), and crime safety ($\alpha = 0.912$) demonstrated adequate to good reliability in this sample. Traffic safety demonstrated poor reliability ($\alpha = 0.258$) in this sample and was thus not included in the exploratory analyses. Preliminarily, Pearson correlations were conducted to assess associations among the three sub-scales. The same statistical procedures were conducted as described earlier for the study aims, except they were repeated three times, once for each NEWS-A sub-scale.

RESULTS

Sample

The survey respondents included 798 Hispanic/Latino adults 18–81 years old ($M = 39.7 \pm 15.1$ years; BMI $M = 28.30 \pm 7.3$ kg/m^2; **Table 1**). Approximately 20% of respondents completed the survey in Spanish, 80% in English. The majority of the sample identified as women (58.6%); Mexican or Mexican American (52%); native English speakers (65.4%); U.S. born (70.0%); educated through 2 years of college or beyond (62%); and employed at least part time (64%). Respondents resided in all major regions of the United States, with the largest portion living in the South (39.6%). Additionally, the largest proportions of respondents had a least one chronic health condition (45.4%); were married or in a civil union (45.6%); had public or private health insurance (87.2%); and an annual household income of $30,000–69,999 (37.6%).

Preliminary Findings

In unadjusted associations, there was a significant inverse association between overall perceived neighborhood walkability and racial discrimination stress ($r = -0.166$, $p < 0.01$). The mean scores of overall perceived neighborhood walkability ($t_{(787)} = -0.695$, $p = 0.487$) and racial discrimination stress ($t_{(792)} = -0.963$, $p = 0.336$) were not significantly different for those with or without a chronic health condition.

Study Aim 1 Results

The covariates retained in aim 1 and aim 2 regression models were age, BMI, and annual household income. There was a significant and inverse association between overall perceived neighborhood walkability and racial discrimination stress ($b = -0.18$, $p < 0.001$; $R^2 = 0.07$).

Table 2 provides an overview of results from the logistic regression analyses. In Model 1, there was a significant and positive association between racial discrimination stress and the presence of a chronic health condition (Odds Ratio [OR] = 1.017; 95% Confidence Interval [CI] [1.004, 1.030]). In Model 2, there was no significant association between overall perceived neighborhood walkability and the presence of a chronic health condition (OR = 0.993; 95% CI [0.72, 1.015]).

Study Aim 2 Results

The full model results displayed in Model 3 within **Table 2** show that the interaction between racial discrimination stress and perceived walkability on having a chronic health condition was not significant (OR = 0.999; 95% CI [0.997, 1.001]), suggesting the association between racial discrimination stress and health did not vary by overall perceived neighborhood walkability. Model 3 explained a total 17.8% of the variance in the presence of a chronic health condition.

Exploratory Results

Unadjusted bivariate associations among the three NEWS-A sub-scales showed crime safety was inversely associated with infrastructure for walking/cycling ($r = -0.106$, $p < 0.01$) and not significantly associated with aesthetics ($r = 0.059$, $p = 0.09$). Infrastructure for walking/cycling was positively associated with aesthetics ($r = 0.520$, $p < 0.01$).

Table 3 shows the association between each NEWS-A sub-scale and racial discrimination stress, adjusted for age, BMI, and annual household income. Only crime safety was significantly and inversely associated with racial discrimination stress ($b = -0.27$, $p < 0.001$).

Among the three NEWS-A sub-scales, there was only a significant and inverse association between crime safety and the presence of a chronic health condition (OR = 0.936; 95% CI [0.887, 0.988]; **Table 4**). There was also a significant moderating effect of crime safety on the association between racial discrimination stress and presence of a chronic health condition. Specifically, there was a significant and positive association between discrimination stress and having a chronic health condition, only among those who perceived their neighborhood to be less safe ($\beta = -0.0043$, SE = 0.0021, CI[−0.0084, −0.0002], $p < 0.05$; **Figure 1**).

TABLE 2 | Logistic regression results for predicting presence of a chronic health condition among U.S. Hispanic/Latino adults.

Variables	Model 1		Model 2		Model 3	
	Odds ratio[a]	95% Confidence interval	Odds ratio	95% Confidence interval	Odds ratio	95% Confidence interval
Age	1.047***	1.036–1.059	1.044***	1.033–1.056	1.047***	1.035–1.059
Annual household income						
<$10,000–$29,000	ref		ref		ref	
$30,000–$69,999	1.396	0.950–2.051	1.452	0.992–2.126	1.417	0.963–2.084
$70,000–$100,000+	1.697**	1.139–2.527	1.763**	1.185–2.622	1.721**	1.152–2.572
Body mass index	1.046***	1.023–1.069	1.047***	1.024–1.070	1.046***	1.023–1.069
Racial discrimination stress	1.017*	1.004–1.030	N/A		1.016*	1.003–1.029
Perceived neighborhood walkability	N/A[c]		0.993	0.972–1.015	0.996	0.974–1.018
Perceived neighborhood walkability X Racial discrimination stress	N/A		N/A		0.999	0.997–1.001
Model diagnostics						
−2 Log likelihood	944.713		957.788		941.563	
Omnibus model chi-square	108.825***		104.122***		109.184***	
Degrees of freedom	5		5		7	
Hosmer and Lemeshow chi-square	15.937*		11.579		12.259	
Degrees of freedom	8		8		8	
Nagelkerke R-squared	0.177		0.169		0.178	

*[a]Odds ratios for the constant not displayed in the table; [b]ref, reference group; [c]N/A, variable is not applicable to the model; [d]Model 3 includes grand-mean centered variables: perceived neighborhood walkability, racial discrimination stress, and the interaction term; * p < 0.05, **p < 0.010, *** p < 0.001 (two-tailed).*

TABLE 3 | Adjusted associations between each Neighborhood Environment Walkability Scale- abbreviated sub-scale and racial discrimination stress among U.S. Hispanic/Latino adults.

Variable	*b*	95% Confidence interval	S.E.[a]	*t*	df[b]	*p*	R^2
Infrastructure for walking/cycling	−0.030	−0.211–0.086	0.076	−0.827	793	0.408	0.033
Aesthetics	−0.036	−0.314–0.103	0.106	−0.991	793	0.322	0.033
Crime safety	−0.265	−0.959–0.595	0.102	−7.472	793	<0.001	0.099

[a]*S.E.: standard error;* [b]*df: degrees of freedom;* [c]*Covariates in the multiple linear regression models include age, body mass index, and annual household income.*

DISCUSSION

The present study examined (1) the associations among overall perceived neighborhood walkability, racial discrimination stress, and having a chronic health condition; and (2) whether overall perceived neighborhood walkability moderated the hypothesized association between racial discrimination stress and having a chronic health condition among a U.S. national sample of Hispanic/Latino adults. Study findings advance the understanding of how experiences such as, how individuals perceive the safety of their neighborhoods and the degree to which individuals experience racial discrimination stress, vary among Hispanics/Latinos in the United States and how these experiences are associated with having a chronic health condition. The study findings can inform next steps in research and practice that aim to eliminate current chronic disease disparities among Hispanic/Latino adults and details for which are provided below (3, 21).

As hypothesized, those who reported experiencing more racial discrimination stress had higher odds of having a chronic health condition after adjusting for age, BMI, and annual household income. This finding is consistent with The Psychological Stress Model (18) and extant literature among Hispanics/Latinos and other racial/ethnic miniories (19, 23, 25, 49). While the increased odds for having a chronic health condition among those who report more racial discrimination stress was marginal in this study, alongside the extant literature, the finding reinforces the importance of reducing racial discrimination against Hispanics/Latinos in the United States in order to promote health equity.

Furthermore, as hypothesized (26, 28, 31), an inverse association, although weak, was found between overall perceived neighborhood walkability and racial discrimination stress. Overall perceived neighborhood walkability is a total of four individual sub-scales. Exploratory results indicated perceived safety from crime, not perceived infrastructure for walking/cycling and aesthetics of one's neighborhood, was the driver of the inverse association found between overall perceived neighborhood walkability and racial discrimination stress. These findings not only advance our understanding of the association between these environmental and social factors among U.S. Hispanic/Latino adults, they are also novel to the broader literature not focused on Hispanics/Latinos. In related literature, a systematic review found consistent support for the inverse association between objectively measured neighborhood walkability and general psychosocial distress (62). In addition to focusing on objective vs. perceived neighborhood walkability, the reviewed studies did not assess racial discrimination stress specifically and only one of the studies, by Brown and colleagues (63), was strictly among U.S. Hispanic/Latino adults (62, 63). Brown et al.'s (63) study involved low socioeconomic, U.S. Hispanic/Latino, older adults and found that front porches were positively associated with social support, which was associated with lower psychological distress (63). The presence of front porches is most similar to items in the infrastructure for walking/cycling sub-scale within the NEWS-A. This association between infrastructure for walking/cycling and racial discrimination stress was not identified in the present study, which could be due to the use of different measures of perceived neighborhood walkability between the studies and substantial demographic differences between the study samples. Future research could investigate social support and other potential links connecting perceived neighborhood crime safety and racial discrimination stress among Hispanic/Latino adults.

Contrary to the hypothesis, overall perceived neighborhood walkability was not associated with having a chronic health condition. However, exploratory findings showed that perceived neighborhood safety from crime was inversely associated with having a chronic health condition. Both of these findings contribute toward filling the gap in knowledge regarding perceived (vs. objective) neighborhood walkability and chronic diseases (4–6, 8). There is a precedent for perceived neighborhood safety playing a pivotal role in behavioral and health risk factors for chronic diseases in the literature. For example, another study of Hispanics/Latinos found infrastructure for walking/cycling was positively associated with physical activity, but only when perceived crime was low (64). Also, a multi-country study by De Bourdeaudhuij and colleagues (7) found perceived neighborhood safety from traffic and crime, and nearness to destinations were inversely associated with BMI, adjusting for relevant demographic factors (7). Where BMI was the dependent variable in De Bourdeaudhuij's (7) study, BMI was a covariate in the present study. The latter approach is advantageous when aiming to reduce chronic disease rates among Hispanics/Latinos, as higher BMI is just one of many risk factors for chronic diseases (65).

Overall perceived neighborhood walkability did not moderate the association between racial discrimination stress and presence of a chronic health condition, contrary to the hypothesis. However, exploratory findings did identify a significant moderating effect of perceived crime safety on the association between racial discrimination stress and

TABLE 4 | Predicting presence of a chronic health condition and testing for moderating effects of perceived neighborhood walkability sub-scales among U.S. Hispanic/Latino adults.

Variables	Main effects models		Moderating models	
	Odds ratio[a]	95% Confidence interval	Odds ratio	95% Confidence interval
PERCEIVED INFRASTRUCTURE FOR WALKING/CYCLING SUB-SCALE				
Age	1.044***	1.033–1.055	1.047	1.036–1.059
Body mass index	1.048***	1.025–1.071	1.046***	1.023–1.070
Annual household income				
<$10,000–$29,000	ref		ref	
$30,000–$69,999	1.424	0.974–2.082	1.397	0.950–2.053
$70,000–$100,000+	1.700**	1.025–2.524	1.1670*	1.117–2.497
Racial discrimination stress	N/A[c]		1.017*	1.004–1.030
Perceived infrastructure for walking/cycling	1.014	0.975–1.054	1.012	0.973–1.053
Perceived infrastructure for walking/cycling X Racial discrimination stress	N/A		1.000	0.997–1.004
Model diagnostics				
−2 Log likelihood	960.059		944.350	
Omnibus model chi-square	104.642***		109.189***	
Degrees of freedom	5		7	
Hosmer and Lemeshow chi-square	12.978		17.507*	
Degrees of freedom	8		8	
Nagelkerke R-squared	0.169		0.178	
PERCEIVED AESTHETICS SUB-SCALE				
Age	1.043***	1.032–1.054	1.047***	1.064–1.059
Body mass index	1.048***	1.025–1.071	1.046***	1.023–1.069
Annual household income				
<$10,000–$29,000	ref		ref	
$30,000–$69,999	1.428	0.976–2.088	1.413	0.961–2.078
$70,000–$100,000+	1.704**	1.147–2.531	1.674*	1.121–2.501
Racial discrimination stress	N/A		1.016*	1.004–1.029
Perceived aesthetics	1.022	0.968–1.079	1.021	0.967–1.078
Perceived aesthetics X Racial discrimination stress	N/A		1.003	0.998–1.007
Model diagnostics				
−2 Log likelihood	959.108		942.063	
Omnibus model chi-square	104.007***		109.887***	
Degrees of freedom	5		7	
Hosmer and Lemeshow chi-square	12.495		23.841	
Degrees of freedom	8		8	
Nagelkerke R-squared	0.169		0.179	
PERCEIVED CRIME SAFETY SUB-SCALE				
Age	1.047***	1.036–1.059	1.049***	1.037–1.061
Body mass index	1.048***	1.025–1.071	1.046***	1.023–2.455
Annual household income				
<$10,000–$29,000	ref		ref	
$30,000–$69,999	1.477*	1.007–2.166	1.426	0.967–2.103
$70,000–$100,000+	1.731**	1.167–2.166	1.644*	1.101–2.455
Racial discrimination stress	N/A		1.009	0.995–1.023
Perceived crime safety	0.936*	0.887–0.988	0.951	0.899–1.007
Perceived crime safety X Racial discrimination stress	N/A		0.996*	0.992–0.999
Model diagnostics				
−2 Log likelihood	953.214		935.718	
Omnibus model chi-square	110.280***		116.615***	

(Continued)

TABLE 4 | Continued

Variables	Main effects models		Moderating models	
	Odds ratio[a]	95% Confidence interval	Odds ratio	95% Confidence interval
Degrees of freedom	5		7	
Hosmer and Lemeshow chi-square	8.952		10.304	
Degrees of freedom	8		8	
Nagelkerke R-squared	0.178		0.189	

*[a]Odds ratios for the constant not displayed in the table; [b]ref, reference group; [c]N/A, variable is not applicable to the model; [d]The models testing for moderation include grand-mean centered variables for perceived neighborhood walkability sub-scales, perceived racial discrimination stress, and the interaction terms; * $p < 0.05$, ** $p < 0.010$, *** $p < 0.001$ (two-tailed).*

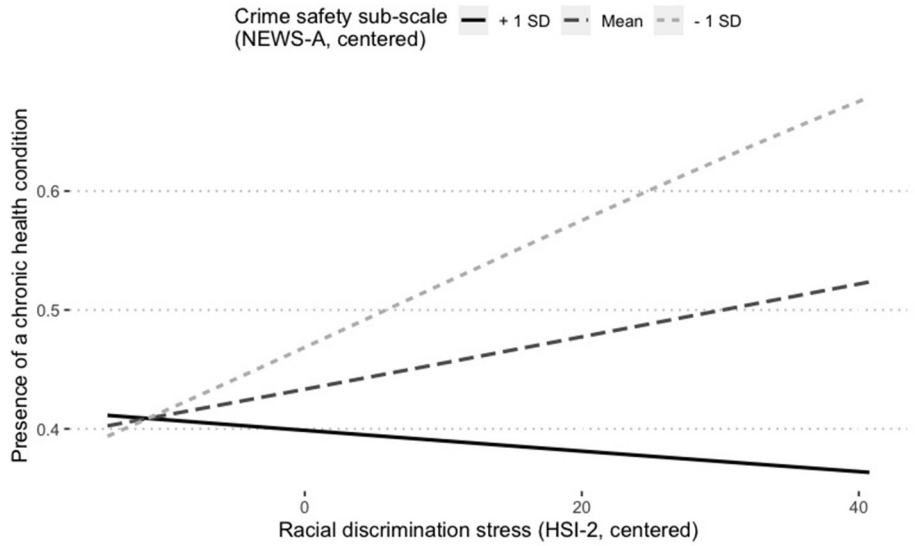

FIGURE 1 | Perceived crime safety moderates the association between racial discrimination stress and having a chronic health condition among U.S. Hispanic/Latino adults. NEWS-A, Neighborhood Environment Walkability Scale-Abbreviated; HSI-2, Hispanic Stress Inventory-2; SD, standard deviation. Simple slopes indicate the positive association between racial discrimination stress and presence of a chronic health condition is significant only among those who report lower perceived neighborhood safety from crime ($\beta = 0.02$, $p = 0.01$).

presence of a chronic health condition. Specifically, the positive association between racial discrimination stress and presence of a chronic health condition is significant only among those who report lower perceived neighborhood safety from crime. This finding is consistent with theoretical models and empirical literature that have characterized the environment as a moderator of the association between psychosocial factors and health/health behaviors (18, 29, 30). The findings also highlight the importance of studying and targeting the perceived walkability of neighborhoods in more specific rather than general ways. Examining the study aims by each NEWS-A sub-scale brought clarity where overall perceived neighborhood walkability could not.

This study's findings suggest perceived neighborhood safety matters, not infrastructure and aesthetics, when it comes to racial discrimination stress and having a chronic health condition among Hispanics/Latinos. Low perceived neighborhood safety from crime could reflect institutional racism, as Hispanics/Latinos are more likely than non-Hispanic Whites to be victims of violent crimes and more likely to live in poverty, which is associated with higher crime rates (66, 67). Improving safety in communities where Hispanic/Latino residents report greater safety concerns may have beneficial effects on racial discrimination stress and health among Hispanic/Latino adults. Testing such an intervention in a longitudinal study is a recommended next step in research.

This study responds to calls in the literature to investigate innovative explanations for health disparities by testing interactions of the physical and social environments (68, 69). A study that examined the moderating role of the environment on racial discrimination stress and health among African Americans found that discrimination experienced in the previous year was positively associated with cortisol concentration among those residing in neighborhoods with more White residents (69). Building on the present study's findings by including an additional aspect of the social environment, such as social capital (70), perceived neighborhood social cohesion (71), or neighborhood racial makeup (69), may explain more of the

total variance in presence of a chronic health condition among Hispanic/Latino adults.

The study sample reflected the Hispanic/Latino population in the United States well on a number of sociodemographic characteristics including proportions by ethnic origins, nativity, employment status, relationship status, and health insurance status (72, 73). The sample appears to over represent women (sample 58% vs. U.S. 49%) and those who have completed 2 years or more of college (sample 62% vs. U.S. 41%), and underrepresent those living in the Western region of the United States (sample 23% vs. 41%) (73, 74). These disproportionate representations in the sample could have implications for the findings, but explanations follow that propose the implications may be minimal. Suspecting the study results could vary by gender, *post hoc* analyses were conducted and the study findings did not change when examined by women and men. Additionally, those with more education are more likely to have a primary healthcare provider and more likely to effectively manage chronic health conditions, like hypertension, than those less educated (75, 76). Thus, this study's findings could reflect the experiences of a healthier group of Hispanics/Latinos than the average national cross-section of Hispanics/Latinos. A RAND Corporation report on nationally representative data from the Medical Expenditure Panel Survey from 2014 shows that 49% of Hispanic/Latino adults in the United States have at least one chronic health condition. This is 3.6% more than respondents endorsed in this study, and the two studies generally assessed the same conditions. Finally, the Western region of the United States, California in particular, is home to the largest proportion of the U.S. Hispanic/Latino population. One national survey found that the West generally fares better on indices of residential, racial integration than other U.S. regions, but the state of race relations between non-Hispanic Whites and Hispanic/Latinos were similar to the rest of the country (77). Region was also included in the initial analyses as a covariate and removed only after it was determined to not be an explanatory contributor to the models.

Strengths and Limitations

The most notable strengths of this study are the several novel findings that advance the literature and inform next steps in practice and research that aim to address health disparities among Hispanic/Latino adults in the United States. Additional study strengths are that the survey was provided in English and Spanish and the sample reflected the U.S. Hispanic/Latino population well on a number of characteristics; both increase generalizability of the study results. A large sample size of Hispanic/Latino adults provides ample power to test for moderation, which is often underpowered in the literature (78), and allows for the examination of within ethnic group variability in experiences and chronic health conditions.

Lastly, there are also study limitations. The cross-sectional design limits the study interpretations to associations rather than causal inferences. The inability to measure survey response rate using Qualtrics Panels and the un-measured differences between those who are more and less likely to participate in electronically delivered surveys makes the study vulnerable to selection bias. Although, a meta-analysis by Walter and colleagues (79) did find similar internal reliability and external validity between online panel and other sampling techniques (79). The self-report measure of current chronic health conditions, as opposed to medically confirmed, likely underestimates the actual proportion of those who have chronic health conditions, as undiagnosed type 2 diabetes is common, especially among people of color in the United States (80). Future longitudinal studies should focus on disentangling mechanisms by chronic condition, as some mechanisms are shared and others are not. Finally, the racial discrimination stress measure was not specific to racial discrimination experienced in one's neighborhood, however, it does capture stress due to racial discrimination in the contexts of one's daily life, which would include the neighborhood in which one lives.

CONCLUSION

Novel insights of this study include the associations among perceived neighborhood walkability, racial discrimination stress, and having a chronic health condition among U.S. Hispanic/Latino adults, as well as evidence that perceived neighborhood safety plays a moderating role in the positive association between racial discrimination stress and having a chronic health condition. Improving safety in communities where Hispanic/Latino residents report greater safety concerns may have beneficial effects on racial discrimination stress and health among Hispanic/Latino adults.

DATA AVAILABILITY STATEMENT

The dataset analyzed for this study can be found in the Harvard Dataverse, https://doi.org/10.7910/DVN/NABLZX.

ETHICS STATEMENT

The study involving human participants was reviewed and approved by Institutional Review Board at the University of Oregon. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

EB contributed to the conception and design of the study, analysis and interpretation of data, and drafting of the full manuscript. NG and NK contributed to the conception and design of the study, analysis and interpretation of data, and manuscript revisions. All authors read and approved the submitted version.

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Health Equity of Rural Residents in Southwest China

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The Chinese government stresses healthcare reform to improve the health of all residents in urban and rural areas. However, much research showed that inequities still existed in health status and health services utilization in China, especially in economically disadvantaged areas. Southwest China's Yunnan Province is an ethnic frontier region with lagging economic development. This study analyzed health equity among rural residents with various socio-economic and demographic statuses in Yunnan Province. Research on this area concerns rural residents. Our study was based on a household study sample consisting of 27,395 participants from six counties in Yunnan. For all participants, data on demographic and socio-economic characteristics, and health status were collected. The chi-square test and logistic regression were used to analyze factors influencing health. The concentration index was used to evaluate health equity. For all respondents, the 2-week prevalence, the prevalence of chronic diseases, and the required hospitalization rate were 7.3, 12.8, and 9.2%, respectively. After adjusting the age proportion of the sixth population census of Yunnan Province, the 2-week prevalence was 7.1%, the prevalence of chronic disease was 10.7%, and the hospitalization rate was 8.4%. The concentration indexes (CIs) reflecting health equity among the respondents with different incomes and educational levels were negative. There was health inequity among respondents with different incomes and educational levels. The respondents with lower incomes and educational levels had worse health. The common influencing factors included gender, age, ethnicity, occupation, marriage status, and the number of family members. Females, the aged, ethnic minorities, farmers, and the divorced or widowed had worse health status than the control groups. Larger numbers of family members correlated with better health. The respondents with lower incomes or educational levels had higher chronic disease prevalences. The associations between the 2-week prevalence, required hospitalization rate, and age were U-shaped; the lowest age group and the highest age group had higher rates. In conclusion, more attention should be paid to females, the aged, ethnic minorities, farmers, the divorced or widowed, residents with low income and low educational level, and those with chronic diseases.

Keywords: health equity, rural residents, Chinese healthcare reforms, disadvantaged area, household study

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INTRODUCTION

The term "health equity" has been defined by many researchers in the public health area, nevertheless, there is little consensus about its meaning (1). This lack of consensus is the principle that, motivates the elimination of disparities in health among various socioeconomic groups (2). The WHO/SIDA suggested that equity is different from equality; the former refers to the distribution of opportunities for survival that should be oriented toward individual needs (3). Pursuing health equity means "striving for equal opportunities for all social groups to be as healthy as possible, with selective focus on improving conditions for those who have had fewer opportunities" (1). Improving health is the ultimate goal of healthcare reform worldwide. The main target of the "Healthy China 2030" initiative proposed by the State Council of China is to achieve a higher national health level (4). To improve people's health, it is necessary to understand health status, identify factors influencing health, and study health equity.

The 4th and 5th National Health Services Survey (NHSS) of China in 2008 and 2013, respectively, found that the 2-week prevalences were 18.9 and 24.1%, respectively; the prevalences of chronic diseases were 24.1 and 33.1%, respectively; required hospitalization rates after medical diagnosis were 6.8 and 9.0%, respectively (5, 6). In other words, the demand for health care services increased in China, and the prevalence of chronic diseases increased rapidly. The 5th NHSS also reported that the required hospitalization rate after medical diagnosis for rural residents in western China was 9.4%, higher than the national average (9.0%).

Health service utilization experienced significant improvement in China since the establishment of China's New Rural Cooperative Medical System (NCMS) in 2003 (7). Healthy China 2020 issued by China's Ministry of Health in 2008, pointed out that citizens' health equity should be taken as an essential indicator to measure social justice and equity, and China's health reform and development should focus on eliminating inequities in health (8). Nevertheless, inequity still exists in health status and health services utilization, especially in economically disadvantaged areas (9–11). Nationwide health inequality exists in several areas, health status in eastern China was better than in other parts (12).

Yunnan is an ethnic frontier underdeveloped province located in southwest China with a minority population accounting for 33.34% of the total population. This study aims to analyze health equity for rural residents in Yunnan and explore the factors influencing rural residents' health equity in southwest China.

METHODS

Participants

This study was based on a household survey from February to August 2013 with a cross-sectional design from Yunnan's six counties. The multi-stage sampling method was used to determine sample sources according to the regional economic level. First, the Dali Bai Autonomous Prefecture (a more developed region) and Zhaotong City (a less developed region) were selected out of 16 cities (regions). Second, three counties among 12 counties in Dali and three counties among 11 counties in Zhaotong were selected according to the economic levels (high, medium, and low). Third, two townships with different economic levels were randomly selected in each county. Fourth, the cluster sampling method was used to select one or two natural villages from each selected township. The household survey was conducted as face-to-face interviews with pretested structured questionnaires among all households in the selected villages.

The survey returned data on the 2-week prevalence, the prevalence of chronic disease, and the required hospitalization rate. Taking the results of the 5th NHSS as a reference, in which the required hospitalization rate (P) was 9.0%, α was 0.05, δ was 10%, the calculation of the sample size was as follows:

$$n = \frac{(z_{\alpha/2})^2 \bullet (1 - P)}{\delta^2 \bullet P}$$

The minimum sample size to be investigated in each region was 3,885. Because this was a cluster sampling, based on the design effect of two, the sample size was 7,770. Based on the average family population of four, 1942 households were investigated.

Questionnaire

The questionnaire included two sections: (1) critical demographic and socioeconomic variables: age, gender, ethnicity, marital status, occupation, education level, annual household income, annual household expenditure, and family size; (2) health status: health condition over the past 2 weeks; required hospitalization over the past year; and chronic diseases over the past year. The reliability and validity of the questionnaire were evaluated using a pre-survey with a sample size of 120. Cronbach's alpha coefficient of 0.82 showed a good inner-reliability. The expert evaluation method was used to evaluate the content validity. The conclusion was that the items of the questionnaire reflected the research content. The questionnaire had ideal reliability and validity.

Variables and Definitions

All respondents were divided into five age groups: 0–12, 13–20, 21–40, 41–60, and 61 years and above. The respondents were divided into five groups according to the quintiles of per capita income: very-low-income, low-income, middle-income, high-income, and very-high-income. Health status was comprehensively measured using the following three indexes: 2-week prevalence, required hospitalization rate, and prevalence of chronic diseases. The 2-week prevalence was calculated as the percentage of respondents who presented with or declared general malaise with or without treatment over the past 2 weeks. The 2-week prevalence refers to (1) conscious physical complaints, injury, or poisoning in the past 2 weeks with treatment measures (including self-treatment); (2) Physical complaints without any treatment measures, but for a few days' rest or stay in bed. The required hospitalization rate was calculated as the percentage of respondents who have required hospitalization after diagnosis by doctors over the past year. The "required hospitalization rate" is used instead of "hospitalization rate," because although some residents are

required to be hospitalized by health workers in local clinics, they do not go to a hospital for various reasons, such as economic reasons, inconvenient transportation, etc. The prevalence of chronic diseases was calculated as the percentage of respondents who had chronic diseases, such as hypertension and diabetes over the past year. Chronic disease refers to (1) A chronic disease (such as hypertension, diabetes, etc.) is diagnosed by a doctor in the past 1 year; (2) A chronic disease is diagnosed a year ago, and there are attacks within a year, and treatment measures were taken.

Data Analysis

SPSS 18.0 (IBM Corporation, Armonk, USA) was used for statistical analysis. The chi-square test and univariate and multivariate logistic regression were used to analyze the influencing factors of health. In logistic regression, we used the ENTER method. All the independent variables have been included in the analysis, and the corresponding OR value of each variable is obtained by adjusting the influence of other independent variables. Concentration index (CI) and concentration curve based on a geometric approach were used to calculate health equity.

$$G = 1 - \sum_{i=0}^{n-1} (x_{i+1} - x_i)(y_{i+1} + y_i)$$

where x_i represents the cumulative percentage of the population ranked by income (education level) and y_i represents the cumulative percentage of the corresponding unhealthy population.

A two-tailed P-value $\leq$ 0.05 was considered statistically significant.

RESULTS

A total of 27,395 residents in 7,399 households were sampled from Dali Bai Autonomous Prefecture and Zhaotong City. All participants responded to the questionnaire. A total of 13,715 residents in 3,702 households were sampled from Dali, of which 5,316 residents in 1,256 households were in Dali City, 4,358 residents in 1,236 households in Weishan Yi and Hui Autonomous County, and 4,041 residents in 1,210 households in Midu County. There were 13,680 residents in 3,697 households sampled from Zhaotong City, of which 4,380 residents in 1,176 households were in Yanjin County, 4,404 residents in 1,258 households in Zhaoyang District, and 4,896 residents in 1,263 households in Ludian County.

Health Status of the Respondents by Socio-Economic and Demographic Characteristics

Table 1 shows health status of the respondents. Approximately 51.8% of respondents were male. Most (83.9%) respondents were of Han ethnicity (the ethnic majority in China). The Bai ethnic group (12.5%) was the Dali's largest minority group; 59.8% were married, 64.8% were illiterate or only had a primary school education, 62.8% were farmers, and 13.8% were aged 61 years and above. Most of the respondents (98.8%) participated in China's basic medical insurance.

The 2-week prevalence was 7.3%. It was highest in the youngest and oldest respondents whereas the respondents aged 13–20 years had the lowest 2-week prevalence. The divorced or widowed respondents had the highest rates, while the single respondents had the lowest rate. The illiterate residents had a higher rate than other educational level groups. Females had a higher rate than males. Concerning occupational distribution, workers had the lowest rate, and farmers had the highest rate. The most common diseases were influenza, headache, dizziness, diarrhea, and fever.

The prevalence of chronic diseases was 12.8%. Older age correlated with a higher prevalence of chronic diseases. The divorced or widowed respondents had the highest rates, and the single respondents had the lowest rate. Lower income correlated with a higher prevalence of chronic diseases. Males had a lower rate than females. The other minority respondents had lower rates than the Han majority and the Bai ethnic group. The illiterate respondents had the highest rate, and the middle school group had the lowest rate. The unemployed respondents had the highest rate, while students had the lowest rate. The major chronic diseases were hypertension (3.35%), rheumatism (1.92%), hyperosteogeny (0.53%), diabetes (0.45%), and gastropathy (0.38%).

The required hospitalization rate was 9.2%. The respondents aged 13–20 years had the lowest rate. For other age groups, the hospitalization rate increased with age. The divorced or widowed respondents had the highest rate, and the single respondents had the lowest rate. The very-low-income respondents had a higher rate than other income respondents. Males had a lower rate than females. The Bai ethnic group had a higher rate than the Han. The illiterates had the highest rate, and the high school and above group had the lowest rate. The unemployed respondents had the highest rate. The significant diseases requiring hospitalization were injury, hypertension, childbirth, heart disease, and appendicitis.

After adjusting the age proportion of the sixth population census of Yunnan Province, the 2-week prevalence was 7.1%, the prevalence of chronic disease was 10.7%, and the hospitalization rate was 8.4%. The gender composition was the same as that of the population census, which did not need to be adjusted.

There were linear trends between income and the prevalence of chronic diseases ($\chi^2 = 187.110$, $P < 0.001$), income and the required hospitalization rate ($\chi^2 = 9.861$, $P = 0.002$), education levels and the 2-week prevalence ($\chi^2 = 35.549$, $P < 0.001$), education levels and the prevalence of chronic diseases ($\chi^2 = 381.834$, $P < 0.001$), and education levels and the required hospitalization rate ($\chi^2 = 73.840$, $P < 0.001$). The prevalence of chronic diseases and the required hospitalization rate decreased when income increased. The 2-week prevalence, the prevalence of chronic diseases, and the required hospitalization rate decreased when the education level increased.

Health Equity

The CIs of the 2-week prevalence, the prevalence of chronic diseases, and the required hospitalization rate among residents with different incomes were −0.01888, −0.12520, and −0.03470,

TABLE 1 | Health status of the respondents [*n* (%)].

Variables	Two-week prevalence		Prevalence of chronic diseases		Required hospitalization rate	
	%	95%CI	%	95%CI	%	95%CI
Total	7.3	7.0, 7.6	12.8	12.4, 13.2	9.2	8.9, 9.5
Age (years)						
0–12	8.9***	8.1, 9.7	0.9***	0.6, 1.2	4.8***	4.2, 5.4
13–20	3.6	3.0, 4.2	1.1	0.8, 1.4	3.6	3.0, 4.2
21–40	5.0	4.5, 5.5	5.4	4.9, 5.9	6.7	6.2, 7.2
41–60	9.3	8.6, 10.0	21.0	20.1, 21.9	11.7	11.0, 12.4
61+	9.9	8.9, 10.9	37.0	35.5, 38.5	19.7	18.4, 21.0
Marriage						
Unmarried	6.1***	5.6, 6.6	1.5***	1.3, 1.7	4.3***	3.9, 4.7
Married	7.8	7.4, 8.2	17.6	17.0, 18.2	11.2	10.7, 11.7
Divorce/widowed	10.1	8.5, 11.7	34.0	31.5, 36.5	18.6	16.5, 20.7
Average annual income (yuan)						
<2,400	8.1	7.4, 8.8	18.4***	17.4, 19.4	10.5***	9.7, 11.3
2,400–4,399	7.4	6.7, 8.1	13.2	12.3, 14.1	8.6	7.8, 9.4
4,400–6,699	7.2	6.5, 7.9	11.5	10.6, 12.4	8.7	7.9, 9.5
6,700–10,199	6.9	6.2, 7.6	10.6	9.8, 11.4	9.3	8.5, 10.1
10,200+	7.5	6.8, 8.2	9.7	8.9, 10.5	8.2	7.5, 8.9
Gender						
Male	6.6***	6.2, 7.0	10.6***	10.1, 11.1	8.0***	7.6, 8.4
Female	8.0	7.5, 8.5	15.2	14.6, 15.8	10.4	9.9, 10.9
Ethnicity						
Han	7.1	6.8, 7.4	13.0*	12.6, 13.4	8.8***	8.4, 9.2
Bai	8.3	7.4, 9.2	12.0	10.9, 13.1	11.1	10.0, 12.2
Other	7.9	6.3, 9.5	10.4	8.6,2.2	10.3	8.5, 12.1
Education						
Illiterate	9.3***	8.6, 10.0	20.7***	19.8, 21.6	12.1***	11.4, 12.8
Primary school	6.9	6.4, 7.4	11.3	10.7, 11.9	8.9	8.3, 9.5
Middle school	6.1	5.5, 6.7	7.9	7.3, 8.5	7.1	6.5, 7.7
High school	6.0	4.7, 7.3	9.1	7.6, 10.6	7.9	6.5, 9.3
Above high school	7.1	5.7, 8.5	8.6	7.0, 10.2	7.2	5.7, 8.7
Occupation						
Farmers	8.1***	7.7, 8.5	17.7***	17.1, 18.3	11.5***	11.0, 12.0
Students	6.7	6.1, 7.3	1.1	0.8, 1.4	3.9	3.4, 4.4
Workers	2.5	1.7, 3.3	6.1	4.8, 7.4	4.8	3.7, 5.9
unemployed	6.7	4.8, 8.6	21.2	18.2, 24.2	14.3	11.7, 16.9
Others	5.7	4.5, 6.9	10.2	8.7, 11.7	7.7	6.3, 9.1

*Chi-square test; *P < 0.05; **P < 0.01; ***P < 0.001.*

respectively (**Figure 1**). The CIs of the 2-week prevalence, the prevalence of chronic diseases, and the required hospitalization rate among respondents with different educational levels were −0.08296, −0.19424, and −0.10274, respectively (**Figure 2**).

Factors Influencing Health

Multivariate logistic regression was used to analyze the 2-week prevalence, chronic diseases, and required hospitalization factors.

Table 2 shows the results of multivariate logistic regression of the 2-week prevalence. Gender, age, nationality, occupation, and the number of family members influenced the 2-week prevalence when other covariates were controlled. The 2-week prevalence for females was 1.19 times that of males. The prevalence of respondents aged 0–12, 13–20, 21–40 years were 1.54 times, 0.58 times, 0.60 times that of those aged 61 years and above, respectively. The 2-week prevalence for the Bai ethnic group was 1.27 times that of the Han respondents. The 2-week prevalence of workers was 0.43 times that of farmers. As the number of family members increased by one unit, the 2-week prevalence dropped by 11%.

The factors influencing the prevalence of chronic diseases were gender, age, occupation, marriage status, income, education level, and the number of family members, when other covariates were controlled. The prevalence of chronic diseases for females

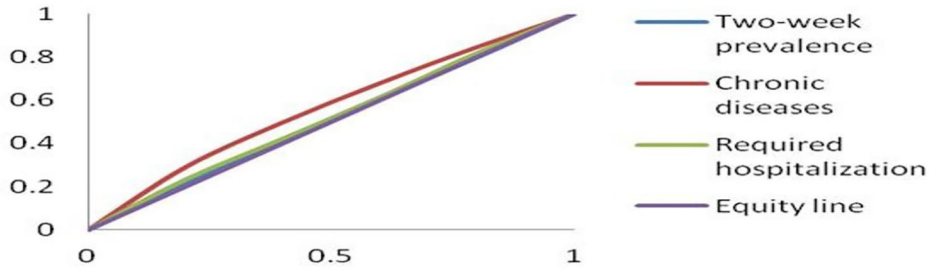

FIGURE 1 | Concentration curves of health with different incomes.

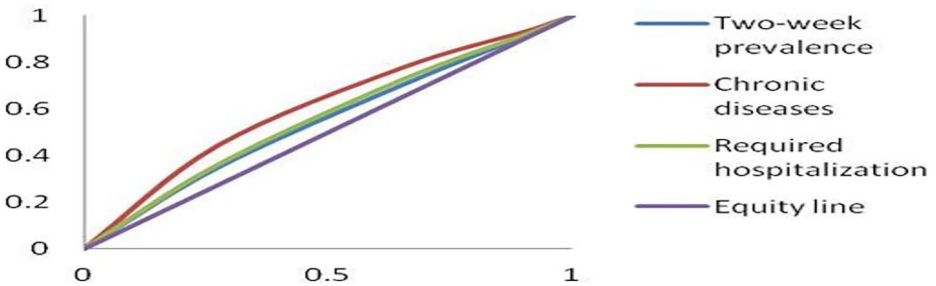

FIGURE 2 | Concentration curves of health with different educational levels.

was 1.39 times that of males. The prevalences for the respondents aged 0–12, 13–20, 21–40, 41–60 years was 0.05, 0.06, 0.15, and 0.55 times that of those aged 61 years and above, respectively. The prevalence for workers was 0.67 times that of farmers. The prevalence for single respondents was 0.45 times that of divorced or widowed respondents. For respondents with very-low, low-, middle-income, the prevalences were 1.58, 1.28, and 1.25 times that of very-high-income, respectively. The prevalences for the illiterates and the primary school groups were 1.66 and 1.44 times those of the high school above group, respectively. The prevalence of chronic diseases decreased by 11% as the number of family members increased by one unit.

The factors influencing the required hospitalization rate were gender, age, nationality, occupation, marriage status, and the number of family members, when other covariates were controlled. The required hospitalization rate for females was 1.25 times as males. The required hospitalization rate for the respondents aged 0–12, 13–20, 21–40, 41–60 years were 0.57, 0.37, 0.37, and 0.59 times that of those aged 60 years and above, respectively. The required hospitalization rate for the Bai respondents and other ethnic respondents were 1.380 times and 1.348 times as the Han respondents, respectively. The required hospitalization rate for students and workers were 0.59 times and 0.58 times that of farmers, respectively. The required hospitalization rate for single respondents was 0.58 times that of divorced or widowed respondents. With each unit increased in the number of family members, the required hospitalization rate decreased by 6.5%.

DISCUSSION

Compared with the report of the 5th NHSS in China, we found that the 2-week prevalences and the prevalences of chronic diseases among the sampled residents were lower (7.3 vs. 24.1%, 12.8 vs. 33.1%, respectively). However, this result was similar to those of other studies in Yunnan (13, 14). The required hospitalization rate was similar to the 5th NHSS (9.2 vs. 9.0%). The possible reasons for the discrepancies are differences in the areas and ages of the samples. According to the 5th NHSS, the prevalence of disease among urban residents was higher than rural residents. The respondents in our study were sampled from rural area, while the respondents in the 5th NHSS included urban and rural areas. The respondents in our study included residents of all ages, whereas the respondents in the 5th NHSS were aged 15 and above.

There were income-related inequities in health. The CIs reflecting the health equity among different incomes were negative, suggesting that the respondents with lower income required more health resources than those with higher income and were less healthy, which agree with those of previous studies (15, 16). Van Doorslaer et al. (17) found that health inequalities benefited high-income individuals in nine countries. Van Doorslaer and Koolman (18) found that significant health inequalities were beneficial to high-income individuals in 13 European countries. These studies also support our results of income-related health inequalities.

Social position exerts a powerful influence on the type, magnitude, and distribution of health in high-, low- and middle-income counties (19). Education, income, and occupation are

TABLE 2 | Logistic regression model fitting results.

Dependent variables	Two-week prevalence		Chronic diseases		Required hospitalization	
	OR	95% CI for OR	OR	95% CI for OR	OR	95% CI for OR
Number of family members	0.89*	(0.86, 0.92)	0.90*	(0.87, 0.92)	0.94*	(0.91, 0.96)
Female	1.19*	(1.08, 1.30)	1.39*	(1.28, 1.51)	1.25*	(1.14, 1.36)
Male (Reference)						
Age (years)						
0–12	1.54*	(1.14, 2.08)	0.05*	(0.03, 0.08)	0.57*	(0.42, 0.77)
13–20	0.58*	(0.42, 0.79)	0.06*	(0.04, 0.09)	0.37*	(0.27, 0.49)
21–40	0.60*	(0.51, 0.71)	0.15*	(0.13, 0.17)	0.37*	(0.33, 0.43)
41–60	1.02	(0.88, 1.18)	0.55*	(0.50, 0.61)	0.59*	(0.52, 0.66)
61+ (Reference)						
Ethnicity						
Bai	1.27*	(1.11, 1.47)	1.06	(0.93, 1.20)	1.38*	(1.22, 1.57)
Others	1.12	(0.89, 1.42)	1.00	(0.81, 1.25)	1.35*	(1.09, 1.66)
Han (Reference)						
Occupation						
Students	0.87	(0.69, 1.08)	0.81	(0.55, 1.19)	0.59*	(0.47, 0.75)
Workers	0.43*	(0.30, 0.60)	0.67*	(0.52, 0.86)	0.58*	(0.45, 0.76)
Unemployed	0.77	(0.57, 1.06)	1.14	(0.91, 1.42)	1.09	(0.85, 1.38)
Other	0.80*	(0.63, 1.01)	0.97	(0.80, 1.18)	0.86	(0.70, 1.06)
Farmers (Reference)						
Marriage						
Single	0.79	(0.58, 1.06)	0.45*	(0.34, 0.60)	0.58*	(0.45, 0.75)
Married	1.04	(0.85, 1.28)	0.93	(0.81, 1.06)	0.92	(0.78, 1.08)
Divorced or widowed (Reference)						
Family Income per person (RMB per year)						
<2400	1.03	(0.89, 1.20)	1.58*	(1.38, 1.79)	1.15	(1.00, 1.33)
2,400–4,399	1.00	(0.86,1.16)	1.28*	(1.12, 1.47)	1.05	(0.91, 1.21)
4,400–6,699	1.02	(0.88, 1.19)	1.25*	(1.09, 1.43)	1.13	(0.98, 1.30)
6,700–10,199	0.92	(0.79, 1.07)	1.11	(0.97, 1.27)	1.19	(1.03, 1.37)
10,200+ (Reference)						
Education						
Illiterate	1.04	(0.82, 1.33)	1.66*	(1.32, 2.08)	1.25	(0.98, 1.59)
Primary school	0.90	(0.70, 1.14)	1.44*	(1.15, 1.81)	1.25	(0.98, 1.58)
Middle school	0.91	(0.71, 1.16)	1.20	(0.95, 1.52)	1.11	(0.87, 1.42)
High school	0.87	(0.63, 1.19)	1.28	(0.96, 1.72)	1.20	(0.89, 1.63)
Above high school (Reference)						

*In logistic regression, we used the ENTER method. All the independent variables have been included in the analysis, and the corresponding OR value of each variable is obtained by adjusting the influence of other independent variables. *P < 0.05.*

critical factors in determining social status and gaining power and social resources. Compared with the high-income group, people with lower income are more likely to experience financial stress, and economic difficulty was a significant obstacle to health care access. Income was also related to lifestyle; those with low income were more likely to smoke, drink excessively, and be overweight and inactive (20). Unhealthy lifestyles, financial stress, and lower health service utilization levels lead to less health in low-income people. Our study also demonstrated that the CI of the prevalence of chronic diseases (−0.12520) was larger than that of the 2-week prevalence (−0.01888) and the required hospitalization rate (−0.03470) among the respondents with different incomes, suggesting that income had a more significant impact on equity of chronic diseases than on required hospitalization or 2-week prevalence. The linear trend tests results also indicated linear trends existed between income and the prevalence of chronic diseases and between income and the required hospitalization rate.

The CIs reflecting health equity among educational levels were negative, suggesting that respondents with lower educational levels required more health resources, and had worse health status than residents with higher educational levels (21). People with higher education levels have more knowledge about health and health care and have better self-management and healthier

lifestyles, and can better utilize health care services. A healthy lifestyle can help people prevent and control diseases, such as chronic diseases and weight gain. Timely diagnosis and treatment can prevent mild illness from becoming severe (22–24). In our study, the CIs of the prevalence of chronic diseases (−0.19424) and the required hospitalization rate (−0.10274) were larger than that of the 2-week prevalence (−0.08296) among the respondents with different educational levels, suggesting that lower education level is a primary factor influencing inequity of chronic diseases and hospitalization, and people with lower educational levels had poorer health knowledge and health care consciousness. Educational level positively correlated with income and age, as low educational level correlated with low income and old age. The older and low-income residents had higher chronic disease rates and hospitalization rates compared to their counterparts. More resources should be allocated to rural populations with low income and low educational levels, and health knowledge should be disseminated in a simple, visual, and easily understandable way, which is conducive to disease prevention and control, especially for chronic diseases.

The females had higher required hospitalization rates than males. Women had more risk of diseases because of their particular physiological structure, including maternity and gynecological diseases (25–27). The 5th NHSS in China showed that the 2-week prevalence and the prevalence of chronic diseases in females were higher than in males. Ren's study (26) found that females had a higher prevalence of chronic diseases than did males; however, Cheng et al. (28) showed the opposite result. This discrepancy might be caused by regional differences, as Cheng's study was in a developed area (Minhang District of Shanghai). Ours and Ren's study were in the countryside of under-developed areas (Yunnan and Ningxia Province). Compared to men, women had lower mortality, but they tended to be sicker than men and have more significant morbidity, worse health-related quality of life, and worse perception of health, including higher levels of depression, psychiatric disorders, and various chronic illnesses (29, 30). In China's rural areas, men are dominant in the family and society, and most resources were allocated to them; there are differences between males and females in education, employment, and economic empowerment (31, 32). It is more likely that women have less power, lower-income, and long-term housework, the health status of other family members, especially male family members, takes precedence over women's health (33). In rural areas, heavy physical labor, economic dependence on men, and lower status in a family all adversely affect women's health.

Compared to farmers, workers required fewer health resources, and students had lower required hospitalization rates. Farmers are less educated than workers, lack healthcare knowledge, and engage in challenging physical work for long periods, leading to poor health status and high morbidity. Chronic disease is an essential factor influencing the required hospitalization rate. Students are young and rarely have chronic diseases. They are the focus of family and health systems, so they have good healthcare, resulting in a low required hospitalization rate.

Ethnicity was a factor influencing the 2-week prevalence and the required hospitalization rate. Compared to the Han respondents, the Bai respondents had a higher 2-week prevalence and a higher required hospitalization rate; other ethnic respondents had higher required hospitalization rates. Previous studies (27, 34, 35) showed that ethnic minorities had worse health status than Han people. The minority respondents had low educational levels and particular lifestyle and eating habits, including drinking problems. When they became ill, they sought the help of non-professional medical persons or medicine men in their villages. This led to poor health conditions.

Marriage status was also a factor influencing rates of chronic diseases and required hospitalization. The divorced or widowed had higher prevalences of chronic diseases and required hospitalization rates than the singles. Education level, marriage status, and age were closely related. The divorced or widowed were relatively older. Older age correlated with lower education level and worse health condition (35).

However, one limitation of our study is that the effect of family clustering was not considered in the data analysis, that is, we have not considered residents in the same household share some similarities and are not independent sampled. This should be discussed in our further study.

CONCLUSIONS

Age, gender, income, education level, and marital status were factors influencing health conditions. More attention should be paid to the aged, females, residents with low income and low educational levels, the divorced or widowed, and residents with chronic diseases. Providing more health knowledge, especially the (35) prevention and treatment of chronic diseases, to residents with lower education levels or older ages will help them carry out health promotion activities and improve their self-management ability and health levels.

There are health inequities among Yunnan residents, especially concerning chronic diseases and the required hospitalization across income and education levels. The respondents with low income and low education levels had worse health status.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee of Kunming Medical University. Written informed consent to participate in this

study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

X-ML, L-PH, ZY, and QM developed the idea and contributed to the study design. X-ML and L-PH carried out the analysis. L-PH wrote the manuscript and takes responsibility for the overall content of the paper. JK and Y-YX revised the manuscript. X-ML, JK, ZY, Y-YX, and QM commented on the paper and have seen and accepted the final version. All authors contributed to the article and approved the submitted version.

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The Associations Between Access to Recreational Facilities and Adherence to the American Heart Association's Physical Activity Guidelines in US Adults

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Physical activity decreases the risk of long-term health consequences including cardiac diseases. According to the American Health Association (AHA), adults should perform at least 75 min of vigorous physical activity (PA) or 150 min of moderate PA per week to impact long-term health. Results of previous studies are varied and have yet to integrate perceived access to facilities with AHA PA guidelines. We investigated whether access to free or low-cost recreational facilities was associated with meeting the AHA PA guidelines.

Methodology: This cross-sectional study utilized data extracted from the Family Life, Activity, Sun, Health, and Eating (FLASHE) database collected in 2017 ($n = 1{,}750$). The main exposure variable was access to free or low-cost recreational facilities. The main outcome variable was meeting the AHA guidelines of 150 min moderate PA or 75 min vigorous PA per week. Covariates included age, sex, level of education, overall health, BMI, ethnicity, hours of work per week, income, and time living at current address. Unadjusted and adjusted logistic regression analysis were used to calculate measures of odds ratio (OR) and corresponding 95% confidence interval (CI).

Results: Of the 1,750 included participants, 61.7% ($n = 1{,}079$) reported to have access to recreational facilities. Of those with access to facilities, 69.9% met AHA PA guidelines while 30.4% did not. After adjusting for covariates, participants who reported access to recreational facilities were 42% more likely to meet AHA PA guidelines compared with participants who did not (adjusted OR 1.42; 95% CI 1.14–1.76). Secondary results suggest that healthier individuals were more likely to have met AHA PA guidelines.

Conclusions: Having access to free or low-cost recreational facilities such as parks, walking trails, bike paths and courts was associated with meeting the AHA PA guidelines.

Increasing prevalence and awareness of neighborhood recreational facilities could assist in access to these facilities and increase the ability of individuals to meet AHA PA guidelines. Future research should determine which types of recreational facilities impact physical activity strongest and discover methods of increasing their awareness.

Keywords: open space access, recreational facilities, built environment, sedentarism, compliance

INTRODUCTION

Physical activity (PA) is known to decrease the risk of developing long term chronic diseases such as cardiovascular disease. Inadequate PA has long been associated with disease-related mortality and increased healthcare costs. Recent estimates in the US reported about 10% of pre-mature deaths were associated with inadequate PA, and $117 billion in annual healthcare costs (1). The current recommendation of the American Heart Association (AHA) for adults is to perform at least 150 min of moderate PA or 75 min of vigorous PA per week to have an impact on long term health (2). However, the U.S. Department of Health and Human Services (HHS) estimated that more than 80% of adults do not currently meet such guidelines (3). In such, it is essential to understand the factors associated with meeting current US guidelines among US populations.

One of the commonly accepted factors for increasing PA participation among populations is having safe and accessible recreational parks around their community (4). While it is known that expansive park networks in neighborhood-built environments are positively associated with multiple aspects of health, well-being, and quality of life (4), populations' access and PA participation in such neighborhood parks is influenced by different variables such as individuals' ability, motivation to be physically active, and parks and leisure centers' proximity to their homes (5). For example, only adolescents living in neighborhoods with available recreational facilities have reported increased frequency and duration of performing PA (6). Insufficient numbers of parks and leisure centers have also been reported for US homes, with only one of five US homes having parks and leisure centers within half a mile radius (3). Nonetheless, reported association between increased PA levels and facility numbers within a neighborhood is inconclusive (7–11), showing either statistically positive (12), negative (7), or no significant association between the two variables (8, 9, 13). For example, Stewart et al., found no association between park's proximity and PA levels among an urban, mostly white, well-educated sample population that was well-served by neighborhood parks (9), though neither their socio-economic status nor their PA access was assessed. West et al., only focused on the largest American cities whilst reporting a positive correlation between park density and PA levels, which may not therefore be generalizable to smaller cities or rural areas (10). Whether and how PA participation is determined by facility access across US populations in large cities are largely unknown.

The objective of this study was to investigate whether access to free or low-cost recreational facilities was associated with meeting the AHA PA guidelines among US adults.

Abbreviations: AHA, American Heart Association; BMI, Body Mass Index; CI, Confidence Interval; FLASHE, Family Life, Activity, Sun, Health, and Eating; HHS, U.S. Department of Health and Human Services; OR, Odds Ratio; PA, Physical Activity; Ref, Reference Group; Rs, Spearman's Rank Correlation Coefficient; US, United States; WHO, World Health Organization.

MATERIALS AND METHODS

Study Design and Population

This was an analytical cross-sectional study utilizing demographics, built environment characteristics, and PA level data obtained from the Family Life, Activity, Sun, Health, and Eating (FLASHE) study conducted by the National Cancer Institute. The survey results in this publicly available online database encompassed a population of adult ($N = 1{,}839$) in the United States in 2017. A non-probability sample was recruited from all U.S. regions through the Ipsos Consumer Opinion Panel, a national market research firm. Based on sex, census division, household income and size, and race/ethnicity, eligible participants were balanced in the U.S. population. Within each household, one adolescent and one parent were randomly selected from eligible household members. Parents were considered eligible if there were at least 18 years of age and lived with at least one child aged between 12 and 17 years of age for >50% of the time. However, in this study we only included the parents. Via three surveys, these individuals were asked questions on demographics, health status, PA status, diet and built environment regarding both themselves and their adolescent (14). The main inclusion criteria included age of 18 years or above, participation in the 2017 FLASHE survey; and response to survey questions being studied including "My neighborhood has several FREE or LOW-COST recreation facilities, such as parks, walking trails, bike paths, recreation centers, playgrounds, etc.", and one of the following: "How much time did you usually spend doing vigorous PA on one of those days?", "How much time did you usually spend doing MODERATE PA on one of those days?" (15). Similarly, participants were excluded from the study if they either missed responses to the survey question assessing the independent variable described below, or if they did not have a response to any one of the two questions addressing the dependent variable.

Variables

The main independent variable in this study was accessibility to free or low-cost recreational facilities. Perceived access to free or low-cost recreational facilities was assessed by the question "My neighborhood has several FREE or LOW-COST recreation facilities, such as parks, walking trails, bike paths, recreation centers, playgrounds, etc." Participants could either respond

"strongly agree," "somewhat agree," "somewhat disagree," or "strongly disagree." To create a dichotomous variable, the answer choices "strongly agree" and "somewhat agree" were combined into "agree"; and "strongly disagree" and "somewhat disagree" into "disagree."

The main outcome variable was adherence to the AHA national PA guidelines. These guidelines recommend that adults should participate in more than 150 min of moderate intensity PA or more than 75 min of vigorous intensity PA per week (2). The self-reported quantitative weekly time spent doing walking, moderate or vigorous PA into one of two categorical variables: (1) at or above national guidelines or (2) below national guidelines. Quantitative data on vigorous activity were collected by the following questions: "During the LAST 7 DAYS, on how many days did you do VIGOROUS PA like heavy lifting, digging, aerobics, or fast bicycling?" and "How much time did you usually spend doing vigorous PA on one of those days?". The amount of moderate PA was assessed by: "During the LAST 7 DAYS, on how many days did you do MODERATE PA like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking," and "How much time did you usually spend doing MODERATE PA on one of those days?", respectively. Individuals were considered above or equal to guidelines if they meet the guideline criteria for either vigorous or moderate PA. Those who do not meet guidelines for either of these two categories were categorized as below national PA guidelines.

This study included the covariates age, sex, level of education, overall health, BMI, ethnicity, employment status, hours of work per week, income, and number of years living at current residence. Age was assessed in the survey using the following categories: 18–34, 35–44, 45–59, and 60 + years-of-age (16). Sex was categorized into male or female. Levels of education were re-categorized into (i) high school or less (ii), some college but not a college degree, (iii) or a 4-year college degree or higher. Overall health status was re-categorized into excellent, very good, good, or fair/poor. BMI was calculated with height and weight and was categorized according to WHO criteria (17). A BMI <18.5 kg/m^2 was considered underweight. A BMI between 18.5 and 24.99 kg/m^2 was considered normal weight. A BMI between 25 and 29.99 kg/m^2 was considered overweight. A BMI 30 kg/m^2 and above was considered obese. Race/ethnicity was divided into four groups: Hispanic, Non-Hispanic Black, Non-Hispanic White, and others. Work status was categorized into not working, 0–30 h, 31–40 h, or 41+ h. Income was dichotomized into $\geq$\$100,000 and $<$\$100,000.

Statistical Analysis

The data was analyzed utilizing Stata 16 software package (StatCorp LLC, College Station, Texas) (18). Primarily, a descriptive analysis was implemented to check the distribution of each variable. A chi-squared was used to perform a bivariate analysis of categorical data according to the main independent and the outcome variable to check for possible confounders. A collinearity check was then performed to check whether there is too much correlation between the variables. Lastly, unadjusted and adjusted logistic regression analyses were used to calculate the odds ratios and corresponding 95% confidence intervals. The Hosmer-Lemeshow test was used to assess the goodness-of-fit of the logistic regression models.

RESULTS

Table 1 presents the characteristics of the study participants of the 2017 FLASHE survey according to access to free or low-cost recreational facilities ($n = 1{,}750$). There was no statistically significant difference in the distribution of the age groups according to whether they had access to free or low-costs facilities or whether they did not (chi-square p-value 0.119). However, there was a statistically significantly higher proportion of men in those with access to free or low-cost facilities (30.6%) compared with those without access (19.4%; p-value < 0.001). In addition, participants' race/ethnicity, health status, BMI, education, work status and household income were statistically significantly different among those with access to free or low-cost recreational facilities compared with those without access (p-values < 0.05). For instance, those with access to recreational facilities had a higher proportion of being normal weight (39.3%) than those without access (31.5%). Moreover, those with access tend to have a higher perceived excellent or very good health compared with participants without access to free or low-cost recreational facilities (59.5 vs. 52.7%). Finally, 24% of the participants who had access to recreational facilities had a household income of at least 100,000 USD/year whereas the corresponding proportion was 15.1% in those without access (p-value < 0.001).

The unadjusted and adjusted associations between respondent characteristics and meeting AHA PA guidelines, which were stratified by access to free or low-cost recreational facilities are presented in **Table 2**. Before adjusting for covariates, participants who had access to free or low-cost recreational facilities had an odds ratio (OR) of meeting AHA PA guidelines of 1.63 (95% CI 1.33–1.99) when compared with participants who did not. After adjustment for the covariates, participants who had access to free or low-cost recreational facilities had statistically significantly higher odds of meeting the AHA PA guidelines compared with participants who disagreed with this statement [adjusted OR (aOR) 1.42; 95% CI 1.14–1.76]. The adjusted odds of meeting the AHA PA guidelines for the 35–44 age group was 0.77 (95% CI 0.54–1.11), for the age 45–59 age group 1.01 (95% CI 0.57–1.21) and for those $\geq$60 years-old 0.88 (95% CI 0.31–1.27) when compared with participants age 18–34 years-old. Participants who reported being male were 1.99 times more likely to meet the AHA PA guidelines compared with females (aOR 1.99; 95% CI 1.49–2.65). Being non-Hispanic white, Hispanic (aOR 1.31; 95% CI 0.83–2.07), non-Hispanic black (aOR 0.85; 95% CI 0.64–1.14) or other (aOR 0.8; 5 95% CI 0.54–1.35) was not associated with meeting AHA PA guidelines. Regarding health status, participants who reported excellent health status were 2.42 times more likely to meet the AHA PA guidelines (aOR 2.42; 95% CI 1.66–3.52), while those who reported very good health status were 1.47 times more likely to meet them (aOR 1.47; 95% CI 1.14–1.90) when compared with those with good health status. Furthermore, obese participants compared with those having a normal BMI had 39% reduced odds to

TABLE 1 | Characteristics distribution of the 2017 FLASHE participants with and without access to free or low-cost recreational facilities.

Characteristics	Access to free or low-cost facilities				*p*-value[a]
	Agree (*n* = 1,079)		Disagree (*n* = 671)		
	%	(*n*)	%	(*n*)	
Age (years)					0.119
18–34	10.9	(118)	11.3	(76)	
35–44	41.9	(452)	46.1	(309)	
45–59	44.7	(482)	39.2	(263)	
60+	2.5	(27)	3.4	(23)	
Sex					<0.001
Male	30.6	(330)	19.4	(130)	
Female	69.4	(749)	80.6	(540)	
Race/ethnicity					<0.001
Hispanic	8.3	(89)	5.3	(35)	
Non-Hispanic black	18.9	(202)	14.9	(99)	
Non-Hispanic white	67	(717)	73.6	(489)	
Other	5.8	(62)	6.2	(41)	
Health status					0.022
Excellent	17.4	(186)	13.9	(93)	
Very good	42.1	(450)	38.8	(260)	
Good	28.6	(306)	34.9	(234)	
Fair/poor	12	(128)	12.4	(83)	
BMI					<0.001
Underweight	1.4	(15)	1.5	(10)	
Normal	39.3	(419)	31.5	(209)	
Overweight	31.9	(340)	28.8	(191)	
Obese	27.4	(292)	38.2	(253)	
Education					<0.001
High school or less	16.5	(177)	20.8	(139)	
Some college	33	(355)	39.8	(266)	
A 4-year college degree	50.5	(543)	39.5	(264)	
Work status					<0.001
Not working	30.9	(332)	39.4	(263)	
0–30 h	15.6	(168)	15.3	(102)	
31–40 h	32.5	(349)	30.6	(204)	
41+ h	21	(225)	14.7	(98)	
Household income					<0.001
<$100,000	75.7	(807)	84.9	(564)	
≥$100,000	24.3	(259)	15.1	(100)	
Time living					0.561
0–3	21.91	(236)	20.45	(137)	
>3–10	36.68	(395)	39.1	(262)	
>10	41.41	(446)	40.45	(271)	

[a]*Chi-square test p-value.*

meet PA guidelines (aOR: 0.61; 95% CI 0.46–0.80). Regarding education, having an educational level of high school or less, some college (aOR 1.09; 95% CI 0.81–1.47), or 4-year college degree (aOR 1.28; 95% CI 0.94–1.75) were all not associated with meeting the AHA PA guidelines. Household income status was not associated with increased or decreased likelihood of meeting the guidelines (aOR 1.32; 95% CI 0.98–1.79).

DISCUSSION

The main finding of the present study is that access to free or low-cost recreational facilities was positively associated with meeting the AHA PA guidelines in US adults. However, such association is also affected by sex, BMI, and health status, which were all associated with complying with the AHA PA

TABLE 2 | Unadjusted and adjusted association between access to free or low-cost recreational facilities and meeting the American Heart Association's Physical Activity Guidelines for Americans, 2017 FLASHE survey.

Characteristics	Meeting American Heart Association Physical Activity Guidelines	
	Unadjusted	Adjusted
	OR[a] (95% CI[b])	aOR[a] (95% CI[b])
Access to free or low-cost facilities		
Disagree	Ref[c]	Ref[c]
Agree	1.63 (1.33–1.99)	1.42 (1.14–1.76)
Sex		
Female	Ref[c]	Ref[c]
Male	2.23 (1.74–2.85)	1.99 (1.49–2.65)
Health status		
Good	Ref[c]	Ref[c]
Excellent	2.89 (1.05–4.06)	2.42 (1.66–3.52)
Very good	1.68 (1.33–2.12)	1.47 (1.14–1.90)
Fair/poor	0.60 (0.44–0.83)	0.70 (0.50–0.99)
BMI		
Normal	Ref[c]	Ref[c]
Underweight	0.63 (0.27–1.45)	0.59 (0.23–1.48)
Overweight	0.74 (0.58–0.96)	0.82 (0.62–1.08)
Obese	0.41 (0.32–0.53)	0.61 (0.46–0.80)

[a]*Age, Sex, Level of education, Overall health, BMI, Ethnicity, Hours of work per week, Household Income, Time living at current address.*
[b]*Odds ratio.*
[c]*Confidence interval.*
[d]*Reference group; p-value of the Hosmer-Lemeshow test for the adjusted model > 0.05.*

guidelines. When controlling for covariates, males were twice likely to meet AHA PA guidelines compared with females, and participants with obesity were 39% less likely to meet AHA PA guidelines compared with those with normal BMI; while those with excellent health status were 2.42 times more likely to meet AHA PA guidelines when compared with those who reported a good health.

Our findings on subjective availability of outdoor recreational facilities and higher levels of total leisure-time PA are in line with previously reported associations. For example, in a survey in five European urban regions, Mackenbach et al. found a 25% difference in weekly min of total leisure-time PA between individuals with and without availability of outdoor recreational facilities. They postulated that the availability of these facilities seemed to be an important underlying mechanism for increased populations' PA, and the proximity was the main motivator for using recreational facilities (19). Several other reports have also showed that individuals who resided in neighborhoods with higher number of public parks and recreational facilities were more likely to be regularly physically active (7–11). One study described an increased amount of park-based PA in people with two parks within one mile (aOR 2.29) and three or more parks in one mile (OR 2.53) compared with those without any parks within one mile radius (8). West et al. reported that significant, positive correlations between park density and reported PA ($r = 0.37$, $p < 0.01$), and between park density and reported performing regular exercise ($r = 0.35$, $p < 0.01$) (10). While availability of public parks is now an established determinant in meeting PA guidelines, the scientific literature is inconsistent when analyzing an association between the proximity of public parks and PA levels. Kaczynski et al. reported that distance was not significantly associated with an increased likelihood of PA at the park (8, 13). Conversely, Cohen et al. reported that people living within one mile of the park averaged 38% more regular exercise sessions per week compared to those living further (IRR 1.38; 95% CI 1.04–1.84) and were four times as likely to visit the park once a week or more than those living further away (12). Therefore, reporting on the access to free and low-cost PA facilities and its positive association with meeting PA AHA guidelines in our study provides a new approach for increasing PA and associated long term health benefits in US populations.

Our study relied on a more subjective reporting when observing the association between access to free and low-cost recreational facilities and an increased likelihood of being physically active among US adults. An important distinction between the subjective (e.g., availability dependent on factors such as cost, safety, and hygiene) and objective availability (e.g., actual access or use) of recreational facilities has been previously reported with a significant association between the subjective availability of recreational facilities and leisure-time PA, however when the analysis was based on the objective availability (or reported use) of recreational facilities the association was not statistically significant (19). This may be due in part because individuals who report access to outdoor recreational facilities do so because they use them regularly—resulting in stronger associations with the perceived measure of PA levels (20).

The secondary outcomes of our analysis suggest that the healthier a person is the more likely they are to have met AHA PA guidelines (aOR = 2.42 and 1.47 for Excellent and Good Health, respectively), which was irrespective of the participants' age (**Table 1**). This may be explained by increased time spent exercising which has previously been associated with better health status (21). Therefore, increased time spent and awareness among those with perceived poor health is necessary when promoting PA access across US populations. Looking at BMI specifically, individuals with obesity were significantly less likely to meet the national PA guidelines which is contradictory to Lee et al.'s finding of obese individuals (BMI 25 and above) having no difference in level of PA when compared with individuals who are not obese (22). Our results most likely differ due to a difference in definition of obesity (over 25 BMI Asian cutoff point vs. over 30 BMI in US) but can also be explained by various reasons including lack of social support, lack of time, choosing a sedentary lifestyle, or lack of motivation to use PA facilities (23, 24). Studies that integrated similar BMI stratification such as Hemmingsson et al. found similar results to ours of a clear association between BMI and level of PA (25). Sex had the largest impact on the odds of meeting PA guidelines where men were twice at odds of meeting PA guidelines than women. This finding is in line with previous studies that describe increased PA in males compared to females (26). It has been proposed in past studies that societal influences are stronger on males than

females regarding PA which can explain the increased likelihood of meeting guidelines for men (27).

Naturally, our study has some limitations. First, our cross-sectional study design lacks the ability to implement causality. While we can illustrate an association between two variables, we are unable to correlate the two due in part to the possibility of reverse causality. The study design also introduces the possibility of various types of bias. Our study measured PA by a self-reported questionnaire, which may over- or underestimate true PA behavior. Thus, there is potential for social acceptability biases. This may be illustrated in part by the larger than expected percentage of individuals that met requirements and the few impossible and few possible but improbable outcomes reported. Nevertheless, the PA questions in this study were validated against an objective PA accelerometer data ($r = 0.52$, $p < 0.01$) (28). Similarly, while this study makes an important distinction from past studies in that it reports people's access to free or low-cost facilities, we recognize that it is somewhat vague in its definition of accessibility. While it is important to recognize that there is an association between access and PA, there is no concrete quantitative data to be used by local governments to best implement new policies. A strength of this study was that it included a national sample from a large, regionally diverse sample of the U.S. population, although not nationally representative. The national sample allowed taking into consideration variation in environmental contexts, socio-demographics, and behaviors. For example, access to recreational facilities vary between most U.S. states. Therefore, using a national sample allows for more generalizable results than a study located in a specific city or state.

In conclusion, our data provides various recommendations that can be extrapolated for use by health professionals, public health officials and the public. We recommend increasing the availability of facilities such as parks, trails, fields, and courts in various neighborhoods, and to increase awareness of the availability of these facilities, perhaps *via* targeted social media, newspapers, magazines, and local television networks so that PA is promoted across wider populations especially females and those with poorer health conditions including those with obesity. Future studies could focus on improving access to free or low-cost recreational PA facilities by understanding individuals' barriers and facilitators to using such facilities and using more objective PA assessment approaches.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: https://cancercontrol.cancer.gov/brp/hbrb/flashe-study.

AUTHOR CONTRIBUTIONS

LA, RG, MM, AA, and NB contributed to the conception and design of the study. GC and PR supervised data collection. LA, RG, and MM organized the dataset and wrote the first draft of the manuscript. LA, RG, MM, GC, and PR performed the statistical analysis. AA, GC, PR, and NB revised the manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

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