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Different modalities of physical activity for psychological wellbeing and health promotion

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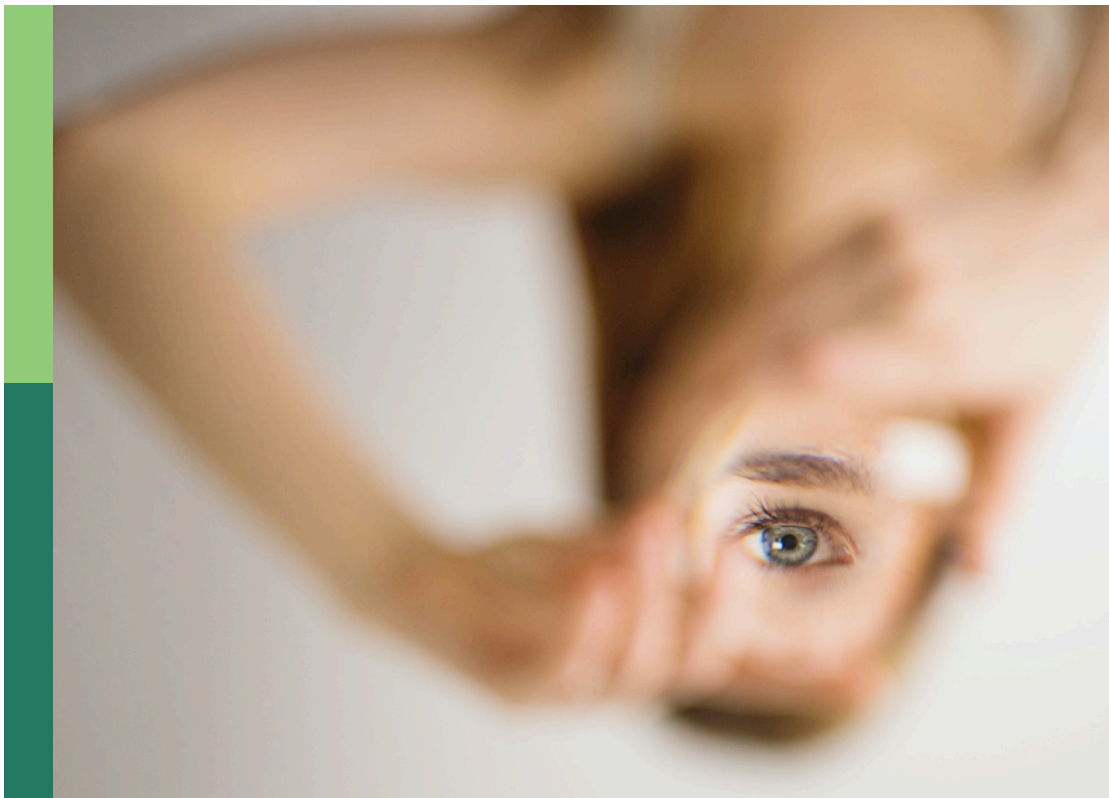

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Different modalities of physical activity for psychological wellbeing and health promotion

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Muscle-strengthening exercise and positive mental health in children and adolescents: An urban survey study

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Background: Much evidence has indicated that physical activity is associated with mental health benefits, such as fewer depression symptoms. Psychological resilience captures a broader mental health phenomenon that may be influenced by other factors as well. Yet, there are few studies examining the association between muscle-strengthening exercises (MSEs) with mental health outcomes, especially positive outcomes (e.g., subjective wellbeing). The study aimed to test the association between MSE with subjective wellbeing and resilience among a large sample of Chinese adolescents.

Materials and methods: A cross-sectional study was conducted among primary and middle school students in Shenzhen, China. MSE frequency, subjective wellbeing, and resilience were measured. Data from a total of 67,281 children and adolescents aged 10–17 years (51.9% men and 48.1% women) were included in the analysis. Mixed effect models were performed to assess how weekly MSE frequency (0–7 days) related to the levels of subjective wellbeing and resilience, adjusting for potential confounding variables (e.g., sex and grade). Sensitivity analyses were also conducted.

Results: Compared to participants with no MSE, the levels of subjective wellbeing were higher in those with higher MSE frequencies [range of β: 0.29 (1 day per week) to 1.98 (7 days per week)]. The frequency of MSE was also positively correlated to better resilience [range of β: 0.50 (1 day per week) to 4.40 (7 days per week)]. All associations remained significant in sensitivity analyses.

Conclusion: More frequent MSE was associated with superior subjective wellbeing and resilience of Chinese children and adolescents. Increasing MSE may be beneficial for promoting positive mental health outcomes among children and adolescents.

KEYWORDS

muscle-strengthening exercise, subjective wellbeing, resilience, adolescents, physical activity, mental health

Introduction

Physical activity has become one of the most significant health-related aspects in the lives of children and adolescents (Belcourt et al., 2016). They are identified as closely related to individual mental health and psychological disease of children and adolescents (Biddle and Asare, 2011). Physical activities have immediate and long-term health benefits at the same time. Recently, researchers have focused on the different modalities of physical activity and their associations with health benefits (Moljord et al., 2014; Belcourt et al., 2016; Rhodes et al., 2017). Among the various different modalities of physical activity, muscle-strengthening exercise (MSE) (Buecker et al., 2021) is an important form of physical activity that has attracted sufficient research interest and much evidence has confirmed the health benefits of meeting the MSE guidelines (the guidelines recommend that young people should do three or more times of MSE per week). The relations between mental health and MSE have attracted the attention of many researchers and the public (Biddle and Asare, 2011). For example, Bennie et al. (2019) drew data from the U.S. 2015 Behavioral Risk Factor Surveillance System. His study stated the relation and associations of MSE with negative symptoms severity among adults in the United States of America. The previous studies demonstrated that depression has been a severe problem in modern society and has significant impacts on children' and adolescents' development or adults' lives (Cohen et al., 2014; LaVigne et al., 2016; Warburton and Bredin, 2017). Studies also stated that both aerobic and MSE are associated with a lower likelihood of depressive symptoms severity (Gelaye et al., 2016; Bennie et al., 2019). Research also stated that physical activity is associated with indicators of sleep health (Gariépy et al., 2016; Werner-Seidler et al., 2017). The previous studies identified the significant functions of physical activity and MSE (Saunders et al., 2016; Yalcinkaya et al., 2017; Zasadzka et al., 2021). Mental health and subjective wellbeing overlap in concept, but can be regarded as different structures. Subjective wellbeing is usually defined according to the overall aspects of young people's life wellbeing (Carson et al., 2016; Wang et al., 2020). Some studies indicate that subjective wellbeing is negatively correlated with emotional disorders (Liu et al., 2014) and externalizing behaviors (Andersen et al., 2017). The latest data from the Millennium Cohort study show the correlation between mental health problems and subjective wellbeing of school-aged students (Hwang et al., 2021). The concept of resilience originates from the observation of its results (Levis et al., 2019): in terms of psychological resilience, it refers to people's health (or rapid recovery) in adversity (Levis et al., 2019). Psychological Resilience reflects a broader phenomenon of mental health, which may also be affected by other factors. It refers to the ability to maintain mental health or recover quickly after stress (Sun et al., 2021). Resilience is our "psychological immunity," which comes from the interaction in the complex and multifaceted biological psychosocial system (Levis et al., 2019). The implication of this complex dynamic system is that elasticity can change from time to time and from environment to environment.

The noted evidence has suggested that participating in more MSE would be beneficial to mental health (Gelaye et al., 2016). Moreover, this study showed that while achieving both aerobic activity and MSE guidelines is promising in improving positive mental health (Plummer et al., 2016; Sun et al., 2021), such as health-related quality of life. But a number of limited studies have been replicated to examine the positive mental health benefits of MSE in adolescents (Biddle and Asare, 2011; Bennie et al., 2020b). It is expectedly possible that young people can gain mental health benefits from MSE. To our knowledge, only one study is examining the association between MSE and mental health disorders in young people. However, concerning the relationship between MSE and positive mental health outcomes, the relevant studies remain scanty. To fill the gaps in this literature, it is needed to explore the association between MSE and positive mental health outcomes in children and adolescents.

Materials and methods

Study design and participants

The data used in the current study came from a sampling survey performed in March 2021, and the large-scale survey was carried out in Shenzhen, one of the developed Chinese cities. By working with the Educational Science Research Institute of Shenzhen, a sampling design involving multiple stages was adopted in the present study, and local students from different middle and primary schools in Shenzhen were included in the study. All the schools included in the study are public schools, and they are supervised by the Shenzhen Education Bureau under the guidance of the Ministry of Education of the People's Republic of China. The inclusion criteria include (1) grade 5 or 6 students of primary schools, or grade 1 or 2 students of junior high school, or grade 1 or 2 students of high school (the grade 3 students of junior high schools or high school, because they are busy with preparing for the college or high school entrance examination, and they can't make time for the survey); (2) students with good reading and understanding ability; (3) the students who are willing to take the survey after being well informed of study details. The exclusion criteria included the students, their guardians, or the teachers who didn't want them to take the survey or didn't think it is suitable for them to take the survey. The questionnaire was posted on the Wenjuanxing platform,[1] a platform for online survey in

1 https://www.wjx.cn/, accessed on March 8, 2022.

China. In this way, the students could conveniently fill out the form and submit it online. The purpose and background of the survey, and the informed consent were posted on the page before the questionnaire was started. All student participants and their teachers and guardians were informed of the details of the survey. The students who were willing to take the survey completed the form online (about 20 min to complete the form). Each class was a survey unit and the students would fill out the form during school time by following the instructions of their teachers under their supervision.

In total, 78,428 questionnaires were retrieved from 135 schools. After screening the questionnaires (for example, the questionnaires from the students who didn't submit on time, or the questionnaires with unidentifiable answers, or with too many repetitive answers). A total of 67,821 valid questionnaires were retrieved from the students aged between 10 and 17 years used in the study. The collection of data had been approved by the Institutional Research Ethics Board of Shenzhen University (grant number: 2020005).

Study measures

Muscle strengthening exercise

When collecting MSE information (Bull et al., 2020) about the students, the following questions were used: "In the last 7 days, how much time did you spend on the exercise to tone or strengthen the muscle, such as lifting weight, sit-ups, or push-ups?" The possible answers included: 0 = none, 1 = 1 day, 2 = 2 days, 3 = 3 days, 4 = 4 days, 5 = 5 days, 6 = 6 days, and 7 = 7 days. The item was adopted for surveillance of health behavior in other countries (Wiese et al., 2018). Moreover, the item was found to show acceptable reliability for children and adolescents with a Kappa coefficient greater than 0.55 (Kavetsos, 2011). Identical with the guidelines of the World Health Organization, children and adolescents who engaged in MSE for 3 days in the last 7 days had been considered as meeting the recommendations (Bottolfs et al., 2020).

Subjective wellbeing and resilience

Subject wellbeing is an indicator of hedonic wellbeing, and it was measured by the Five-item Wellbeing Index developed by the World Health Organization (Chinese version). Participants who had positive feelings in the past 2 weeks ranged from at no time to at all of the time on a 6-point scale. The higher the summed scores, the greater the levels of the subjective wellbeing. Psychometric properties of WHO-5 (Chinese version) were confirmed among adolescents in China, with a Cronbach's α coefficient of 0.94 for WHO-5.

Resilience, an indicator of eudaimonic wellbeing, was measured by the Connor–Davidson Resilience Scale (Chinese version), also known as CD-RISC-10, which includes 10 items. The CD-RISC-10 includes response options and the answers are scored from 0 to 4. Here, "0" stands for never, while "4" stands for almost always. The higher the total score, the greater the resilience level. The CD-RISC-10 was found to be suitable for the survey on Chinese adolescents. The Cronbach's α coefficient was 0.93 for CD-RISC-10 in Chinese adolescents.

Covariates

In addition to this, we also consider some sociodemographic factors as covariates in the further analysis, such as sex, age, grade, parental education level, perceived family affluence, and living with parents or not.

Statistical analysis

In the current study, all the statistical analyses were completed using STATA (BE/17.0 version). Descriptive statistics were used to report information on sample characteristics, which percentage was used for categorical variables while the mean was used for continuous variables. Two level-mixed effect models were performed to estimate the association between MSE and mental health indicators. Since the outcomes were tested as a normal distribution, adjusted beta coefficient (β) with corresponding 95% confidence intervals (95% *CIs*) were described. The lowest level of MSE was set as a reference for comparing the estimated results for outcomes to those with higher levels of MSE. In addition, to reduce the risk of estimation, we conducted a sensitivity analysis by stratifying MSE, of which were (1) 0–7 days; (2) 0–2 days, 3–5 days, and 6–7 days based on the previous studies (Bennie et al., 2020b); (3) meeting or not meeting the MSE guidelines according to the physical activity guidelines (Bull et al., 2020).

Results

The sample consisted of 51.9% men and 48.1% women, with a mean age of 13.04 years. The proportion of participants in each grade was 41.5, 40.3, and 18.10%, respectively. Approximately 76.2% of the participants perceived their families in middle economic status, and 72.5% of participants were in normal body mass index status. More than half of the participants had MSEs for 0–2 days, namely not meeting the MSE guideline. More detailed sample characteristics are provided in **Table 1**.

The association between MSE and subjective wellbeing scores is clearly presented in **Table 2**. Identifying the MSE day as a continuous variable, conducting MSE 1–7 days was positively associated with greater subjective wellbeing scores compared to exercise 0 day. Conducting MSE 3–5 days [β = 0.77, (0.67, 0.86)] and 6–7 days [β = 1.58, (1.43, 1.74)], was positively associated with greater subjective wellbeing scores compared to exercise 0–2 days when identifying exercise day as a 3 cut-offs variable. A positive association between meeting the MSE guidelines and

TABLE 1 Sample characteristics in this study.

Categorical variables	Proportion (%)
Sex	
Male	51.9
Female	48.1
Siblings	
Only child	25.8
Non-only child	74.2
Father's educational level	
Junior middle school or below	21.7
High school or equivalent	27.0
Bachelor or equivalent	38.7
Master or above	4.2
Unclear	8.4
Mother's educational level	
Junior middle school or below	26.2
High school or equivalent	27.8
Bachelor or equivalent	35.6
Master or above	2.4
Unclear	8.0
Living	
Living with parents	93.4
Not living with parents	6.6
Subjective economic status	
Low	17.9
Middle	76.2
High	5.9
Grade	
Primary school	41.5
Junior middle school	40.3
High school	18.1
Body mass index	
Normal	72.5
Overweight	12.3
Obese	15.2
Muscle-strengthening exercise days (continuous)	
0 days	24.9
1 day	18.1
2 days	18.4
3 days	15.9
4 days	6.7
5 days	7.9
6 days	1.6
7 days	6.4
Muscle-strengthening exercise days (3 cut-offs)	
0–2 days	61.4
3–5 days	30.6
6–7 days	8.0
Muscle-strengthening exercise guideline	
Not meet	61.4
Meet	38.6
Age	13.04
Subjective wellbeing scores	20.15
Resilience scores	34.61

TABLE 2 Results for the associations between muscle strengthening exercise and subjective wellbeing scores.

Subjective wellbeing scores	β	95%CI		*P*-value
Muscle strengthening exercise days (continuous)				
0 days			Ref	
1 day	0.29	0.16	0.42	0.000
2 days	0.63	0.50	0.76	0.000
3 days	0.86	0.73	1.00	0.000
4 days	1.20	1.01	1.38	0.000
5 days	1.37	1.20	1.55	0.000
6 days	1.50	1.16	1.84	0.000
7 days	1.98	1.80	2.17	0.000
Muscle strengthening exercise days (3 cut-offs)				
0–2 days			Ref	
3–5 days	0.77	0.67	0.86	0.000
6–7 days	1.58	1.43	1.74	0.000
Muscle strengthening exercise guidelines				
Not meet			Ref	
Meet	0.93	0.84	1.02	0.000

β, beta coefficient; CI, confidence interval; Ref, reference group.

TABLE 3 Results for the associations between muscle strengthening exercise and resilience scores.

Resilience scores	β	95%CI		*P*-value
Muscle strengthening exercise days (continuous)				
0 days			Ref	
1 day	0.50	0.32	0.69	0.000
2 days	1.24	1.05	1.42	0.000
3 days	1.78	1.58	1.97	0.000
4 days	2.54	2.28	2.80	0.000
5 days	2.82	2.57	3.07	0.000
6 days	3.32	2.83	3.80	0.000
7 days	4.40	4.13	4.66	0.000
Muscle strengthening exercise days (3 cut-offs)				
0–2 days			Ref	
3–5 days	1.64	1.51	1.78	0.000
6–7 days	3.60	3.38	3.83	0.000
Muscle strengthening exercise guidelines				
Not meet			Ref	
Meet	2.04	1.91	2.17	0.000

β, beta coefficient; CI, confidence interval; Ref, reference group.

greater subjective wellbeing scores [β = 0.93, (0.84, 1.02)], was observed compared to not meeting MSE guidelines.

It is shown clearly in Table 3 that conducting MSE 1–7 days, when exercise day was identified as a continuous variable, was positively associated with greater resilience scores compared to exercise 0 day. When identifying MSE day as a 3 cut-offs variable, conducting MSE 3–5 days [β = 1.64, (1.51, 1.78)] and 6–7 days [β = 3.60, (3.38, 3.83)], was positively associated with

the greater resilience scores compared to conducting exercise 0–2 days. A positive association between meeting MSE guidelines [$\beta = 2.04$, (1.91, 2.17)] and greater resilience scores was observed when compared to not meeting MSE guidelines.

Discussion

The present study investigated the associations of MSE with subjective wellbeing and resilience in children and adolescents from an urban city in China. We mainly found that more participation in MSE was favorably associated with subjective wellbeing and resilience scores in children and adolescents in this study. To our knowledge, our study is the very one first to explore whether MSE or not would be associated with better subjective wellbeing and resilience in children and adolescents. This study can advance the knowledge in mental health promotion. The below presents detailed discussions on the association between MSE and mental health indicators.

The previous study conducted that resistance training can effectively improve all areas of positive mental health (Bennie et al., 2019). Similarly, data showed that the mental health status of the strength training group was significantly improved after 12 weeks compared with the control group (Yu et al., 2021). Contrary to the results of current studies, some studies have pointed out that resistance training is effective in improving positive mental health (Kjaer, 1992; Smith et al., 2014; Yeatts et al., 2017). In addition, the previous studies have confirmed the positive association between physical activity and subjective wellbeing (Lubans and Cliff, 2011; Ortega et al., 2012; Rodriguez-Ayllon et al., 2018). In addition to this, there has been evidence suggesting sufficient physical activity role in promotion resilience in children and adolescents (Bottolfs et al., 2020). Such a research finding is replicated in other studies (Skrove et al., 2013; Moljord et al., 2014). Although evidence concerning the association between sufficient physical activity and subjective wellbeing and resilience is, at present relatively, the art of state in the literature can support the desirable effects of physical activity in improving mental health wellbeing indicators in children and adolescents. The above evidence can collectively support the current study. The sensitive analysis indicated that MSE was positively with both subjective wellbeing and resilience scores irrespective of cut-offs for the independent in children and adolescents. This result suggests that any increases in MSE would be a contributor of better mental health indicators. Because MSE is a specific type of physical activity, it is expected that MSE can play a similar role of physical activity, in terms of positive mental health promotion. In this regard, it would seem that promoting MSE for children and adolescents is a feasible approach for mental health interventions. Our study results maintain this expectation and provide cross-sectional evidence. Based on our research finding, it would be possible to increase positive mental health through MSE promotion in children and adolescents.

However, to better explain the association between MSE and subjective wellbeing and resilience, some possible underlying mechanisms can be proposed but need further supportive evidence. First of all, participation in physical activity can enhance adolescents' wellbeing (Biddle and Asare, 2011). As MSE is a specific kind of physical activity, it is reasonable that participating in more MSE can enhance the mental wellbeing outcomes, such as subjective wellbeing and resilience. Another explanation is that MSE has been found to be negatively associated with mental health disorder indicators. For example, some observational studies have revealed an association between MSE and depression (Bennie et al., 2019, 2020a,b; Yu et al., 2021). Since mental wellbeing outcomes are conversely associated with the mental disorder indicators, it is sensible that MSE reduces the odds of mental disorder indicators, which in turn increase scores of mental wellbeing outcomes. However, this explanation needs further studies to examine, especially mediation studies. From the perspective of fitness promotion, participating in MSE at sufficient intensity can improve health-related fitness (i.e., muscular fitness), which may be necessary to induce neurobiological adaptations. According to the cross-stressor adaptation (CSA) hypothesis (Kjaer, 1992), participants who regularly engage in MSE have a higher response similar to that following exposure to a psychosocial stressor (i.e., increase in heart rate, respiration, and blood cortisol). The CSA hypothesis posits that the beneficial adaptation of the hypothalamic–pituitary–adrenocortical axis and the sympathoadrenal medullary system during physical exercise can generalize to psychosocial stressors and may improve positive mental health (Mücke and Ludyga, 2018).

Moreover, multiple studies using various muscle strength indices have linked MSE with mental health symptoms. It has been suggested that MSE may have unique mental health benefits for adolescents (Biddle and Asare, 2011; Smith et al., 2014; Yeatts et al., 2017). A recent study found that absolute upper- and lower-body muscular strength was positively associated with self-esteem in a small sample of overweight/obese children (Rodriguez-Ayllon et al., 2018). In another study involving adolescents, MSE was found to be positively associated with physical self-perceptions (i.e., perceived appearance and sports competence) (Lubans and Cliff, 2011), which are known to generalize to global self-esteem. The relationship between handgrip strength and perceived stress was dose-dependent for both sexes. Low handgrip strength was associated with poor mental health among boys (Hwang et al., 2021). These positive relationships support that MSE can improve the mental health through the better physical fitness

levels. Powerful evidence for the benefits of MSE for mental health can be observed in a 24-year longitudinal study involving more than one million male adolescents (16–19 years) (Ortega et al., 2012). Another longitudinal study involving middle school students revealed that higher levels of physical fitness, such as MSE, were associated with improved mental health (i.e., lower levels of depression, peer rejection, loneliness, internalizing symptoms as well as higher levels of adaptive functioning, externalizing symptoms, self-worth, and perceived competence) (LaVigne et al., 2016).

Study limitations and strengths

A key limitation is that the cross-sectional design limits inferences of causality for the association between MSE and mental outcomes. Longitudinal and experimental evidence related to this topic is scarce and future studies should adopt the longitudinal and experimental design to examine the findings from cross-sectional studies. Due to the age range of 10–17 years involved in this study, there may be some limitations. A further limitation concerns the measurement of MSE. Following the recommendation raised by the WHO, which only focuses on the frequency of MSE, we did not capture other aspects of MSE, such as duration and type. However, these factors might affect the association between the frequency of MSE and health outcomes. Future studies are encouraged to investigate more information about MSE and its potential health benefits. As for the strengths of this study, the large sample size is notable. More importantly, considering that most studies that aimed to examine the relationship between physical activity and mental health outcomes used negative outcomes or psychological symptoms (e.g., depression and anxiety), we set positive mental health indicators as the outcomes, which add new evidence to the existing knowledge base from another perspective. Meanwhile, in addition to demographic factors, depression and anxiety scores were adjusted in the models to better clarify the relationship between MSE and positive mental health outcomes. Besides, it should be noted that we used reliable and valid questionnaires to measure the mental outcomes.

Conclusion

Among a large sample of Chinese children and adolescents, the weekly frequency (days) of MSE was associated with a higher level of subjective wellbeing and resilience. Although longitudinal and experimental studies are needed to better verify the association, our preliminary evidence suggests that at least 1 day of MSE might be related to improved positive mental health outcomes. Hence, MSE deserves more attention in physical activity programs targeted at children and adolescents. These findings highlight an urgent unmet need in future MSE public health intervention for children and adolescents. Moreover, the benefits of MSE on mental health may also be emphasized in health education.

Data availability statement

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

Author contributions

XHZ developed the screen strategy, drafted the manuscript, and summarized the findings. CJ contributed to methodology, summarized the findings, and drafted the manuscript. XCZ contributed to formal analysis, review, and editing and assessed the manuscript. XC contributed to resources, data curation, and analysis. XHZ and CJ reviewed and edited the final manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

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

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Associations of muscle-strengthening exercise with overweight, obesity, and depressive symptoms in adolescents: Findings from 2019 Youth Risk Behavior Surveillance system

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Background: Previous studies have focused on the opposite relation between muscle strength, obesity, and depression in adults. Moreover, the evidence has indicated that obesity and depression in adults might be significantly decreased with Muscle Strength Exercise (MSE) albeit it might be insufficient. Therefore, the current study aimed to investigate the association between MSE, adiposity, and depression among United States adolescents.

Materials and methods: This cross-sectional study used the Youth Risk Behavioral Survey (YRBS) data. In YRBS, a cluster sample was used, and the investigation was divided into three stages. The study surveyed 13,677 high school students and conducted self-reported questionnaires on sex, grade, race/ethnicity, MSE days, overweight, obesity, and depressive symptoms. The study got the nationally representative population of American students in Grade 9 to 12 (around 12–18 years).

Results: A total of 13,677 participants (female = 6,885, male = 6641) were included in the final analysis. The participants meeting the guidelines' requirements seemed more likely to be obese than those not meeting (OR = 1.28, 95% CI = 1.06–1.55). There was no statistical significance in the relations between the MSE guidelines and overweight and depression (OR = 0.86, 95% CI = 0.73–1.01: OR = 0.94, 95% CI = 0.83–1.06). For all the participants, the prevalence of those conforming to MSE was 30.1%. One-fifth of the participants reported no MSE per week, 7.8% reported 3 days of MSE per week, and 7.7% reported 7 days.

Conclusion: The main finding of this study indicated a positive relationship between the normative MSE required in guidelines and low-level obesity. Beyond that, the evidence was insufficient to confirm the positive links between MSE and depression among American adolescents. Our study could offer evidence for future MSE interventions in adolescents.

KEYWORDS

muscle-strengthening exercise, body mass index, high school students, the Youth Risk Behavior Surveillance, overweight

Introduction

Overweight and obesity are excessive or abnormal fat accumulation that is risky to people's health (Abdelaal et al., 2017; Piché et al., 2020). A person is overweight if the Body Mass Index (BMI) exceeds a certain value. People are obese if their BMI exceeds 30 (Ho-Pham et al., 2015; World Health Organization, 2021). Obesity is a critical risk factor for mortality and morbidity, as it also accounts for a life expectancy drop (Abdelaal et al., 2017; Blüher, 2019). For example, according to past research, there is an association between obesity and metabolic diseases (fatty liver disease and type 2 diabetes), cardiovascular diseases such as stroke, myocardial infarction, and hypertension, mental health such as self-esteem and depression, musculoskeletal diseases, bullying, and some cancers (Daniels et al., 2009; Osier et al., 2017). In the past 50 years, the prevalence of obesity has been high globally. For instance, from 1975 to 2016, the overweight prevalence increased significantly, considering the number of obese adolescents and children aged between 5 and 18 years increased by four times, from 4 to 18% worldwide (Suder et al., 2017; Magriplis et al., 2021; World Health Organization, 2021). Similarly, the results of some research indicated that the trend of increased obesity cases was identified among adolescents in the US, and the problem of obesity might lead to medical expenditures of up to 300 billion dollars every year (Kosti and Panagiotakos, 2006; Hammond and Levine, 2010).

Considering the negative impacts of obesity, reducing the prevalence of obesity among adolescents has become a high priority for most countries. The World Health Organization (WHO) recommended that children and adolescents aged 5–17 years should participate in vigorous-intensity aerobic physical activities and Muscle Strength Exercise (MSE) at least 3 days a week (Foster et al., 2018; Bull et al., 2020; Lin and Yan, 2020; World Health Organization, 2020; Gu et al., 2022; Shi et al., 2022). Several studies revealed that physical activity intervention combined with a nutritional component was a major effective way to decrease obesity and overweight among children and adolescents (Kelley and Kelley, 2013; Mei et al., 2016; Godoy-Cumillaf et al., 2019, 2020). Other studies indicated that traditional physical activity approaches might exert small effects on preventing youth obesity (Guerra et al., 2014; Peirson et al., 2015). Besides, one study showed that aerobic training intervention had small effects on reducing body fat and body mass percentage among adolescents (Schranz et al., 2013). Although regular aerobic moderate-to-vigorous physical activities are of great health significance (Shen et al., 2020; Chen et al., 2022), MSE can be an alternative form of physical activities for those people who have barriers to perform traditional physical activities (e.g., adolescents with disabilities) (Bennie et al., 2020a).

Muscle strength exercise can be defined as a voluntary strength/weight/resistance activity that includes using weight machines, exercise bands, hand-held weights, or own body weight (Ratamess et al., 2009; Lin and Yan, 2020). MSE is beneficial to increasing muscle strength and endurance, aerobic fitness, and bone mineral density, improving body composition, and obtaining lower body pressure among adolescents (Faigenbaum and Myer, 2010; Chen et al., 2022; Gu et al., 2022). According to emerging epidemiological evidence, muscle strength was inversely associated with obesity (Thivel et al., 2016) and a lower level of cardiovascular disease risk factors (Grøntved et al., 2015) among young people. For instance, a cross-sectional study conducted among children and adolescents indicated that overweight or obesity was linked to a lower level of handgrip strength among boys and girls (Palacio-Agüero et al., 2020).

Early studies have suggested the association between individuals' physical characteristics and mood disorders. In the longitudinal research conducted by Okholm et al. (2021), the researchers recruited 630,807 male participants from Denmark. After following the participants for 26 years and collecting relevant information about their physical activities and health data, the study suggested that individuals with lower BMI have lower risks of mood disorders as they become adults. Nevertheless, this study's sample only involved Danish men aged from 18 to 24 years old, and the findings might not be generalizable to a larger population such as American adolescents. Also, Bao et al. (2022) conducted a 7-year

longitudinal study to investigate the relationship between individuals' muscle strength and the risk of depression. As the findings suggested, an individual's muscle mass developed a significant negative association with the development of depressive symptoms. Furthermore, the study demonstrated that lack of muscle mass might be a predictive risk factor for depression among middle-aged and elderly individuals (Bao et al., 2022). However, the impact of MSE on depression remained unclear.

Moreover, a significant association between physical activities and depressive symptoms among adults over 45 years old has been found. In a newly published study conducted by Kim (2022), it has been suggested that individuals' daily exercise time duration might be negatively linked with symptoms of depression, suggesting the preventive effect of regular exercise on depression. However, the participants of this study were adults over 45 years old, and this finding might not be generalizable to the younger adolescent population.

Previous studies investigated the relationship between daily exercise levels and depression. Little evidence has been found to demonstrate the association between MSE and individuals' depressive symptoms, especially for this kind of sample based on the national representative. Therefore, this cross-sectional study targeted identifying the association between MSE, adiposity, and depression among American adolescents.

Materials and methods

Study population

This study used the 2019 Youth Risk Behavior Surveillance System data (YRBS), a national survey conducted by the Centers for Disease Control and Prevention (CDC). More details on the YRBS can be found through the link.[1] In 2019, a self-administered survey of YRBS was conducted, and the survey involved 13,677 students of high schools based on a cluster-sample design of three stages. The population with national representativeness is obtained from the students in grades 9 to 12 in the United States. The general response rate is 60%. Based on the YRBS sample, estimates are obtained with accuracy within $\pm$ 5% at a 95% confidence level.

Overweight/obesity

Within the YRBS, the determination of overweight and obesity was derived from body mass index (BMI) percentiles. Self-reported height and weight of study participants were collected and converted into BMI for classifying overweight or obesity according to CDC BMI age- and sex-specific percentiles (BMI was $\geq$ 85th percentile). In sum, of the total eligible study participants, 27.2% of them were classified as overweight or obese.

Muscle-strengthening exercise

It was required for participants to submit their information on MSE. The question was "How many MSEs did you do last week to build muscle?" MSE referred to activities involving major muscle groups in this study, such as push-ups, weightlifting, crunches, or pull-ups, and the definition can offer assistance to participants in understanding and filling out questionnaires. Participants' response times ranged from 0 to 7 days. This method was taken as a reliable and effective method to evaluate the MSE of young people (Song et al., 2013; Gu et al., 2022). According to the well-recognized MSE guidelines (WHO, 2020), in this study, the variable of MSE was treated as a binary variable in the statistical analyses (0 = not meet [reporting 0–2 days], 1 = meet [reporting 3–7 days]).

Covariates

Information on study participants' sex (female/male), grade, race/ethnicity, eating behavior relative variables (drinking fruit juice and milk, eating fruit, green salad, potatoes, carrots, other vegetables, breakfast), and participating in physical activity, and watching television were measured by a self-reported questionnaire. These factors were treated as covariates in further statistical analysis (see **Supplementary Table 1**).

Statistical analysis

Statistical Product and Service Solutions (SPSS) version 26.0 was used for all statistical analyses. The complex survey commands based on design were adopted to adjust the complex design of the YRBS survey sample. Population weights were included to adjust unequal selection possibilities. The complete case was performed to process the missing data (all the cases with missing data were removed). Descriptive analysis was applied to report the characteristics of the individual sample. Binary analyses of logistic regression were performed to check the relationship between meeting combinations of the MSE guidelines for obesity (yes or no), overweight (yes or no), depressive symptoms (yes or no), eating behavior (yes or no), physical activity at least 60 min per day 5 days or more days (yes or no), watched television three or more hours per day (yes or no), played video or computer games or used a computer three or more hours per day (yes or no), played on at least one sports team (yes or no). A generalized linear model was

1 https://www.cdc.gov/healthyyouth/data/yrbs/index.htm

performed to predict relations between MSE guidelines and obesity, overweight, and depression. Statistical significance has been defined as $P < 0.05$.

Results

Characteristics of the study sample are displayed in Table 1. The sample consisted of 50.3% girls (n = 6,885) and 48.6% boys (n = 6,641), and grade 10 was the most participants (27.2%). One in five participants reported zero days of MSE per week, followed by three (7.8%) and seven (7.7%) days. In total, 30.1% met the MSE recommendation. Around four in five adolescents who were overweight (n = 10,207, 74.6%) or obese (n = 10,345, 75.6%) failed to meet MSE guidelines, and there was more than one in three participants under depressive symptoms (n = 4,926, 36.0%).

Table 2 shows the results of multilevel logistic regression, and it can be found that there is a relationship between the potential correlations and meeting the MSE guidelines in the study sample. Participants who meet guidelines are more likely to be obese than those who are not (OR = 1.28, 95% CI = 1.06–1.55). The associations between MSE guidelines and overweight, depressive symptoms were no longer statistically significant in the adjusted model (OR = 0.86, 95% CI = 0.73–1.01: OR = 0.94, 95% CI = 0.83–1.06).

TABLE 1 Sample characteristics of study participants.

		n	%	Weighted %	95% CI	
Sex	Girl	6,885	50.3	49.4	47.9	50.9
	Boy	6,641	48.6	50.6	49.1	52.1
	Missing	151	1.1			
Grade	9	3,637	26.6	26.6	25.4	28.0
	10	3,717	27.2	25.5	24.7	26.3
	11	3,322	24.3	24.3	23.2	25.4
	12	2,850	20.8	23.6	22.4	24.8
	Missing	151	1.1			
Race/ethnicity	White	6,668	48.8	51.2	46.4	56.0
	Black or African American	2,040	14.9	12.2	10.2	14.6
	Hispanic/Latino	3,038	22.2	26.1	21.8	30.9
	All other races	1,493	10.9	10.5	7.9	13.9
	Missing	438	3.2			
MSE days	0 days	2,568	18.8	29.7	27.6	32.0
	1 day	812	5.9	9.2	8.4	10.2
	2 days	973	7.1	11.6	10.8	12.5
	3 days	1,067	7.8	12.6	11.3	14.1
	4 days	763	5.6	9.1	8.4	9.9
	5 days	877	6.4	10.5	9.4	11.8
	6 days	361	2.6	4.4	3.8	5.1
	7 days	1,053	7.7	12.8	11.9	13.8
	Missing	5,203	38			
MSE guidelines	Meeting	4,121	30.1	49.5	47.6	51.3
	Not meeting	4,353	31.8	50.5	48.7	52.4
	Missing	5,203	38			
Overweight	Yes	1,933	14.1	16.1	14.9	17.5
	No	10,207	74.6	83.9	82.5	85.1
	Missing	1,537	11.2			
Obesity	Yes	1,795	13.1	15.5	13.8	17.3
	No	10,345	75.6	84.5	82.7	86.2
	Missing	1,537	11.2			
Depressive symptoms	Yes	4,926	36	36.7	35.1	38.3
	No	8,495	62.1	63.3	61.7	64.9
	Missing	256	1.9			

MSE, muscle-strengthening exercise; CI, confidence interval.
MSE guidelines: children and adolescents should amass three times per week; adults should amass two times per week.

TABLE 2 Association between muscle strength exercise (MSE) guidelines and obesity, overweight, and depressive symptoms.

		OR	95% CI	
Obesity MSE guidelines	No	1.28	1.06	1.55
	Yes		REF	
Overweight MSE guidelines	No	0.86	0.73	1.01
	Yes		REF	
Depressive symptoms MSE guidelines	No	0.94	0.83	1.06
	Yes		REF	

MSE, muscle-strengthening exercise; CI, confidence interval.
MSE guidelines: children and adolescents should amass three times per week; adults should amass two times per week; The model controlled: sex (female/male), grade and race/ethnicity.

Discussion

This study aimed to examine the association between meeting MSE guidelines and the prevalence of overweight or obesity and depression among American adolescents. Since few studies focused on this association, this study could provide a new perspective for preventing obesity among adolescents. The main findings indicated that regardless of sex, meeting the MSE guideline was associated with a lower level of obesity rather than overweight.

The present study revealed that meeting MSE recommendations were related to a lower probability of obesity. Even if limited population-based studies were concentrated on the association between meeting MSE guidelines and obesity, considerable experimental evidence proved that MSE positively impacted obesity among adolescents (Shaibi et al., 2006; Behm et al., 2008; Lee et al., 2012; Dias et al., 2015). To name but a few, one review study implied that moderate-intensity of MSE could reduce obesity and overweight among adolescents (Dietz et al., 2012). Another study showed that body fat reduction was significant after exposure to a 12-week MSE in obese adolescents (Dias et al., 2015). Beyond that, the body fat decreased significantly after accepting a 16-week resistance training program among male adolescents (Shaibi et al., 2006). One randomized controlled trial demonstrated that resistance exercise was correlated with the reduction of abdominal fat in obese male adolescents (Lee et al., 2012). Given the limitation of samples (Shaibi et al., 2006; Lee et al., 2012), it is necessary to delve into the association between MSE and obesity in both boys and girls in the future. Similar to one cross-sectional study on children and adolescents (Palacio-Agüero et al., 2020), our study also found that the MSE was inversely associated with obesity among American adolescents. However, MSE days were irrelevant to a lower level of obesity among American adolescents in the present study. According to the WHO recommendations, positive impacts will be possible when adolescents participate in muscle strength exercises at least 3 days a week (World Health Organization, 2020). Previous studies demonstrated that MSE could increase metabolic rate and/or total energy expenditure (Buzzachera et al., 2015). Hence, the MSE at least 3 days/week might be viewed as a benefit for a healthy weight, and an accumulated dose might be required for the positive effects of the MSE on low-level obesity among adolescents.

The MSE was not associated with overweight among adolescents in this population-based study, which was consistent with several studies. For example, the previous studies demonstrated that the MSE (e.g., weight training) had little effect on reducing overweight among adolescents (Atlantis et al., 2006). However, the included studies in this review implied that the weight training frequency was less than 3 days/week (Atlantis et al., 2006; Haykowsky et al., 2007; Caron et al., 2016), which might be a possible reason for the heterogeneity between this review and MSE guidelines. An evidence-based review proved that participating in resistance training programs did not impact adolescents' weight and body composition (Malina, 2006). Due to the large heterogeneity in the measurement of the MSE in the previous studies and the lack of comparable cross-sectional studies, as well as adolescents in a period of rapid changes in the body, there are limited studies to identify the relationship between the MSE and overweight. In the future, more studies should focus on this topic.

The current study found no association between meeting the MSE guidelines and depression. Based on the results of this study, no significant association between meeting MSE guidelines and depressive symptoms was discovered. For instance, as Bennie et al. (2019) suggested, individuals who meet the guidelines for the MSE had lower risks of developing depression. A potential explanation of the current results was that the previous studies were mainly conducted among the adult population, and the findings are not generalizable to younger adolescents populations. Furthermore, it might be possible that the preventive effect of the MSE on depression is only significant for those with severe depressive symptoms. In a study conducted in Germany, the researchers recruited over 20 thousand respondents, proving a negative relationship between MSE levels and the occurrence of depression (Bennie et al., 2020b). Moreover, this correlation seems to become increasingly significant with participants who suffer from more severe depressive symptoms. As a result, further studies need to consider the severity of depression when investigating the relationship between physical activity level and depressive disorders.

Practical implication

Our study has revealed that MSE is inversely associated with obesity among American adolescents, in contrast, no significant relationship has been identified between MSE and depression, which is worthy of further investigation. Overall, the finding

implicates the role of strength training in the treatment of overweight. The fact is that adding resistance training to the workout routine can greatly preserve muscle mass and elevate metabolism to support weight reduction. However, contrary to the result of trustworthy scientific research, a large portion of people prefer aerobic activities instead of strength training as they suppose that it is only applicable to bodybuilders. This is quite a popular misunderstanding. From a clinical perspective, this study suggests that fitness coaches or doctors can add individualized strength training to obese people to improve muscle strength, improve exercise performance and complete more high-intensity fat-burning exercises. Further, the finding indicates that not only obese people but others with chronic health problems can work out to meet MSE guidelines since promoted strength and coordination brought by MSE are required for daily activities and benefit every one of all ages.

Strengths and limitations

This study could contribute to this topic in the following aspects. On the one hand, we used a representative sample to delve into the association between the MSE guidelines and obesity and overweight. On the other hand, this study might be one of the limited ones focusing on adolescents.

Several limitations should be acknowledged. First and foremost, due to the limitation of cross-sectional investigation, the causal inferences between the MSE guidelines and obesity are not the scope of our study. Other factors like dietary, mental health, and aerobic physical activity should be considered in future studies. Besides, only adolescents were included in this study, but other population subgroups should be included in future studies. Finally, future large-scale interventions or longitudinal studies should further confirm the association between MSE guidelines and obesity, overweight and depressive symptoms in varied populations.

Conclusion

The main finding of this study is that meeting MSE guidelines was positively associated with a lower level of obesity, but this association is not found between days of MSE and a lower prevalence of obesity among United States adolescents. Besides, no association was observed between meeting MSE guidelines and depression in United States adolescents.

Data availability statement

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

Ethics statement

Ethical review and approval were not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

JS: writing—original draft. JY and MG: formal analysis. XX, JY, and XZ: writing—review and editing. MG and XZ: supervision. JY: project administration. XZ and JS: funding acquisition. All authors read and agreed to the published version of the manuscript.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.980076/full#supplementary-material

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Exploring the self-reported physical fitness and self-rated health, mental health disorders, and body satisfaction among Chinese adolescents: A cross-sectional study

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Background: Physical activity (PA) and Physical fitness (PF) have received tremendous attention in the field of physical and mental health. However, limited attention has been given to the associations of self-reported physical fitness with some health-related outcomes. Given the COVID-19 pandemic is still active in many Chinese regions, assessing health-related physical fitness (HRPF) in adolescents using field-based assessment (such as a shuttle run for cardiorespiratory fitness) is unrealistic, therefore, this study was conducted via a self-reported questionnaire.

Purpose: The present cross-sectional study was aimed at delving into the relationship between self-reported physical fitness with self-rated health, depression, anxiety, and body satisfaction in adolescents. Three thousand eight hundred and seven study participants from 12 public schools in South-eastern China were recruited and 2,407 of them provided valid data on variables that this study needed for analysis.

Materials and methods: Study participants were asked to self-report their sociodemographic factors (e.g., sex, grade, age), independence, and outcomes. Generalized linear models were used to explore the associations of self-reported physical fitness (comprising general physical fitness, cardiorespiratory fitness, muscular strength, speed and agility, and flexibility) with depression, anxiety, and body satisfaction. A total of 2,407 children and adolescents with a mean age of 13.82 (±2.1) years were included in the final study analysis.

Results: Higher self-reported levels of general physical fitness and cardiorespiratory fitness were associated with better self-rated health, and body satisfaction but with lower risks of depression and anxiety.

Conclusion: The current study offered evidence on the roles of self-reported physical fitness and health-related outcomes. To facilitate health in children and adolescents, advocating fitness education, and promotion could be a feasible approach.

KEYWORDS

fitness promotion, overall health, depression, anxiety, body, school-aged student

Introduction

There is a causal relationship between physical activity (PA) and physical fitness (PF) (Zhang et al., 2022). PA has been considered one of the most significant health-related aspects of the lives of children and adolescents (Bermejo-Cantarero et al., 2021; Ren et al., 2021). It is well-established that regular engaging PA has proven to be a vital method for improving body and tissue functions (D'Isanto et al., 2019; Chen and Yan, 2020; Ren et al., 2021). Evidence demonstrates that regular PA can prevent and treat physical diseases (Eather et al., 2013; Lin and Yan, 2020; Shen et al., 2020), as well as play a crucial role in improving mental health (Stanton et al., 2014; Liu et al., 2022).

It is widely accepted that PF can be evaluated as the comprehensive ability of the body to adapt to the surrounding environment (Ullah et al., 2012; Chen et al., 2022; Shi et al., 2022). The definition endowed by Marques et al. (2017) is that it enables everyone to choose the most suitable form and intensity of exercise for their own needs in all kinds of situations to improve their physical fitness and maintain the best health. The authors summarized fitness as the support of four factors, including the ability to perform physical activities that require speed, endurance, strength, and flexibility (Marques et al., 2017). Physical fitness is divided into health-related and skill-related health (Grier et al., 2017; Smits-Engelsman et al., 2020). The five components that get involved in health-related physical fitness (HRPF) include cardiorespiratory fitness, body composition, muscle strength, muscle endurance, and flexibility (Gu et al., 2016; Kim et al., 2021). There is considerable evidence that increasing HRPF levels among adolescents have health and academic benefits (Cattuzzo et al., 2016). For instance, adolescents with high HRPF levels are only less likely to develop cardiovascular disease later in life (Baumgartner et al., 2020). Adolescents' cardiopulmonary health has a positive correlation with their academic performance due to its promoting effect on psychological emotion and learning concentration (Bailey et al., 2009; Padilla-Moledo et al., 2020; Liu et al., 2022), and a study by Del Giudice et al. (2021) found that a lack of daily step counts would have higher odds of being hypogonadal. Muscle health, such as strength and endurance, makes adolescents with low-risk obesity more likely to be active in physical activities (Malm et al., 2019; Chen and Yan, 2020; Lin and Yan, 2020; Comeras-Chueca et al., 2021; Gu et al., 2022). Moreover, a random control trial study by Mavilidi et al. (2021) found that PF can significantly improve children and adolescents' cognitive control, working memory, and subjective vitality in a school setting. Of note, cross-sectional research has revealed that children and youth with higher fitness levels have greater hippocampal volume and memory performance compared with lower-fit children (Chaddock et al., 2010). It can be explained that regular engaging PT could stimulate angiogenesis and neurogenesis in areas of the brain, which ultimately influence cognitive performance (Leahy et al., 2020).

Self-reported physical fitness through questionnaire scale tools such as comprehensive evaluation of adolescent health contains four independent variables, including health, anxiety, as well as body satisfaction (Moliner-Urdiales et al., 2010; Barnes et al., 2020). First and foremost, self-rated health shows a positive correlation with physical fitness, and the self-rated health assessment of adolescents is affected by gender and grade (Vingilis et al., 2002; Warnoff et al., 2016). For example, according to Schrotenboer's (2018) interview data in 2018, male students were significantly more satisfied with their physical and mental conditions and learning status than that female students, showing the differences in psychological characteristics and content of attention between men and women (Schrotenboer, 2018). They also paid less attention to their health and behavior, and their emotional experiences were less profound than those of their female counterparts. What's more, depression and anxiety are both manifestations of emotional loss, which can cause great trouble to teenagers' life and studies (Michl et al., 2013). In terms of these two indicators, teenagers who think their mental state is relatively satisfied generally argue that their physical fitness is at an intermediate or upper level (Mulasi-Pokhriyal and Smith, 2010; Csikszentmihalyi and Hunter, 2014). However, teenagers who rate themselves poorly also have lower health ratings and are more likely to be academically disadvantaged (Suldo and Shaffer, 2008). Thirdly, body satisfaction is often a factor that determines whether teenagers have emotional problems, and it is mainly attributed to their confidence in their appearance and body (Carlson Jones, 2004; Presnell et al., 2004).

Some studies get involved in the degree of interference of external factors on adolescents' self-health cognition and life satisfaction. Novak et al. (2017) suggested that there was a significant correlation between values and life satisfaction in special fields, but the correlation coefficients were all very low. By contrast, the correlation between self-concept and life satisfaction was higher, implying that the relationship between self-concept and life satisfaction might be closer than that between values input from the external environment and life satisfaction (Brillhart, 2005). At the same time, Galán et al. (2013) took regional and family environment as dependent variables to reveal the overall satisfaction of urban students and the satisfaction score of school and living environment was significantly higher than that of rural students. As a result, it is suggested that schools and communities should make efforts to reinforce adolescent sports activities and health evaluation systems to make sure the establishment of basic life satisfaction for adolescents (Oberle et al., 2011; Padilla-Moledo et al., 2020).

With the COVID-19 pandemic still ongoing in many Chinese areas, assessing HRPF in youth using field-based assessment (such as a shuttle run for cardiorespiratory fitness) is unrealistic. Therefore, finding an alternative to assess HRPF in adolescents is necessary. The International Fitness Scale (IFIS) is an option that can consider adolescents' HRPF conveniently (Ortega et al., 2011). This study was targeted at further estimating the relationship between self-reported fitness and health-related independent variables to highlight the role of fitness concerning self-rated health, depression, anxiety, and body satisfaction by using a sample of Chinese adolescents.

Materials and methods

Study design and participants

This cross-sectional study has been conducted in south-eastern China from March to October 2021. Using convenience sampling, 12 public schools were invited, and these schools were located in four cities in south-eastern China, that is, two high schools, five middle schools, and five elementary schools. For each school, we have randomly selected one or three classes, and a contact person is sent to each school. Once a potential school had expressed interest in this study, the first author emailed, phoned, or zoom called the representative(s) (e.g., the principal and administrative staff), to elaborate on the study requirements and process. The self-report scales were applied at the school by the staff teacher staff or headmaster of the school and they helped to manage and fill out the questionnaire in the form of paper-based. Having completed this step, we have recruited the first group of respondents comprising 3,807 adolescents and children (ages 11–17).

Study participants providing information on variables of interest were included in this study, while those who did not report data on any variables (e.g., independents, outcomes and covariates) of interest that this study needed were excluded from the initial sample. For this study and further analysis, a total of 2,407 study participants were included as they provided valid data on variables this study needed. Moreover, we have informed all the respondents and their guardians and parents that they are completely voluntary to take the survey. The study procedure

TABLE 1 Sample characteristics of this study.

		n/Mean	%/SD
Gender	Boy	1,236	52.7
	Girl	1,108	47.3
Residence	Rural	266	11.3
	Suburban	514	21.9
	Urban	1,564	66.7
Siblings	Yes	1,155	49.3
	No	1,189	50.7
Live with parent	Yes	1,972	84.1
	No	372	15.9

TABLE 2 The proportion of different categories of self-reported physical fitness.

		n	%
Self-reported physical fitness	Very poor	75	3.2
	Poor	290	12.4
	Average	1,231	52.5
	Good	559	23.8
	Very good	189	8.1
Self-reported cardiorespiratory fitness	Very poor	88	3.8
	Poor	335	14.3
	Average	1,113	47.5
	Good	599	25.6
	Very good	209	8.9
Self-reported muscle strength	Very poor	83	3.5
	Poor	372	15.9
	Average	1,207	51.5
	Good	534	22.8
	Very good	148	6.3
Self-reported speed and agility	Very poor	61	2.6
	Poor	300	12.8
	Average	1,095	46.7
	Good	646	27.6
	Very good	242	10.3
Self-reported flexibility	Very poor	161	6.9
	Poor	517	22.1
	Average	1,009	43.0
	Good	477	20.3
	Very good	180	7.7

and protocol have been performed upon approval from the Institutional Review Board (IRB) of the Shanghai University of Sport, and the grant number is 102772021RT071.

Physical fitness

With the 5-point Likert scale (very bad, bad, fair, good, and excellent), this study used the International Fitness Scale (IFIS) for assessing physical fitness. There are five components in IFIS, which are respectively general fitness, cardiorespiratory fitness, muscle strength, speed and agility, and flexibility. One of the questions used in this study is as follows: What is my general physical condition? (1 = very bad, 2 = bad, 3 = fair, 4 = good, 5 = excellent). The acceptable credibility and validity in teenagers (Ortega et al., 2011) have been reported by the scale. Furthermore, this study recruited 544 Chinese teenagers to attend credibility research. The research results demonstrated the acceptable credibility of IFIS in Chinese children and teenagers (weighted Kappa: 0.42–0.52 for the IFIS component, Cronbach alpha 0.72) (Bao et al., 2022).

Nine-item patient health questionnaire depression

The Chinese version of the 9-item Patient Health Questionnaire (PHQ-9) was applied to analyse depressive symptoms, including nine items relating to experiences of depressive symptoms in the past 2 weeks. Every item was scored in line with the Likert Scale with four grades, varying from 0 (no scoring) to 3 (almost scoring every day). The total scores ranged from 0 to 27, showing that the higher scores, the more serious depressive symptoms. The severity of depressive symptoms could be divided according to PHQ-9 scores: 20–27 (severe), 15–19 (moderately severe), 10–14 (moderate), 5–9 (mild), and 0–4 (minimal) (Levis et al., 2019). The psychometric properties of PHQ-9 have been tested on Chinese children, showing sufficient validity and reliability (Li et al., 2021).

TABLE 3 The proportion of different categories of outcomes of this study.

		n	%
Depression severity	Normal	1,337	57.5
	Mild	627	26.9
	Moderate	194	8.3
	Moderately severe	90	3.9
	Severe	79	3.4
Anxiety severity	Normal	1,595	68.5
	Mild	466	20.0
	Moderate	146	6.3
	Severe	120	5.2
Body satisfaction	Very dissatisfied	268	11.4
	Dissatisfied	732	31.2
	Neither	768	32.8
	Satisfied	317	13.5
	very satisfied	259	11.0
Self-rated health	Very poor	150	6.4
	Poor	851	36.3
	Average	715	30.5
	Good	356	15.2
	Very good	272	11.6

Seven-item generalized anxiety disorder scale anxiety

Seven-item Generalized Anxiety Disorder Scale (GAD-7) was used to assess anxiety disorders, including seven items, in which each item's response had a four-point Likert scale (ranging from 0 to 3) (Maggi et al., 2019). The total scores of GAD-7 ranged from 0 to 21, implying that the higher scores, the higher severity of anxiety. The severity of anxiety could be divided into severe (15–21), moderate (10–14), mild (5–9), and minimal (0–4) (Plummer et al., 2016). The translated GAD-7 has been widely applied among Chinese children and adolescents, showing acceptable validity and reliability (Sun et al., 2021).

Self-rated health

By asking the following questions, self-rated life satisfaction is measured. Generally, how do you consider your life satisfaction? The possible answers included: "Excellent (5)," "Very good (4)," "Good (4)," "Fair (3)," and "Poor (1)" (Mewes and Giordano, 2017). As for self-rated life satisfaction and its items, sound validity has been documented in previous studies (Zhang et al., 2019; Chai et al., 2020).

Body satisfaction

The status of body satisfaction is evaluated by asking the question "do you feel satisfied with your body weight of yours" There are five options for the answer ranging from "very satisfied" to "very dissatisfied" (Ren et al., 2018). In the analysis of data, the options of "somewhat dissatisfied" and "very dissatisfied" are combined as one option, that is, "dissatisfaction," while "very satisfied" and "somewhat dissatisfied" is turned into "satisfaction." Therefore, the status of body satisfaction has three types, satisfaction, neither and dissatisfaction.

Demographic characteristics

Age, sex, residence, siblings, living with parents and family affluence were collected as demographic characteristics in the current study. These variables were assessed *via* the following measurement questions: age (continuous), sex (boy or girl), residence (rural, suburban and urban), siblings (yes or no), living with parent (yes or no), and family affluence (0–10 scale).

Statistical analysis

All analyses were conducted using the Statistical Package for the Social Sciences v.26 (SPSS Inc., Chicago, IL, USA), and the alpha level was set at $p < 0.05$. Descriptive statistics (mean/standard deviation and percentage) were used to report on the basic characteristics of the study sample. Mean value with standard deviation was a continuous variable (e.g., age), whilst percentage was a categorical variable (e.g., sex, residence). Four regression models were established, including self-reported physical fitness and self-rated health, self-reported physical fitness and body satisfaction, self-reported physical fitness and depression, and self-reported physical fitness and anxiety. In each model, the indicators of self-reported physical fitness were entered into the model concurrently while controlling for covariates. A generalized linear model with ordinal logistic regression was used to achieve the association estimation above noted.

Results

Table 1 demonstrates that these samples were concentrated at the age of 13.9 (± 2.1), and were evenly distributed between boys and girls. Boys accounted for 5.4% more than girls, with 1,236 males and 1,108 girls. More information on the study participants can be found in Table 1.

Table 2 shows that adolescents are generally in their health assessment and choose "Average." This answer accounted for the highest proportion in the five self-assessments of physical fitness, cardiovascular health, muscle strength, speed and agility, and flexibility. More than 50% of teenagers chose "Average" for Physical Fitness and Muscle Strength. Compared with the other four factors, adolescents had the most negative evaluation of flexibility, 161 of them thought very poorly, and more than 1/5 of them thought poor, 517 of them. In addition, in the sample, the evaluation of comprehensive Physical Fitness was more positive, except for average, accounting

TABLE 4 The association between self-reported physical fitness and self-rated health.

		OR	95% CI		*P*-value
General physical fitness	Very good	14.95	7.53	29.68	0.000
	Good	4.18	2.35	7.43	0.000
	Average	1.90	1.09	3.29	0.023
	Poor	1.34	0.76	2.39	0.314
	Very poor		REF		
Self-reported cardiorespiratory fitness	Very good	4.34	2.24	8.43	0.000
	Good	4.98	2.80	8.86	0.000
	Average	3.22	1.84	5.62	0.000
	Poor	2.45	1.37	4.37	0.002
	Very poor		REF		
Self-reported muscle strength	Very good	1.84	0.93	3.65	0.080
	Good	1.29	0.73	2.28	0.384
	Average	1.51	0.87	2.64	0.146
	Poor	1.13	0.64	2.01	0.676
	Very poor		REF		
Self-reported speed and agility	Very good	1.00	0.48	2.05	0.990
	Good	1.05	0.54	2.06	0.878
	Average	0.99	0.51	1.91	0.977
	Poor	0.66	0.34	1.29	0.225
	Very poor	REF	.	.	
Self-reported flexibility	Very good	0.76	0.48	1.20	0.238
	Good	1.31	0.91	1.89	0.147
	Average	1.10	0.78	1.55	0.584
	Poor	1.00	0.70	1.43	0.999
	Very poor	REF	.	.	

OR, odds ratio; CI, confidence interval; REF, reference.

TABLE 5 The association between self-reported physical fitness and body satisfaction.

		OR	95% CI		*P*-value
General physical fitness	Very good	3.62	1.89	6.93	0.000
	Good	2.41	1.39	4.18	0.002
	Average	1.83	1.08	3.10	0.024
	Poor	1.20	0.69	2.09	0.515
	Very poor		REF		
Self-reported cardiorespiratory fitness	Very good	2.55	1.39	4.67	0.003
	Good	2.04	1.19	3.50	0.010
	Average	1.42	0.84	2.39	0.188
	Poor	1.29	0.75	2.23	0.352
	Very poor		REF		
Self-reported muscle strength	Very good	0.46	0.24	0.90	0.022
	Good	0.62	0.36	1.05	0.076
	Average	0.86	0.51	1.44	0.559
	Poor	0.85	0.50	1.45	0.556
	Very poor		REF		
Self-reported speed and agility	Very good	1.38	0.72	2.64	0.334
	Good	0.87	0.48	1.60	0.663
	Average	0.64	0.35	1.16	0.140
	Poor	0.53	0.29	0.96	0.038
	Very poor		REF		
Self-reported flexibility	Very good	1.73	1.10	2.70	0.017
	Good	1.84	1.28	2.64	0.001
	Average	1.68	1.19	2.37	0.003
	Poor	1.88	1.32	2.66	0.000
	Very poor		REF		

OR, odds ratio; CI, confidence interval; REF, reference.

for 52.5%, and those who thought "good" and "very good" accounted for 31.9%.

Table 3 displays the emotion and satisfaction of adolescents. In terms of Depression severity and anxiety severity, they show a similar trend, which is more than half of the teenagers thought they were normal. However, in terms of body satisfaction, the proportion of Dissatisfied and Neither was close, both roughly 30%. Concerning self-rated health, most the youth choose poor health, the detailed information can be found in Table 3.

Table 4 presents that the independent variable analysis of self-rated health was strongly correlated with the result of self-rated physical fitness. In detail, compared with those who reported "very poor" self-rated health, adolescents who reported "very good" were more likely to have a high-level physical fitness ([very good] OR = 14.95, 95% CI: 7.53–29.68; [good] OR = 4.18, 95% CI: 2.35–7.43; [average] OR = 1.90, 95% CI: 1.09–3.29; [poor] OR = 1.34, 95% CI: 0.76–2.39). However, the evaluation of flexibility and speed were not the basis for them to identify high physical fitness, and there was no positive correlation.

Table 5 displays the association between self-reported physical fitness and body satisfaction. Similarly, compared with those who reported "very poor" body satisfaction, adolescents who reported "very good" were more likely to have a high-level physical fitness ([very good] OR = 3.62, 95% CI: 1.89–6.93; [good] OR = 2.41, 95% CI: 1.39–4.18; [average] OR = 1.83, 95% CI: 1.08–3.10; [poor] OR = 1.20, 95% CI: 0.69–2.09). However, youth who rated themselves low on flexibility or muscle strength were also likely to report better body satisfaction.

In contrast, Table 6 demonstrates adolescents who rated their higher depression were more likely to have lower physical fitness ([very good] OR = 0.21, 95% CI: 0.10–0.41; [good] OR = 0.29, 95% CI: 0.17–0.51; [average] OR = 0.36, 95% CI: 0.22–0.61; [poor] OR = 0.50, 95% CI: 0.29–0.86), which is showing a strong inverse correlation. Secondly, depression was also inversely correlated with the reported physical fitness scores, but not strongly correlated with cardiopulmonary health. There was no correlation between muscle strength and depression, that is, adolescents with high recognition of their muscle strength also had high levels of depression. Depression was not associated with flexibility, and there were no significant differences in depression among different grades of flexibility, more information can be found in Table 6.

Table 7 displays that anxiety and depression shows similar trends ([very good] OR = 0.22, 95% CI: 0.11–0.47; [good] OR = 0.26, 95% CI: 0.14–0.46; [average] OR = 0.31, 95% CI: 0.18–0.53; [poor] OR = 0.42, 95% CI: 0.24–0.75). More information can be found in Table 6.

TABLE 6 The association between self-reported physical fitness and depression.

		OR	95% CI		*P*-value
General physical fitness	Very good	0.21	0.10	0.41	0.000
	Good	0.29	0.17	0.51	0.000
	Average	0.36	0.22	0.61	0.000
	Poor	0.50	0.29	0.86	0.012
	Very poor		REF		
Self-reported cardiorespiratory fitness	Very good	0.67	0.35	1.30	0.240
	Good	0.75	0.43	1.31	0.316
	Average	0.70	0.41	1.18	0.181
	Poor	0.92	0.53	1.60	0.768
	Very poor		REF		
Self-reported muscle strength	Very good	1.02	0.51	2.03	0.959
	Good	0.78	0.45	1.33	0.357
	Average	0.69	0.41	1.16	0.161
	Poor	0.80	0.46	1.37	0.414
	Very poor		REF		
Self-reported speed and agility	Very good	0.78	0.38	1.60	0.495
	Good	1.23	0.64	2.39	0.533
	Average	1.14	0.60	2.19	0.690
	Poor	1.35	0.70	2.61	0.370
	Very poor	REF			
Self-reported flexibility	Very good	0.66	0.41	1.06	0.083
	Good	0.56	0.38	0.81	0.002
	Average	0.61	0.43	0.86	0.005
	Poor	0.66	0.46	0.94	0.020
	Very poor		REF		

OR, odds ratio; CI, confidence interval; REF, reference.

Discussion

The primary of this study was to examine the association between self-reported fitness and health-related independent variables in adolescents (aged 11–17) by using the self-reported questionnaire, owing to the COVID-19 pandemic in many regions in China. Our study highlights the role of physical variables in adopting physical activity during adolescence, which proposes specific measures for communities and schools to improve adolescents' physical and mental health through the mechanism of influence.

The results demonstrated that cardiorespiratory health, muscle health, and speed agility were all related to the perceived health condition, which is consistent with previous findings (Marques et al., 2017; Redondo-Tébar et al., 2019; Bermejo-Cantarero et al., 2021). The healthier respondents are more likely to evaluate themselves with higher scores on physical condition. Among the four components of evaluating general physical fitness, cardiorespiratory health and muscle strength show a significant relationship with self-reported physical health. However, no significant correlation has been identified between flexibility or speed and agility. This shows that in the evaluation of physical health, greater consideration has been given to cardiorespiratory health and muscle strength than flexibility, speed and agility. The same condition has also been detected in the scale of body satisfaction. Adolescents with lower self-perceived muscle strength and flexibility can also report a higher level of body satisfaction. Based on the above discussion, it can be drawn that adolescents report their overall fitness condition based on their perception of cardiorespiratory function and muscle strength. This result is in line with what Marques et al. (2017) have discovered, whose evidence showed a positive relationship between cardiorespiratory fitness and overall fitness level. Therefore, it is of great importance to improve adolescents' overall health perception by improving their physical fitness level by concentrating on cardiorespiratory function other than improving flexibility and speed. The possible explanation is that people who get high scores in self-rated health tend to increase their perceived health through active exercise. Eriksen et al. (2013) further explained that Such self-motivated exercise formed a virtuous circle to encourage teenagers to keep fit. Jaakkola et al. (2019) also showed that teenagers who perform well in physical fitness tests are also full of confidence in their sports ability, which will further affect the social aspects of life achieved through sports activities.

In terms of emotional health conditions, the study measured the effects of two variables: depression and anxiety. Evidence

TABLE 7 The association between self-reported physical fitness and anxiety.

		OR	95% CI		*P*-value
General physical fitness	Very good	0.22	0.11	0.47	0.000
	Good	0.26	0.14	0.46	0.000
	Average	0.31	0.18	0.53	0.000
	Poor	0.42	0.24	0.75	0.003
	Very poor		REF		
Self-reported cardiorespiratory fitness	Very good	0.49	0.24	0.99	0.047
	Good	0.65	0.36	1.17	0.152
	Average	0.67	0.38	1.17	0.158
	Poor	0.71	0.40	1.28	0.255
	Very poor		REF		
Self-reported muscle strength	Very good	0.94	0.46	1.94	0.877
	Good	0.65	0.37	1.14	0.135
	Average	0.69	0.40	1.18	0.169
	Poor	0.76	0.44	1.34	0.348
	Very poor		REF		
Self-reported speed and agility	Very good	1.47	0.67	3.23	0.337
	Good	1.81	0.88	3.72	0.106
	Average	1.58	0.78	3.21	0.206
	Poor	1.47	0.72	3.01	0.292
	Very poor		REF		
Self-reported flexibility	Very good	0.84	0.51	1.38	0.490
	Good	0.61	0.41	0.90	0.014
	Average	0.64	0.44	0.92	0.017
	Poor	0.65	0.44	0.95	0.026
	Very poor		REF		

showed that there was a negative relationship between the degree of depression and cardiorespiratory function. To be more specific, adolescents with poor cardiorespiratory function are more likely to score lower in their emotional functions. No significant correlation was discovered between the score of muscle strength and the level of depression in adolescents. This reflects the unique and important positive impact of cardiorespiratory function on teenagers' emotional function. Correspondingly, the degree of anxiety and cardiorespiratory function are negatively correlated with each other. Adolescents with a higher level of anxiety are more likely to have poor cardiorespiratory health. Although a correlation was found between self-reported health and all health-related outcomes, the other three parameters did not show statistical significance with self-reported health. Nevertheless, despite the different voices, the majority of scholars recognized the positive correlation between overall physical fitness and emotional state. Many studies have been done to investigate the relationship between physical fitness and emotional wellbeing. For example, Harvey et al. (2018) believes that only 30 min of moderate exercise per week is related to a reduced risk of depression. However, some evidence indicated other factors that contributed more to mental health. For example, the data shown in this study is inconsistent with the results of Hallgren et al. (2020), who explored the relationship between cardiorespiratory health and mental health symptoms. This finding shows that it is exercise frequency, rather than cardiorespiratory factor, has a stronger correlation with mental health symptoms as the longer average weekly exercise time (lasting 1–2, 3–4, and 5–6 h, respectively) does not bring additional protection to the body. In addition, evidence also exists illustrating that only special forms of exercise, such as resistance training, have been proved to be effective in the treatment of emotional disorders and related symptoms (Gordon et al., 2018), but may not significantly improve cardiorespiratory levels. Besides physical exercise, the randomized controlled trial performed by Cunningham et al. (2021) revealed that both relaxation training and physical activities have buffering effects to reduce problematic emotions, indicating further research on different interventions to decide which one is more effective. In conclusion, cardiorespiratory health serves as an option to prevent common mental health symptoms, but necessarily the exclusive one.

Although the health measures adopted are self-evaluated, the results are consistent with other experimental research about physical fitness. Haverkamp et al. (2022) employed 361 adolescents to assess the relationship between their physical fitness and psychosocial health. The selected evaluation of physical and mental health is similar to this study: the evaluation of physical fitness includes muscle strength, speed and agility,

as well as body mass index. Social mental health includes self-concept, depression, and anxiety. The results showed that adolescents with better cardiorespiratory function had higher self-concept and fewer depression and anxiety symptoms. In general, this evidence proves that cardiopulmonary function has an important impact on adolescents' physical and mental health, which is not only reflected in self-perceived physical health but also reflected in mental health. The enhancement of muscle strength has a positive correlation with physical health but has little correlation with mental health. This indicates that schools and communities can pay more attention to the training of cardiopulmonary function and assist a certain degree of muscle strength training in enhancing the physical and mental state of adolescents. Some studies have proposed possible explanations for this result. Mücke et al. (2018) stated that young people with good cardiopulmonary and muscle functions will naturally participate in more sports activities. Sports have been proved to improve the level of endorphins in the brain and reduce the activity of sympathetic nerves, which can effectively reduce the psychological problems of teenagers (Nabkasorn et al., 2006; Shahr-Jerdy et al., 2012). In consequence, this study shed light on the importance of physical exercise to improve adolescents' physical and mental health, especially cardiopulmonary training. The results also suggest that self-rated health and fitness level can be an important indicator to determine the health level of adolescents.

This study has had inherent limitations in its research design, measures, and participants. First of all, owing to the cross-sectional research design, the current study could not draw some causal conclusions; the directionality of the association between independent and outcomes could not be determined. Beyond that, this study utilized self-reported measures to collect data on all the variables, which were subject to recall bias and social desirability of the participants. Thirdly, as this study adopted a convenient and non-probabilistic sampling method, the research findings might be more regionally replicable than nationally replicable. Furthermore, the response rate was 63%, which was relatively low in the present study. Last but not least, although adolescents' self-reported nature introduces several biases, the literature is consistent with self-reported validity and reliability; and self-reported use during the pandemic allowed continuing to assess physical fitness when it was impossible by objective methods. Given these limitations, future studies will be encouraged to address them to generate stronger evidence.

Conclusion

This study offered some evidence concerning the associations between self-reported physical fitness in children and adolescents with some mental health-related outcomes, highlighting the roles of self-reported physical fitness in preventing mental health disorders.

Data availability statement

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

Ethics statement

The study procedure and protocol have been performed upon approval from the Institutional Review Board (IRB) of the Shanghai University of Sport (102772021RT071). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

CS and JY: writing – original draft. JY and LW: formal analysis. CS and HS: writing – review and editing as well as supervision. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

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Movement behaviours and anxiety symptoms in Chinese college students: A compositional data analysis

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In the current research, sleep duration, sedentary behaviour, physical activity, and their relationship with several anxiety symptoms among college students were examined. This study was a cross-sectional study, and study respondents were recruited from college students. A total of 1,475 of college students were included for analysis. Sedentary behaviours and physical activity were assessed by the International Physical Activity Questionnaire Short Form, while sleep duration was assessed by the Chinese version Pittsburgh Sleep Quality Index. To assess the anxiety symptoms of study respondents, the Generalised Anxiety Disorder-7 was used. The compositional data was analysed in R to estimate the associations between replacements among physical activities, sedentary behaviours, and sleep and anxiety symptoms. Results indicated a greater impact was imposed on the alleviation of anxiety symptoms by substituting sedentary behaviours with physical activity at moderate to vigorous intensity. In the current research, the significance of moderate to vigorous physical activity should be highlighted in preventing anxiety among Chinese college students.

KEYWORDS

anxiety, sleep, sedentary behaviour, moderate to vigorous physical activity, young adults

Introduction

Since the outbreak of COVID-19, people's life has been affected from various aspects around the world (Pokhrel and Chhetri, 2021). In the meanwhile, many measures have been taken by individuals to avoid contracting the disease, such as working from home, quarantine, and going out less frequently (Lim et al., 2020). Consequently, people's lifestyles have changed. For example, people's sleep habits have been disturbed. Such lifestyle changes have further led to mental health issues in different populations, such as college students. During the pandemic period, universities all over the world mostly closed their campuses and turned to provide online teaching for their students

(Yıldırım et al., 2021). These measures may have changed students' living and studying patterns to a certain extent, resulting in mental health problems, such as depression or anxiety among college students (Rajab et al., 2020). Hence, the effect of the COVID-19 on individual's mental health has become a great concern for higher education students all over the world.

As defined by previous research, movement behaviour refers to various activities that individuals engage in their daily lives (Chen and Yan, 2020; Shen et al., 2020). This includes physical activity and sedentary behaviours (Mañas et al., 2018; Huang et al., 2021; Chen et al., 2022). Sleep is also a component of movement behaviour that has a significant impact on people's physical and mental health (Chen and Yan, 2020; Shen et al., 2020; Liu et al., 2022). Studies have shown that changes in movement behaviours would result in mental health issues of college students (Savage et al., 2020). Many researchers have found that with increasing sedentary behaviours hours, college students tend to experience a rising level of anxiety (Lee and Kim, 2019; Chen and Yan, 2020; Shen et al., 2020; Liu et al., 2022). Jiang et al. (2020) also reached a similar conclusion that sedentary behaviours was positively associated with anxiety and even suicidal attempts among first-year college students based on one empirical study conducted in Chinese college students. Besides, researchers also investigated the associations between sedentary behaviours, physical activity with mental health issues. Yasunaga et al. (2018) conducted a study using cross-sectional analysis and suggested that light physical activity, as the replacement of sedentary behaviours with other components of movement behaviours, might result in a lower level of depression. Likewise, Pengpid and Peltzer (2019) studied the relationship between sedentary behaviours and physical activity with mental health issues. This study found a negative association between the duration of sedentary behaviours and physical activities and symptoms of depression and/or anxiety, researchers also further examined and compared the effects of moderate to vigorous physical activity and light physical activity on these mental health issues, respectively (Shi et al., 2022). Moreover, previous research has indicated that changes in sleep were significantly associated with individuals' mental health. In a nationwide study conducted in Japan, researchers recruited 99,668 participants to complete a questionnaire regarding their lifestyle and mental health status (Kaneita et al., 2007). The results demonstrated that there was a U-shape association between individuals' average daily sleep time and mental health. Individuals who have 7–9 h of sleep appear to have the healthiest mental health status, while people who sleep less than 7 hours or more than 9 hours a day have lower scores on the mental health assessment. According to a meta-analysis conducted by Baglioni et al. (2016), sleep deprivation was significantly associated with mental illnesses such as depressive and general anxiety disorder. Therefore, it is significant to take sleep into account when investigating individuals' behavioural factors associate with anxiety symptoms.

Nevertheless, when examining the association between physical activity and mental health status among Chinese college students, the results appear to be mixed and unclear. A cross-sectional study gathered data from 1,846 Chinese undergraduates, and it demonstrated that individuals who engaged in higher levels of physical activity tend to have lower risks of experiencing anxiety symptoms, which indicated a negative relationship between individuals' physical activities and anxiety levels (Gupta et al., 2020). On the contrary, a recent study conducted by Feng et al. (2022) investigated the relationship between physical activity and posttraumatic stress disorder during the COVID-19 pandemic. The results suggested that individuals with higher physical activity levels appear to have lower odds of experiencing posttraumatic stress disorder symptoms after the pandemic, which is contrary to the researchers' hypothesis and the findings of many previous studies. As a result of those mixed findings, it is significant to further investigate the relationship between physical activity and mental health status among the Chinese undergraduate population.

Apart from the numerous studies conducted to examine the associations between sedentary behaviours, physical activities, sleep, and mental health including depression and anxiety, a novel statistical analysis approach, compositional data analysis, has become popular in such research (Bu et al., 2021). Individuals' lifestyle behaviours can be influenced with different components of movement behaviours, implying that time spent in a certain activity (e.g., sedentary behaviours) is closely intertwined with time spent on other activities. Hence, the compositional data analysis has been commonly applied by researchers to explore the relationship between the intertwined components of movement behaviours and individuals' mental health, given the compositional nature of time allocation among movement behaviours (Gupta et al., 2018). Kitano et al. (2020) have illustrated a significant association between the time distribution of 24-hour movement behaviours and mental health among workers. Also, Kitano et al. (2020) also investigated the effects of reallocating different movement behaviours, clearly demonstrating relationships between activity substitutions and mental health. As the COVID-19 epidemic is ongoing, an increasing number of studies have embarked on delving into the relationships between individuals' movement behaviours and mental health during the epidemic, relying on personal lifestyle changes, such as increased sedentary behaviours or sleep with decreased physical activity. For example, the newly released research implemented by Brusaca et al. (2021) discussed the change in people's lifestyles and investigates the relationship between movement behaviour change and mental health issues such as stress and anxiety by using the compositional data analysis approach. Another study conducted by Chong et al. (2021) also suggested the

distinct relationship between different movement behaviours including sleep and psychological distress with a compositional data analysis method. The use of the compositional data analysis technique can provide an efficient reference for the public to allocate their time to activities contributing to mental health.

During the period of COVID-19, it is essential to utilise the compositional data analysis approach to delve into the relationship between components of movement behaviours and anxiety symptoms among college students, considering the reallocations of sleep, sedentary behaviours, and physical activity. This can give recommendations to college students so that their mental health can be improved.

Materials and methods

Study participants

This present study was a cross-sectional study. In this study, an online survey network was used to recruit the participants. Firstly, study participants were determined based on a convenient sampling method. Then, study participants who agreed to participate in research were sent a survey link, and they were required to complete the online questionnaire about approving the recruitment and data collection process of research participants as well as the details of the research protocol. Before filling out the questionnaire, study participants offered online consent, only those who have provided informed consent can be eligible to participate. In total, 1,942 college students took part in this survey, 1,846 of them provided responses, with a response rate of 95.1%. Finally, 1,475 college students were included, since they offered valid and complete data for analysis.

Measures

Sedentary behaviour and physical activity

To assess sedentary behaviours and physical activity, the International Physical Activity Questionnaire Short Form (IPAQ-SF) was used. Moreover, study respondents were instructed to report their walking (light physical activity), moderate to vigorous physical activity and time spent sitting (sedentary behaviours) in the last week. According to the previous research, IPAQ-SF displays good validity and reliability in Chinese adults (Qi et al., 2020). In details, as for the IPAQ-SF, there is a high intraclass correlation coefficient (ICC), which is 0.97 (95% confidence interval [CI]: 0.95, 0.98) for SB, and an ICC of 0.85 (95% CI: 0.75, 0.91) for moderate physical activity, and 0.75 (95% CI: 0.60, 0.85) for vigorous PA. The IPAQ-SF is a reliable assessment for estimation of sedentary behaviours and physical activity in Chinese adults (Yıldırım et al., 2021). As for the validity, according to the prior study, IPAQ-SF displays sound validity against a device-based measure (Maher et al., 2018; Kurth and Klenosky, 2021).

Sleep duration at night

Questions are designed by referring to the Chinese version of the Pittsburgh Sleep Quality Index (PSQI) to assess sleep duration, that is, "how long did you sleep at night during the past 30 days?" (Chung et al., 2009). The item of measure displays sound reliability and validity in Chinese adults (Wu et al., 2019; Chi et al., 2021).

Anxiety symptoms

Anxiety symptoms of study participants was assessed by the 20-item self-report questionnaire, that is the Zung Self-Rating Anxiety Scale (Z-SAS) (Dunstan and Scott, 2020). The Z-SAS includes measures of state and trait anxiety based on scoring in four groups of manifestations: cognitive, autonomic, motor, and central nervous system symptoms. Responses to each item range from 1 (a little of the time) to 4 (most of the time) with higher scores indicating more severe anxiety. Standardised scores of the Z-SAS were used in the statistical analysis of our study.

Sociodemographic

Sociodemographic variables contain weight (in kilogramme, for BMI, that is, body mass index), perceived family affluence (scaled 0–10), self-reported height (cm), dwelling place (urban or rural), age, gender, and siblings (yes or no). For the statistical model, those variables were considered as covariates.

Statistical analysis

Using compositions (version 1.40-1) (Van den Boogaart and Tolosana-Delgado, 2008) and RGB compositions (version 0.92-7), R, and latest (version 0.9-35) (Templ et al., 2011) packages, the analysis of compositional data has been performed in R[1] (R Core Team, version 3.6.1, 2019). For compositional and standard descriptive statistics, the comparison is performed by calculating them. The compositional means have been obtained through the calculation of the geometric mean of every behaviour (time spent on moderate to vigorous physical activity, light physical activity, sedentary behaviours and sleep), and the data has been normalised to the identical constant. The measure is identical to the relative and symmetrical scale of data (Aitchison, 1982). In the current research, a compositional approach based on an isometric log-ratio (ILR) data transformation has been adopted, and such an approach has been adapted from Hron (Hron et al., 2012) to adjust the models for time spent on other behaviours. To sum up, a sequential binary partition process has been adopted to generate the ILR coordinates (Egozcue and Pawlowsky-Glahn, 2005),

1 http://cran.r-project.org

and it was obtained by composition partitioning because one set was designated to appear in the first ILR coordinate numerator, while the other in the denominator. Moreover, one set has been separated into two sets, while the parts have been coded to be in the uninvolved parts (0), the denominator (−1), and numerator (+1) respectively. The final ILR is the geometric mean of normalised log ratios of the parts (Dumuid et al., 2019). In addition, apart from that, covariates have been considered as the explanatory variables. To not violate the assumption, the multiple linear regression models of ILR have been examined for linearity, homoscedasticity, normality and outliers. Moreover, the significance of the composition of physical behaviours has been measured with the function of 'car: Anova', in which Wald Chi-squared has been adopted to conduct Type II tests. By the following marginality as a principle, every covariate has been examined. In addition, the models of ILR multiple linear regression have been adopted to check the difference in outcome variable associated with the reallocation of a fixed period between different physical actions, while the 3rd and 4th remain unchanged. Five minutes of reallocation between different pairs of physical behaviours can be simulated through the systematic creation of specific new composition of activity, with the mean composition of the sample as the baseline, or composition start. As for new compositions, they have been demoted as coordinate sets of ILR, and each value has been subtracted from average composition ILR coordinates to generate the ILR differences. Therefore, *ilr* differences have been adopted in the linear models so that the estimated difference can be determined (95% CI). Meanwhile, it is performed once again for pairwise reallocation, with 5 minutes as an increment (5–15 minutes) respectively. The reallocation rationale at 5 minutes is based on the revised version of PA guidelines in 2019 for the United Kingdom (Smith et al., 2021) and the United States (Bezerra et al., 2021), and the 10-minute minimum has been removed concerning the duration of all age groups, as a result of evidence insufficiency. All statistical analyses were conducted at a significance level of $p < 0.05$.

Results

A total of 1,475 study participants with a mean age of 20.7 years old were included in the final analysis (**Table 1**). Of them, 68% were females and 33.8% had siblings. 68.9% of study participants lived in urban areas. The mean of perceived family affluence was 5.70 with a standard deviation of 1.63. The study sample spent 50% of the day (24 hours) in sleep, 39.77% in sedentary behaviour, 5.60% in light physical activity, and 4.63% in moderate to vigorous physical activity. Lastly, the mean score of anxiety symptoms was 41.79 with a standard deviation of 9.82. The mean body mass index of study participants was 20.13 (standard deviation: 2.82).

When data were considered as a composition, adjusted for all the sociodemographic variables; the components of movement behaviours was significantly associated (95% CI) with anxiety symptoms scores ($p < 0.0001$). The results based on temporal substitution can be found at **Table 2**, we found that increases in moderate to vigorous physical activity, light physical activity, or Sleep, at the expense of sedentary behaviours, was associated with a negative change in anxiety symptoms scores. Moreover, the addition of moderate to vigorous physical activity conferred the greatest decrease in anxiety symptoms scores, whilst the addition of sleep or light physical activity yielded improvements of roughly same magnitude. Specifically, we found that anxiety symptoms scores decreased significantly from adding MVPA (−0.10, 95%CI: −0.16, −0.04), light physical activity (−0.05, 95%CI: −0.08, −0.02), or sleep (−0.00, 95%CI: 0.00, 0.01) at the expense of SB at 5 minutes, ranging to −0.22 (95%CI: −0.36, −0.09), −0.12 (−0.20, −0.04), and 0.00 (−0.01, 0.02) for moderate to vigorous physical activity, light physical activity, and sleep, respectively, at 15 minutes.

Discussion

This research aimed at investigating the relationship between reallocation of time-use behaviours and anxiety symptoms during the pandemic period in Chinese college students, providing evidence-base for public health interventions aimed at preventing anxiety. In general, this research found that the redistribution of the 24-hour time-use component was related to anxiety symptoms in Chinese college students during the pandemic period. However, this study primarily illustrated that either the increased sleep replaced from reduced sedentary behaviours was not associated with anxiety symptoms scores. In spite of this, other replacements

TABLE 1 Participant characteristics.

Characteristics (n = 1475)	
Age, mean (SD), year	20.7 (1.60)
Female, *n* (%)	1,003 (68.0)
With siblings, *n* (%)	498 (33.8)
Residence (urban), *n* (%)	1,016 (68.9)
Perceived family affluence, mean (SD)	5.70 (1.63)
Time use[a], *n* (%), min/d	
Sleep	720.03 (50)
Sedentary	572.69 (39.77)
LPA	80.61 (5.60)
MVPA	66.67 (4.63)
Body mass index, mean (SD)	20.13 (2.82)
Anxiety symptoms scores, mean (SD)	41.79 (9.82)

[a]Time-use composition is presented as geometric means, adjusted to a sum of 1,440 minutes and 100%. LPA, light physical activity; MVPA, moderate to vigorous physical activity.

have shown their relationship with anxiety scores respectively. In particular, the reduction of light physical activity from other sedentary behaviours was positively related to higher anxiety scores (regardless of the duration of the replacement). Besides, adding moderate to vigorous physical activity from removing sleep, sedentary, or light physical activity can consistently lead to a lower anxiety score. A detailed discussion of the results is presented below.

The results obtained in this study highlighted the positive effects of moderate to vigorous physical activity on preventing anxiety in college students, since increased moderate to vigorous physical activity together with reduced SB can contribute to decreased anxiety symptom. Meanwhile, substantial evidence has also explained the positive effect of moderate to vigorous physical activity on anxiety, regardless of age, gender, education level and other confounders. Importantly, Carter et al. (2021) concluded that physical activity can be an effective approach to reduce anxiety symptoms among children and adolescents. Other earlier studies have also acknowledged the health benefits of physical activity in addressing anxiety disorder (Penedo and Dahn, 2005; McCurley et al., 2017; de Oliveira et al., 2019). Ströhle (2009) further suggested that regular physical activity can decrease symptoms of anxiety. As breaking out COVID-19, irregular sleep or sedentary lifestyles have become more popular, triggering more people tend to stay at home. This probably further contributes to individual emotional problems such as anxiety disorder. Hence, when people participate in moderate to vigorous physical activity, their anxiety symptoms may decrease to a certain extent. In this research, increasing moderate to vigorous physical activity while removing sedentary behaviours at 5, 10, or 15 minutes presented a negative relationship with anxiety symptoms, which confirmed the negative association between moderate to vigorous physical activity and anxiety. This finding concurs with previous studies using novel research methods. For example, Strong et al. (2005) demonstrated that increased level of moderate to vigorous physical activity could facilitate mental health and prevent anxiety problems in adolescents. Beyond that, based on the cross-sectional analysis, one empirical study conducted by McCurley et al. (2017) suggested a relationship between moderate to vigorous physical activity and fewer anxiety symptoms and status among the elderly. However, it should be noted that these studies were conducted before the COVID-19 outbreak. Nevertheless, there have been studies investigating the relationship between moderate to vigorous physical activity and anxiety symptoms, which also display similar results. A cross-sectional research carried out by Schuch et al. (2020) in Brazil indicated that there was less possibility for people participating in moderate to vigorous physical activity to show anxiety symptoms. Additionally, an investigation conducted by McCormack et al. (2020) concentrated on the relationship between physical activity and anxiety among American children during the COVID-19 outbreak. Their findings displayed a negative relationship between moderate to vigorous physical activityand anxiety symptoms, implying that frequent participation in moderate to vigorous physical activity could greatly reduce or even prevent anxiety symptoms among young people. Therefore, this study could serve as additional evidence to the literature that moderate to vigorous physical activity would be good for reducing anxiety symptoms and

TABLE 2 Estimated differences in anxiety symptoms scores changes among reallocations sleep, sedentary behaviour and physical activity.

		Prediction	95% CI		*p*
5 min					
Sleep	Sedentary	0.00	0.00	0.01	1.0000
Sleep	LPA	0.05	0.02	0.09	0.0051
Sleep	MVPA	0.16	0.06	0.26	0.0018
Sedentary	Sleep	0.00	−0.01	0.00	1.0000
Sedentary	LPA	0.05	0.02	0.09	0.0051
Sedentary	MVPA	0.16	0.06	0.26	0.0018
LPA	Sleep	−0.05	−0.08	−0.02	0.0011
LPA	Sedentary	−0.05	−0.08	−0.02	0.0011
LPA	MVPA	0.11	0.01	0.22	0.0397
MVPA	Sleep	−0.10	−0.16	−0.04	0.0011
MVPA	Sedentary	−0.10	−0.16	−0.04	0.0011
MVPA	LPA	−0.04	−0.12	0.03	0.3000
10 min					
Sleep	Sedentary	0.00	−0.01	0.01	1.0000
Sleep	LPA	0.12	0.04	0.20	0.0033
Sleep	MVPA	0.70	0.28	1.12	0.0011
Sedentary	Sleep	0.00	−0.01	0.01	1.0000
Sedentary	LPA	0.12	0.04	0.20	0.0033
Sedentary	MVPA	0.70	0.28	1.12	0.0011
LPA	Sleep	−0.09	−0.14	−0.03	0.0014
LPA	Sedentary	−0.09	−0.14	−0.03	0.0014
LPA	MVPA	0.61	0.17	1.05	0.0066
MVPA	Sleep	−0.17	−0.27	−0.07	0.0009
MVPA	Sedentary	−0.17	−0.27	−0.07	0.0009
MVPA	LPA	−0.05	−0.19	0.09	0.4937
15 min					
Sleep	Sedentary	0.00	−0.01	0.02	1.0000
Sleep	LPA	0.20	0.07	0.33	0.0026
Sleep	MVPA	−0.78	−1.25	−0.30	0.0013
Sedentary	Sleep	0.00	−0.02	0.01	1.0000
Sedentary	LPA	0.20	0.07	0.33	0.0026
Sedentary	MVPA	−0.78	−1.26	−0.30	0.0015
LPA	Sleep	−0.12	−0.20	−0.04	0.0033
LPA	Sedentary	−0.12	−0.20	−0.04	0.0033
LPA	MVPA	−0.93	−1.41	−0.45	0.0002
MVPA	Sleep	−0.23	−0.36	−0.09	0.0009
MVPA	Sedentary	−0.22	−0.36	−0.09	0.0015
MVPA	LPA	−0.03	−0.24	0.18	0.7919

Min, minutes; LPA, light physical activity; MVPA, moderate to vigorous physical activity; CI, confidence interval.

should be useful in promoting policies on related issues, such as encouraging people to participate in moderate to vigorous physical activity.

Another result worthy discussing in this research concerns replacing sleep or sedentary behaviours with light physical activity and its associated effects on anxiety symptoms. As shown by the results based on 5, 10, or 15 minutes reallocations, the estimated differences in anxiety symptoms scores appear to be similar when sleep or sedentary behaviours was substituted by light physical activity. More specifically, replacing either sleep or sedentary behaviours with light physical activity generally reduced anxiety symptoms in this research, which suggests that the substitution of sleep or sedentary behaviours with light physical activity would probably prevent anxiety. By contrast, some earlier studies displayed results different from our study. According to the research by Fanning et al. (2017), it does not witness significant effects of replacing sedentary behaviours with light physical activity, which contradicts our results. Although certain previous studies have not reached a similar conclusion to this study, different studies illustrated the relationship between adding light physical activity with removing sleep or sedentary and anxiety symptoms. In a cross-sectional study conducted by Helgadóttir et al. (2015), the authors suggested that individuals suffering from anxiety disorders should be encouraged to reduce sedentary time and add more light physical activity. Moreover, contrary to the findings achieved by Fanning et al. (2017) discussed above, Dillon et al. (2018) have concluded a significant decline in anxiety symptoms by substituting light physical activity for sedentary behaviours among the middle-aged. Even though the results of the study conducted by Fanning et al. (2017) and the research by Dillon et al. (2018) are different, it should be highlighted that Fanning et al. (2017) concentrated on the relationship among the elderly while Dillon et al. (2018) surveyed the middle-aged people. Hence, age is probably a factor influencing the association between.

A point that should be illustrated in this research refers to the differences in reduced sedentary behaviours between increased light physical activity and increased moderate to vigorous physical activity. According to the results, increased moderate to vigorous physical activity has a more significant effect on lowering anxiety symptoms than increased light physical activity does with declined sedentary behaviours. In detail, when it comes to differences in anxiety scores, moderate to vigorous physical activity can be almost twice as effective as light physical activity. However, this finding was somewhat consistent with most studies, yet the other half has called for a debate. On the one hand, previous research indicated that replacing sedentary behaviours with moderate to vigorous physical activity could reduce or prevent anxiety symptoms (Meyer et al., 2020; Tully et al., 2020; Kandola et al., 2021). On the other hand, several studies had doubt on the impact of substituting sedentary behaviours for light physical activity. A research conducted by Kandola et al. (2021), the researchers suggested that replacing sedentary behaviours with light physical activity could not only decrease depressive symptoms but might necessarily decrease anxiety symptoms. Nevertheless, researchers have not completely denied the effects of replacing sedentary behaviours with light physical activity and assert that further studies are needed to examine. One study conducted by Tully et al. (2020) found that replacing sedentary behaviours with light physical activity or moderate to vigorous physical activity could decline anxiety symptoms among older people, in support of the results in this study even if time duration in the two studies were different. Furthermore, the study carried out by Meyer et al. (2020) illustrated that both replacing sedentary behaviours with either light physical activity or moderate to vigorous physical activity could reduce anxiety symptoms in young adults.

There are several limitations carried by the current study. Firstly, the data of this present research was collected by implementing a cross-sectional method. Although significant correlations were found between the variables, the data should be interpreted with caution and causal relationships cannot be concluded from this study. Also, a third variable cannot be eliminated from the positive correlation between physical activity and participants' lower anxiety scores. For instance, a past study has demonstrated that individuals' socio-economical status would contribute to their higher likelihood of adopting a healthy lifestyle, while the socio-economical status background also acts as a protective factor for people's mental health status. Future studies should be conducted to further examine the relationship between physical activity and anxiety symptoms by taking the socio-economical status factor into account.

Moreover, the current study only recruited participants from the Chinese college student in southern China, and the findings may not be generalisable to populations living in other regions. Also, the current study used self-reported questionnaires to collect data, which is subject to respondents' bias and social desirability. Last, cross-sectional study design fails to allow us to determine cause-and-effect inference. Despite the limitations, the findings of the current study have significant implications. In general, as anxiety disorders are prevalent in Chinese college students and can lead to problematic behaviours, it is important to explore potential solutions to reduce the symptoms. Based on the current study, promoting health literacy and an active lifestyle might be helpful to prevent anxiety disorder in Chinese college students, as research has indicated that the promotion of an active lifestyle is positively associated with fewer mental health problems. Potential practices that have a positive impact on individuals' physical activity might also be effective to reduce anxiety symptoms of Chinese college students. Future studies are needed to further explore the effectiveness of these planned actions.

Conclusion

This study offered evidence concerning favourable replacements among sleep, sedentary behaviour, light physical activity, and moderate to vigorous physical activity were associated with anxiety symptoms among Chinese college students. Replacing more sedentary behaviour with moderate to vigorous physical activity might result in greater effects on reducing anxiety symptoms. Future studies are encouraged to adopt improved study designs for confirmation or negation of our research findings.

Data availability statement

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

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

LC: writing—original draft. RM: formal analysis. LC and RM: writing—review and editing. WJ: data curation. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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The relationship between physical exercise and mobile phone addiction among Chinese college students: Testing mediation and moderation effects

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Background: During the COVID-19 pandemic, suspensions of activities and long periods of self-isolation led to a sharp increase in excessive use of mobile phones, which sparked public concern about mobile phone addiction (MPA). In recent years, more and more attention has been paid to physical exercise as a protective effect of MPA. However, more studies are needed to reveal this relationship and the exact mechanisms, based on which this study tested the mediating and moderating roles of self-control, rumination, psychological distress, and loneliness between physical exercise and MPA.

Methods: In this cross-sectional study, primary data was collected by questionnaire from 1,843 college students (19.75±1.3) from five universities in Sichuan Province in Mainland China. Mobile Phone Addiction Tendency Scale (MPATS), Physical Activity Rating Scale-3 (PARS-3), Self-Control Scale (SCS), Ruminative Response Scale (RRS), Depression Anxiety Stress Scale-21 (DASS-21), and UCLA Loneliness Scale (UCLA-20) were investigated. The mediating models were examined using SPSS PROCESS macro 3.3 software, in which the mediation variables were self-control, rumination, and psychological distress, and the moderation was loneliness. Gender, major, and grade were included as control variables.

Result: Self-control, rumination, and psychological distress played a simple mediating role between physical exercise and MPA. Moreover, not only self-control and rumination but also self-control and psychological distress played the chain mediating roles between physical exercise and MPA. The chain pathways were moderated by loneliness. Specifically, the effect was more substantial among college students with higher loneliness.

Conclusion: The conclusions corroborate and clarify that self-control, rumination, and psychological distress mediated the association between physical exercise and MPA, and the mediation effects were moderated *via* loneliness. This present study advanced our understanding of how and when

college students' physical exercise was related to MPA. It also illustrates that educators and parents should pay more attention to college students' physical exercise.

KEYWORDS

physical exercise, Mobile phone addiction, college students, self-control, rumination, psychological distress, loneliness

Introduction

Mobile phone user groups are growing rapidly with the development and popularity of mobile internet devices. Globally, 90% of people own mobile phones (Lian et al., 2021). According to the 49th statistical report released by the China Internet Network Information Center, as of December 2021, mobile phone users had reached 10.29 billion, and 99.7% of netizens used mobile phones to surf the Internet (Center, 2022). The mobile phone has become an integral part of human life. Particularly during the COVID-19 pandemic, due to the pandemic and the government's policy of staying safe, people's behavioral patterns and mental health were changed, and college students' sedentary time and mobile phone use increased rapidly (Huckins et al., 2020). Among them, mobile phone use increased by 27.6% for men and 57.2% for women (Saadeh et al., 2021). It is reported that the mean prevalence of MPA in Chinese college students was 32%, indicating that excessive use of mobile phones by college students would increase the risk of MPA (Guo et al., 2022). As is known to all, MPA harms college students' physical and mental health (Liu et al., 2022). Studies have found that MPA was closely linked to Physical pain (Demir and Sumer, 2019; Mustafaoglu et al., 2021), blurred vision (Liu et al., 2022), sleep quality (Demir and Sumer, 2019), depression, anxiety, and stress (Gao et al., 2018). In addition, MPA would seriously affect college students' academic performance (Liu et al., 2022), interpersonal competence (Lee et al., 2018), and life quality (Liu et al., 2022). For instance, it is found that mobile phone users may experience high anxiety levels and poor academic performance (Andrew et al., 2014). Thereby, MPA has become a serious public health concern, and effective interventions are urgently needed to prevent MPA among college students.

MPA is also known as "unreasonable use of mobile phones" or "mobile phone dependence" (Liu et al., 2022), which is defined as uncontrollable use of mobile phones (Daniel, 2014), and similar non-substance addiction symptoms in mobile phone use were observed (Panova and Carbonell, 2018). Physical exercise, an essential part of a healthy life, is also a critical factor in preventing and managing mental illness and behavioral addictions (Marconcin et al., 2022). In recent years, physical activity has been proven to be an essential protective factor in MPA (Kim et al., 2015; Liu S. et al., 2019). For instance, a study of 1,433 college students in China showed that physical exercise negatively predicted MPA (Guo et al., 2022). When physical exercise increased from sedentary to moderate, the dose- dependent relationship between physical exercise and MPA was most apparent (Lian et al., 2021). In a 12-week intervention experiment involving Baduanjin and basketball, researchers found that physical exercise effectively reduced MPA among college students (Daniel, 2014). Moreover, among the psychological theories, the "distraction" argues that diversion from unpleasant stimuli or painful somatic complaint leads to improved emotion following exercise sessions (Morgan, 1985). The well-known mastery hypothesis and the self-efficacy theory focus on the post-exercise sense of revitalization and achievement, promoting positive moods (Marcus, 1995; Paluska and Schwenk, 2000). While in the Interaction of Person-Affect-Cognition-Execution (I-PACE) model, emotional and cognitive responses were the core characteristics of addictive behaviors (Brand et al., 2019). Therefore, individuals with moderate exercise would not devote extensive energy to problematic cell phone use (Tao et al., 2020). Previous studies have shown that physical exercise can reduce the negative emotions related to MPA (such as anxiety, depression, and stress; Grasdalsmoen et al., 2020) and has a positive role in the treatment of some psychological diseases and the suppression of MPA (Fan et al., 2021). Therefore, it is reasonable to believe that physical exercise is an essential protection against MPA.

In recent years, the negative correlation between physical exercise and MPA has been confirmed, but the link between mediating (i.e., how physical exercise relates to college students' MPA) and moderating mechanisms (i.e., when physical exercise is the most effective intervention on MPA) needs further exploration. Based on the theory of the Interaction of Person-Affect-Cognition-Execution (I-PACE) model (Brand et al., 2019), time self-regulation of physical activity (Hall and Fong, 2015), Salmon's unifying theory (Salmon, 2001) and compensatory Internet Use theory (Li J. et al., 2021), this study takes self-control, ruminant thinking, psychological distress, and loneliness as mediating and regulatory variables to construct a moderating mediation model.

The mediating role of self-control

Self-control has been conceptualized as a state and a trait, which is a relatively stable trait associated with various positive

outcomes (Tangney et al., 2004). Thus, this study focuses on the trait of self-control: "the stable ability to handle self-control dilemmas in such a way that the desired goal is prioritized" (Schuler et al., 2019). Under different conditions, due to overlapping definitions and structures, self-control has also been referred to as effort control, inhibitory control, cognitive control, and executive function (Duckworth et al., 2019). It can help individuals to quickly adjust themselves appropriately to adapt to the surrounding environment (Romero-Tena et al., 2021). Low self-control was closely related to drug abuse, addictive behavior, and maladjustment (Losada-Baltar et al., 2021). Empirical studies have proved that people with low self-control were more likely to develop MPA than those with high self-control ability (Xiang et al., 2019). When they lack self-control, individuals show more impulsive and irrational decisions (Testa et al., 2020). According to the addictive behavior model (I-PACE), the reduction of individual executive control and inhibitory control led to the reduction of motivation seeking and desire suppression, which led to excessive addictive behavior (Brand et al., 2016). The reduced inhibitory control was a vulnerability factor for addictive behaviors and a moderator of the relationship between specific emotional responses that trigger stimuli and the decision to engage in specific behaviors (Brand et al., 2019). Previous studies have also shown a positive correlation between low self-control and MPA (Jiang and Zhao, 2016). Therefore, lack of self-control was a significant risk factor for MPA.

Meanwhile, research on exercise psychology showed that physical exercise was one of the effective means to improve self-control (Guiney and Machado, 2013; Fan et al., 2021). Physical activity is closely related to executive function. According to the temporal self-regulation theory for physical activity, individuals with solid executive control are better able to engage in physical activity, which in turn helps to strengthen the executive control network (Hall and Fong, 2015). Some researchers regard MPA as a response to losing control over one's body (Jiang and Zhao, 2016). Salmon's unifying theory suggests that physical activity may enhance the executive functions controlling behavior, thoughts, and emotions (Salmon, 2001). The strength model of self-control suggests that self-control could be effectively improved or enhanced *via* regular physical activity or exercise (Yang et al., 2019). Previous studies have shown that different types and intensities of exercise positively affect self-control (Contreras-Osorio et al., 2021; Tian et al., 2021). For instance, one longitudinal study found that both acute and chronic physical exercise can be beneficial to the enhancement of self-control (Benzing et al., 2018). It is proved that high-intensity intermittent exercise could be a time-efficient approach for enhancing inhibitory control (Tian et al., 2021). Moreover, exercise might positively affect the cognitive control system of the brain (Smith et al., 2010; Dwyer et al., 2014). Physiological indicators showed that the cognitive control system was closely associated with the executive control network (ECN), commonly involved in executive control, working memory, and decision-making (Yin et al., 2022). Functional magnetic resonance imaging (fMRI) research studies have found that small metabolic changes in brain regions might be associated with executive function during physical exercise (Davis et al., 2011). Therefore, physical exercise may indirectly influence MPA through self-control (Hypothesis 1).

The mediating role of rumination

Rumination refers to a mode of responding to distress that involves a repetitive focus on one's distress, as well as its causes and consequences, rather than actively solving problems to relieve the negative emotions (Shaw et al., 2019). According to the response styles theory, rumination maintains and exacerbates negative moods by enhancing negative thinking (Shaw et al., 2019). Numerous studies suggest that rumination was an influential factor in depressive symptoms, anxiety (Candea and Szentagotai-Tatar, 2017), perceived stress (Ruscio et al., 2015), and suicidal ideation (Ruscio et al., 2015; Candea and Szentagotai-Tatar, 2017; Holdaway et al., 2018). Given that depression, anxiety, and stress are important risk factors for MPA (Elhai et al., 2020a,b; Gao et al., 2018), rumination may induce and exacerbate MPA. Studies on the relationship between rumination and MPA have also confirmed that rumination was an important predictor of MPA (Peng et al., 2022). For instance, in a cross-sectional study of rumination and MPA, rumination can further predict MPA with the enhancement of excessive assurance-seeking behavior (Elhai et al., 2020a,b).

Given that rumination is a risk factor for MPA (Elhai et al., 2020a,b), various factors that may prevent rumination have been of great concern. Physical exercise has been shown to be effective as a monotherapy for rumination (Cooney et al., 2013) and a psychotherapy enhancement strategy (Abdollahi et al., 2017). According to Salmon's unified theory, physical exercise can improve cognitive responses, arouse benign attributions of fear stimuli, and prevent panic factors caused by negative emotions (Salmon, 2001). Previous studies have shown that exercise reduces rumination and affects depressive symptoms in general (Bernstein and Mcnally, 2017). In biology, studies have reported evidence for increased neuroplasticity, especially in the hippocampus, which is relevant to cognitive-emotional processing (Medina et al., 2015; Kandola et al., 2019). The research identified that physical exercise increases neuroplasticity in the hippocampal circuit, and changes in this circuit may allow individuals to process emotional information differently to reduce the automatic prioritization of negative information and thus reduce rumination (Hamilton and Gotlib, 2008). In addition, studies have found that rumination in patients with mental disorders is negatively associated with aerobic exercise (Brand et al., 2018). Physical exercise plays a positive role in the improvement of rumination. Therefore, rumination could be regarded as a mediator between physical exercise with MPA (Hypothesis 2).

The mediating role of psychological distress

Psychological distress is a state of emotional distress associated with anxiety, depression, stress, and general mood disorders, reflecting the internal state of an individual's mental health (Wong et al., 2014; Liu R.D. et al., 2019). The cause of psychological distress may be related to individual needs that are not met (Wong et al., 2014). According to compensatory Internet use theory, psychologically troubled individuals tend to use the Internet to deal with negative emotions or compensate for problems in reality (Daniel, 2014). For instance, due to social difficulties and negative emotions caused by shyness, individuals may resort to the online world to relieve negative emotions and meet their needs (Cole et al., 2019). Once relief and satisfaction can be obtained from mobile phone interaction, people are more likely to view mobile phone use as a useful coping strategy, leading to automatic activation and potentially addictive behavior (Nicholls et al., 2014). Cognitive behavioral models show that psychological distress such as depression, anxiety, and other negative emotions are risk factors for problematic Internet use (Davis, 2001). A growing number of studies have also confirmed a positive correlation between psychological distress and MPA (Liu R.D. et al., 2019). For example, a cross-sectional study found that psychological distress, such as anxiety and depression, can predict problematic internet use (Arrivillaga et al., 2022), which might increase the risk of MPA (Geng et al., 2021). In addition, with the increase in stress, depression, and anxiety, the level of MPA was also increased (Gao et al., 2018). Therefore, it is reasonable to postulate that psychological distress is closely associated with increased MPA.

It is well known that physical exercise improves physical and mental health. Physical exercise, as a non-drug intervention for depression and anxiety symptoms, has attracted researchers` attention (Brondino et al., 2017). For example, a meta-analysis reported a significant effect of physical exercise in alleviating depressive symptoms (Kvam et al., 2016). At the same time, some studies have found that depression, anxiety, and other negative emotions are closely related to cognitive dysfunction (Shilyansky et al., 2016), and that physical exercise could positively affect cognitive function. For instance, in terms of biology, it has been found that physical exercise can promote prominent plasticity in the hippocampus through brain-derived neurotrophic factor (BDNF), and elevate BDNF levels, thus promoting cognitive development (Aguiar et al., 2011). Empirical studies have shown that physical exercise was associated with cognitive improvement in individuals with mild cognitive impairment (Zheng et al., 2016). Therefore, physical exercise can relieve psychological distress by improving cognition. Meanwhile, according to salmon's unified theory, physical exercise may trigger more beneficial processes that indirectly improve mental health (Salmon, 2001), such as enhancing the executive ability to control behavior (Wang et al., 2022), thoughts, emotions, and enhancing resistance to physical and emotional consequences of psychological stressors (Audiffren and Andre, 2019). In the Boehm and Kubzansky model, exercise is classified as a restorative behavior associated with psychological distress (Boehm and Kubzansky, 2012). A population-based longitudinal study also suggests that light and moderate physical activity can protect against future psychological distress (Sheikh et al., 2018). Therefore, this study hypothesized that psychological distress might act as an intermediary linking physical exercise and MPA (Hypothesis 3).

The chain mediating roles of self-control and rumination

Numerous studies have revealed the protective effects of attention control, cognitive control, executive function, and mindfulness on rumination (DeJong et al., 2019; du Pont et al., 2019). Although few studies have shown a direct relationship between self-control and rumination, self-control has also been justified as a predictor of rumination (Breithaupt et al., 2016). According to the response style theory of rumination, rumination is closely associated with the cognitive ability to promote goal-related behaviors by regulating thoughts and behaviors (Friedman and Miyake, 2017). The impaired disengagement hypothesis suggests that low levels of attentional control led to prolonged and habitual rumination (du Pont et al., 2019). For instance, most people experience negative and critical self-focused thoughts as incongruent with their positive self-image, which leads to conflicting signals from the negative thoughts (Koster et al., 2011). However, disruptions of conflict signaling processes (e.g., with reduced attentional control) can lead to a sustained focus on negative thoughts and habitual engagement in rumination (De Raedt and Koster, 2010). The dual process model of cognitive land vulnerability and resource allocation hypothesis suggests that rumination and limited cognitive resources require cognitive control (Levens et al., 2009). These hypotheses all reflect the correlation between self-control and rumination. Meanwhile, studies have found that aerobic exercise combined with meditation significantly enhances cognitive control processes and reduces rumination patterns (Lavadera et al., 2020). Based on these accumulated findings, physical exercise may indirectly influence MPA through the chain mediating effect of self-control and rumination (Hypothesis 4).

The chain mediating roles of self-control and psychological distress

Given that psychological distress is a risk factor for MPA and self-control is associated with mental health (Cheung et al., 2014; Gao et al., 2018), this study further explored the protective effect of self-control on psychological distress. Self-control is always defined as the capacity to alter the predominant response to promote desirable long-term goals (Li et al., 2015), which was associated with many mental health indicators such as satisfaction

with life, happiness and self-esteem (Cheung et al., 2014). Which has also been linked to lower levels of depression and anxiety (Li et al., 2019; Liu R.D. et al., 2019). Previous studies have found that high levels of self-control can protect teenagers from psychological distress. Cognitive theories of emotion suggest that self-control plays a vital role in adaptive and maladaptive emotional processes (Ainsworth and Garner, 2013). This is supported by empirical studies indicating that higher anxiety was associated with inhibitory control deficits in individuals (Ansari and Derakshan, 2011). Furthermore, a meta-analysis has shown that lower self-control is associated with increased depression and anxiety (Ran et al., 2019). Therefore, self-control plays a positive role in reducing psychological distress. Based on the above research results, we hypothesize that physical exercise may indirectly affect MPA through the chain mediating effect of self-control and psychological distress (Hypothesis 5).

The moderating role of loneliness

Although physical exercise might be related to MPA through self-control and rumination or self-control and psychological distress, this effect may vary according to individual characteristics. According to the Interaction of Person-Affect-Cognition-Execution (I-PACE) model, a person's characteristics may influence their internal responses (execution, cognitive response, and affect), leading to the establishment and intensification of problematic behavioral outcomes (Li J. et al., 2021). Loneliness as a personality trait has attracted more and more attention (Li X. et al., 2021). Thus, we would further introduce loneliness as individual factor and investigate whether the relationship between physical exercise and MPA can be buffered by loneliness.

Loneliness is an experience of negative emotional experience caused by an interpersonal relationship gap and the resulting emotions (Fan et al., 2022). As described by multidimensional models of loneliness, this negative experience has far-reaching affective (e.g., depression), cognitive (e.g., maladaptive perceptions), and behavioral consequences (e.g., risk-related behavior), which negatively impact psychological and physiological health and well-being (Arpin and Mohr, 2019). Firstly, loneliness may moderate the positive effect of self-control on rumination. Loneliness is related to the ability of individuals to process emotions and regulate their feelings, and high levels of loneliness may prolong or deepen the negative emotions felt and increase the risk of rumination (Hards et al., 2022). According to the ruminative stress response model, individuals who experience more negative experiences (e.g., Loneliness,) may ruminate more about their life and emotional states (Tong et al., 2021). Loneliness has been shown to be a crucial risk factor in rumination (Tong et al., 2021). In a cross-sectional study of young adults, high loneliness is usually correlated with low levels of positive emotion and other features that reflect high levels of negative emotion (Zawadzki et al., 2013). A longitudinal study of older adults found that individuals with high levels of loneliness tend to experience more rumination (Gan et al., 2015). Therefore, at the same level of self-control, individuals with high loneliness will acquire more rumination, and the effect of self-control ability on rumination will be enhanced. That is, as loneliness increases, the relationship between self-control and rumination becomes stronger. Therefore, loneliness might act as a buffer in the link between self-control and rumination (Hypothesis 6a).

Secondly, Loneliness may also buffer the influence of self-control on psychological distress. A substantial body of empirical studies has confirmed that loneliness reduces the ability of individual emotion regulation. For instance, a systematic review found that loneliness is associated with worse mental health outcomes, including worse depression and anxiety symptoms and poorer remission of depression (Hards et al., 2022). Many studies have shown that loneliness was a significant predictor of psychological distress, with people who report more loneliness also reporting more depression and higher stress levels (Lam et al., 2017; Yung et al., 2021). This finding was supported by studies of older adults and adolescents. Longitudinal studies of loneliness in older adults predicted depressive symptoms 2–12 years later (Lee et al., 2020). A similar phenomenon has been found in studies of young adults and adolescents (Qualter et al., 2010). A meta-analysis of 63 studies found that loneliness had a negative impact on the mental health of adolescents and young adults for up to 9 years, with the most significance on depression (Loades et al., 2020). Many longitudinal studies have found a correlation between loneliness and depression, and the relationship was more robust in the early stages of depression (Hsueh et al., 2019; Santini et al., 2020). Therefore, increased loneliness raises the risk of psychological distress. In addition, loneliness is accompanied by a social environment of isolation and loss of support. Individuals without social support are in a fragile psychological state, leading to the onset or amplification of psychological distress (Hards et al., 2022). According to the interpersonal theory and stress generation theory, increasing social isolation and loneliness will increase the individual's response to stressors, anxiety, depression, and other negative emotions (Flynn et al., 2010). Therefore, low social support and high levels of loneliness enhance the effects of high self-control on psychological distress. As loneliness increased, the relationship between self-control and psychological distress became more pronounced. Therefore, self-control might be able to moderate the relationship between self-control and psychological distress (Hypothesis 6b).

The present study

Considering the harm of MPA to college students' physical and mental health, it is imperative to examine the protective mechanism of physical exercise on MPA. Thus, the present study examined the direct effects of physical exercise on MPA in college students and assessed whether any detected association of physical exercise with MPA was mediated by self-control, rumination, and psychological

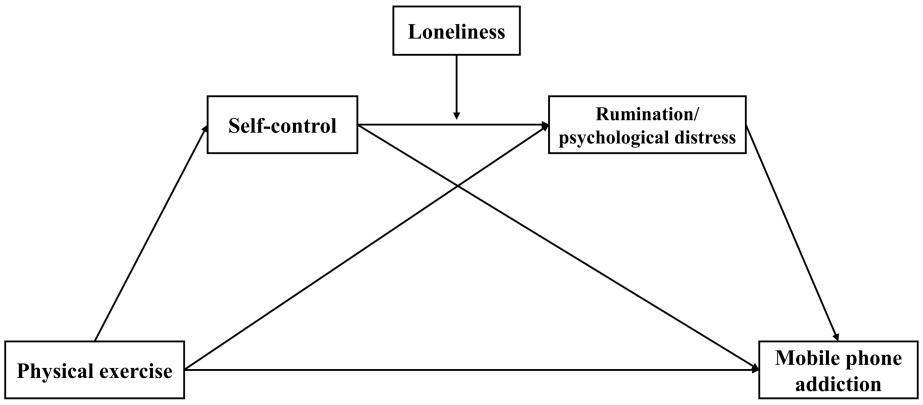

FIGURE 1
The proposed model.

distress and modulated by loneliness. The proposed model is illustrated in Figure 1. The specific assumptions were as follows:

Hypothesis 1: Self-control plays a mediating role between Physical Exercise and MPA. (H1)

Hypothesis 2: Rumination plays a mediating role between Physical Exercise and MPA. (H2)

Hypothesis 3: Psychological Distress plays a mediating role between Physical Exercise and MPA. (H3)

Hypothesis 4: Self-control and Rumination play a chain mediating role between Physical Exercise and MPA. (H4)

Hypothesis 5: Self-control and Psychological Distress play a chain mediating role between Physical Exercise and MPA. (H5)

Hypothesis 6a: Loneliness modulates the chain mediating role of Self-control and Rumination. (H6a)

Hypothesis 6b: Loneliness modulates the chain mediating role of Self-control and Psychological Distress. (H6b)

Materials and methods

Participants and procedures

A cross-sectional survey was conducted by using the convenience sampling method, in five universities in Sichuan province from October to November 2021. Participants were recruited before class and asked to complete paper questionnaires in class. We recruited 1,963 college students aged 17–27 years. More details of the selection process are outlined in Figure 2. The response sample ($n = 1{,}900$) included a total of 1,843 participants (56.9% female) in the final analysis. The effective response rate was 97%. The mean age of the participants was 19.75 years (SD = 1.3). Participants understood the requirements of the survey through personal explanation, and all questionnaires were completed within 30 min. The study followed the guidelines of the STROBE checklist, complied with the principles of the Declaration of Helsinki, and it is supported and approved by the Institutional Review Board of Sichuan University. Signed informed consent forms were obtained from students.

Measures

Mobile phone addiction

The Mobile Phone Addiction Tendency Scale (MPATS) was applied to estimate the MPA for college students (Jie et al., 2012), which has been used in Chinese college students and young adults with good reliability and validity (Yang et al., 2019). The MPATS is a 5-point-Likert scale consisting of 16 items and four dimensions: withdrawal symptoms (WS), salience behavior (SB), social comfort (SC), and mood changes (MC; e.g., "I would rather chat on my cell phone than face to face"). Each item is rated from 1 (completely disagree) to 5 (completely agree), and the total score will be from 16 to 80, and a higher score may mean a deeper degree of MPA (Kimberly, 1998). The internal consistency coefficient and retest reliability of MPATS were 0.83 and 0.91, respectively, (Jie et al., 2012). In the present study, confirmatory factor analysis results demonstrated that a single-factors model fit the data satisfactorily: $\chi^2/df = 5.29$, CFI = 0.97, TLI = 0.95, RMSEA = 0.048, SRMR = 0.038, and the Cronbach's α was 0.88.

Physical exercise

Physical exercise (PE) was measured by the Physical Activity Rating Scale-3 (PARS-3; Yang et al., 2021), which has been used in Chinese college students and young adults with good reliability

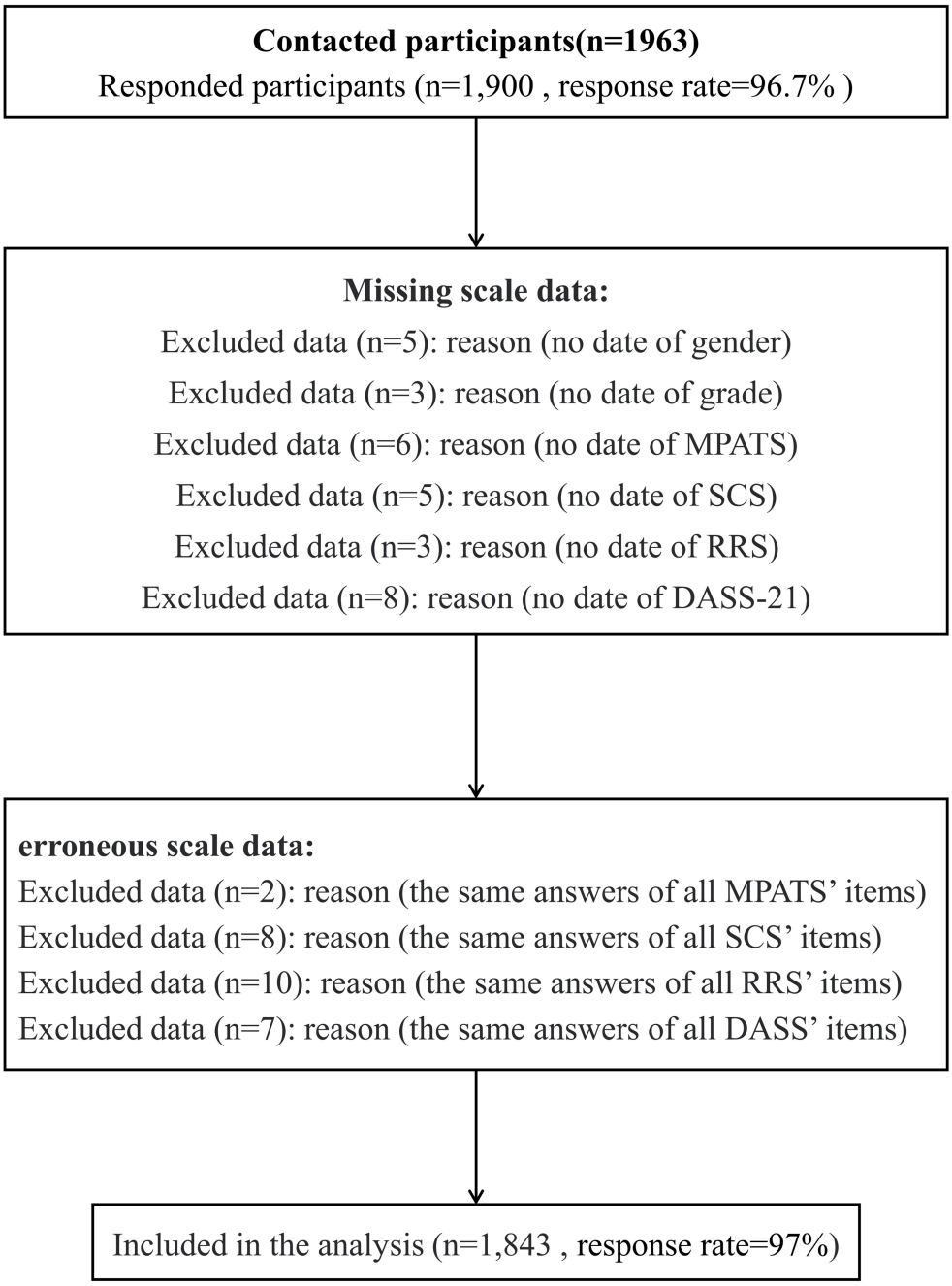

FIGURE 2
The procedure of obtaining final study sample.

and validity (Yang et al., 2021). The PARS-3 is a three-item self-reported scale containing exercise intensity, exercise time, and exercise frequency (e.g., "How hard do you exercise?"; Yang et al., 2019). Each item is rated from 1 to 5, and the following equation computes the total score of physical activity: intensity × (time-1) × frequency, with a range of 0–100. The PARS-3 has excellent test–retest reliability ($r = 0.82$; Yang et al., 2019). The internal consistency of PARS-3 in this study was basically satisfactory, and the Cronbach's α was 0.6.

Self-control

Self-control (SC) was evaluated by the self-control scale (SCS; Yang et al., 2019), which was modified based on Tangney's Self-Control Scale and showed good reliability and validity among Chinese college students (Tangney et al., 2004; Geng et al., 2021). The SCS is a 5-point-Likert scale and comprises 19 items. It has five dimensions: controlling impulses, keeping healthy habits, resisting temptation, concentrating on work, and controlling entertainment. Fifteen items were scored in reverse, and four were scored in a

positive direction (e.g., "It is difficult for me to break bad habits"). Each item is valued from 1 (completely disagree) to 5 (completely agree). The total score can be from 19 to 95, and a higher score shows a higher level of individual self-control (Ma et al., 2020). The SCS has a fair internal consistency coefficient ($\alpha = 0.86$) and retest reliability ($r = 0.89$; Jiang and Zhao, 2016). In the present study, confirmatory factor analysis results demonstrated that a single-factors model fit the data satisfactorily: $\chi^2/df = 5.01$, CFI = 0.96, TLI = 0.93, RMSEA = 0.047, SRMR = 0.04, and the Cronbach's α was 0.85.

Rumination

Rumination (RA) was measured by the Chinese version of the Ruminative Response Scale (RRS; Lei et al., 2017) developed by Nolen-Hoeksema (1991) and showed good reliability and validity among Chinese college students (Lian et al., 2021). Participants responded to the 22 items on a Likert-type scale ranging from 1 (never) to 4 (always; e.g., "Go some-place alone to think about your feelings" and "I often think about the situation and wish it would change for the better"). Higher scores reflect a higher tendency to respond to negative factors with a ruminative response style (Lei et al., 2017). In this study, confirmatory factor analysis results demonstrated that a single-factors model fit the data satisfactorily: $\chi^2/df = 5.21$, CFI = 0.97, TLI = 0.95, RMSEA = 0.048, SRMR = 0.02, and the Cronbach's α was 0.931.

Psychological distress

Psychological distress (PD) was assessed by the Chinese version of Depression Anxiety Stress Scale-21 (DASS-21), which has been widely used to measure individual psychological distress (Wang et al., 2016) and showed good reliability and validity in Chinese samples (Li Y. et al., 2021). The scale consists of 21 items that cover three subscales: depressive symptoms scale (e.g., "I could not seem to experience any positive feeling at all"), anxiety symptoms scale (e.g., "I was aware of dryness of my mouth"), and stress symptoms scale (e.g., "I found it hard to wind down"). All items were rated on a four-point scale ranging from 0 (did not apply to me at all) to 3 (applied to me very much or most of the time). The higher the score, the more psychological distress (Chen et al., 2021). In this study, confirmatory factor analysis results demonstrated that a single-factors model fit the data satisfactorily: $\chi^2/df = 5.50$, CFI = 0.96, TLI = 0.95, RMSEA = 0.049, SRMR = 0.02, and the Cronbach's α was 0.933.

Loneliness

Loneliness was assessed using the Chinese version of the UCLA Loneliness Scale (Jianfeng et al., 2016), which was modified based on Russell's UCLA Loneliness Scale (Russell, 1996) and showed good reliability and validity among Chinese college students (Xia and Yang, 2019). It consists of a total loneliness scale and three subscales that correspond to three self-related facets of loneliness and social connectedness: Isolation, Relational Connectedness, and Collective Connectedness. Participants responded to 20 questions on a Likert-type scale (e.g., Are you lonely?; Padmanabhanunni and Pretorius, 2021). All items are rated on a four-point scale, from 1 (never) to 4 (always). Furthermore, 11 items in the project are scored forward, and nine items are scored backward; the higher the score, the more loneliness. In the present study, confirmatory factor analysis results demonstrated that a single-factors model fit the data satisfactorily: $\chi^2/df = 5.94$, CFI = 0.95, TLI = 0.92, RMSEA = 0.052, SRMR = 0.038, and the Cronbach's α was 0.88.

Statistical analyses

Amos 24.0 was used for confirmatory factor analysis to test the validity of variables, and SPSS 26 was used to study descriptive statistics, Pearson correlation, and bias analysis of common methods. Descriptive characteristics of the participants are presented as means (M) and standard deviation (SD). Gender, major, and grade were selected as covariates since they were associated with the main variables. Partial correlation coefficients were estimated to examine the associations among physical exercise, self-control, rumination, psychological distress, loneliness, and MPA. Harman's single-factor test was used to test for common method bias. According to the study's recommendation (Qian et al., 2022). Using process macros in SPSS26 to examine our model. Firstly, we used process model 4 to test the simple mediating models of self-control, rumination, and psychological distress. Secondly, using model 6 to test the chain mediated model of self-control, rumination, and psychological distress. Next, model 91 is applicable to test the moderated mediation effect in the conceptual model shown in Figure 1. Mediation and moderation hypotheses were tested with bootstrapping using resampling of 5,000 samples to calculate 95% confidence intervals (CIs). The results were deemed statistically significant if the 95% CI did not contain zero and the p value was <0.05. In addition, this study referred to effect sizes of the correlation coefficient r (Yang et al., 2021) to estimate the magnitude of significant differences during statistical analysis.

Results

Common method deviation test

Because the data in this study was obtained in the form of questionnaire self-report, to avoid common method bias, Harman's single-factor test was used to test the bias of common methods (Gao et al., 2020; Peng et al., 2020). The results show that the original roots of 17 factors are more significant than 1. The cumulative variance explained by the first factor was 9.44% (the threshold was 40%). This indicates that this study has no major problems with common methodological bias.

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TABLE 1 Results of confirmatory factor analyses.

Models	Variables	χ^2	df	c^2/df	CFI	TLI	SRMR	RMSEA
Five-factor model	PE, SC, RA, PD, MPA	788,384	87	9.062	0.945	0.924	0.03	0.066
Four-factor model	PE, SC, RA + PD, MPA	1620.45	98	16.535	0.88	0.853	0.32	0.092
Three-factor model	PE, SC, RA + PD + MPA	2807.595	101	27.798	0.787	0.747	0.054	0.121
Two-factor model	PE + SC, RA + PD + MPA	3452.441	103	33.519	0.736	0.693	0.087	0.133
Single-factor model	PE + SC + RA + PD + MPA	4488.229	104	43.156	0.655	0.601	0.092	0.151

PE, physical exercise; MPA, mobile phone addiction; SC, self-control; RA, Rumination; PD, psychological distress.

TABLE 2 Descriptive statistics and interrelations among of the observed variable.

Variable	M	SD	1	2	3	4	5	6	7	8	9
1. Gender	1.57	0.50	1								
2. Major	1.98	1.48	−0.20**	1							
3. Grade	1.60	0.64	0.10**	0.03	1						
4. PE	27.08	23.49	−0.29**	0.51**	−0.04	1					
5. MPA	2.61	0.66	0.18**	−0.06*	0.09**	−0.14**	1				
6. SC	3.12	0.54	−0.17**	0.09**	−0.09**	0.15**	−0.45**	1			
7. RA	2.09	0.53	0.03	−0.04	0.04	−0.08**	0.36**	−0.41**	1		
8. PD	1.72	0.53	−0.03	0.01	0.03	−0.05*	0.37**	−0.45**	0.70**	1	
9. LN	2.16	0.43	0.06*	−0.02	−0.001	−0.12**	0.26**	−0.27**	0.46**	0.49**	1

N = 1,843. PE, physical exercise; MPA, mobile phone addiction; SC, self-control; RA, Rumination; PD, psychological distress; LN, loneliness.
**p < 0.01; *p < 0.05.

Confirmatory factor analysis

Before testing the hypothesis, we used confirmatory factor analysis (CFA) to validate the measurement model (Li and Peng, 2022). The measurement model includes five potential factors: physical exercise, self-control, rumination, psychological distress, and MPA. The CFA results of this study are shown in Table 1. Results showed that the data of the five-factor model were in good fit [χ^2 (87) = 788.384, values of CFI = 0.945, TLI = 0.924, SRMR = 0.03, RMSEA = 0.066]. This proved that the model's goodness of fit is significantly better than other factor models. These results of CFAs provided full support for the discriminate validity of our study instruments.

Primary analysis

Table 2 shows all observed variables' mean, standard deviation, and correlation. Physical exercise was positively correlated with self-control and negatively correlated with MPA, rumination, and psychological distress. Self-control was negatively correlated with MPA, rumination, and psychological distress. Loneliness was positively correlated with rumination and psychological distress. Rumination and psychological distress were positively correlated with MPA.

Testing for the simple mediation model

The results are shown in Table 3. As expected, the overall effect of physical exercise on MPA was significant in all simple mediation models ($\beta = -0.11$, $p < 0.001$). In the mediating model of self-control, physical exercise has a positive predictive effect on self-control ($\beta = 0.094$, $p < 0.001$), self-control ($\beta = -0.43$, $p < 0.001$), and physical exercise ($\beta = -0.066$, $p < 0.01$) negatively predicts MPA. In the mediating model of rumination, physical exercise has a negative predictive effect on rumination ($\beta = -0.072$, $p < 0.01$), rumination ($\beta = 0.35$, $p < 0.001$) positively predicts MPA, and physical exercise ($\beta = -0.08$, $p < 0.01$) negatively predicted MPA. In the mediating model of psychological distress, physical exercise has a negative predictive effect on psychological distress ($\beta = -0.084$, $p < 0.01$), Psychological distress ($\beta = 0.37$, $p < 0.001$) positively predicts MPA, and physical exercise ($\beta = -0.08$, $p < 0.01$) negatively predicted MPA. The bias-corrected bootstrapping mediation test indicated the process of physical exercise predicting MPA through self-control, rumination, and psychological distress were significant in the simple mediation model. Therefore, hypothesis 1, hypothesis 2, and hypothesis 3 were supported.

Testing for the chain mediation model

The path statistics are presented in Table 4. The overall effect of physical exercise on MPA was significant in all chain mediation

TABLE 3 Regression analysis of the simple mediation model.

Variable	Outcome: SC			Outcome: RA			Outcome: PD			Outcome: MPA											
										Total			Mediator: SC			Mediator: RA			Mediator: PD		
	B	SE	*p*	*B*	SE	*p*	*B*	SE	*p*	*B*	SE	*p*	*B*	SE	*p*	*B*	SE	*p*	*B*	SE	*p*
1 Gender	−0.13**	0.05	$p < 0.001$	0.01	0.05	0.8	−0.05	0.05	0.05	0.15***	0.05	$p < 0.001$	0.1***	0.04	$p < 0.001$	0.15***	0.05	$p < 0.001$	0.17***	0.045	$p < 0.001$
2 Major	0.02	0.02	0.38	−0.01	0.02	0.89	0.04	0.02	0.12	0.03	0.02	0.33	0.04	0.02	0.14	0.03	0.02	0.28	0.01	0.02	0.68
3 Grade	−0.07**	0.04	$p < 0.01$	0.04	0.04	0.12	0.03	0.04	0.25	0.07**	0.04	$p < 0.01$	0.042*	0.03	$p < 0.05$	0.06**	0.03	$p < 0.01$	0.06**	0.03	$p < 0.01$
4 PE	0.09***	0.03	$p < 0.001$	−0.07**	0.03	$p < 0.01$	−0.08**	0.03	$p < 0.01$	−0.11***	0.03	$p < 0.001$	−0.07**	0.02	$p < 0.01$	−0.08**	0.03	$p < 0.01$	−0.08**	0.03	$p < 0.01$
5 SC													−0.43***	0.02	$p < 0.001$	–	–	–	–	–	–
6 RA													–	–	–	0.35***	0.02	$p < 0.001$	–	–	–
7 PD													–	–	–	–	–	–	0.4***	0.02	$p < 0.001$

Results of bootstrapping mediation effect examination

Mediating effects	indirect	95%CI	Proportion	Degree of mediation
PE → SC → MPA (H1)	−0.04**	[−0.065, −0.017]	37.73%	Partial mediation
PE → RA → MPA (H2)	−0.025**	[−0.046, −0.006]	23.36%	Partial mediation
PE → PD → MPA (H3)	−0.031**	[−0.052, −0.011]	28.97%	Partial mediation

$N = 1{,}843$. M, meditation; PE, physical exercise; MPA, mobile phone addiction; SC, self-control; RA, Rumination; PD, psychological distress. Unstandardized regression coefficients are reported. Bootstrap sample size = 5,000.
***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.

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TABLE 4 Regression analysis of the chain mediating model.

variable	Outcome: SC			Outcome: RA			Outcome: PD			Outcome: MPA								
										Total			mediator: SC-RA			mediator: SC-PD		
	B	SE	*p*	*B*	SE	*p*	*B*	SE	*p*	*B*	SE	*p*	*B*	SE	*p*	*B*	SE	*p*
1 Gender	−0.13***	0.05	$p < 0.001$	−0.05*	0.05	$p < 0.05$	−0.11***	0.04	$p < 0.001$	0.15***	0.05	$p < 0.001$	0.11***	0.04	$p < 0.001$	0.12***	0.04	$p < 0.001$
2 Major	0.02	0.02	0.38	0.01	0.02	0.81	0.05*	0.02	$p < 0.05$	0.03	0.02	0.33	0.04	0.02	0.14	0.02	0.02	0.31
3 Grade	−0.07**	0.04	$p < 0.01$	0.01	0.03	0.72	−0.01	0.03	0.78	0.072**	0.04	$p < 0.01$	0.04*	0.03	$p < 0.05$	0.04*	0.03	$p < 0.05$
4 PE	0.09***	0.03	$p < 0.001$	−0.03	0.03	0.19	−0.04	0.02	0.1	−0.11***	0.03	$p < 0.001$	−0.06*	0.02	$p < 0.05$	−0.06*	0.02	$p < 0.05$
5 SC				−0.41***	0.02	$p < 0.001$	−0.46***	0.02	$p < 0.001$				−0.34***	0.02	$p < 0.001$	−0.32***	0.02	$p < 0.001$
6 RA													0.22***	0.02	$p < 0.001$	-	-	-
7 PD																0.23***	0.02	$p < 0.001$
R^2		0.043			0.168			0.21			0.047			0.26			0.26	
F		20.57***			73.93***			98.4***			22.77***			108.57***			109.39***	

Results of bootstrapping mediation effect examination

Mediating effects	indirect	95%CI	Proportion	Degree of mediation
PE → SC → RA → MPA (H4)	−0.008**	[−0.014, −0.003]	17.40%	partial mediation
PE → SC → PD → MPA (H5)	−0.01**	[−0.017, −0.004]	19.76%	partial mediation

$N = 1{,}843$. M, meditation; PE, physical exercise; MPA, mobile phone addiction; SC, self-control; RA, Rumination; PD, psychological distress. Unstandardized regression coefficients are reported. Bootstrap sample size = 5,000.
***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.

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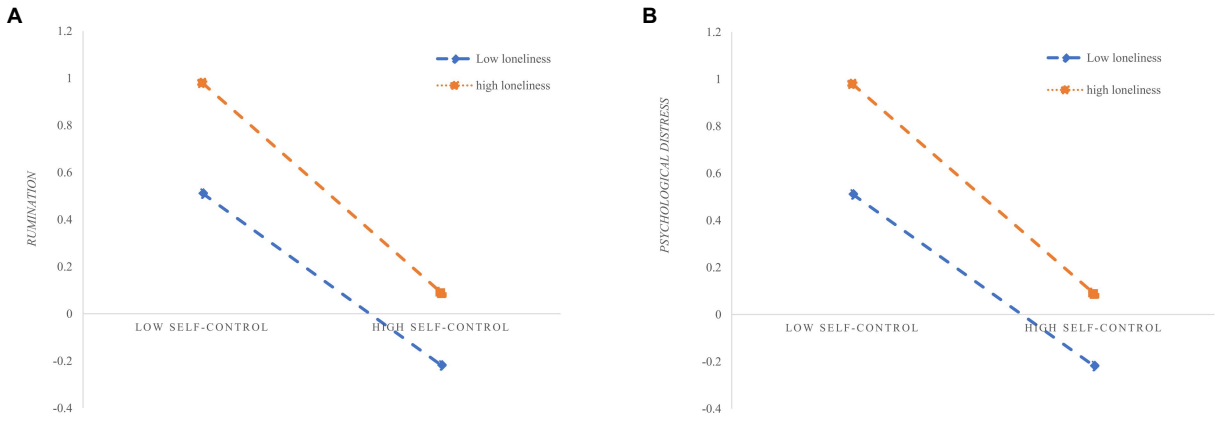

FIGURE 3
(A) Loneliness moderates the relation between self-control and rumination. **(B)** Loneliness moderates the relation between self-control and psychological distress.

models ($\beta = -0.11$, $p < 0.001$). In the serial mediating effecting, physical exercise can positively predict self-control ($\beta = -0.094$, $p < 0.001$), self-control negatively predicted rumination ($\beta = -0.41$, $p < 0.001$) and psychological distress ($\beta = -0.46$, $p < 0.001$), rumination positively predicted MPA ($\beta = 0.22$, $p < 0.001$), psychological distress positively predicted MPA ($\beta = 0.23$, $p < 0.001$). The bias-corrected bootstrapping mediation test indicated that it was significant, the process of physical exercise predicting MPA through self-control and rumination (ab = −0.008, Boot SE = 0.003, 95% CI = [−0.014, −0.003]), and through the self-control and psychological distress (ab = −0.01, Boot SE = 0.003, 95% CI = [−0.017, −0.004]). Therefore, hypothesis 4 and hypothesis 5 were supported.

Testing for the moderated mediation model

Figure 3 shows the main results. As shown in Figures 3A,B, self-control x loneliness interaction had significant effects on rumination ($\beta = -0.056$, $p < 0.001$) and psychological distress ($\beta = -0.081$, $p < 0.001$). These findings indicated that both the association between self-control and rumination and between self-control and psychological distress were moderated by loneliness. In addition, simple slope analyses were conducted to illustrate these significant interactions and explore whether slopes for the high-loneliness group (1 SD above the mean) were different from slopes for the low-loneliness group (1 SD below the mean) in the two models. The results were plotted in Figures 3A,B. It showed the relationship between self-control and rumination as well as self-control and psychological distress at two loneliness levels (M + 1SD and M − 1SD). As shown in the figure, self-control was negatively correlated with rumination ($\beta = -0.26$, $t = -10.0$, $p < 0.001$) and psychological distress ($\beta = -0.28$, $t = -11.6$, $p < 0.001$) for college students with low loneliness (M − 1SD). In addition, for college students with high loneliness (M + 1SD), self-control was stronger negatively correlated with rumination ($\beta = -0.37$, $t = -0.37$, $p < 0.001$) and psychological distress ($\beta = -0.45$, $t = -16.98$, $p < 0.001$). In other words, regardless of the degree of self-control, students with higher levels of loneliness reported higher levels of rumination and psychological distress, while students with lower levels of loneliness reported lower levels of rumination and psychological distress. Therefore, hypothesis 6a and hypothesis 6b were supported (Table 5).

Discussion

With the continuous progress of technology and the normalized development of the epidemic, mobile phones have become an indispensable part of daily life (Zhang and Wu, 2020). The problem of addiction caused by excessive use of mobile phones is also becoming more and more common among college students (Xiang et al., 2019). Recent studies have found that physical exercise positively protects MPA (Guo et al., 2022). However, more studies are needed to reveal the exact mechanisms. Based on theory and practice study, the study formulated the moderated mediation model to find the intrinsic relationship between physical exercise and MPA, and they also provide insights into the intervention of behaviors of MPA among undergraduates.

In the study, physical exercise is negatively associated with MPA and could positively predict MPA. The study reinforces the relationship between physical activity and MPA. Active participation may decrease screen time and sedentary behavior among college students so that they have less time to devote to mobile phone use and a lower chance of becoming addicted to it (Li Y. et al., 2021). According to the theory of Ternary Interaction, the environment, the individual and behavior influence each other (Flynn et al., 2010). As a significant external environmental stimulus, physical exercise can not only effectively improve individual physical health but also play an essential role in reducing behavioral addiction (Guo et al., 2022). In addition, the

TABLE 5 Regression results of moderated mediation.

	R^2	F	df_1	df_2	p	B	Boot SE	t	p
SC * LN → RA	0.31	115.34	7	1,835	<0.001	−0.056***	0.02	−3.38	<0.001
SC * LN → PD	0.36	149.28	7	1,835	<0.001	−0.08***	0.02	−5.08	<0.001
The conditional effect analysis of loneliness value (M ± SD) between self-control and rumination									
						B	**Boot SE**	**Boot LLCL**	**Boot ULCL**
M − 1SD (−1)						−0.26	0.03	−0.31	−0.21
M (0)						−0.31	0.02	−0.35	−0.27
M + 1SD (1)						−0.37	0.03	−0.42	−0.31
The conditional effect analysis of loneliness value (M ± SD) between self-control and psychological distress									
						B	**Boot SE**	**Boot LLCL**	**Boot ULCL**
M − 1SD (−1)						−0.28	0.02	−0.33	−0.24
M (0)						−0.36	0.02	−0.4	−0.33
M + 1SD (1)						−0.45	0.03	−0.5	−0.39

N = 1,843. M, mean; SD, Standard deviation; PE, physical exercise; MPA, mobile phone addiction; SC, self-control; RA, Rumination; PD, psychological distress; LN, loneliness.
***$p < 0.001$.

distraction hypothesis holds that the stimulation of physical exercise can divert the individual's attention to negative emotions and then replace the effect of mobile phone use in diverting the individual's negative emotions (Marconcin et al., 2022). From a neurophysiological perspective, studies have found that physical exercise can restore and adjust highly excited nerve cells, improving mobile phone addicts' adaptability to external changes (Guo et al., 2022). In addition, physical exercise and cell phone use can activate similar neurobiological pathways in the brain. For example, inducing similar reward-based effects, activating brain regions associated with reward, and promoting dopamine release (Liu S. et al., 2019). Long-term exercise increases reward-related neural plasticity in brain structures, such as the dorsal striatum, nucleus accumbens, and lateral ventral tegmental area, and reduces MPA *via* its effects on reward stimulation (Cassilhas et al., 2016). In empirical studies, physical exercise has been shown to improve a range of problems associated with symptoms of addiction, such as withdrawal and mood changes (Chen et al., 2021; Cheng et al., 2021). These results suggest that physical exercise may provide valuable contribution to ameliorating MPA in college students. Therefore, on the issue of MPA, we should pay attention to the role of physical exercise.

Consistent with our hypothesis 1, the results showed that self-control played an indirect role as an independent mediating variable in the association of physical exercise and MPA, and a close association between physical exercise and self-control was found (Yang et al., 2019). When physical exercise decreased, screen use and sedentary behavior increased, the ability to limit and successfully manage their behavior decreased, and the individual's ability to inhibit and control undesired behavior also decreased (Yang et al., 2019). Exercise was also shown to improve inhibitory, which was explained by better performance on the allocation of attention and larger amplitude of the P3 event-related potential (Xue et al., 2019). In addition, a lack of self-control will lead to behavior changes in college students' responses to bad emotions, and the risk of MPA will increase accordingly. From a physiological perspective, MPA is associated with inhibitory control areas of the brain (Liu S. et al., 2019), and based on the effect of exercise on prefrontal cortex-dependent executive function, and physical exercise may mitigate addictive behaviors through its effect on inhibitory control (Verburgh et al., 2014). Previous studies have found that exercise can improve the inhibition and control ability deficits of individuals with MPA (Davis et al., 2011). When faced with cognitive tasks, the scores of MPA of individuals doing more exercise were significantly lower (Zhou and Wang, 2022). Thus, increasing self-control and physical exercise may prevent or alleviate MPA.

Consistent with our hypothesis 2, the results showed that rumination played an indirect role as an independent mediating variable in the association of physical exercise with MPA, and found a close association between physical exercise and rumination. Previous studies have found that exercise improves emotional processing (Brand et al., 2018), alleviates negative thinking (Abdollahi et al., 2017), and regular exercise (Lavadera et al., 2020) can reduce rumination by changing the way individuals process and respond to emotions (Bernstein and Mcnally, 2017). Meanwhile, physical exercise linked to memory bias can increase neuroplasticity in the hippocampal circuit (Hamilton and Gotlib, 2008), reducing rumination symptoms (Schnell and Krampe, 2020). In addition, studies have found that rumination mediates the relationship between stress and MPA, suggesting that rumination can predict MPA (Peng et al., 2022). Davis's cognitive behavioral theory suggests that the distal contributory causes of pathological Internet use (PIU) is stressful life event (i.e., reduced physical exercise) and the proximal contributory causes is maladaptive cognitions (i.e., rumination), which provide a sufficient condition for the formation of PIU (Davis, 2001). Furthermore, self-focused rumination leads an individual to recall more reinforced memories about the Internet, thus maintaining the vicious cycle of MPA (Peng et al., 2022). Thus, it is understandable that physical exercise affects MPA indirectly through rumination.

Consistent with our hypothesis 3, the results showed that psychological distress, as an independent mediating variable,

played an indirect role in the association of physical exercise with MPA, and found a close association between physical exercise and rumination. Physiological indicators showed that exercise may be linked to decreased psychological distress by leading to greater diversity in the microbiome (Dalton et al., 2019). Meanwhile, exercise has been shown to increase the brain's production of endorphins, when the increased release of endorphins can reduce pain or cause euphoria, which in turn can reduce symptoms of depression or anxiety (Li Y. et al., 2021). The sedentary individuals may also be interfered by the hypothalamic–pituitary–adrenal axis and their serum cortisol levels might be altered to cause psychological distress (Uddin et al., 2020). In an exercise intervention study, physical exercise has been proven to be an effective way to improve psychological problems (loneliness, anxiety, lyrical disorders; Mandolesi et al., 2018). In addition, previous studies have acknowledged that psychological distress is an essential catalyst for the development of MPA (Chen et al., 2021). Elhai and Dvorak found that people with depression or anxiety were more likely to use mobile phones and have a high risk of MPA (Elhai et al., 2017). According to the Psychological Decompensation Hypothesis (King and Delfabbro, 2014), when individuals experience negative emotions, such as stress, depression, and anxiety, they are more likely to cope with and alleviate their negative feelings through compensatory mobile phone use. Thus, along with increasing physical exercise, decreasing psychological distress may prevent or alleviate MPA.

In order to offer a more granular understanding of the pathways that associate physical exercise with MPA. The study uses chain mediation models to analyze the four-way association of physical exercise, self-control, rumination, and MPA. Consistent with our hypothesis 4. The results suggest that the association was partially mediated by self-control and rumination. The pathway indicated that physical exercise was sequentially correlated with self-control in the first step and further affected rumination, which was associated with the risk of MPA. The results supported an association between self-control and rumination, that is, an increase in the self-control is associated with a decrease in the rumination. Previous research found that college students with low cognitive control ability may engage in self-focused reflection to reduce the interference in daily life caused by uncontrolled use of mobile phones (Friedman and Miyake, 2017). In the process, if their reflection focuses on the causes and/or consequences of excessive use of mobile phones, rather than measures aimed at reducing their dependence on mobile phones, then the reflection of daily life disruption due to excessive use of mobile phones may promote rumination (Dwyer et al., 2014). In other words, when physical exercise is insufficient, it leads to decreased self-control, increased habitual rumination, and further raised the risk of MPA. Therefore, factors of both self-control and rumination should be considered when designing strategies to reduce MPA through physical exercise.

Consistent with our hypothesis 5, The study analyzes the four-way association of physical exercise, self-control, psychological distress, and MPA using chain mediation models. The results suggest that the association was partially mediated by self-control and psychological distress. The pathway indicated that physical exercise was sequentially correlated with self-control in the first step and further affected psychological distress, which was associated with the risk of MPA. This study supports that self-control is negatively correlated with psychological distress. According to the dual systems model of self-control, the behavior of individuals with low self-control is more easily affected by the impulse system. When encountering negative life events, college students with low level of self-control may be more immersed in negative emotions and more inclined to satisfy the impulse of using smartphones immediately to seek consolation, which leads to MPA (Chen et al., 2021). The mastery hypothesis showed that as exercisers become more confident and gain mastery of their physical skills, they may take this feeling of control and success into their everyday lives and improve their mental health (Mellion, 1985). In addition, previous studies have confirmed that individuals with low self-control had lower timidity in performing inhibitory control tasks, which led to excessive consumption of psychological resources and increased psychological distress (Schnell and Krampe, 2020). Thus, factors of both self-control and psychological distress should be considered when designing strategies aimed at reducing MPA through physical exercise.

Consistent with Hypothesis 6a, loneliness moderates the relationship between self-control and rumination in the chain pathway. Specifically, the indirect effects of physical exercise on MPA through self-control and rumination were buffered by loneliness, with this effect being more substantial for college students with higher levels of loneliness. This result might indicate that loneliness, as a negative personality trait, could have an adverse effect on mental health. Our findings were consistent with the ruminative stress response model: high loneliness, social exclusion, and social isolation would make individuals more likely to reflect on their life and emotional state and then indulge in rumination (Cacioppo et al., 2015). Meanwhile, individuals who feel lonely have particular-cognitive biases and attributional styles. There is evidence that individuals with high loneliness indulge in negative evaluations, stimulate negative cognitive attributions, and lack interpersonal trust (Mann et al., 2017). In addition, college students with low loneliness are more likely to obtain social support and relationships and adjust their cognitive biases and rumination responses in social interaction (Labrague et al., 2021). Therefore, low loneliness can effectively reduce rumination and affect the relationship between self-control and rumination.

Consistent with Hypothesis 6b, loneliness moderates the relationship between self-control and psychological distress in the chain pathway. Specifically, the indirect effects of physical exercise on MPA through self-control and psychological distress were buffered by loneliness. This can be explained by the lack of belonging among college students. Problems experienced during the period of puberty make college students who believe that nobody understands them to experience feelings of loneliness which may cause depression (Erzen and Cikrikci, 2018). In addition, when entering a new environment, individuals in adolescence have imperfect social skills, and social adequacy is insufficient, which leads to loneliness in the social environment and may indirectly trigger the development of

depression (Zhang et al., 2014). That is, individuals with high loneliness may be seen as unsociable and more likely to be isolated and ostracized. These negative experiences may increase individuals' automatic cognitive and emotional responses to stimuli, leading to psychological distress, including depressive symptoms, anxiety, and stress (Labrague et al., 2021). In addition, Houtjes et al. found that loneliness had an independent effect on the course of depression (Houtjes et al., 2014). Therefore, high loneliness will increase the susceptibility of individuals to anxiety, depression, and other negative emotions, and affect the relationship between self-control and psychological distress.

In conclusion, our findings provide theoretical and practical implications for understanding the prevention and alleviation of MPA. On the theoretical level, it provides supporting evidence for the Interaction of Person-Affect-Cognition-Execution (I-PACE) model, the compensatory Internet theory, Salmon's unifying theory, and the temporal self-regulation theory for physical activity and offers a reinforcement addition to these theories. Our findings confirm the association between physical exercise and MPA and further clarify the underlying mechanisms. These findings may be useful for future research studying the causal association between health and risk-related behaviors and psychological health. In terms of practical implications, the results from our model suggested that physical exercise, self-control, rumination, loneliness, and psychological distress were directly or indirectly associated with MPA. This means that when designing physical exercise programs to improve MPA in college students, incorporating methods to increase self-control, reduce rumination, reduce loneliness, and improve psychological distress might need to be taken into consideration.

Limitations

Firstly, this study used a cross-sectional design, which cannot provide evidence for causality. Future studies could use randomized controlled trial (RCT) to explore the causal relationship between physical exercise and MPA. In addition, our sample of convenience, limits the extent to which we were able to generalize our results to individuals with the most severe of MPA. Secondly, this study only used self-reported questionnaires as the research object of college students, so there may be social expectation bias. Future studies should use multidimensional scale analysis to collect more objective data from multiple information providers, including parents and peers. Thirdly, this study focused primarily on college students, and more research is needed to explore whether the results apply to other samples, such as adults and adolescents. Despite these limitations, this study reinforces previous research by revealing the mediating and regulating mechanisms between physical exercise and MPA.

Conclusion

In conclusion, this study expands our understanding of the association and mechanism between physical exercise and MPA. We investigated self-control, rumination, psychological distress as mediators, and loneliness as moderators to explain the relationship between physical exercise and MPA. The results showed that self-control, rumination, and psychological distress partially mediated the relationship between physical exercise and MPA. Physical exercise has an indirect effect on MPA through self-control and rumination, and has an indirect effect on MPA through self-control and psychological distress. Moreover, these effects are more substantial for college students with higher a degree of loneliness. Our findings highlight the importance of enhancing physical exercise and reducing loneliness among interventions to prevent MPA among Chinese college students. In addition, considering that self-control, rumination, and psychological distress play a bridging role in the relationship between physical exercise and MPA, parents and educators should help college students avoid MPA by increasing exercise and reducing loneliness to improve their self-control ability, reduce rumination and psychological distress.

Data availability statement

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

Ethics statement

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

Author contributions

MZ, JS, SC, XZ, JZ, and XC designed the work and were responsible for the overall development of this study, including the planning of sample collection, data analysis, writing, and polishing of the manuscript. MZ, XZ, and JZ were in charge of data collection and analysis of this study. MZ, JS, and XC were in charge of the main revision for this manuscript. SC and MZ were responsible for revising the manuscript and made a great contribution to the final acceptance of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.1000109/full#supplementary-material

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Combination of physical activity and screen time on life satisfaction in adults: A cross-sectional survey

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Background: Sufficient physical activity (PA) and limited screen time (ST) have been shown to be positively associated with a variety of mental health outcomes. It has been known that PA and ST are independently associated with life satisfaction. Whereas, little is known about the association between combinations of PA and ST with life satisfaction in adults. This study aimed to explore the associations between PA and ST (in insolation or combination) and life satisfaction in adults.

Methods: Data from the 2014 European Social Survey (ESS) round 7 consisting of 22 countries were analyzed in this study. In total, self-reported data from 40,185 adults were included in the final analysis. The self-administered method was used to collect demographic information, PA, ST, and life satisfaction. The prevalence of meeting PA guidelines (at least 150 min per week) and ST guidelines (no more than 3 h per day) was calculated according to Canadian 24-h Movement Guidelines for Adults.

Results: Adults who were engaged in sufficient PA and limited ST were more likely to report a higher level of life satisfaction. Meeting PA or ST guidelines was more likely to report higher life satisfaction scores [odds ratio (OR) = 1.31, 95% CI: 1.16–1.47]. Compared with not meeting any guidelines, those who met both PA and ST guidelines had a higher OR (OR = 1.55, 95% CI: 1.37–1.76).

Conclusion: This study found that participating PA while limiting ST concurrently was linked with better life satisfaction. Creating an active lifestyle is important to population's well-being.

KEYWORDS

physical activity, television viewing, psychological wellbeing, adults, population health

Introduction

A judgment of life satisfaction can be made on the basis of a person's extensive evaluation of life. This is the subjective evaluation of their personal experience. It is a self-report measure (Pavot and Diener, 2008), and people are required to score their overall life satisfaction from 0 to 10. However, the distribution of life satisfaction in the Organization for Economic Co-operation and Development (OECD) countries is uneven. Moreover, the overall life satisfaction of some countries, such as Colombia, Greece, South Korea, Portugal, and Turkey, is relatively low, and the average score is less than 6. Relatively, the scores in Denmark, Finland, Iceland, the Netherlands, and Switzerland could be 7.5 or even higher (OECD) and show that men's life satisfaction increases with age, but the results for women are different. In early and late adulthood, the life satisfaction scores of the two sexes diverge. For both women and men in early and late middle age, the score is insignificant. The predictive variables' intensity is varied in middle-aged people, especially for people in late middle age (Medley, 1980). Research indicates that life satisfaction is associated with psychological health results (Nes et al., 2013), which can forecast mortality (St John et al., 2013). Based on two recent reviews of healthy people, life satisfaction is related to mortality (Chida and Steptoe, 2008). Additionally, it is linked with other positive results, such as job performance, organizational commitment, and turnover intentions (Erdogan et al., 2012). Life satisfaction is associated with a series of impressive results. In a recent meta-analysis, life satisfaction was linked to a reduction in mortality, and wellbeing was associated with a reduction in cardiovascular mortality (Chida and Steptoe, 2008). Other benefits include lower levels of sleep complaints (Brand et al., 2010) and burnout syndrome (Zavaleta et al., 2017).

In 2009, physical inactivity was considered one of the major risk factors leading to non-communicable diseases, and millions of deaths that could have been prevented have been caused by it (World Health Organization, 2009). Nevertheless, about one-third of adults in the world do not perform enough exercise to keep healthy (Hallal et al., 2012). As reported by studies performed in Australia (Milligan et al., 2007), Canada (Bryan and Katzmarzyk, 2009), the United States of America (Piercy et al., 2018), and Europe (Gerovasili et al., 2015; Marques et al., 2015), more than 33% of adults spend only a little time on exercise in their daily life, even though physical activity (PA) benefits health (Powell and Pratt, 1996; Warburton and Bredin, 2019). A number of institutions, such as the World Health Organization (WHO), the U.S. Department of Health and Human Services, and the European Union, have recommended that healthy adults should spend 30 min or longer time performing aerobic activities of moderate intensity for at least 5 days a week if they wish to stay healthy (Andersen et al., 2008; Fulton and Kohl, 2008; World Health Organization, 2010). Moreover, sedentary behavior (SB) refers to behaviors that expend energy less than 1.5 metabolic equivalents, such as watching television, lying down, and sitting (Tremblay et al., 2017). Most published works that have conducted a survey on SB based on population have been conducted in developed countries, and there is only a little worldwide data on adults in this respect. Recently, there was an assessment based on accelerometer usage that was a part of research involving a large-scale demographical survey of representative respondents, and it showed that adults spend a median of 8.2 h every day on SB (ranging from 4.9 to 11.9) (Bauman et al., 2018). Adults spend 9 or 10 h on SB every day in America and Canada (Prince et al., 2020; Matthews et al., 2021). It seems that adults spend a long time on SB than previously expected, and most of it is during leisure time and work (Matthews et al., 2021). Previous studies also provided evidence that SB, such as watching TV, leads to hampered mental health (Huang et al., 2020). In 2018, the health-related recommendations on PA were updated by the WHO based on the latest findings in science, and SB was also discussed in this aspect (World Health Organization, 2018).

In the future, life satisfaction and PA will be changed (Heller et al., 2006; Conroy et al., 2011; Maher et al., 2013). People can restore their vitality, reduce fatigue, and increase pleasure by engaging in more PA every day (Puetz et al., 2006; Reed and Ones, 2006). When daily PA is increased, people are inclined to be more satisfied with their life as compared to days of a regular amount of PA (Maher and Conroy, 2017), such as during interpersonal communication. Previous results of research concerning the elderly and middle-aged people are identical in terms of the following: a normal level of PA is related to satisfaction *via* fitness and health-related adaptation that improve mental and physical health. However, based on surveys of respondents of the younger generation, the general level of PA does not have much relation to life satisfaction. However, there is scarce research on the relationship between life satisfaction and daily PA among the elderly and the middle-aged, but there is a possible relationship between daily PA and life satisfaction among all age groups (Maher and Conroy, 2017) because it has been found that PA has an immediate recovery effect on all adults. Moreover, according to recent evidence, life satisfaction might be lower among the elderly and younger generations due to declines and challenges in developmental stages (Arnett, 2000; Gerstorf et al., 2008, 2010). Moreover, life satisfaction is greater among middle-aged people, partly because they gradually turn their attention inward to themselves rather than others, such as their children (Lachman and Firth, 2004). Increased sedentary time may be associated with a decline in life satisfaction among those between 18 and 25 years old; however, at these ages, the levels of PA are decreasing (Troiano et al., 2008). It remains unknown whether there is any relationship between SB and life satisfaction or between physical inactivity and life satisfaction. Despite limited studies on the relationship between life satisfaction and SB in adults, it is possible that

TABLE 1 Sample characteristics of this study.

		Estimate	95%CI	
Age (mean)		47.5	47.1	47.8
Body mass index (mean)		25.6	25.5	25.7
Years of education (mean)		12.9	12.8	13.0
Number of household member (mean)		2.9	2.9	2.9
Sex%				
	Male	48.5%	47.7%	49.3%
	Female	51.5%	50.7%	52.3%
Marital status%				
	Legally married	52.1%	51.3%	52.9%
	In a legally registered civil union	1.3%	1.1%	1.5%
	Legally separated	0.4%	0.3%	0.5%
	Legally divorced/civil union dissolved	8.0%	7.6%	8.4%
	Widowed/civil partner died	6.8%	6.4%	7.2%
	None of these (never married or in legally registered civil union)	31.4%	30.7%	32.2%
Household income level%				
	1st decile	8.7%	8.2%	9.3%
	2nd decile	10.0%	9.4%	10.5%
	3rd decile	10.4%	9.9%	10.9%
	4th decile	10.7%	10.2%	11.3%
	5th decile	10.3%	9.8%	10.8%
	6th decile	10.5%	9.9%	11.0%
	7th decile	10.7%	10.1%	11.2%
	8th decile	10.4%	9.8%	10.9%
	9th decile	8.9%	8.4%	9.5%
	10th decile	9.5%	8.9%	10.1%

sedentary people—for example, those who watch TV—also show decreased life satisfaction on average (Frey et al., 2007; Depp et al., 2010).

To our knowledge, no study has analyzed the relationship between PA and screen time (ST) on life satisfaction in adults using European Social Survey (ESS) data. This study aimed to test the associations between PA and ST (in insolation or combination) and life satisfaction in adults.

Materials and methods

European Social Survey (2014)

The ESS is an academically driven, cross-border survey that has been conducted throughout Europe since 2001. Every 2 years, a new cross-sectional sample is determined, and participants are interviewed in person. The ESS measures attitudes, beliefs, and behavior patterns in a diverse group of people. In the 2014 ESS (round 7), the survey covered 22 countries. The 2014 ESS selected a representative sample of countries consisting of residents aged 15 and older; self-report data were collected from 40,185 adults, except for the homeless and the sheltered. The 2014 ESS was funded by members, observers, and guests of the ESS European Research Infrastructure Alliance (ESS ERIC), which represents governments. Participating countries directly finance ESS ERIC's central coordination costs, as well as fieldwork and national coordination costs in their own countries. The 2014 ESS included strict random probability sampling, a minimum target response rate of 70%, and strict translation protocols. During the 1-h face-to-face interview, participants were asked questions on various core themes repeated in previous rounds of the ESS, along with two modules developed for round 7 on social inequality in health (ESS, 2014). More information on the ESS, such as questionnaires and data collection, can be found on the ESS website, i.e., https://ess-search.nsd.no/en/study/ccd56840-e949-4320-945a-927c49e1dc4f.

Physical activity and screen time

Information about PA was obtained through a single item that assessed the frequency of spending at least 30 min on walking very fast, exercising, or engaging in other PA in the past

TABLE 2 Results for independents and outcome.

		Estimate	95%CI	
Life satisfaction				
	Low	7.6%	7.2%	8.1%
	Medium	39.9%	39.1%	40.7%
	High	52.5%	51.6%	53.4%
Physical activity days				
	0 days	25.6%	24.9%	26.4%
	1 day	10.3%	9.8%	10.8%
	2 days	11.4%	10.9%	11.9%
	3 days	11.9%	11.4%	12.5%
	4 days	7.8%	7.4%	8.3%
	5 days	7.8%	7.4%	8.3%
	6 days	3.4%	3.1%	3.8%
	7 days	21.7%	21.0%	22.4%
Television viewing time				
	No time at all	4.8%	4.5%	5.2%
	Less than 0.5 h	6.4%	6.0%	6.8%
	0.5–1 h	14.0%	13.5%	14.6%
	More than 1 h, up to 1.5 h	14.5%	13.9%	15.0%
	More than 1.5 h, up to 2 h	16.5%	15.9%	17.2%
	More than 2 h, up to 2.5 h	13.7%	13.1%	14.3%
	More than 2.5 h, up to 3 h	12.1%	11.5%	12.6%
	More than 3 h	18.0%	17.4%	18.7%
Physical activity guidelines				
	Not meet	67.0%	66.2%	67.8%
	Meet	33.0%	32.2%	33.8%
Screen time guidelines				
	Not meet	18.0%	17.4%	18.7%
	Meet	82.0%	81.3%	82.6%
Combination of physical activity and screen time				
	Meet neither	12.9%	12.3%	13.5%
	Meet either	59.2%	58.4%	60.1%
	Meet both	27.9%	27.1%	28.6%

week (On how many of the last 7 days did you walk quickly, do sports, or other PA for 30 min or longer?). Options ranged from "0" to "7 days." Previous studies have shown that the item is reliable (Wanner et al., 2014).

Participants' average amount of time spent watching TV per day (how much time, in total, and do you spend watching TV on an average weekday) was also assessed (Santos et al., 2022). Based on the previous study (Keadle et al., 2015), options ranged from "no time at all" to "more than 3 h," with an interval of 30 min.

According to Canadian 24-h Movement Guidelines for Adults aged 18–64 years and adults aged 65 and older, adults need to participate in PA for at least 150 min per week (PA guideline) and no more than 3 h of ST (ST guidelines) (Ross et al., 2020). This study used question options of 5–7 days to calculate the attainment of PA guidelines.

Life satisfaction

Life satisfaction was assessed by the item "how satisfied are you with your whole life?" The answers were indicated on a scale ranging from 0 "extremely dissatisfied" to 10 "extremely satisfied." Previous research suggested that such an item could be a robust indicator and reliably estimate life satisfaction (Cheung and Lucas, 2014).

Covariates

Sex (male/female), age (years), years of education, body mass index (BMI), marital status, number of household members, and household income level were included as covariates. Regarding marital status, respondents were asked

whether they lived with their husband/wife/partner and their legal status. In terms of the number of household members, respondents were asked whether they had children and how many family members they lived with regularly. Household income was determined in tenths.

Statistical analysis

All statistical analysis was performed using SPSS version 23.0. Results were weighted based on the complex sampling survey design, and the weighted percentage of the sample was reported. Descriptive statistics were used to report sample characteristics (covariates), independent variables, and outcome variables. Logistic regression models were used to explore the associations of PA, ST, and their combinations with life satisfaction, adjusting for sex, age, years of education, BMI, marital status, number of household members, and household income level. The statistical significance level was set to $p < 0.05$, as previously illustrated.

Results

Demographic characteristics

The characteristics of participants' demographics and socio-economic statuses are shown in Table 1. The average age of the participants was 47.5 years, with a balanced gender proportion of 51.5% women. The mean BMI in study participants was 25.6, while the mean year of education was 12.9. Each participant had approximately three household members, while more than half (52.1%) of the participants were legally married. In terms of socioeconomic status, participants were evenly distributed between the 1st decile and the 10th decile, with percentages ranging from the lowest of 8.7% in the 1st decile to the highest of 10.7% in the 4th and 7th deciles.

Prevalence of life satisfaction, physical activity, and screen time

As shown in Table 2, more than half (52.5%) of the participants had have high levels of life satisfaction, while 39.9% of the participants have medium levels of life satisfaction. In terms of PA days, 25.6% of the participants responded that they did not participate in PA even once a week, while approximately a quarter of the participants reported that they performed PA 7 days a week. A total of 4.8 and 6.4% of the participants, respectively, reported that they did not watch or watched less than 0.5 h of television per day, while the highest percentage of participants who watched more than 3 h of television per day was 18.0%. According to the comparison of PA and ST guidelines, most of the participants (67.0%) did not meet the PA guidelines, whereas the majority of the participants met the ST guidelines (82.0%). Near three-fifths (67.1%) of the participants met either of the guidelines, 12.9% met neither, and 27.9% met both, respectively.

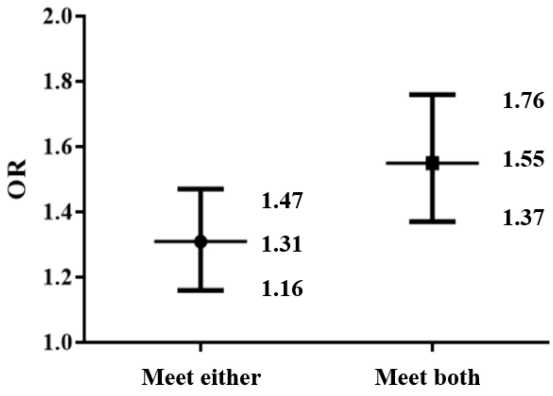

FIGURE 1
The associations between physical activity and screen time guidelines (in insolation or combination) and life satisfaction.

Association between physical activity, screen time, and life satisfaction

The results of multivariable regression are presented in Table 3. In terms of PA days, we observed that participation in PA greater than or equal to 1 day per week was a positive factor for higher life satisfaction. According to ST, watching television for more than 0 h per day was a negative factor for higher life satisfaction. In Figure 1, we can see that meeting either guidelines [odds ratio (OR) = 1.31 (1.16, 1.47)] and meeting both guidelines [OR = 1.55 (1.37, 1.76)] were positive factors for higher life satisfaction.

Discussion

Participating in more PA and higher ST was positively and negatively associated with life satisfaction, respectively. Compared with meeting neither of the guidelines, participants meeting either of the guidelines in isolation were more likely to report higher life satisfaction scores. Moreover, meeting both PA and ST guidelines might be related to higher life satisfaction scores.

There is a positive correlation between PA and increased life satisfaction, and this was consistent with previous research. Prior studies clarified that daily PA might have a top-down or bottom-up impact on life satisfaction. From a top-down perspective, more physically active people should report overall higher life satisfaction (Maher et al., 2013). This study showed that overall PA might improve physical health, while daily PA

TABLE 3 Results for the associations between physical activity, televising viewing time, and life satisfaction (higher).

		OR	95%CI	
Physical activity days				
	0 days		Reference	
	1 day	1.22	1.06	1.40
	2 days	1.33	1.18	1.51
	3 days	1.45	1.28	1.65
	4 days	1.49	1.28	1.73
	5 days	1.43	1.23	1.67
	6 days	1.35	1.08	1.68
	7 days	1.51	1.36	1.69
Television viewing time				
	No time at all		Reference	
	Less than 0.5 h	0.92	0.73	1.15
	0.5–1 h	0.82	0.68	0.98
	More than 1 h, up to 1.5 h	0.85	0.71	1.03
	More than 1.5 h, up to 2 h	0.84	0.69	1.02
	More than 2 h, up to 2.5 h	0.80	0.66	0.97
	More than 2.5 h, up to 3 h	0.76	0.62	0.93
	More than 3 h	0.67	0.55	0.81

Adjusted for sex, age, years of education, body mass index (BMI), marital status, number of household members, and household income level.

might reduce anxiety, or improving self-esteem could reinforce life satisfaction. Prospective research on the elderly indicated that regular participation in sports activities was indirectly associated with improved life satisfaction (Elavsky and McAuley, 2005; Elavsky et al., 2005; McAuley et al., 2008). Studies showed that PA could indirectly improve life satisfaction by affecting emotional health, self-efficacy, and mental health (Elavsky and McAuley, 2005; Elavsky et al., 2005; McAuley et al., 2008). Moreover, from a bottom-up perspective, being more or less physically active on a given day than usual should affect a person's life satisfaction for that day. The level and intensity of PA decrease throughout adulthood (Troiano et al., 2008), and these changes might help to explain the decline in life satisfaction during this development period; however, it is unclear whether the association between PA and life satisfaction found in the elderly is applicable to adults. However, the current research results indicate that publicity or minor changes in daily might be a way to offset the decline in life satisfaction in adulthood (Maher et al., 2013).

Previous studies implied that prolonged screening might also lead to poor health (Biswas et al., 2015; Zhai et al., 2015; Wang et al., 2019; Mougharbel and Goldfield, 2020). Studies indicated that ST was related to depressive symptoms in adults (Madhav et al., 2017). There have been different findings on the association between SB and life satisfaction when using subjective and objective measurements. Research showed that there was no correlation between self-reported SB and life satisfaction in the elderly (Maher and Conroy, 2017), revealing the effects on perceived time use rather than the actual sitting time. Understanding the nature of sedentary activity might have an important impact on the relationship between SB and life satisfaction (Maher and Conroy, 2017). Research revealed that different changes in types and ST on weekdays and weekends affect the intensity of the relationship between screen-based SB and depressive symptoms. A survey indicated that 66 and 88% of adults spent more than 2 h on the screen on weekdays and weekends, respectively (Schoeppe et al., 2016). Beyond that, studies indicated that an increased risk of depression was linked to the long-time use of mobile phones for at least 2 h on weekdays but at least 5 h on weekends (Liu et al., 2019). The extent to which adults perceive certain sedentary activities as beneficial is an important finding of future research because it is relevant to identifying which sedentary activities increase or decrease life satisfaction.

The results of this study suggested that meeting both PA and ST guidelines was possibly linked to cumulatively higher life satisfaction during adulthood. This research also demonstrated that decreased PA and increased ST were associated with higher levels of negative mental health and lower positive mental health. Almost all participants with greater ST reported higher levels of negative mental health and lower levels of positive mental health as compared to participants with less ST. ST is often defined as psychologically passive SB, which can be explained by the correlation between ST and mental health (Meyer et al., 2020). There is a significant correlation between life satisfaction and mental health, implying that life satisfaction may be a psychological predictor (Bao et al., 2013). Moreover, studies realized that those who met PA guidelines but were more sedentary, as well as those with insufficient PA and less sedentary time, were more inclined to be obese than those with adequate

PA and less sedentary time (Sugiyama et al., 2008). In other words, participants in the PA-deficient/high ST category were significantly more likely to be overweight relative to the active PA/low ST category (Liao et al., 2011). Studies manifested that both perceived and actual weight exerted an impact on people's level of life satisfaction, and it has also been shown that BMI and perceived weight were linked to a higher probability of having a low level of life satisfaction (Herman et al., 2013).

This study adds to the evidence about the associations between PA, ST, and life satisfaction. Moreover, due to the large sample size, there was adequate statistical power. Some limitations should be acknowledged. Study variables were self-reported and were thus susceptible to bias. Future research could focus on using an objective measurement of PA and ST variables. Furthermore, the cross-sectional design implies that no causal inferences can be made, and future research should use a longitudinal design to analyze the relationship.

Conclusion

The current findings strongly supported that participation in more PA per week was a positive factor for improved life satisfaction. According to ST, less ST per day was a negative factor for higher life satisfaction. This study also indicated that meeting both guidelines (meeting ST and PA guidelines) was a positive factor for higher life satisfaction. Future studies need to investigate, in large adult samples, PA/ST type and PA/ST's association with life satisfaction and examine the variation between weekdays and weekends.

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.

Author contributions

ZC summarized the findings and drafted the manuscript. JS contributed to the formal analysis and editing of the manuscript. ZC and WZ developed the strategy of the manuscript and reviewed and edited the final manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

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

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Physical activity and subjective well-being of older adults during COVID-19 prevention and control normalization: Mediating role of outdoor exercise environment and regulating role of exercise form

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Since the outbreak of the COVID-19 pandemic, the physical and mental health of older adults has been threatened. Promoting physical and mental health through physical activity has therefore become a strategy for healthy aging. In order to better understand the impact of the participation of older adults in physical activity, this paper selects different types of physical activity, and examines the relationship between them and subjective well-being through the analysis of the mediation effect of outdoor exercise environment and the regulating effect of exercise form. In this cross-sectional study, a questionnaire survey was conducted in mainland China. The main data come from 903 older adults in five urban areas in Chengdu, Sichuan Province. The surveys were carried out using the Physical Activity Rating Scale, Newfoundland Subjective Well-Being Scale, Exercise Environment Scale, and Exercise Form Scale. SPSS was used for statistical analysis, linear regression analysis was adopted for processing data, and AMOS was used to establish a mediation model. The mediating variable is the outdoor exercise environment, and the moderating variable is exercise form; gender, age, education level, and monthly income were used as control variables. The study results showed that different physical activities (tai chi; health qigong; walking and jogging) were significantly, positively correlated with the subjective well-being of older adults (tai chi: R =0.351, p <0.01; health qigong: R =0.340, p <0.01; walking and jogging: R =0.245, p <0.01); among the activities, tai chi had the strongest effect on the subjective well-being of older adults (R =0.351, p <0.01). Outdoor exercise environment played a mediating role between different physical activity types and subjective well-being of older adults [tai chi: β =0.030, 95% CI (0.005, 0.031); health qigong: β =0.018, 95% CI (0.000, 0.021); walking and jogging: β =0.034, 95% CI (0.008, 0.035)]. Exercise form moderated the subjective well-being of older adults in different physical activities (tai chi: 0.006, p <0.05;

health qigong: 0.006, p <0.05; walking and jogging: 0.009, p <0.001). The results of this study demonstrate that the outdoor exercise environment plays a mediating role between different physical activities and the subjective well-being of older adults, and the form of exercise can also moderate the impact of different physical activities on the subjective well-being of older adults. This study has enlightening significance for psychological intervention with older adults facing stress, anxiety and depression.

KEYWORDS

physical activity, subjective well-being, older adults, outdoor exercise environment, exercise form, COVID-19 pandemic

Introduction

With the increase in the total number of older adults, population aging has become one of the major problems facing countries around the world (Ferhan and Vesile, 2011). At the end of 2020, China's population over the age of 60 was 264.01 million, accounting for 18.70% of the national population, of which 190.63 million were aged 65 and over, for an aged rate of 13.50% (National Bureau of Statistics of China, 2021). Obviously, China has become an aged society, and the physical and mental health of older adults has become a topic of universal concern. Since the outbreak of COVID-19, the pandemic has become a major public health emergency (WTTC, 2020), due to the variety of transmission routes, long incubation period, and rapid spread of this highly infectious virus, resulting in tremendous changes in the lifestyle, daily behavior, and life quality of older adults, posing further threat to their physical and mental health. Although the degree of physical weakness and psychological disorders in older adults varies from person to person, relevant studies have found that older adults are more likely than younger people to experience negative emotions during the pandemic (Banerjee, 2020). The psychological disorder detection rate in older adults has increased exponentially, which has made the aged group a main object of psychological counseling and assistance during the pandemic (Xu, 2022). Therefore, a primary task is to reduce adults' psychological barriers to promote mental health and enhance subjective happiness.

Subjective well-being is an important indicator of mental health and quality of life in older adults (Peterson et al., 2014). It reflects an individual's overall evaluation of life conditions, including life satisfaction and positive and negative emotions (Diener et al., 2002). Kozma and Stones (1980) conceptualized subjective well-being of older adults as positive affect, negative affect, positive experience, and negative experience. For now, physical activity has been identified as a "meaningful" activity that induces subjective well-being (Tkach and Lyubomirsky, 2006). Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen, et al.,1985). Studies have shown that regular physical activity is a prerequisite for a happy life in older adults (Sasidharan et al., 2006). First, it can bring positive experiences to older adults and promote happy, optimistic, positive emotions (Heo et al., 2010), improving their subjective evaluation of quality of life satisfaction and overall quality of life (Ragheb and Griffith, 1982); moreover, at the same time, negative states of mind such as depression and sense of worthlessness in older adults can be eliminated (Kim et al., 2017), and the tension brought by negative emotions such as nervousness, anxiety, and anger can be lowered (Lampinen et al., 2006).

At present, it has not been determined what type of physical activities older adults should besty participate in to improve their sense of well-being. Walking and jogging can bring exercise effect to older adults, and are a low-cost and low-impact way to maintain health (Cunningham et al., 2005). It has been proved that walking and jogging can promote the mental health of older adults (Kelly et al., 2017), and can effectively improve their negative emotions (Ekkekakis et al., 2000), thus also improving their quality of life and subjective well-being (Fisher and Li, 2004). Tai chi has the comprehensive characteristics of aerobic exercise, strength exercise, and flexibility exercise (Chang et al., 2010), so it is especially suitable for older adults. Previous studies have found that tai chi can significantly promote the subjective well-being of older adults (Blake and Hawley, 2012), and can reduce their psychological pressure, anxiety, depression and emotional disorders (Wang et al., 2010, 2014). Health qigong is a form of physical and mental exercise (Gallagher, 2003) that cannot only improve the physical function of older adults (Tsang et al., 2002) and enhance the resistance of the human body (Feng et al., 2020) but also help to regulate the mood of older adults (Chow et al., 2012), improve mental health (Rogers et al., 2009; Liu et al., 2010), and make an essential contribution to subjective well-being. Therefore, this paper selects different physical activities (walking and jogging, tai chi, health qigong) that older adults participate in daily to explore their relationships with subjective well-being.

There are many studies on physical activity and subjective well-being during the COVID-19 pandemic, targeting various groups—professional athletes (Schinke et al., 2020), children (Yarımkaya and Esentürk, 2020), middle school students (Okuyama et al., 2021), university students (Wang et al., 2022), and adults (Qi et al., 2020). However, there have been few studies

on physical activity and subjective well-being in older adults, focusing mainly on whether physical activity participation has a positive effect on subjective well-being during this specific period (Carriedo et al., 2020; Goethals et al., 2020; Son et al., 2021). Besides, there is a lack of research on how individual subjective well-being is affected and how subjective well-being can be enhanced. Due to the normalization of the pandemic, indoor gyms and other indoor entertainment facilities have become inaccessible (Constandt et al., 2020), which results in limited places for older adults to exercise, so more older adults have chosen to exercise outdoors (Levinger et al., 2022). Studies have demonstrated that they are susceptible to the influences of their surroundings when exercising (Humpel et al., 2002). Outdoor exercise environment is more conducive than indoor ones to improving individual mental health and enhancing subjective well-being (Shanahan et al., 2016). But studies during the COVID-19 pandemic focused primarily on the effects of exercise environments at home on subjective well-being (Mutz and Gerke, 2021), while ignoring the effects of outdoor exercise settings on subjective well-being in older adults. With the adoption of regular pandemic prevention and control, the Chinese COVID-19 slogan of "no gathering together" is deeply rooted in the hearts of the people, and thus the form of physical exercise for older adults in the outdoors will also be affected. Studies have also shown that participation in collective physical exercise in older adults is more helpful than solo exercise for relieving negative emotions and enhancing subjective well-being (Gomez-Cabello et al., 2018). Therefore, the form of exercise should also be one of the main factors affecting the subjective well-being of older adults.

Existing studies fail to explain the subjective well-being of older adults who participate in different physical activities changes due to changing outdoor exercise environment and exercise form during this period, and how its internal mechanisms affect subjective well-being. Based on this, this study hopes to explore the relationship between different physical activities, outdoor exercise environment, exercise form, and subjective well-being during the normalization of the pandemic, as well as their internal mechanisms, so as to provide a reference for the promotion of psychological well-being interventions in older adults.

Development of hypotheses

Relationship between physical activity and subjective well-being

Physical exercise, as one of the ways in which older people engage in physical activity, plays an important role in social life (Wang et al., 2018). Relevant studies have confirmed that regular physical activity promotes mental health and helps to improve well-being among older adults (Won et al., 2020) and that the subjective well-being and life satisfaction of older adults who participate in physical exercise are significantly higher than in those who do not participate in physical exercise (Sato et al., 2014; Heo et al., 2016). Moreover, by participating in physical exercise, participants' subjective well-being can be directly increased, leading to the experience of pleasurable, smooth, peak emotional effects (Peluso and De Andrade, 2005). Studies such as Csikszentmihalyi and Hunter (2014) point out that the longer one participates in physical exercise, the happier one feels.

As age increases, older adults' body function and athletic capacity decrease, their level of physical activity decreases, and their risk of chronic diseases and fall injuries increases. Therefore, older adults need to perform different types of physical exercise, especially flexibility exercises and step-by-step resistance exercises, to help maintain physical function (Bird et al., 2009; Liu and Latham, 2009). According to related survey results, walking and jogging is the first choice in physical exercise programs for older adults in all regions of China, while tai chi and health qigong are the most popular exercises among older adults (Yang et al., 2019). Walking and jogging can relieve mental tensions, eliminate brain fatigue and tension while walking, and consume calories to control weight (Haskell et al., 2007), making people happy and positive. Subjective well-being can thus be enhanced. Thus, long-term exercise walking and jogging can adjust the human nervous system, stimulate the body and mind, and enhance physical fitness (Kelly et al., 2018). Tai chi and health qigong are traditional elements of Chinese national physical culture, and since their inception, relevant studies have shown that they provide different degrees of improvement on the mental and physical health of exercisers. Previous studies have shown that tai chi can reduce anxiety and depression, improve sleep quality, and elevate spirits while reducing autonomic nervousness and improving neurobehavioral function (Sandlund and Norlander, 2000). Long-term exercise can effectively reduce damage caused by free radicals to the body, improve the metabolic function of cells, delay the aging process to a certain extent, and improve mental health and subjective well-being (Wang et al., 2010). Participation in health qigong helps form positive mood and reduce anxiety and depression (Hui et al., 2006; Johansson et al., 2011). Meanwhile, regular practice of qigong brings mental health, relaxation, improvement in physical ability, and increased subjective well-being (Tsang et al., 2006). Therefore, in this article, the physical activities focused on are walking and jogging, tai chi, health qigong.

Based on this, this study proposes:

> *Hypothesis I*: Different physical activities (walking and jogging, tai chi, health qigong) show different level of positive correlations with the subjective well-being of older adults.

The mediation effects of the outdoor exercise environment

Human beings rely on a favorable environment for survival and development. With the progress of people's lives, more and more scholars have recognized the importance of environmental

influences on physical activity (Kaczynski and Henderson, 2007). The interaction of physical activity with the environment is verified in the theory of socio-ecological systems, which focuses on the relationship between the individual and the environment, emphasizing the significant impact of the environment on human behavior (Sallis and Owen, 1998). Forsyth argue that socio-ecological theory is particularly applicable to older adults, because the environment can influence older adults' perception and thus their behavior (Forsyth et al., 2009). The exercise environment leaves direct or indirect positive and negative effects on physical activity (Xiong, 2003). The exercise environment is a material prerequisite for older adults to achieve exercise expectations and meet multidimensional needs, and it is also an external cause stimulating enthusiasm and building habits (Van Cauwenberg et al., 2018). The exercise space is a general term for all fitness venues and open spaces suitable for physical exercise, including indoor and outdoor venues and spaces. When older adults participate in physical activity, choice of exercise space will be considered. Existing studies have shown that although exercise venues preferences among older adults are somewhat different across various regions of China, they mainly prefer outdoor places (such as parks, green spaces, squares), supplemented by free indoor venues (Dai, 2017). Other studies have shown that outdoor environments are much safer places to carry out physical activity because the transmission rate of the COVID-19 virus in indoor environments is about 18.7 times higher than that in outdoor environments (Wu et al., 2020). The positive effects of outdoor environment on subjective well-being have been discussed in terms of the comfort, safety, pleasure, and accessibility of the environment (Coon et al., 2011). Participants in outdoor exercise reported relief from tension, confusion, anger, and depression compared to those indoors (Bowler et al., 2010). Therefore, exercising outdoors is more conducive to the subjective well-being of older adults.

Based on this, this study presents.

> *Hypothesis II*: Outdoor exercise environment mediate between physical activity and subjective well-being.

The regulating effects of the exercise form

Physical exercise is accompanied by a certain degree of mental health effect as it produces physiological effects. Given the diversity and complexity of physical exercise form, there are differences in the degree of emotional experience of joy, satisfaction, pleasure, excitement, pride, tension and anxiety that exercisers receive from them, and the psychological effects brought by different exercise forms may also be different. The main ways of physical exercise for the older adults includes group-based exercise and individual exercise. Studies have shown that when older adults participate in collective physical exercise, they expand the scope of their interpersonal interactions and increase their social cognition (Williams and Lord, 1997). Regular participation in collective physical exercise over long periods of time makes it easier to gain social support, improve interpersonal relationships, and gain more mental health (Fox et al., 2007; Orsega-Smith et al., 2007). In the process, they give and receive more material, emotional and spiritual support than those who perform individual exercise. The more collective the form of exercise, the greater the impacts physical activity leaves on the subjective well-being of older adults. That is, collective physical exercise will strengthen the relationship between physical activity and subjective well-being.

On this basis, this study proposes.

> *Hypothesis III*: Exercise form moderates the relationship between physical activity and subjective well-being.

In summary, this study hopes to examine the mediation (outdoor exercise environment) and regulation (exercise form) mechanisms working between three different physical activities (walking and jogging, tai chi, health qigong) and subjective well-being (Figure 1), so as to provide a theoretical basis for further explanation of the relationship between different physical activities and subjective well-being and to offer ideas for improving the subjective well-being of older adults.

Materials and methods

Study design and participants

From the perspective of economic development, Chengdu ranks in the forefront of Chinese cities and has played an exemplary role in China's urbanization process. It has been ranked at the top of the list of the happiest cities in China for 13 consecutive years (Dang, 2022). In the process of aging, the proportion of older adults aged 60 and above has come to exceed 17%, and the aging rate has exceeded 13% (National Bureau of Statistics of China, 2021), indicating an aging society. Therefore,

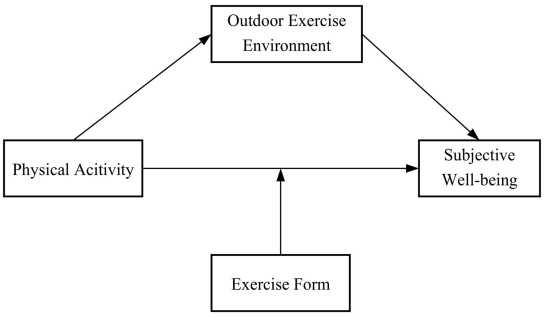

FIGURE 1
A hypothetical model of physical activity affecting subjective well-being.

Chengdu is selected as the research city, and the results are of great significance to explore the subjective well-being of older adults. From March 15 to May 1, 2022, questionnaires were distributed in five urban areas of Chengdu: Qingyang, Jinniu, Chenghua, Jinjiang and Wuhou. Considering that many older adults find it inconvenient to operate smart phones, in this survey, the questionnaire was mainly on-site, supplemented by an electronic questionnaire published on the "questionnaire star" website; the on-site questionnaire content is truthfully summarized in the database. In order to ensure the rationality of sample distribution, the number of questionnaires in each urban area is fundamentally controlled at about 200.

The selection criteria for this survey include (1) older adults aged 60 and above; (2) older adults with good reading and understanding ability; (3) older adults who have practiced tai chi, health qigong, or walking and jogging; (4) older adults who are willing to participate in the survey after fully understanding the purpose of the survey. Offline exclusion criteria include older adults who have no graphic recognition ability and have hearing impairment; online exclusion criteria include: for questionnaires lacking integrity and authenticity, those with the same answers and a response time of less than 75 s ("questionnaire star" will evaluate the time they spent answering all questions) are regarded as invalid questionnaires and will be removed. Finally, 923 offline questionnaires and 214 online questionnaires were recovered, totaling 1,137. After deleting the questionnaires according to the above exclusion criteria, 903 effective questionnaires were obtained, there were 311 effective questionnaires for walking and jogging, 306 effective questionnaires for tai chi and 286 effective questionnaires for health qigong, with an effective recovery rate of 79.42%. See Table 1 for sample composition.

TABLE 1 Participant demographics.

Demographic category	Frequency	Percent
Gender		
Male	447	49.50
Female	456	50.50
Age		
60–64	272	30.12
65–69	257	28.46
70–74	202	22.37
75–79	98	10.85
80 and above	74	8.19
Educational level		
Primary school and below	406	44.96
middle school	193	21.37
High school or technical secondary school	151	16.72
College (including higher vocational education)	66	7.31
Bachelor degree or above	87	9.63
Monthly income		
1,500 and below	305	33.78
1,501–3,500	294	32.56
3,501–5,000	175	19.38
5001and above	129	14.28

Measurement tool design and reliability testing

Physical activity scale

The assessment of the amount of exercise undertaken by older adults uses the physical activity rating scale (PARS-3) revised by Liang (1994). The scale is divided into three dimensions: tai chi, health qigong, and walking and jogging. It examines the amount of exercise in terms of three aspects: intensity, time, and frequency. Amount of Exercise = Intensity × Frequency × Time, in which intensity and frequency are subdivided into 5 grades, recording 1 to 5 points accordingly, and time is subdivided into 5 grades, recording 0 to 4 points. The highest score is thus 100 points, and the lowest score is 0 points. As for the exercise amount evaluation criteria: recording less than 19 is regarded as mild exercise; between 20 and 42, moderate exercise; and after 43 intense exercise. Since tai chi, health qigong and walking and jogging in the Physical Activity Scale are all one-dimensional variables, the structural effect test of the three-factor model composed of nine items using these three variables is examined in this paper, and the fit indices of the model are as follows: $\chi^2/24 = 1.2$, $p < 0.001$, RMSEA = 0.015, NFI = 0.988, GFI = 0.993, AGFI = 0.987, IFI = 0.988, CFI = 0.998. In addition, the Cronbach's coefficients of the three sub-scales are 0.755, 0.804, and 0.775, respectively.

Subjective well-being scale

Subjective well-being is measured with the Memorial University of Newfoundland Scale of Happiness (MUNSH; 1980). It includes four indicators, namely positive affect (PA), negative affect (NA), positive experience (PE), and negative experience (NE). The scale is scored on 3 points (0 = "no," 1 = "unclear," 2 = "yes"). Overall Well-being = PA-NA + PE-NE. It should be noted that this study canceled the reverse scoring setting. That is, the overall well-being score ranges from 0 to 48, and the higher the score, the stronger the subjective well-being. The fit indices for the model are as follows: $\chi^2/246 = 1.477$, $p < 0.001$, RMEEA = 0.023, NFI = 0.983, GFI = 0.968, AGFI = 0.961, IFI = 0.983, CFI = 0.994, and the Cronbach coefficient is 0.972.

Exercise environment scale

With reference to the study of Tan et al. (2020), the exercise environment of older adults was investigated in terms of three aspects: the suitability of the exercise space, the comfort of the exercise atmosphere, and the convenience of the exercise facilities. The suitability of the exercise space includes three questions on issues such as site safety; the comfortable exercise atmosphere element includes three questions on issues such as environmental hygiene; the convenience of exercise facilities section includes two questions, such as the wide distribution of exercise facilities. The question score uses a 5-point Likert scale,

which contains five levels from strongly disagree to strongly agree, and is recorded from 1 to 5 accordingly. The Cronbach coefficient is 0.826.

Exercise form scale

A question is set: "What kind of physical activities do you do during the long-term control and prevention of Covid-19?" There are 5 options for this question: (1) 100% individual exercise; (2) Ready to try collective physical exercise; (3) If time allows, prefer to participate in collective physical exercise; (4) Considering increasing the frequency of collective physical exercise, and strive to increase that ratio to 100%; (5) 100% collective physical exercise. The 5 options are recoded as 1–5 points respectively, and the higher the score, the higher the tendency to participate in collective activity. Reliability analysis shows that after the introduction of this variable, the Cronbach coefficient reflecting the internal consistency of the questionnaire is 0.907.

Control variables

Gender, age, educational background, and monthly income are used as control variables in this study, as these socio-demographic variables have been found to be associated with well-being. A review of relevant studies on well-being reveals that the gender and age of participants have become variables that scholars need to control in their studies (Lehnert et al., 2012; Kim et al., 2021). According to Gerdtham and Johannesson (2001), well-being is significantly associated with factors such as educational background, marital status, and occupation. In addition, Luhmann et al. (2011) found that the relationship between subjective well-being and income is primarily driven by stable differences. The study use gender data as a dummy variable and and the age classifications of Sun (2017), education classification of Zhang (2016), and the China Longitudinal Aging Social Survey (2014) as reference for monthly income options.

Statistical analysis

After collecting the valid questionnaire data, they were analyzed with SPSS26.0 software. The direct impact of different physical activities and outdoor exercise environment on the subjective well-being of older adults was investigated by correlation analysis and linear regression analysis. The model was validated using the Amos24.0 software package and the structural validity of the scale was verified. At present, the Bootstrap method is a common method for testing mediation effects. The method performs repeated sampling out of the original samples and tests whether the coefficients of the mediation effect are significant, with a 95% confidence interval (Davison and Hinkley, 1997). Therefore, this study used the Bootstrap method to examine whether there is a mediation effect between different physical activities and subjective well-being in outdoor exercise environment. Finally, linear regression was used to test the moderating role of exercise form in the relationship between different physical activities and subjective well-being.

Validity testing

To further test the convergent validity and reliability of the scale, Average Variance Extracted (AVE) and Construct Reliability (CR) are used as evaluation parameters. From Table 2, AVE of each item is higher than 0.5, proving that convergent degree of the model is acceptable; the CR value of each item is higher than 0.7, proving that the questions in each scale can consistently explain this underlying variable, and all the scales have good construction reliability. In summary, the questionnaires set in this paper present a high degree of reliability and validity.

In order to observe better the effects of different physical activities on subjective well-being, Univariate Analysis of Variance (ANOVA) was used to study the different influences of exercise amount on the items listed on the subjective well-being Scale, that is, PA, PE, NA, and NE. From Table 3, it can be seen that different exercise amount samples influence the four dimensions of the subjective well-being scale significantly ($p < 0.05$), showing that different exercise amount samples had varying differences on PA, PE, NA, and NE. Figure 0.01 ($F = 61.801$, $p < 0$ 0.001) shows that the amount of exercise influences subjective well-being significantly. By comparing means between subjective happiness and its four dimensions, the result is moderate exercise > intense exercise > mild exercise.

TABLE 2 Validity and reliability test of the questionnaires.

Variable	AVE	CR
TC	0.507	0.755
HQ	0.578	0.804
W and J	0.535	0.775
OEE	0.544	0.827
SWB	0.695	0.901

CR, composite reliability; AVE, average variance extracted; TC, tai chi; HQ, health qigong; W and J, walking and jogging; OEE, outdoor exercise environment; SWB, subjective well-being.

TABLE 3 ANOVA results of the effects of physical exercise on subjective well-being in older adults.

Variable	Exercise amount (M ± S.D.)			F	p
	Mild exercise	Moderate exercise	Intense exercise		
SWB	15.66 ± 2.02	33.96 ± 2.18	27.24 ± 2.16	61.801	0.000**
PA	3.72 ± 0.58	8.28 ± 0.65	6.84 ± 0.62	40.851	0.000**
PE	4.38 ± 0.60	8.28 ± 0.66	6.78 ± 0.63	33.137	0.000**
NA	3.48 ± 0.59	8.70 ± 0.61	6.66 ± 0.62	64.23	0.000**
NE	4.14 ± 0.61	8.70 ± 0.62	6.90 ± 0.60	50.677	0.000**

PA, positive emotion; NA, negative emotion; PE, positive experience; NE, negative experience; M, Mean, S.D., Standard Deviation. **$p < 0.01$.

Results

Descriptive statistics for study variables

The means, standard deviations, and correlation coefficients for each of the main variables are shown in Table 4. Significant positive correlations of different physical activities with subjective well-being can be seen (TC: $R = 0.351$, $p < 0.01$; HQ: $R = 0.340$, $p < 0.01$; W and J: $R = 0.245$, $p < 0.01$). In addition, Different physical activities showed positive correlations with outdoor exercise environment (TC: $R = 0.128$, $p < 0.01$; HQ: $R = 0.079$, $p < 0.05$; W and J: $R = 0.158$, $p < 0.01$), and outdoor exercise environment and subjective well-being also showed a positive correlation ($R = 0.297$, $p < 0.01$). In addition, Table 4 also shows that forms of exercise are strongly correlated with different forms of physical activity and subjective well-being, with correlation coefficients being 0.455 and 0.044, and significance levels all below 0.01. Overall, the three hypothesis, H1, H2, and H3, are initially supported.

Analysis of model mediation effects

In order to verify the mediation role of outdoor exercise environment between different physical activities and subjective well-being, the fit analysis of the conceptual framework mediation model is analyzed by AMOS24.0 software package; the standardized path coefficient model of subjective well-being as affected by different physical activity and outdoor exercise environment is shown in Figure 2. According to Hou and Chen (1999), the fit indices of the model generally takes the Chi-Squared (χ^2) test value $p > 0.05$, $\chi^2/df < 3$, GFI, NFI, CFI, IFI, and AGFI >0.9, RMSEA <0.05 as reference standards. The results of the fit analysis of the moderation effect model for different physical activities, outdoor exercise environment, and subjective well-being are shown in Table 5, and the various parameters of model fit present an excellent level, indicating that the mediation model in which different physical activities improve the happiness of older adults is reasonable. In Figure 2, the path coefficients (TC: $\beta = 0.030$; HQ: $\beta = 0.018$; W and J: $\beta = 0.034$) of different forms of physical activity → subjective well-being are significant, indicating that different physical activity formats has a direct effect on subjective well-being, proving that H1 is true. The path coefficients of different physical activities → outdoor exercise environment (TC: $\beta = 0.15$; HQ: $\beta = 0.09$; W and J; $\beta = 0.17$) and of outdoor exercise environment → subjective well-being ($\beta = 0.20$) were both significant, indicating that different physical activities have a mediation effect between the outdoor exercise environment and subjective well-being, proving that H2 is true.

Hayes (2009) proposes that in the Bootstrap mediation effects test, at least 1,000 repeated samples out of the original samples are needed. If Bootstrap mediation effects test results show that the Bootstrap test CI does not contain a value of 0, it means that the indirect effect is proven (Zhao et al., 2010). In this study, the mediation effects test was performed by estimating the Booststrap 95% CI for mediation effect by sampling 2000 samples; the results are shown in Table 6. Point estimates that the indirect effects of the different physical activities → outdoor exercise environment → subjective well-being were 0.017, 0.010 and 0.021 respectively, and standard deviation (S.D.) 0.007, 0.005, and 0.007 respectively; Z-values were 2.429, 2.000 and 3.000, respectively. The indirect effects of the Bootstrap 95% CI produced by this path did not contain the value 0, indicating that the mediation effect between different physical activities and subjective well-being in outdoor exercise environment was significant. The point estimates of the direct effects of different physical activities → subjective well-being were 0.206, 0.112, and 0.089, the standard deviations were 0.030, 0.022, and 0.028, and the Z-values were 6.867, 5.091, and 3.179, respectively. The direct effects of the Bootstrap 95% CI produced by this path did not contain 0. The point estimates of the total effects of different physical activity → subjective well-being were 0.223, 0.123, 0.110; the standard deviation was 0.030, 0.023, 0.028; and Z values were 7.433, 5.348, 3.929 respectively, and the total effects of Bootstrap 95% CI produced by that path did not contain 0. This shows that the direct and total effects of outdoor exercise environment → different physical activities are significant. In addition, comparing the total effect sizes of tai chi, health qigong, walking and jogging on subjective well-being, it can be found that different physical activities in terms of their respective influence on the subjective well-being of older adults are ranked as follows: tai chi > health qigong > walking and jogging.

TABLE 4 Descriptive statistics and correlations for primary variables.

Variable	M	S.D.	TC	HQ	W and J	OEE	EF	SWB
TC	26.422	24.156	1					
HQ	26.323	25.023	0.001	1				
W and J	26.12	24.183	−0.03	0.032	1			
OEE	3.288	0.862	0.128**	0.079*	0.158**	1		
EF	3.419	1.51	0.06	0.049	0.055	0.455**	1	
SWB	5.102	2.309	0.351**	0.340**	0.245**	0.297**	0.044	1

$n = 903$; M, mean; S.D., standard deviation; TC, tai chi; HQ, health qigong; W and J, walking and jogging; OEE, outdoor exercise environment; EF, exercise form; SWB, subjective well-being. *$p < 0.05$; **$p < 0.01$.

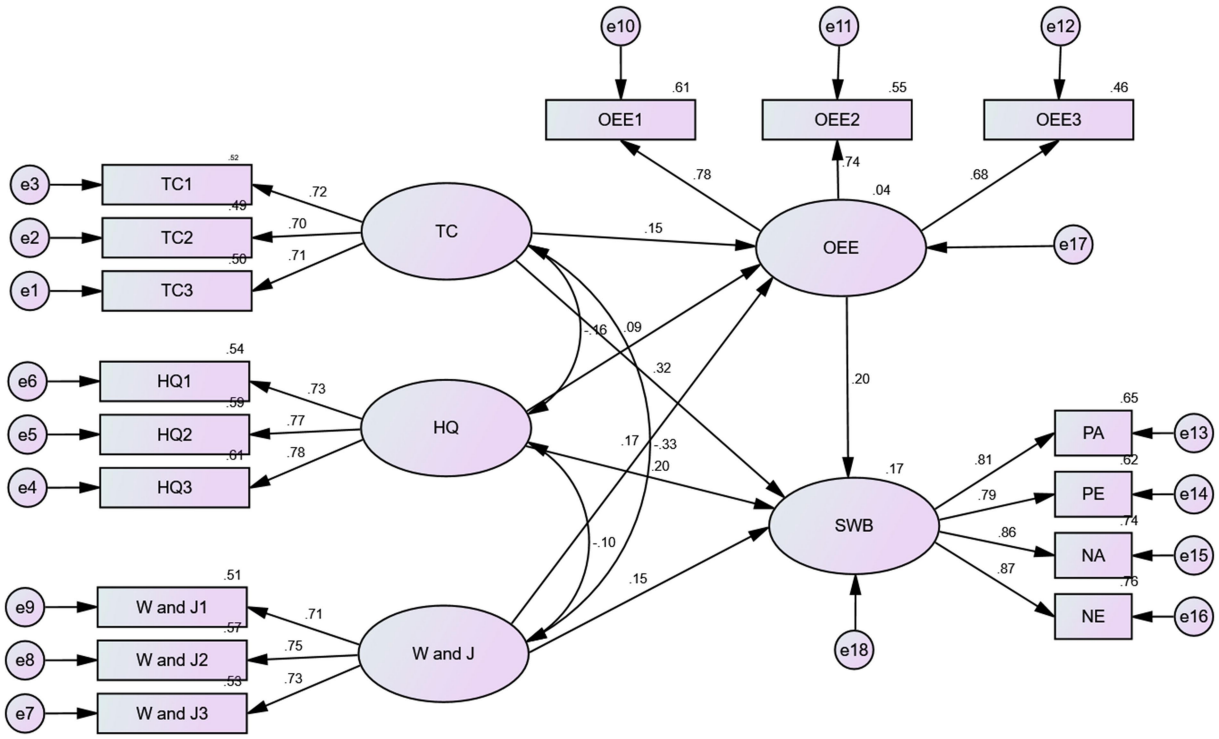

FIGURE 2
The structural equation model regarding the mediation effects of outdoor exercise environment on the association between different physical activity and subjective well-being. OEE, outdoor exercise environment; SWB, subjective well-being; TC 1-TC 3, Three parcels of evaluative concerns on the intensity of Tai Chi exercise; HQ 1-HQ 3, three parcels of evaluative concerns on the intensity of Health Qigong exercise; W and J 1-W and J 3 three parcels of evaluative concerns on the intensity of walking and jogging exercise. All the path coefficients are standardized.

TABLE 5 Model fit indices of mediation effect of different physical activity, outdoor exercise environment, and subjective well-being.

	χ^2	df	χ^2/df	p	GFI	AGFI	CFI	NFI	IFI	RMSEA
Model	115.094	109	1.056	0.326	0.985	0.979	0.999	0.981	0.999	0.008

Analysis of model regulation effect

H3 in this paper assumes that the more collective the form of exercise is, the greater the influence of different physical activities on subjective well-being. We used the three-step test method of Hierarchical Moderated Regression (HMR) analysis and the interaction terms of variables to test the regulation effects. Specifically, we used the following steps for empirical testing, using SPSS26.0 to statistically analyze different physical activities (tai chi, health qigong, walking and jogging) separately. On the basis of testing for common method variance, a correlated analysis is used for initial hypothesis testing, followed by linear regression analysis for regulation model test. It is divided into three linear regression models. First, in model 1 (M1), gender, age, education level, and monthly income are used as control variables, and different physical activity scores are used as independent variables for regression fit; next, model 2 (M2) adds a regulatory variable to model 1 (M1); finally, M3 adds a product term of the independent variable and the adjustment variable to M2. According to the recommendations of Frazier et al. (2004), all predictors are centralized in each model, and the variance inflation factor of all predictors is not higher than 1.17, so there is no multicollinearity problem.

For Model 1, the aim was to investigate the influence of the independent variable (different physical activities) on the dependent variable (subjective well-being) without considering the interference of the regulatory variable (exercise form). From Table 7, it can be seen that different physical activities show significance (TC: $t = 7.174$, $p < 0.001$; HQ: $t = 6.492$, $p < 0.001$; W and J: $t = 2.041$, $p < 0.05$). This implies that different physical activity has a significant impact on subjective well-being, further supporting the H1. Based on an examination of the interaction of different physical activity and exercise forms on subjective well-being (M2 and M3), the results showed that F value changed significantly from M2 to M3 (TC: $F = 17.871$, $p < 0.001 \rightarrow F = 14.866$, $p < 0.001$; HQ: $F = 14.533$, $p < 0.001 \rightarrow F = 12.593$, $p < 0.001$; W and J: $F = 1.860$, $p = 0.135 \rightarrow F = 4.571$, $p < 0.001$). Different physical activities and exercise forms can have an effect on subjective well-being, and the coefficients of different physical activity × exercise form have also reached significant levels (TC × EF: B = 0.006, $p < 0.05$; HQ × EF: B = 0.006, $p < 0.05$; W and J × EF: B = 0.009,

TABLE 6 Test results of mediation effects.

	Path	Point estimate	S.D.	Z	Bootstrapping				Effect size
					Bias-corrected		Percentile		
					Lower	Upper	Lower	Upper	
Indirect effect	TC → OEE → SWB	0.017	0.007	2.429	0.005	0.031	0.006	0.033	0.030
	HQ → OEE → SWB	0.010	0.005	2.000	0.000	0.021	0.001	0.022	0.018
	W and J → OEE → SWB	0.021	0.007	3.000	0.008	0.035	0.010	0.038	0.034
Direct effect	TC → SWB	0.206	0.030	6.867	0.148	0.266	0.147	0.266	0.320
	HQ → SWB	0.112	0.022	5.091	0.072	0.158	0.070	0.157	0.200
	W and J → SWB	0.089	0.028	3.179	0.036	0.148	0.036	0.148	0.150
Total effect	TC → SWB	0.223	0.030	7.433	0.164	0.284	0.164	0.284	0.350
	HQ → SWB	0.123	0.023	5.348	0.080	0.171	0.080	0.170	0.218
	W and J → SWB	0.110	0.028	3.929	0.056	0.169	0.055	0.166	0.184

The Bootstrap sample size is set at 2000. TC, tai chi; HQ, health qigong; W and J, walking and jogging; OEE, outdoor exercise environment; SWB, subjective well-being.

TABLE 7 Testing the moderation roles of exercise form.

	Variable	Model 1		Model 2		Model 3	
		B	*t*	B	*t*	B	*t*
TC	Constant	5.284***	15.306	5.295***	15.330	5.253***	15.224
	TC	0.022***	7.174	0.022***	7.22	0.021***	6.577
	EF			−0.051	−1.025	−0.063	−1.271
	TC × EF					0.006*	2.362
	R^2	0.058		0.059		0.064	
	Adjusted R^2	0.052		0.052		0.057	
	F-value	10.925***		9.285888		8.744***	
	ΔR^2	0.058		0.001		0.005	
	ΔF value	10.925***		1.081, $p = 0.299$		5.228*	
HQ	Constant	5.204***	15.008	5.210***	15.014	5.172***	14.935
	HQ	0.02***	6.492	0.02***	6.491	0.018***	6.054
	EF			−0.031	−0.623	0.03	0.539
	HQ × EF					0.006*	2.551
	R^2	0.047		0.048		0.055	
	Adjusted R^2	0.042		0.041		0.047	
	F-value	8.865***		7.450***		7.359***	
	ΔR^2	0.047		0.000		0.007	
	ΔF value	8.865***		0.406, $p = 0.524$		6.534*	
W and J	Constant	5.190***	14.653	5.196***	14.659	5.220***	14.819
	W and J	0.006*	2.041	0.006	2.042	0.005	1.52
	EF			−0.031	−0.611	0.066	1.144
	W and J × EF					0.009***	3.554
	R^2	0.007		0.008		0.021	
	Adjusted R^2	0.002		0.001		0.014	
	F-value	1.308, $p = 0.258$		1.152, $p = 0.330$		2.788**	
	ΔR^2	0.007		0.000		0.014	
	ΔF value	1.308, $p = 0.258$		0.378, $p = 0.539$		12.512***	

B, unstandardized coefficient; dependent variable is subjective well-being; TC, tai chi; HQ, health qigong; W and J, walking and jogging; EF, exercise for.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

$p < 0.001$), indicating that exercise form play a positive regulatory role when different physical activities affect subjective well-being; thus, H3 of this paper is supported.

In order to reveal the nature of the interaction effect and explain more clearly the regulatory role of exercise form in different physical activities and subjective well-being, according to the method suggested

by Aiken et al. (1991), in this study a standard deviation (SD) is added to and subtracted by the means of exercise form, and groups with a high score or a low score were formed and performed a simple slope test. The results of the test (Figure 3) showed that different physical activities had a significant effect on subjective well-being, whether in the case of group or individual exercise. However, the slope of collective physical exercise is greater than that of individual exercise, which indicates that for older adults who prefer collective physical exercise (M+1SD) different physical activities have a significant positive predictive effect on their subjective well-being; for older adults who do not have a strong sense of group-based exercise (M-1SD), although different physical activities also had a positive predictive effect on their subjective well-being, their predictive effect is minor, which indicates that with more engagement in group-based exercise, the predictive effect of different physical activities on the subjective well-being of older adults is gradually increased, proving that H3 is valid. In addition, as shown in Table 8, by comparing the slopes of different physical activities, it can be concluded that group walking and jogging has the strongest regulatory effect, followed by tai chi, and then health qigong.

Discussion

Different physical activity and subjective well-being in older adults

This paper mainly studied the relationship between the participation of different physical activities and subjective well-being among older adults in China, and the results showed that tai chi, health qigong, and walking and jogging all had a direct effect on the subjective well-being of older adults This is consistent with the findings of previous studies (Gillick, 1984; Li et al., 2001; Chow et al., 2012; Singleton, 2019). It is worth recalling that this study found the subjective well-being of older adults who practice tai chi to be the highest, maybe because during the normalization of pandemic prevention and control, a large number of basic studies found that clinical exercises based on aerobic breathing training can reduce airway resistance, increase lung function, improve body balance, improve immunity and quality of life (Mohamed and Alawna, 2020). Tai chi combines martial arts with health maintenance, and the adjustment of technical movements and mental breathing can effectively regulate and enhance the functional body systems of older adults. The gentle, smooth, slow, and natural technical characteristics of tai chi avoid damage caused by older adults' participation in strenuous exercise, and the unpleasant emotions of life will also be released in the process of tai chi practice, and older adults' overall evaluation of their own happiness level will be significantly improved. In addition, the study further concluded that physical activity is positively associated with various dimensions of subjective well-being in older adults. Studies have suggested that, in general, there is an inverse relationship between exercise intensity and positive affective responses; that is, the greater the intensity of exercise, the less pleasure is obtained (Ekkekakis et al., 2011). Intense physical activity may have greater health benefits but may also adversely affect mental health (Asztalos et al., 2009). Wicker and Frick (2015) analyzed survey data from 28 European countries and found that for people who participated in moderate-intensity exercise, the higher the frequency of exercise they did in the morning and the longer the time, the higher the level of subjective well-being. At the same time, for people who participated in high-intensity exercise or a mixture of moderate-intensity exercise and high-intensity exercise, exercise intensity and duration had a significant negative impact on subjective well-being. That is, high exercise intensity or excessive duration of exercise would reduce subjective well-being. Reed and Buck (2009) found that recreational physical activity programs with low-intensity (about 30% VO_2max, 30–35 min/cycle, 3–5 days/week, and 10–12 weeks) had the strongest happiness effect in a comprehensive analysis of the effects of regular aerobic exercise on self-reported positive mood. Our study found that the subjective well-being and dimension scores of older adults who exercised moderately and with high intensity were higher than those in the low intensity group. This result further supports the idea that moderate- and high-intensity exercise has a more positive effect on the subjective well-being of older adults than lower-intensity exercise.

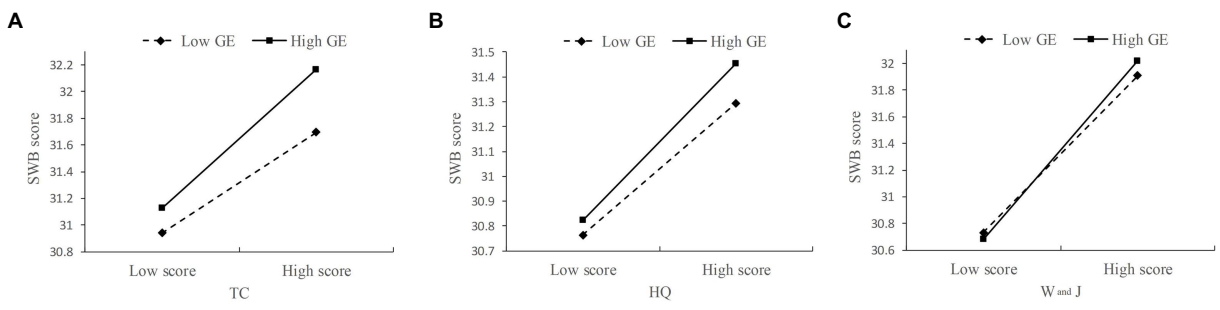

FIGURE 3
The moderation effect of exercise form between different physical activities and subjective well-being. **(A)** Simple slope analysis of the moderating effect of practice form on the relationship between tai chi and subjective well-being; **(B)** Simple slope analysis of the moderating effect of practice form on the relationship between health qigong and subjective well-being; **(C)** Simple slope analysis of the moderating effect of practice form on the relationship between walking and jogging and subjective well-being. SWB, subjective well-being; TC, tai chi; HQ, health qigong; W and J, walking and jogging; GE, group-based exercise.

TABLE 8 The slope of different physical activities.

	TC	HQ	W and J	*p*
High collectivity	0.010	0.006	0.013	***
Low collectivity	0.008	0.005	0.012	***

TC, tai chi; HQ, health qigong; *W and J*, walking and jogging. ***$p < 0.001$.

The mediation effect of outdoor exercise environment

The research demonstrates that outdoor exercise environment, as an intermediary variable, plays an intermediary role between physical activity and subjective well-being. Wolf and Wohlfart (2014) believe that outdoor exercise environment can better provide physical activity opportunities for older adults and can also promote their mental health. The research found that the needs of different physical activities in the outdoor exercise environment played a positive guiding role in the subjective well-being of older adults. This is consistent with the results of previous studies (Sugiyama and Thompson, 2007; Loureiro and Veloso, 2014). In addition, the study also found that different physical activities have different needs for outdoor exercise environment, of which walking and jogging has the highest demand for outdoor exercise environment, followed by tai chi and health qigong. One possible explanation is that during the normalization of the pandemic, the places where older adults can exercise are restricted, and the demand for the exercise environment will change accordingly. Among all the sports, walking and jogging depends least on exercise conditions, and it is also the most common outdoor exercise (Stodolska et al., 2010). From the perspective of environmental psychology (Gehl, 2002), when people are in a good natural environment and living environment, they will spontaneously choose the appropriate outdoor exercise out of their own mentality or preference. In addition, for obese older adults, tai chi and health qigong cannot produce satisfactory effects enhancing cardiopulmonary function (Wang et al., 2004; Burini et al., 2006) due to insufficient exercise intensity, in contrast to walking and jogging, which can. In short, brisk walking and jogging, with relative exercise intensity, make higher demands on outdoor exercise environment. Lawton et al. (2017) argue that the exercise environment in which physical activity is performed is the most important factor for the production of mental health outcomes, and that people with exercise habits are more sensitive to the exercise environment, and the outdoor exercise environment is more conducive to reducing negative emotions and promoting mental health. Pretty et al. (2005) similarly mention that "green exercise" is more effective in improving cardiovascular and mental health than is exercise in unnatural environments. The results of the present paper further confirm this argument. Older adults who participate in physical activity generally have a higher frequency of exercise and belong to the "regular exercise population," and the outdoor exercise environment plays a positive role in the subjective well-being of older adults.

The regulation effect of exercise form

This study finds that exercise form play a positive regulatory role in the relationship between physical activity and subjective well-being; that is, when older adults participate in group-based exercise, the degree of influence of physical activity on subjective well-being is increased. This shows that when older people exercise in groups, physical activity has important implications for their subjective well-being. This is consistent with previous studies (Farrance et al., 2016), where the subjective well-being of older adults who participate in group activities is higher than that of older adults who participate in individual activities. Previous studies have also shown that regular, planned, and organized physical activity can effectively improve the emotional status of older adults (Komatsu et al., 2017). Possible explanations are as follows. First, organized exercise teams are usually equipped with exercise knowledge and can guide the members to choose exercises that match their cardiopulmonary function considering their own health status and underlying diseases, so that older adults can get a good exercise experience and wellbeing benefits. In addition, in the process of exercise, older adults have more opportunities for communication. They can search for common topics, cultivate common interests, which not only strengthens neighborhood relations within a community and increase the sense of social identity, but also plays an important role in their personal life satisfaction, mental health, and the resolving of setbacks (McAuley et al., 2000). In addition, the more older people engage in collective physical exercise, the more actively they face life and the lower their level of anxiety and depression are (Sebastião and Mirda, 2021). The intrinsic induction of mutual attraction and resonance that arises in interaction also helps to enliven the atmosphere and heighten the feeling of pleasure. Ku et al. (2016) and others believe that group walking can improve the subjective well-being of older adults, and older adults with higher activity frequency have higher levels of well-being. This result further supports the regulatory effect of collective exercise on the subjective well-being of older adults.

Influences

This article makes some contributions to the mental health of older adults. First, the roles of walking and jogging, tai chi, and health qigong in enhancing subjective well-being are discussed by linking outdoor exercise environment, exercise form, and subjective well-being, in a more detailed way than in previous studies. By dividing physical activities into walking and jogging, tai chi, and health qigong, the relationship between different physical activities and subjective well-being is discussed more clearly. Secondly, the study used the AMOS path analysis method, evaluating the relationship between different physical activities and subjective well-being by using the outdoor exercise environment as the mediation variable within the mediation model, while the regulatory effect of exercise form (group and individual) was analyzed through linear regression. Finally, the study clarifies the relationship between different physical activities

and subjective well-being and its internal mechanisms, and provides new theoretical insights and practical guidance for study of how to improve the subjective well-being of older adults. The authors argue that in order to improve the subjective happiness index, older adults should cultivate a sense of engaging in long-term physical activities, and that older adults' moderate- and high-intensity exercise in outdoor environment is more conducive to improving the subjective well-being index, while encouraging older adults to participate in regular, organized, and planned group-based exercise.

Limitations and future research directions

This study defines the relationship between different physical activities and subjective well-being and its internal mechanism, which has theoretical and practical significance. However, this study also has some limitations. First of all, this study is an investigation against the background of the long-term control and prevention of the COVID-19 pandemic. Large-scale public health events like this are not common, and under the influence of such events, the research results are also unusual. Second, physical activities include all types of activities, such as activities related to sports, leisure and occupation, general activities in daily life, and non-sedentary behaviors broadly (Caspersen et al., 1985). This paper only refers to the physical exercises that older adults participate in daily, ignoring other types of physical activities. Future research can focus on other types of physical activities of older adults, such as daily work, housework and gardening, transportation and leisure. In addition, there are certain limitations at the methodological level. This paper uses the PARS-3 scale to measure the physical exercise that older adults participate in daily from the three dimensions of exercise intensity, time and frequency, but fails to consider the measurement of other types of physical activities. In future research, the international physical activity questionnaire can be augmented to investigate different types of physical activities. At present, researchers have accurately pointed out that more accurate qualitative, intuitive, and quantitative methods need to be used to improve the measurement of subjective well-being (Nima et al., 2020). In this paper, the MUNSH scale is used to investigate the subjective well-being of older adults based on the four dimensions of PA, NA, PE and NE, there is a lack of providing direct measurement of the subjective well-being of older adults. In future research, we can consider adding the positive affect negative affect schedule, satisfaction with life scale, harmony in life scale, etc., so as to intuitively, accurately and comprehensively evaluate the subjective well-being of older adults. In-depth interviews with participants can also be implemented to supplement the gaps in qualitative research methods. Finally, this study adopts a cross-sectional model, which means that the research results cannot be compared at different time points, so the evidence is limited in this regard. In the future, research on different physical activities and subjective well-being of older adults can be tested through follow-up design and experimental research. At the same time, there are many internal mechanisms between different physical activities and subjective well-being in older adults. For example, sociological factors (including living areas, social support, interpersonal relationships, etc.) can be considered. The model needs to be further expanded in future research.

Conclusion

The present study is unique in that it examines the relationship between different physical activities, outdoor exercise environment, exercise form, and subjective well-being in a sample of Chinese older adults. This study found that different physical activity types were positively correlated with the subjective well-being of older adults, such that older adults who practiced tai chi had the strongest subjective well-being. The outdoor exercise environment was identified as a mediator of different physical activities and subjective well-being, the exercise form can also moderate the impact of different physical activities on the subjective well-being of older adults. That is to say, the environment and the collective practice method will improve the subjective well-being of older adults. The identification of the correlation path between different physical activities and subjective well-being provides evidence to clarify the relationship between different physical activities and the subjective well-being of older adults. This study provides a reference for mental health intervention in older adults.

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.

Author contributions

XM and BZ: conceptualization and project administration. XM and FZ: methodology. XM and QY: formal analysis, investigation, and writing—original draft preparation. XM, FZ, and QY: validation. XM: data curation and funding acquisition. XM, GJ, and YT: writing—review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

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Changes in health behaviors and conditions during COVID-19 pandemic strict campus lockdown among Chinese university students

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Objective: To explore how a stringent campus lockdown affects the physical activity (PA), sleep and mental health of Chinese university students living in student dormitories during the COVID-19 pandemic.

Methods: Data on PA, sleep and mental health were collected between 24 March and 4 April 2022 from 2084 university students (mean age=22.4years, 61.1% male students) *via* an online questionnaire distributed by the students' advisers of each dormitory. The Chinese short version of the International Physical Activity Questionnaire (IPAQ-C), Athens Insomnia Scale (CAIS) and General Health Questionnaire 12-item (GHQ-12) were applied. The Mann–Whitney test and Kruskal-Wallis tests were used to evaluate the PA profile differences between genders, before and during the lockdown period and between students' living environments. Chi-squared ($\chi 2$) or Fisher's exact test was used to assess changes in health behaviors by gender and students' living environment compared to before the lockdown. A mediation model was used to examine whether sleep disorder mediated the relationship between PA and mental health in different students' living environments.

Results: Participants reported a significant decrease in weekly total PA levels (63.9%). Mean daily sedentary time increased by 21.4% and daily lying time increased by 10.7% compared to before lockdown. Among the participants, 21.2% had experienced insomnia, and 39.0% reported having high mental distress. Female students reported 10% higher rates of sleep disorders than male students ($p<0.001$), and also experienced a higher incidence of mental disorders ($p<0.001$). Students living with three roommates had a larger decrease in frequencies and durations of participation in light PA than other students ($p<0.001$). PA was negatively associated with sleep and mental health, and sleep disorder was a mediating factor between PA and mental health in the students living with two and three roommates.

Conclusion: This study showed that strict lockdowns within university dormitories during the COVID-19 pandemic had a negative effect on the health of university students by changing their health behaviors, physical activity and sleep. Our findings indicate a need for strategies to promote an active lifestyle for students in space-limited dormitories in order to maintain health during a prolonged lockdown.

KEYWORDS

COVID-19, university students, mental health, physical activity, sleep disorders, strict lockdown

Introduction

The coronavirus disease (COVID-19) has brought dramatic political and economic changes around the world since the outbreaks in late 2019. The frequency and stringency of prevention measures vary from country to country as the outbreak continues to develop (Hale et al., 2020). Although more than 2 years have passed, conditions of strict confinement in place to control the pandemic themselves present a challenge to the physical and mental health of diverse populations (Odone et al., 2020; World Health Organization, 2022). On 26 November 2021, the WHO classified Omicron as a new variant of the SARS-CoV-2 (World Health Organization, 2021). Through observations and lessons learned from the strained healthcare systems in Hong Kong and Shenzhen, Shanghai adopted a strict and extensive containment control strategy to prevent the spread of Omicron following the emergence of Omicron cases (Zhang et al., 2022). Schools and universities in Shanghai complied with the policy of closing campuses (Shanghai Municipal Health Commission, 2022a) and students had to switch to learning online and dormitory quarantine with necessities delivered by volunteers. The only outdoor activities were walking to the nucleic acid PCR testing stations nearby.

According to the Shanghai Municipal Health Commission, as of 31 March 2022, 32,648 cases of asymptomatic infection, 1,937 cases have been identified, and 1,340 people have treated in hospital (Shanghai Municipal Health Commission, 2022b). A systematic review and meta-analysis showed that the mental health of university students can be influenced by factors such as national policy and the survey date (Li et al., 2021). Negative moods as a result of isolation and stressors create potential physical and psychological health risks among university students, as has been reported previously (Li et al., 2021). The stresses and restrictions associated with strict confinement due to the COVID-19 outbreak put university students at greater risk of adverse impacts on their physical activity (PA), academic achievement, social interactions, future careers and personal opportunities (Zhang et al., 2022). Based on the stress buffer hypothesis (Cohen and Wills, 1985), social support can protect individuals from the potentially pathogenic effects of stress. This hypothesis assumes increased physical activity can buffer the negative health effects of stress, and maintaining physical activity during a high-stress period may reduce its negative impact on students' sleep and mental health (Hamer et al., 2006; Tsatsoulis and Fountoulakis, 2006; Gerber and Pühse, 2009). While Sudden outbreaks may make university students more prone to changes in PA (Wang et al., 2020) and psychological stress (Serafini et al., 2012; Zhang et al., 2020).

Numerous studies have found that physical activity and sleep were important factors that influence mental health, with increased physical activity having a direct or indirect positive effect on sleep and psychological well-being (Baglioni et al., 2011; Ghrouz et al., 2019; Trabelsi et al., 2021). In a randomized controlled trial, Scott et al. found that sleep disturbance may be at the root of mood disorders and depression (Scott et al., 2017). Low levels of physical activity during COVID-19 were found to be highly associated with an increased risk of mental disorders in a Brazilian study (Puccinelli et al., 2021). Gender differences were also found in facing the psychological stress caused by COVID-19. And recent empirical research regarding gender differences in mental and physical health found that females perceived greater anxiety and depressive symptoms among university students in Iceland (Gestsdottir et al., 2021). Likewise, the latest investigation indicated negative impacts of COVID-19 home isolation, and females reported a higher prevalence of anxiety (Bigalke et al., 2020).

Differences in living environments can intensify changes in people's lifestyles during the period of confinement. In a typical university dormitory in China, 4–8 students share a 20^2 m living space. Living in small apartments (<60^2 m) and having inadequate privacy were strongly correlated with moderate-to-severe and severe depressive symptoms during a COVID-19 lockdown (Amerio et al., 2020). Furthermore, evidence suggests that sleep quality is critical in modulating the effects of PA on mental health (Wunsch et al., 2017; Wang et al., 2020), but the correlation between PA, sleep, and mental health during a period of lockdown remains controversial. Wilson et al. (2021) found that PA and mental health among US college students declined significantly during the COVID-19 pandemic compared to before the pandemic, but PA did not affect mental health. On the other hand,

one study from South Africa found that PA affected mental health outcomes during the lockdown, and low PA predicted greater insomnia symptom severity, which in turn predicted increased depressive-and anxiety-related symptoms (Lewis et al., 2021). However, little is known about the effects of the number of students sharing a dormitory during a period of campus lockdown on PA, sleep, and mental health.

With increasingly stringent quarantine requirements, understanding the changes in PA, sleep and health behavior of university students before and after the COVID-19 outbreak lockdown may guide to subsequent development of isolation policy to minimize the adverse effects. Therefore, the purpose of this study is to, (1) describe the changes in university students' PA, sleep, mental health and health behavior condition patterns in dormitories during and before lockdown; (2) assess the differences in these parameters across the different number of roommates in university students; (3) investigate the relationships among PA, sleep and mental health and how they relate to the different numbers of students sharing a dormitory. Based on previous studies, our main hypothesis is that the PA levels of university students under strict campus lockdown will be significantly reduced and that low PA levels will be highly correlated with worse sleep and mental health. Moreover, this relationship varies across university students' living environments (number of roommates). It was anticipated that this study could provide useful PA, sleep, and psychological advice for university students and authorities in responding to such public health emergencies in the future.

Materials and methods

Study design and procedure

The study was a cross-sectional design with a convenience sample that targeted students studying and living on the (Minhang district) campus of Shanghai Jiao Tong University. The study was launched on March 24, 2022, which is 2 weeks after the start of the enforced quarantine on campus. We collected data on PA, sedentary time, insomnia symptoms, mental health and sociodemographic information using a commercial online survey platform (i.e., Wen Juan Wang).[1] Electronic informed consent was obtained from each participant prior to the beginning of the survey. Eligible participants were contacted through the students' advisers of each dormitory, and about 10% of students from each dormitory (a total of 69 dormitories) was involved. A QR code of the questionnaire was provided *via* WeChat. The questionnaire was anonymous and produced de-identified data. The participants were volunteers without a monetary incentive, and they were informed about the use of their information. After the questionnaires were obtained, a researcher reviewed the collected questionnaire to ensure the quality of the responses. The structured questionnaire included four sections: (1) socio-demographic characteristics (i.e., age, height, weight, gender, college degree, discipline and number of roommates), (2) health behavior and condition changes (i.e., screen time, body weight change, sleep behavior, etc.,) compared to 2 weeks before the lockdown, and (3) the condition of PA, SB before and during the lockdown, (4) sleep disorder and mental health during the lockdown. The study was performed according to the Declaration of Helsinki and was approved by the ethics committee of Shanghai Jiao Tong University, China (B2022185M).

Participants

The participants were from the Shanghai Jiao Tong University who were currently stated at the university. The inclusion criteria were that participants were aged older than 18 years, could read and understand the Chinese language and the purpose of the survey. We exclude questionnaires with apparent errors (e.g., sum of all activities hours exceeding 24 a day) and participants who subjectively reported physical or mental disability.

PA and SB

The Chinese short version of the International Physical Activity Questionnaire (IPAQ-C) was used, and has good reliability across domains (ICC: from 0.81 to 0.89) and moderate validity (Deng et al., 2008). The Chinese version consists of 7 items recall measure of 7 days. The items were modified relative to before and during campus lockdown (i.e., "what is your vigorous PA level during the campus lockdown?") For the level of PA, participants reported the frequency (days per week) and duration (hours and minutes) of vigorous, moderate and light PA performed previously and during the lockdown weeks (Wang et al., 2020). The calculation of continuous scores followed the IPAQ–SF scoring protocol (Committee, 2005) to estimate the weekly Metabolic Equivalent of Task (MET) by multiplying the minutes of days, days per week, and MET value of light, moderate and vigorous levels of PA (3.3, 4.0 and 8.0 METs, respectively). Then the participants' PA was categorized into three levels: light (<600 MET minutes/week), moderate (600–1,499 MET minutes/week), and vigorous(≥1,500 MET minutes/week) based on the total metabolic equivalents (METs) per week (Lee et al., 2011). In addition, the participants were asked to report SB time by stating the time in hours and minutes spent in sitting and lying down during and before the lockdown (i.e., "How many hours do you sit in a 24-h day?," "How many hours do you lying down in a 24-h day?").

Athens insomnia scale

The Chinese version of the Athens Insomnia Scale (CAIS) was used to assess sleep disorders and particularly insomnia symptoms

1 https://www.wenjuan.com

and consists of eight self-administered items (i.e., "During the recent past, how was your total sleep duration?," "How was your sense of well-being during the day?") (Chiang et al., 2009). The item scoring of the CAIS uses a 4-point Likert scale, rating from 0 to 3, and the total scores are calculated values from 0 to 24. According to the original AIS version (Soldatos et al., 2003), the optimal cutoff is set at 6 or higher to discriminate and identify a person with severe insomnia symptoms. Higher scores suggest severe insomnia symptoms, with lower scores indicating fewer insomnia symptoms. The CAIS has demonstrated good validity and reliability with the Cronbach's a of internal consistency of 0.84 and a test-rest reliability of 0.86 (Chiang et al., 2009), and Cronbach's alpha coefficient for CAIS was 0.82 in the present sample.

General health questionnaire

Mental health was assessed using the Chinese version of the General Health Questionnaire 12-item (GHQ-12; Chan and Chan, 1983). Items 2, 5, 6, 9, 10, and 11 are negatively phrased. The original and preferable Goldberg bimodal scoring method (0-0-1-1) was applied, and higher total scores (0–12) represented poorer mental health/psychological distress (Goldberg and Hillier, 1979; Goldberg and Williams, 1988). The items concern a variety of psychological constructs, such as anxiety, depression, and social dysfunction (i.e., "Have you recently been feeling unhappy and depressed?," "Have you recently been losing confidence in yourself?"). A factor score is calculated by adding the item score, and values span 0–12, with higher scores indicating poorer mental health. The GHQ-12 has demonstrated both convergent validity ($r = 0.47–0.76$, $p < 0.05$) and internal consistency (Cronbach's $\alpha = 0.89$) (Zhong et al., 2021). Cronbach's alpha coefficient for GHQ-12 was 0.85 in the present sample.

Statistical analyzes

The Shapiro–Wilk test was used to check the normality of data distribution. If data were not normally distributed, they were analyzed with non-parametric analysis methods. Descriptive statistics were used to present the continuous data as the mean and 95% confidence interval (CI) and categorical data as numbers (n) and proportions (%). The Mann–Whitney test was used to evaluate the PA profile differences between genders, and between before and during the lockdown period. Kruskal-Wallis tests were used to compare the different PA variables between students' living environments. We stratified the analysis between males and females and between students' living environment profiles. A cross-table Chi-squared (χ^2) or Fisher's exact test were used where appropriate to assess the changes in health behaviors by gender and students´ living environment compared with before the lockdown, and Cramer's V for estimation of effect size (small, medium or large) (McHugh, 2013; Kim, 2017). Change rates ($\triangle$%) in PA profiles were calculated by subtracting the value during the lockdown from the value before the lockdown, and then dividing it by the value before the lockdown.

In addition, mediation models were used to test whether sleep disorder mediated the relationship between PA and mental health with different numbers of roommates, adjusted for age and gender. According to Zhao et al. (2010), we chose the indirect path a*b test as the first step to estimate the mediating effect. In the mediation models, PA was considered as an independent variable, while sleep disorder was used as the mediator variable and mental health was treated as a dependent variable (Figure 1). Three regression models were established to verify the mediating effect. Coefficients for the regression of PA on mental health were calculated in the first regression model (path a). The regression coefficients of PA and sleep disorder were calculated in the second regression model (paths b and c'). The predictor effect of PA on mental health excluding sleep disorder is shown in the third regression model (path model c). Continuous variables including age, PA, sleep disorder and mental health were standardized. The mediated effect was examined with 95% bootstrapped confidence intervals (CIs), using 5,000 bootstrapped samples and bootstrap bias-corrected confidence intervals from the models were reported (Efron, 1987). The percentage of mediation was calculated by the equation = 100*indirect effect/total effect. Statistical significance was set at 0.05. All analyzes were performed using the R program (4.1 version, The R Project for Statistical Computing).[2] The lavaan package in R was used to perform the mediation analyzes (Rosseel, 2011).

Results

Basic information of the participants

Of the final analytical sample ($n = 2084$), 1,274 (61.1%) were male and 810 (38.9%) were female (Table 1). By discipline, 1,363 students (65.4%) were majoring in Technology, 394 students (18.9%) were majoring in Natural Science, and 327 students (15.7%) were majoring in Liberal Arts, Medicine and Agricultural. By college degree, 985 students (47.3%) were undergraduate, 680 students (32.6%) were postgraduate, 419 (20.1%) were doctoral students. The age range of the participants was 18–35 years, and the mean BMI was 22.2 (95%CI, 22.1–22.4).

During the lockdown period, 172 (8.3%) students lived in a dormitory without roommate, 694 (33.3%) students shared a dormitory with one roommate (2 persons in a room), 628 students (30.1%) lived with two roommates (3 persons in a room), and 590 students (28.3%) had three roommates (4 persons in a room). The dormitories are similar in size, with an average size of 15 square meters each. As the proportion of students living without

2 https://www.R-project.org/

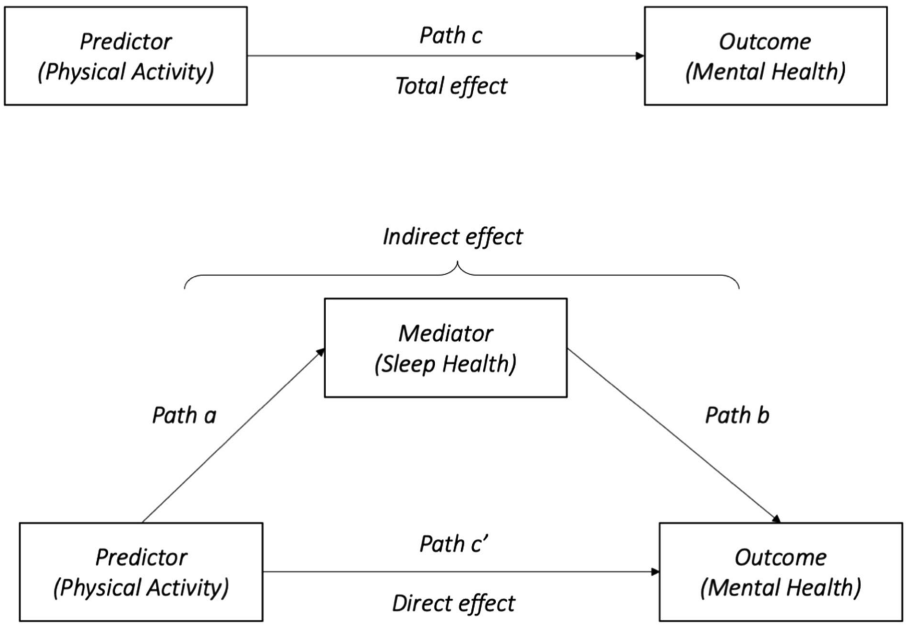

FIGURE 1
Conceptual model: how sleep disorder mediates the association between physical activity and mental health. a, b, c, and c′ refer to the path of models.

TABLE 1 Participants' demographic characteristics.

	Total ($N = 2084$)
	Mean (95%CI)
Age	22.4 (22.2–22.5)
Height (cm)	171.5 (171.1–171.8)
Weight (kg)	65.8 (65.1–66.4)
Body Mass Index (BMI, kg/m^2)	22.2 (22.1–22.4)
Number (proportion)	**No. (%)**
Gender	
Male	1,274 (61.1)
Female	810 (38.9)
Discipline	
Technology	1,363 (65.4)
Natural Science	394 (18.9)
Liberal Arts & Medicine & Agricultural	327 (15.7)
College degree	
Undergraduate	985 (47.3)
Postgraduate	680 (32.6)
Doctoral student	419 (20.1)
Number of roommates	
Zero	172 (8.3)
One	694 (33.3)
Two	628 (30.1)
Three	590 (28.3)

roommate was relatively small, therefore, we combined them with students who had one roommate in the subsequent analysis of the results.

Changes in PA and SB

The average number of days that students were physically active at vigorous intensity during the lockdown period was 1.22 times, with a duration of 14.5 min (Figure 2A). The average number of times of moderate-intensity PA was 1.77 times, and the duration was 17.6 min, and the average number of times light-intensity PA was 1.01 times and the duration was 12.6 min. The average daily sedentary time was 11.2 h and lying time was 9.5 h (Figure 2A).

There was a significant gender difference in the duration of moderate and light-intensity PA, with female students having more moderate physical activity participation time than male students, and male students having more light-intensity physical activity engagement time than female students (Figure 2Bb).

In addition, male students had more sedentary hours than female students. Conversely, female students spent more time lying down than male students (Figure 2Bc). All PA profiles before and during lockdown are presented in detail in Table 2. There was a significant reduction in the total weekly PA level during lockdown (63.9%). The mean daily sedentary time increased by 21.4% and the mean daily lying time increased by 10.7% compared to the before lockdown period ($p < 0.001$). There were differences in the changes of different levels of intense physical activity between male and female students. Vigorous-intensity physical activity and moderate-intensity physical activity decreased by 52.4 and 63.2% for male students, respectively, while in females the corresponding changes were smaller at 36.9 and 46.9%, for vigorous intensity and moderate-intensity physical activity, respectively. In addition, the change in light-intensity physical activity was bigger among female students than male students (88.2% vs. 82.3%, $p < 0.001$).

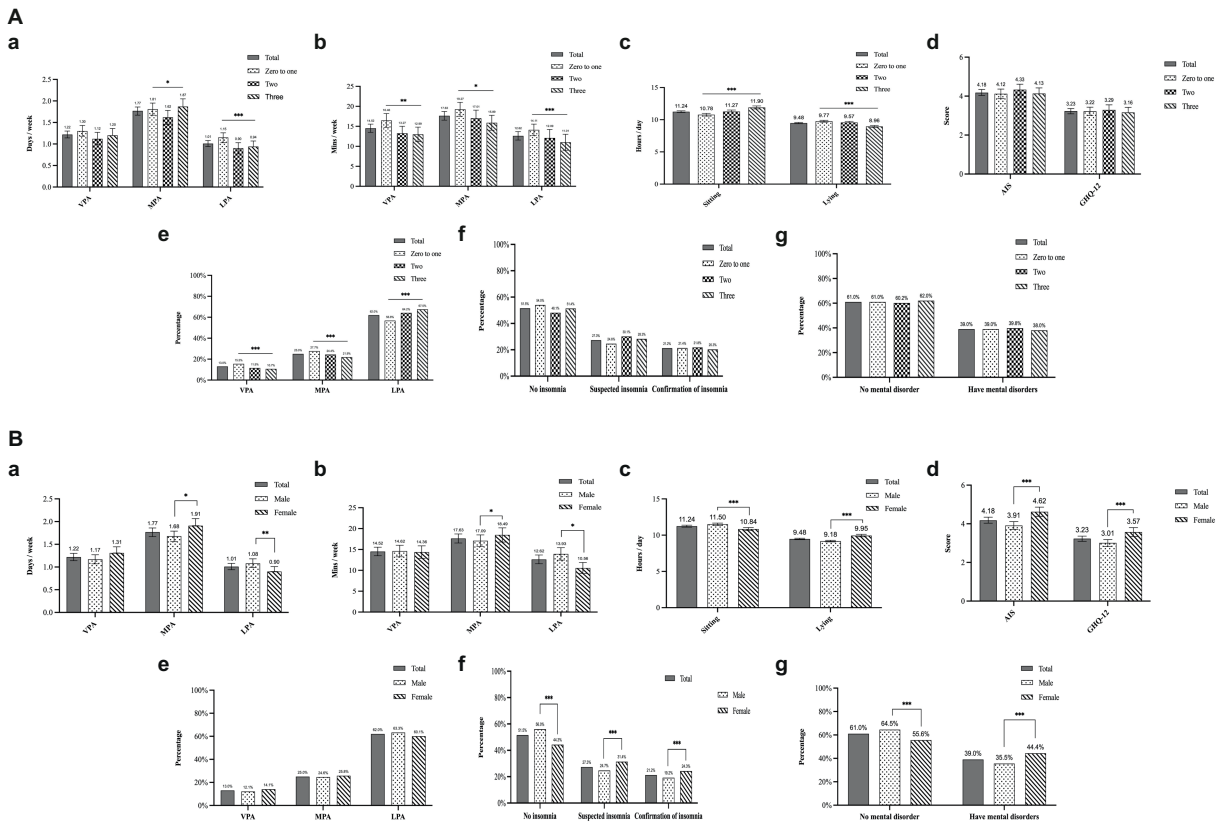

FIGURE 2
(A) PA behavior, sleep disorder, and mental health during the lockdown among different living conditions. *p<0.05, **p<0.01, ***p<0.001. **(B)** PA behavior, sleep disorder, and mental health during the lockdown among gender. *p<0.05, **p<0.01, ***p<0.001.

Changes in health condition

Most of the students (74.6%) reported that their health condition was the same as before the lockdown, while nearly 18.4% reported a decrease in health condition and 7% reported better condition than before the lockdown. Nearly 59% of students reported no change in their weight compared to before the lockdown, 19.5% were unclear about their weight change, 13.0% reported weight gain, and 8.4% reported weight loss. On changes in screen time, nearly 84% of students reported an increase in their daily screen time from before the lockdown, about 14.7% reported no change in screen time, and nearly 1.3% reported a decrease in screen time from before the lockdown (Figure 3).

In addition, sleep behavior also changed significantly during the lockdown period. Compared to before the lockdown period, nearly 29.4% of students reported going to bed earlier and 27% of students reported going to bed later, while 43.6% reported no change in bedtime. Nearly 35.6% of students reported waking up later, 46.1% reported an increase in the total number of hours of sleep and 28.3% reported poorer sleep quality.

There were gender differences in sleep behavior changes during the lockdown. Female students had a higher percentage of earlier bedtimes and later wake-up bedtimes than male students, and a greater percentage of females reported an increase in total sleep time than male students during the lockdown period (p<0.001). The mean score of the Athens Insomnia Scale was 4.18 (Figure 2Bd). Compared to male students, female students had significantly higher AIS scores, and experienced worse sleep disorders. In addition, nearly 31.4% of female students were diagnosed with suspected insomnia and nearly 24.3% were diagnosed with insomnia, while male students reported significantly less sleep disorder than female students (Figure 2Bf).

Regarding mental health during the lockdown period, female students scored significantly higher on average on the GHQ-12 scale than male students, and nearly 44.4% of female students were diagnosed with a mental disorder as opposed to 35.5% of male students (Figure 2Bg).

Influences on PA and health behaviors in living dormitory conditions

Differences in physical activity participation also existed by dormitory conditions (Figures 2Aa,b). Students without or with one roommate spent significantly more time participating in all intensity of activities than those with two and three roommates.

TABLE 2 Changes in physical activity behavior.

		Total ($N = 2084$) Mean (95%CI)	Gender		Number of roommates		
			Male ($N = 1,274$) Mean (95%CI)	Female ($N = 810$) Mean (95%CI)	Zero to one ($N = 866$) Mean (95%CI)	Two ($N = 628$) Mean (95%CI)	Three ($N = 590$) Mean (95%CI)
Vigorous MET	Pre	703 (653–753)	775 (712–838)	591 (508–674)	701 (620–781)	732 (632–832)	676 (596–755)
minutes/week	Post	370 (333–407)	369 (318–419)	373 (321–425)	432.01 (368–496)	326.37 (266–387)	326.1 (263–389)
	Δ%	47.3	52.4	36.9	38.3	55.4	51.8
	p–value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Moderate MET	Pre	553 (522–584)	578 (538–619)	512 (463–561)	542 (495–590)	566 (505–626)	554 (499–608)
minutes/week	Post	236 (216–256)	213 (190–236)	272 (236–308)	260 (227–293)	231 (191–272)	205 (179–232)
	Δ%	57.3	63.2	46.9	52.1	59.1	62.9
	p–value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Light MET	Pre	740 (709–770)	729 (691–768)	756 (706–805)	763 (712–813)	724 (670–779)	722 (670–774)
minutes/week	Post	114 (100–127)	129 (110–148)	89.0 (72.4–106)	122 (103–141)	115 (87.7–143)	99.4 (74.5–124)
	Δ%	84.6	82.3	88.2	84.0	84.1	86.2
	p–value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sitting hours/day	Pre	9.26 (9.13–9.39)	9.37 (9.21–9.54)	9.08 (8.88–9.28)	9.06 (8.86–9.26)	9.32 (9.10–9.54)	9.49 (9.24–9.73)
	Post	11.2 (11.1–11.4)	11.5 (11.3–11.7)	10.8 (10.6–11.1)	10.8 (10.6–11.0)	11.3 (11.0–11.5)	11.9 (11.7–12.1)
	Δ%	21.4	22.7	19.4	19.0	20.9	25.4
	p–value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lying hours/day	Pre	8.56 (8.49–8.63)	8.48 (8.39–8.57)	8.69 (8.57–8.80)	8.63 (8.53–8.73)	8.75 (8.62–8.88)	8.25 (8.11–8.4)
	Post	9.48 (9.38–9.58)	9.18 (9.07–9.29)	9.95 (9.78–10.1)	9.77 (9.62–9.92)	9.57 (9.39–9.75)	8.96 (8.8–9.12)
	Δ%	10.7	8.3	14.5	13.2	9.4	8.6
	p–value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total PA	Pre	1995 (1907–2083)	2082 (1968–2,196)	1858 (1721–1996)	2006 (1865–2,146)	2022 (1853–2,190)	1952 (1804–3,000)
	Post	720 (662–777)	710 (632–788)	734 (649–819)	814 (715–912)	673 (567–779)	631 (540–721)
	Δ%	63.9	65.9	60.5	59.4	66.7	67.7
	p–value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

PA, physical activity.

However, their lying hours were significantly longer than those with two and three roommates.

Those having one roommate or no roommate had less variation in total physical activity level than those having two roommates or having three roommates (59.4% vs. 66.7% vs. 67.7%). Also, similar differences between different dormitory conditions existed in changes of physical activity at different intensities.

Male students had more sedentary time compared to before the lockdown than female students. However female students had longer lying hours compared to before the lockdown than the male students. Students with three roommates had a greater change in sedentary hours than students in other dormitory conditions, spending more time sitting than before the lockdown. Those with one roommate or no roommate had a greater change in lying hours than those in other dormitory conditions, having more lying hours than before the lockdown. No differences were found in sleep and mental health by dormitory conditions (Figures 2Af,g).

Students with two and three roommates had worse health conditions during the lockdown compared to those with one and no roommates (19.4% vs. 20.0% vs. 16.6%, $p = 0.029$). In terms of change in bedtime, a greater proportion of students with three roommates reported going to bed earlier during the lockdown than those with one roommate or no roommate (34.6% vs. 26.2%, $p = 0.002$). In contrast, a larger proportion of students with one roommate and no roommate reported waking up later during lockdown than those with three roommates (40.3% vs. 30.5%, $p < 0.001$). On the change in total sleep time, students with three roommates reported a greater percentage of decreased total sleep time than students with two roommates and those with one roommate or no roommate (20.5% vs. 16.6% vs. 13.3%, $p = 0.004$). In turn, the proportion of students who had one roommate or no roommate and who had better sleep quality than before the lockdown was higher than those who had two roommates and those who had three roommates (17.6% vs. 11.8% vs. 14.1%, $p = 0.016$).

Mediation effects of sleep disorder in the relationship between PA and mental health

The results of bootstrapped mediation models in different dormitory conditions after controlling for age and gender are

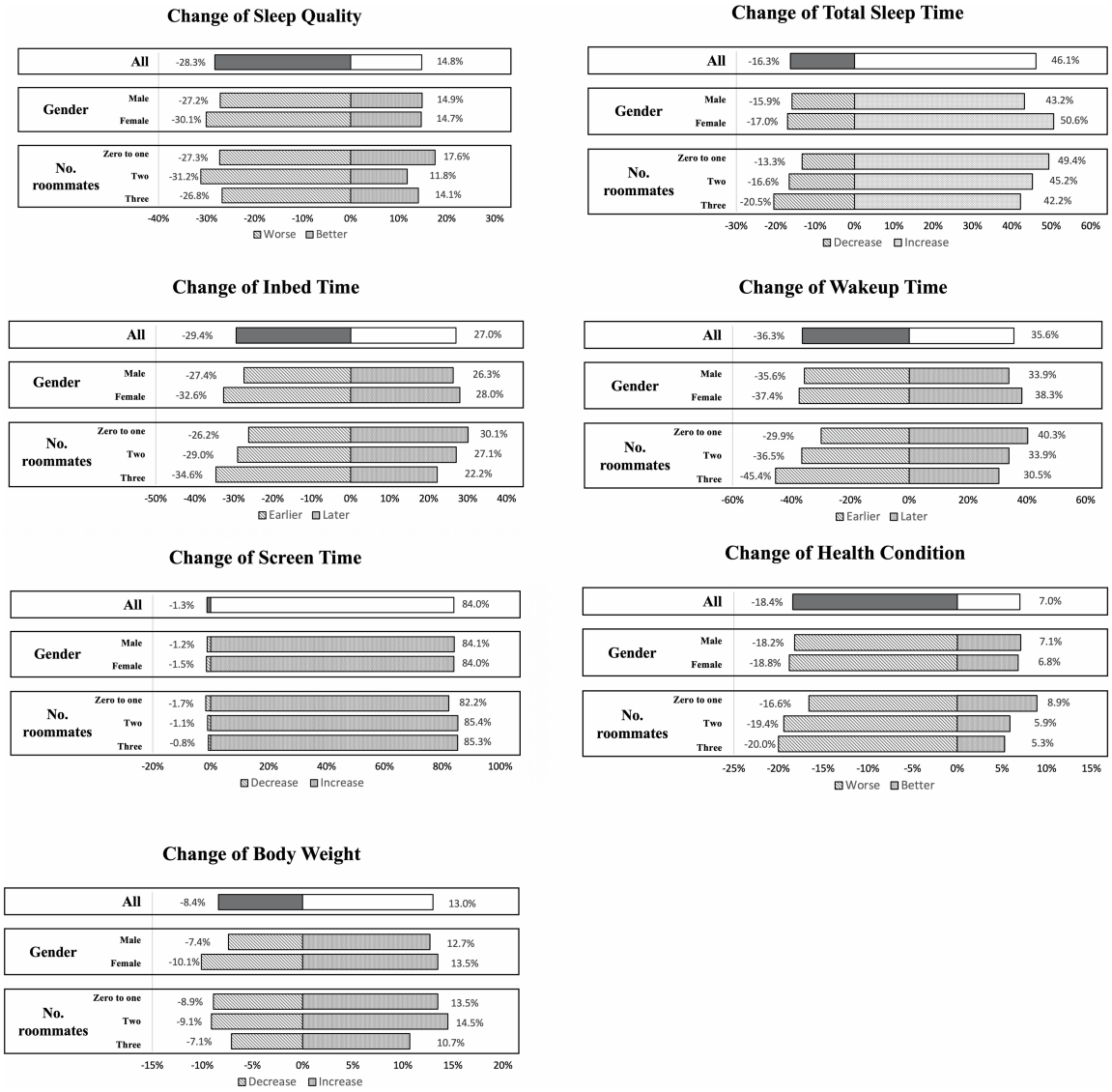

FIGURE 3
Changes in health behavior and condition among different gender and living environments.

presented in Table 3. In the path a, PA was negatively associated with sleep disorder in students who have three roommates. The total (path c) and direct (path c') effects of PA on mental health in the model were significant when the dormitory conditions were having one roommate or no roommate, and having two roommates. In the group of students with three roommates, sleep disorder was positively associated with mental health (path b), although there was no significant association between PA and mental health (path c').

As shown in Table 4, sleep disorder did not mediate the relationship between PA and mental health in students who had one roommate or no roommate, whereas among students with two roommates there was a slight tendency for an indirect effect ($p = 0.088$), with a mediation rate of 28.2% (partial mediating effect). Only the bootstrapped CI of indirect effects in students who had three roommates was statistically significant, with 75.6% as a percentage of mediation (complete mediating effect). Specifically, sleep disorder mediated the relationships between PA and mental health.

Discussion

In this study, more than two-thousand university students responded to our online survey on their PA, SB, and health behaviors. The results indicated significant reductions in participation time for all three intensity levels of PA compared to before the lockdown, and are largely consistent with those previously observed in university students (Wathelet et al., 2020; DeYoung and Li, 2022; Nirala et al., 2022). Dormitory

TABLE 3 Mediation analyzes: association between physical activity and mental health *via* sleep disorder.

		Total effect model (mental health)					Mediator (sleep disorder)					Direct effect model (mental health)				
					Bootstrap 95% C.I.					Bootstrap 95% C.I.					Bootstrap 95% C.I.	
Group	**Variables**	***β***	**SE**	***p*-value**	**CI.L**	**CI.U**	***β***	**SE**	***p*-value**	**CI.L**	**CI.U**	***β***	**SE**	***p*-value**	**CI.L**	**CI.U**
All	PA	−0.106	0.07	<0.001***	−0.481	−0.205	−0.072	0.079	0.001***	−0.411	−0.103	−0.064	0.056	<0.001***	−0.315	−0.095
	Sleep disorder											0.585	0.016	<0.001***	0.494	0.556
	Gender	0.083	0.146	<0.001***	0.261	0.834	0.097	0.163	<0.001	1.035	0.097	0.026	0.121	0.154	−0.075	0.401
	Age	0.033	0.024	0.137	−0.011	0.082	0.01	0.027	0.639	−0.04	0.065	0.027	0.019	0.123	−0.007	0.067
Zero to one	PA	−0.088	0.104	0.008**	−0.482	−0.074	−0.044	0.116	0.171	−0.387	0.075	−0.063	0.082	0.015*	−0.366	−0.043
	Sleep disorder											0.564	0.026	<0.001***	0.448	0.55
	Gender	0.083	0.222	0.013*	0.114	0.985	0.045	0.131	0.024*	0.041	0.551	0.039	0.184	0.166	−0.097	0.621
	Age	0.014	0.111	0.691	−0.173	0.261	0.001	0.067	0.991	−0.127	0.138	0.014	0.082	0.599	−0.112	0.208
Two	PA	−0.149	0.132	<0.001***	−0.751	−0.233	−0.07	0.146	0.084	−0.529	0.051	−0.107	0.108	0.001**	−0.566	−0.139
	Sleep disorder											0.605	0.035	<0.001***	0.487	0.623
	Gender	0.064	0.259	0.104	−0.086	0.928	0.078	0.16	0.001**	0.234	0.853	−0.016	0.22	0.633	−0.525	0.321
	Age	0.063	0.17	0.232	−0.13	0.536	0.012	0.102	0.704	−0.156	0.245	0.05	0.141	0.242	−0.103	0.449
Three	PA	−0.090	0.138	0.035*	−0.563	−0.021	−0.114	0.145	0.005**	−0.686	−0.12	−0.022	0.114	0.525	−0.296	0.15
	Sleep disorder											0.593	0.03	<0.001***	0.476	0.595
	Gender	0.105	0.301	0.021*	0.107	1.29	0.048	0.175	0.066	−0.027	0.656	0.056	0.239	0.116	−0.072	0.855
	Age	0.235	0.283	0.007**	0.204	1.31	0.119	0.152	0.011*	0.093	0.694	0.114	0.24	0.122	−0.106	0.834

PA, physical activity level during the lockdown; Mental health, General Health Questionnaire-12 items; Sleep disorder, Athens Insomnia Scale. β: Path coefficients; SE: Standard Error; CI.L: Lower limit of 95% Confidence interval; CI.U: Upper limit of 95% Confidence interval.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 4 Total, direct, and indirect effects of the mediation analyzes investigating sleep disorder as a mediator between physical activity and mental health.

					Bootstrap 95% C.I.		
Group	**Model**	***β***	**SE**	***p*-value**	**CI.L**	**CI.U**	**Percent of mediation (%)**
All	Total effect	−0.106	0.07	<0.001***	−0.481	−0.205	
	Indirect effect	−0.042	0.04	<0.001***	−0.214	−0.056	39.6
	Direct effect	−0.064	0.056	<0.001***	−0.315	−0.095	60.4
Zero to one	Total effect	−0.088	0.104	0.008**	−0.482	−0.074	-
	Indirect effect	−0.025	0.058	0.172	−0.193	0.038	-
	Direct effect	−0.063	0.082	0.015*	−0.366	−0.043	-
Two	Total effect	−0.149	0.132	<0.001***	−0.751	−0.233	-
	Indirect effect	−0.042	0.082	0.088	−0.295	0.028	28.2
	Direct effect	−0.107	0.108	<0.001***	−0.378	−0.066	71.8
Three	Total effect	−0.090	0.138	0.035*	−0.563	−0.021	-
	Indirect effect	−0.068	0.08	0.006**	−0.378	−0.066	75.6
	Direct effect	−0.022	0.114	0.525	−0.296	0.15	24.4

β: Path coefficients; SE: Standard error; CI.L: Lower limit of 95% confidence interval; CI.U: Upper limit of 95% confidence interval; Percent of mediation = 100 * indirect effect/total effect.
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

living condition (number of roommates) was found to be a key factor affecting the students' PA level during the isolation period, and also regulated the mediating role of sleep disorders in PA and mental health. These results suggest that the PA of university students isolated in dormitories is substantially affected by their living conditions.

The PA and SB pattern during the strict lockdown period

Students' total weekly energy expenditure in PA decreased by 63.9%, and sedentary and lying time increased by 21.4 and 10.7%, respectively during lockdown. These results are in agreement with those observed in earlier studies (Wang et al., 2020; Li et al., 2021; Alshammari et al., 2022). A study investigating the PA and SB of the young adult in Kosovo during COVID-19 confinement found that the total weekly energy expenditure of respondents decreased by 26.2% compared with that before the confinement. Of note is that the sample of this Kosovo study were isolated at home, and had more opportunities for housework and other activities than the university students who were in dormitory lockdown in our study. These university students had all their meals delivered to their door by volunteers, and they did not participate in household chores.

Gender differences in sleep and mental health during the lockdown period

The current study found that female students showed greater variation in sleep habits than male students during the COVID-19 lockdown. Their sleep and mental health were also poorer than those of male students. These results mirrored the findings of previous studies that female students experienced greater insomnia (Zhou et al., 2020; Tasso et al., 2021), anxiety and depressive symptoms (Pieh et al., 2020; Al Mamun et al., 2021; Lewis et al., 2021). A global study examining sleep patterns based on wearable devices found that even though women have longer sleep duration, they have more nighttime awakenings at any age and are also at higher risk of sleep disorders and insomnia than men (Jonasdottir et al., 2020; Otten et al., 2021). A possible explanation is that women may be more prone to stress and anxiety when faced with some traumatic events (McLean et al., 2011; Al Mamun et al., 2021) and that this affects their sleep behavior, while men show better resilience and consistency (Axinn et al., 2013). The evidence suggests that there are consistent gender differences in both sleep and mental health, and further research should focus more on effective interventions to improve women's sleep and mental health.

Effects of living conditions on PA, and the mediation role of sleep among PA and mental health

Previous studies have found that university students had significantly lower physical activity during the pandemic lockdown and worse sleep and psychological state than in normal life (Wang et al., 2020; Hargreaves et al., 2021; Lewis et al., 2021; Wilson et al., 2021). Our study is the first to use university students' living conditions context as a factor to explore changes in PA, sleep and mental health during a COVID-19 lockdown. Importantly, the PA differences we observed across living conditions only existed during lockdown period. We found that physical activity decreased with number of roommates, with those with more roommates reporting less physical activity time (Hargreaves et al., 2021). This differs from most previous research settings that have used Chinese university students as participants (Deng et al., 2020). The environmental specificity of Chinese university dormitories, which have a high density of indoor occupancy (Evans et al., 2001), with students sharing with other students (Tao et al., 2016) and having very limited space to move around aside from beds and desks and closets, tends to increases sedentary and lying hours among students under lockdown. In addition, confronted with lockdown restrictions in dormitories with limited space, the motivation to engage in PA is likely to decline. Similarly, PA changes were more significant for those living in apartments than those living in other areas and PA was significantly lower than before the lockdown (Aguilar-Farias et al., 2020). Our findings show that students who live in a dormitory alone or share with one other student have higher PA levels than students who share a dorm with 2 or 3 other students. The dorm sizes are similar, thus more roommates results in less living space for each student. Therefore, the decrease in PA was mainly attributed to the limited physical space and the students not being used to exercising in dormitories. This finding urges us to develop novel approaches to promote PA among university students in such limited living conditions in the post-pandemic era.

Little is known about the relationship between PA, sleep, and mental health among Chinese university students in COVID-19 dormitory lockdown. To clarify the role of PA on the relationship between sleep disorder and mental health, we further conducted a series of mediation analyzes and found that PA had a positive impact on sleep and mental health. In normal life without the COVID-19 pandemic, the severity of insomnia symptoms has been shown to be associated with an increase in mental health symptoms such as depression and anxiety (Alvaro et al., 2013; Lewis et al., 2021). Increasing PA can improve the sleep health of university students and also regulate their mental health (Wu et al., 2015). Notably, our findings align with those of previous studies (Teychenne et al., 2008) that PA was a predictor of mental distress and PA was negatively associated with depression symptoms caused by COVID-19 lockdown (Deng et al., 2020; Brailovskaia et al., 2021).

Most notably, sleep disorder became relevant in predicting the indirect relationship between PA and mental health during the COVID-19 lockdown period. This finding is consistent with that of Lewis et al., who found that individuals with high levels of PA reported fewer symptoms of insomnia, which in turn was associated with fewer symptoms of depression and anxiety (Lewis et al., 2021). However, they also found that this indirect relationship did not exist before lockdown. This result may be explained by the negative psychological effects of lockdown, and the absence of various outlets for stress (Brooks et al., 2020). Furthermore, it is worth noting that this indirect relationship is only present in students with more than two and three roommates. This is consistent with our hypothesis and is likely due to the overcrowding of available space per student, highlighting the positive effects of PA on mental health. Even though

the size of the indirect effect was moderate, despite worse sleep quality, students may experience a further improvement in mental wellness if they are more physically-active. Therefore, students who are isolated in university dormitories such as indoor high-density living environments during COVID-19 lockdown should keep physically active and keep good sleep habits to reduce the risk of insomnia and mental disorders.

Limitations and strengths of the study

The main limitation of the present study was not able to determine causal relationships from the cross-sectional design. Second, the participants need to recall their daily activity and sleep habits before the lockdown, and this study could not observe the actual volume of daily activity and sleep habits using objective markers. Third, our participants were from the same university which may be not representative of the entire Chinese university student population. Besides, reported subjective information such as height and weight may be prone to recall bias. Further study may use wearable devices to obtain accurate behavioral and mental health data when conditions permit. Despite above mentioned limitations, this study has several strengths. To the best of our knowledge, this is the first study to investigate the PA, sleep and mental health of Chinese university students after nearly 1-month of dormitory isolation during COVID-19. The present study extends the previous results on PA, sleep, and psychological conditions and better explains the impact of strict quarantine on dormitory-resident university students. The findings may also provide a timely and helpful report on the challenge of lifestyle change and psychological disturbances to relevant university and student bodies. Moreover, this study explored the number of roommates that might evoke various experiences and conditions during the lockdown.

Conclusion

This study showed that strict lockdown during the COVID-19 pandemic caused a significant decrease in physical activity and altered daily routines such as sleep, which had a negative impact on the health behavior among university students living in dormitories. Even with limited space, engaging in PA was associated with better sleep and mental health. Sleep disorder mediated the relationship between PA and mental health when the number of students in the dormitory was three and four. These results may provide useful suggestions for relevant authorities, for example to adjust the student dormitory occupancy to one or two students sharing a room, and to take steps to encourage students to exercise in a limited space.

Practical implications

The reported reduction in participation time for all levels of PA might affect students' well-being. Therefore, the universities should continue cooperation among units to embed health and physical literacy in fostering students' knowledge and skills to maintain an active lifestyle during pandemics or other public health emergencies. The findings indicated that the living environment might affect students' health during confinement, and nonetheless suggest universities and stakeholders relocate residents and adopt to single or twin rooms in the early stage of lockdown and suggest offering students more space with adequate privacy where is possible. Moreover, providing timely access to psychological counseling and advice for female students may minimize the adverse effects on their health and wellness. Furthermore, identify the early sign of distress and give appropriate services to safeguard university students' holistic health during a public health crisis.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Shanghai Jiao Tong University. Written informed consent was obtained from all participants for their participation in this study.

Author contributions

SC, XW, and BZ developed the idea of the manuscript. BZ, SML, SC, and XW drafted the paper plan and conducted manuscript preparation, review, and revision. QG and SL participated in data collection and reviewed the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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The effect of exercise on academic fatigue and sleep quality among university students

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Background: Routine academic events may cause fatigue and impair sleep quality. This research aimed to examine the prevalence and risk factors for academic fatigue among college students and its adverse effects on well-being and sleep. A brief exercise intervention was also evaluated.

Methods: A total of 864 college students (33.5% female) filled out self-reported questionnaires with few open-ended questions. Fatigue and sleep quality were assessed using the translated version of the Smith Well-being Questionnaire and the Chinese version of the Pittsburgh Sleep Quality Index (PSQI). Spearman correlations, logistic regression analysis, and *t*-tests were used to test the hypotheses. In a second study, 29 female participants took part in an exercise intervention aimed at reducing fatigue and improving sleep.

Results: Among the effective respondents, nearly 40% reported higher academic-related fatigue, and a few reported high-quality sleep. Negative coping styles, workload, stress, and disturbed surroundings had a significant positive predictive effect on academic fatigue. In addition, adverse consequences of fatigue were found for physical health and academic-life balance, and a significant, positive relationship was observed between the degree of fatigue and PSQI score ($p<0.01$). The exercise study showed some beneficial effects of the intervention for both sleep and fatigue outcomes.

Conclusion: Fatigue is common and widely reported among Chinese college students, and it may have a major negative impact on their health. Increased awareness of daily academic fatigue and its impact on college students is important for individuals, schools, and society. Exercise may be a simple way to improve sleep and reduce fatigue.

KEYWORDS

stress, academic fatigue, sleep quality, college students' health, exercise

Introduction

Fatigue is a psychophysiological state of decreased ability and effectiveness (Simonson and Weiser, 1976; Phillips, 2015) that typically occurs during highly demanding tasks requiring long periods of mental and physical input (van der Linden et al., 2003; Dolezal et al., 2017), and it may have a great impact on the individual's performance and well-being, including sleep-disturbance (Rodrigue et al., 2010; Hockey, 2013; Weaver and Barger, 2019). The existing research on fatigue and sleep issues has primarily focused on the workplaces that are known to cause fatigue (e.g., road transport, healthcare, aviation, etc. see Dawson et al., 2021 for a review). Academic responsibilities during college provide numerous challenges and lead to fatigue becoming an everyday occurrence for many students. A typical workplace may cause fatigue (Salmela-Aro et al., 2008). However, the academic environment may be an often-overlooked part of the picture. In the present study, we were interested in a more detailed profile of academic-related fatigue among college students and its causes and effects.

With the increasingly intense competition for employment, many college students are under greater academic pressure to achieve outstanding performance at school. Particularly in East Asia, there is a strong culture in which academic achievements stand for social acceptance and status (Huang and Chou, 2010; Park et al., 2021). To make themselves more employable, students invest a lot of time in their studies. It's no wonder then that they suffer from academic fatigue due to enduring hours of lessons, examinations, competition, and schoolwork with their heads buried in textbooks (Archer and Lamnin, 1985; McDonald, 2001; Hughes, 2004, 2005; Likhon, 2021). The demands-resources-individual effects (DRIVE) model is one model in the field of occupational fatigue research used to analyze the key elements of the stress process (Mark, 2008). It has provided valuable insight into the factors that contribute to increased fatigue, including (1) work demands (e.g., workload, extrinsic effort), (2) job characteristics (e.g., social support, rewards), and (3) individual differences (e.g., personality trait, lifestyle; Ranjan and Prasad, 2017). College students need to attend regular and structured classes and complete their assignments every day, which is comparable with the work of formal employees. That is, students' main activities at school can be considered a form of work, so daily academic fatigue occurs due to coping with academic stress accrued from routine experiences (Schaufeli et al., 2002; Salmela-Aro et al., 2009). However, there is scanty research reporting academic-related fatigue and its associated factors. For this reason, the current study aims to estimate the prevalence of fatigue and identify risk factors among university students in China using the DRIVE model as a framework.

Health problems of young people have always been a concern. Fatigue is often accompanied by a lack of physical and mental strength and a decline in motivation (Boksem et al., 2006), which could hinder the healthy growth of young people. The DRIVE model attempted to account for the associations between subjective fatigue perceptions and health outcomes and demonstrated that central adverse effects of fatigue are related to poor health conditions, illness, lack of work-life balance, and impaired performance (Mark and Smith, 2008; Smith, 2021).

However, an overlooked negative outcome of stress is decreased sleep quality. Daily academic fatigue inevitably has repercussions on college students' sleep. It has been shown that people are particularly susceptible to inadequate sleep and report significant impairments in sleep quantity and quality under higher daily stress (Pilcher et al., 1997; Lund et al., 2010; Becker et al., 2018). With an increase in daytime pressure, individuals are more likely to feel tired, and this, in turn, causes difficulties in falling asleep, maintaining sleep, and ensuring sleep quality (Yang et al., 2014; Wang and Bíro, 2021). Several studies on college students have linked academic stress to shorter sleep times during exam periods (e.g., Harsh et al., 2007; Zhang et al., 2017; Campbell et al., 2018). Poor sleep can lead to subsequent fatigue. These studies all corroborate that college students are at risk for poor sleep during exam periods. Nevertheless, few studies target fatigue in the daily life of college students and test its impact directly on sleep quality. Accordingly, the secondary aim of this study was to investigate the relationship between daily academic fatigue and sleep quality in college students.

Fatigue impairs young people's attention, leading to slowed thinking and poor perception (Boksem et al., 2005), and lack of sleep impairs adolescents' academic ability, social–emotional and behavioral functioning, and academic performance (Castilhos Beauvalet et al., 2017; Elfering et al., 2020), adversely affecting college students' learning efficiency and academic outcomes. These negative consequences have prompted researchers to explore effective interventions to reduce the effects of fatigue and improve sleep quality in young people.

Exercise as a non-pharmacological means has low cost, low side effects, and convenience. Numerous studies have shown that exercise interventions can effectively reduce students' fatigue and improve individual sleep quality (Erlacher et al., 2015; Brand et al., 2014; Kredlow et al., 2015; Lang et al., 2016; Ezati et al., 2020). Psychological and physiological mechanisms may explain the effect of exercise on academic fatigue. Students may reduce fatigue by exercising in a way that creates "psychological separation" (Otto and Smits, 2011; Sonnentag, 2012). Exercise allows students to temporarily divert their attention while enhancing their physical fitness and engaging in learning in a more relaxed way. People who exercise regularly also have less stress, anxiety, and depression (Driver and Taylor, 2000). In addition, it has long been shown that people who exercise regularly have fewer self-reported sleep problems and are less likely to be sleepy during the day than sedentary people (Dolezal et al., 2017). Exercise has a moderate to a large positive effect on all subscales of the Pittsburgh sleep quality index (PSQI). Also, long-term exercise increases total sleep time and sleep efficiency to some extent and has a small to moderate effect on sleep latency (SOL) (Kredlow et al., 2015).

Research on academic fatigue and sleep in young adults or college students is still scarce, with most studies focusing on sick

populations, and there is still some uncertainty about the effect of exercise on sleep. Some researchers have been skeptical about the role of exercise in affecting sleep, the study found that exercise appeared to have little effect on improving sleep, and suggesting that the positive effects of exercise have been exaggerated (Coleman et al., 2012). In a review of exercise and sleep, it was stated that four researchers did not find any difference in sleep from exercise, and one study even claimed that exercise had a negative effect on sleep (Dolezal et al., 2017). Furthermore, sedentary behavior and physical activity were not necessarily associated with sleep quality in all populations. The researchers noted that the relationship between physical activity and self-reported sleep duration was dependent on age and gender (McClain et al., 2014). Differences in the exercise regimens studied (e.g., aerobic or anaerobic, intensity, duration) and interactions between individual characteristics (e.g., health, age, and gender) make the experimental evidence for a sleep-enhancing effect of exercise less supportive. However, at the same time, some researchers have commented that, regardless of the pattern and intensity of activity, exercise improves sleep efficiency and duration, especially in people with medical conditions (Dolezal et al., 2017).

Gender differences also need to be taken into account when studying academic stress and sleep problems. A study showed that women, but not men, experienced a significant reduction in fatigue after a 6-month exercise intervention (Surakka et al., 2004). The results from a survey showed that the average score of females' perception of academic stress is higher than that of men (Calaguas, 2011). Meanwhile, studies have found that women have a higher prevalence of poor sleep quality than men (Dolezal et al., 2017; Bani-issa et al., 2018), and another study has shown that female college students went to bed and woke up early, had a long sleep latency, woke up more often, and had poor sleep quality than males (Tsai and Li, 2004). All these show that female college students are more typical poor sleepers. It is important to conduct research on academic stress and sleep for the female college student population. Therefore, the third aim of this study was to find out whether different forms and intensities of exercise can have a positive effect on academic fatigue and sleep in female college students. In addition, most studies on exercise interventions for fatigue and sleep have been longer than 8 weeks, and we wanted to investigate whether a short-term intervention (e.g., 1 week) could also change academic-related fatigue and sleep in college students.

Routine academic events may cause fatigue in college students. However, there are very few studies that have systematically evaluated the prevalence and predictors of such fatigue. Also, the associations of sleep problems with the various aspects of fatigue in college students remain unclear. There is also the question of whether exercise is an effective tool to help female university students improve their daily academic fatigue and sleep quality. The present study sought to investigate (a) whether college students exhibit academic-related fatigue, (b) the contribution of academic events to the explanation of academic fatigue by individual differences, school resources, social support, as well as workload, and (c) the interaction between fatigue, health, and sleep problems in young adults in China, and (d) The extent to which exercise reduces academic fatigue and improves sleep among female university students.

Two studies were carried out to address these questions. Study 1 was a survey of a sample of college students. Previous studies have revealed that academic pressure is one of the most influential factors in college students' daily lives (El Ansari et al., 2014) but have not reported clear causes and results of this impact. Thus, we used the DRIVE model as the research framework and conducted our assessment using a multi-dimension questionnaire, which is suitable for the investigation of the causes and results of workload and fatigue. Specifically, it was hypothesized that (1) the fatigue experienced among college students would be significantly associated with academic events, individual differences (i.e., personality, self-efficacy, coping style, and lifestyle), school resources (i.e., studying environment), and social support, and academic workload. Regarding the negative outcomes of academic fatigue, it was hypothesized that (2) academic-related fatigue is not only associated with negative mental well-being and physical illness but also with sleep problems. In terms of gender differences, consistent with previous studies, it was hypothesized that (3) female university students would have higher levels of academic fatigue and lower quality sleep compared to males.

In study 2, female university students with high levels of fatigue and poor sleep quality were selected from responses to the survey given in study 1 and given a 6-day short-term exercise intervention in which they were asked to perform a total of 30 min of moderate intensity, any type of physical activity each day. In addition, sleep-related indicators were measured by actigraphy over the six-day period, and changes in the participants' perceptions of academic fatigue before and after the exercise intervention were measured by an online questionnaire. It was hypothesized that: Short-term exercise would be effective in decreasing fatigue and improving sleep efficiency and quality of sleep in a typical group of female university students with academic fatigue and sleep problems.

Study 1

To investigate the risk factors for academic stress and its correlation with fatigue among college students, as well as the correlation between the consequence of academic fatigue and sleep, we used the SWELL Questionnaire (Smith Wellbeing Questionnaire), the Pittsburgh Sleep Quality Index (Buysse et al., 1989) and academic-related questions were combined and developed into an online questionnaire that was widely distributed to college students. At the same time, this study wanted to compare the findings of previous studies that used male college students, female college students have significantly higher levels of academic anxiety (Calaguas, 2011) and lower sleep quality (Bani-issa et al., 2018) also hold in this study. The questionnaires

collected were also used to screen a group of female college students who met the requirements for the subsequent exercise intervention experiment.

Methods

Participants

We used G*Power to calculate the sample size, effect size $f = 0.3$, $\alpha = 0.05$, $1\text{-}\beta = 0.8$, and calculated the required sample size to be 82. Based on the calculated subject size, 846 students from Shenzhen University were recruited as participants in order to improve the scientific validity of the study findings. The participants were aged between 18 and 28 years recruited using posters on campus and an online forum. All were enrolled in the survey on a voluntary basis, with the option of withdrawing at any point without any disadvantages. After excluding respondents who answered too quickly or too slowly, response rest, and random or regular answers, a total of 756 college students (32.5% female, $M_{age} = 20.55$ years, $SD = 1.35$ years) were included in the full analysis.

Task and procedure

The design of this study was reviewed and approved by the Research Ethics Committee of the School of Psychology, Shenzhen University. Before data collection, each participant read and approved the online informed consent statement. During the testing sessions, participants filled out a series of online self-reported questionnaires consisting of (1) respondents' demographic characteristics (e.g., gender, age, and grades) and recent academic assignments, (2) self-statements about the cause and outcomes of daily academic fatigue, and (3) self-reported measures of sleep quality. The survey took between 15 and 20 min to complete. There was no monetary compensation for participation in the study, but those who accomplished the task entered a lucky draw, which gave them a chance to win campus postcards, sleeping masks, or other gifts.

Measurements

Smith well-being questionnaire

Students' academic fatigue was assessed using the Smith Well-being Questionnaire (SWELL; Smith and Smith, 2017), which was established based on the DRIVE model for a comprehensive range of outcomes related to health and performance efficiency. This is a single-item scale, the items of SWELL are based on the single-item design of the Well-being Process Questionnaire (WPQ), and previous researchers have compared single-item and multiple items (WPQ) and have confirmed the validity and reliability of this single-item measure of well-being (Williams and Smith, 2016). In addition, previous studies have modified the questionnaire for use with students and found that it is suitable for the assessment of students' fatigue (Alharbi and Smith, 2019; Nor and Smith, 2019). The participants were asked to respond to 37 self-report items, within the last 3 months, most of which were on a 10-point scale, with the rest as yes/no questions.

The self-statements consisted of two blocks: the predictors and the outcomes of academic fatigue. Questions for the predictors block measured the factors that led to fatigue, including academic characteristics (e.g., "Overall, how stressful is your academic life?"), individual differences (e.g., "To what extent do you try to positively cope with stress, such as trying to solve problems or seeking social support?"), social support (e.g., "I feel that I have the social support I need."), and the learning environment (e.g., "Are you exposed to noise in your learning environment?"). Questions for the results block measured well-being outcomes included physical health (e.g., "Do you suffer from musculoskeletal disorders such as back pain or headaches?"), positive well-being (e.g., "To what extent do you have positive feelings at work, such as feel happiness, excitement, relaxation, and sociability?"), academic-life balance (e.g., "Do you find that your work interferes with other aspects of your life?"), and academic performance, including academic efficacy and academic satisfaction (e.g., "How efficiently do you learn?"). The variables mentioned in the results of the follow-up study were measured using the SWELL questionnaire.

Both forward and reverse translations were used to translate this survey into Chinese. The forward translation of SWELL from English to Chinese was carried out by two researchers who were fluent in both languages. The backward translation was then carried out by an impartial translator who was unaware of the assessment. Before making any last-minute changes to the questionnaire, the original English and the reverse translated English versions were compared and any differences were reviewed.

Pittsburgh sleep quality index

Sleep during the past month was assessed using the PSQI, one of the most commonly used tools for sleep quality assessment (Buysse et al., 1989). The PSQI is a self-rated questionnaire that enables to assess of overall sleep quality with 19 items generating seven components: (1) subjective sleep quality, (2) sleep latency, (3) sleep duration, (4) habitual sleep efficiency, (5) sleep disturbances, (6) use of sleeping medication, and (7) daytime dysfunction. Sleep duration was recorded as hours: minutes, and sleep latency was measured in minutes. Each component was coded and scored from 0 to 3 and then summed into a global PSQI score, with higher scores indicating poorer sleep quality. Cronbach's α was 0.83 when it was developed (Buysse et al., 1989) and 0.88 in this study.

Statistical analysis

Data analysis was performed using IBM SPSS for Mac, version 25. Descriptive statistics were first calculated to examine the frequency of responses, and a series of bivariate correlations among the variables were examined using Pearson correlation tests. Next, hierarchical multiple analysis was performed to uncover which factors predicted academic fatigue. The variables

were dichotomized into two broad and distinct groups of groups (usually by using the thresholds, e.g., above thresholds for a high group), and an independent *t*-test was conducted to assess whether well-being outcomes and academic performance were associated with academic fatigue. Finally, the association between academic fatigue and sleep quality was assessed. Correlation analysis and independent *t*-tests were conducted to assess the sleep quality (according to the self-report questions on PSQI) according to those with high and low levels of academic fatigue (based on the single item score of SWELL questionnaires).

Results

Descriptive statistics

Among the effective respondents, there were 510 men and 246 women, and most participants were in their first year (65.7%). Two-thirds of participants scored themselves as having negative personalities (63.4%), and about half thought they had unhealthy lifestyles (53.3%). The mean fatigue score was in the mid-range (4.98 ± 2.45), and 41% of students reported high fatigue (above the median). Higher fatigue levels were reported by participants in response to challenges, such as applications for studying abroad (66.7%), taking part in the postgraduate entrance exams (64.6%), and preparing for graduation theses (55.9%) when applying median split to fatigue. The mean sleep duration of the participants was 6. 85 ± 0.95 h, and the average PSQI global score was 6.93 ± 3.17, with the minority of respondents having a good sleep (34.8%).

Risk factors for academic-related fatigue

Bivariate correlations between the observed variables are presented in Table 1. The pattern of associations between the main study variables was generally in line with expected. Fatigue was significantly and positively related to a negative coping style, psychological detachment, negative emotion, workload, stress, physical health, and academic-life balance. Academic-related fatigue was significantly and negatively associated with lifestyles, positive well-being, and academic satisfaction.

The predictors of academic fatigue were then examined by carrying out a hierarchical multiple regression analysis. According to the variance inflation factor and tolerance statistics, there was no multi-collinearity among the independent variables in any regression models. Results are summarized in Table 2. In step 1 of the analysis, individual differences accounted for 11.5% of the variance in academic-related fatigue ($R^2 = 0.115$, $p < 0.001$), with the coping style, psychological detachment, emotion, and lifestyle as predictors ($p < 0.001$). The inclusion of academic characteristics in step 2 accounted for an additional 20.8% of the variance in academic fatigue (R^2 change = 0.208, $p < 0.001$), with the workload and stress ($p < 0.001$) as the significant predictors. In the last two steps of the analysis, the learning environment accounted for an additional 3.6% of the variance in academic fatigue (R^2 change = 0.036, $p < 0.001$), with the disturbed or noisy surroundings as a significant predictor ($\beta = 0.199$, $p < 0.001$). It should be noted that individual differences, including coping style and lifestyle, as well as academic characteristics, presented as the most common significant predictors of fatigue in each step of the analysis.

Adverse outcomes associated with fatigue

To understand the adverse consequences of various fatigue among college students, thresholds were used to dichotomize the variables into low and high fatigue groups, and an independent *t*-test was conducted. Results (see Table 3) showed that fatigue may have more negative effects on students' physical health but no significant effect on well-being or academic performance. More specifically, students with higher academic fatigue reported poor physical health ($t = -16.08$, $p < 0.001$), and lack of academic-life balance ($t = -11.04$, $p < 0.001$) than those with low academic fatigue.

The relationships between fatigue and sleep quality

Table 4 presents the means, standard deviations, and bivariate correlation analyses of fatigue and various aspects of sleep scores. As expected, fatigue was significantly and positively related to self-reported sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, daytime dysfunction, and global PSQI scores. There was no significant association between fatigue and the use of sleeping medication.

To assess associations between fatigue shaped and sleep quality among college students, an independent *t*-test was also conducted, and the results showed a significant difference between groups. Compared to those with lower fatigue, students with higher academic fatigue reported poor sleep quality ($t = -5.60$, $p < 0.001$) and sleep latency ($t = -5.31$, $p < 0.001$), shorter sleep duration ($t = -4.05$, $p < 0.001$), more sleep disturbances ($t = -5.47$, $p < 0.001$), and more severe daytime dysfunction ($t = -7.22$, $p < 0.001$). Higher fatigue indicated a high full PSQI score ($t = -7.52$, $p < 0.001$) as well, indicating a worse sleep quality they lead. However, neither sleep efficiency nor the use of sleeping medications was found to make a significant difference ($p > 0.05$).

Gender differences in sleep quality and fatigue among college students

To understand the difference in sleep quality between male and female college students, an independent samples *t*-test was conducted, and the results (Table 5) showed that there was a significant difference between the sleep quality of male and female college students, specifically, the sleep quality of female college students was significantly worse than that of male college students ($t = -4.987$, $p < 0.001$).

Table 6 presents the differences in academic fatigue feelings between male and female college students, and the results show that there are significant differences between male and female

TABLE 1 Bivariate correlations between observed variables.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Fatigue	1																
2. Positive personality	−0.063	1															
3. Positive coping style	0.002	0.553**	1														
4. Negative coping style	0.297**	−0.165**	−0.160**	1													
5. Self-efficacy	−0.057	0.708**	0.603**	−0.112**	1												
6. Psychological detachment	0.204**	0.250**	0.361**	0.021	0.298**	1											
7. Lifestyle	−0.141**	0.425**	0.369**	−0.080*	0.389**	0.201**	1										
8. Negative emotion	0.334**	−0.074*	0.03	0.370**	−0.089*	0.118**	−0.103**	1									
9. Workload	0.496**	0.037	0.058	0.249**	0.026	0.280**	−0.039	0.258**	1								
10. Stress	0.594**	−0.105**	−0.018	0.261**	−0.170**	0.209**	−0.092*	0.374**	0.479**	1							
11. Social support	0.06	−0.185**	−0.189**	0.099**	−0.212**	−0.162**	−0.162**	0.071	0.085*	0.111**	1						
12. Environments	0.362**	0.003	−0.04	0.222**	−0.003	0.116**	−0.095**	0.129**	0.256**	0.263**	0.048	1					
13. Physical health	0.627**	−0.092*	−0.011	0.308**	−0.108**	0.164**	−0.176**	0.299**	0.438**	0.397**	0.087*	0.401**	1				
14. Positive well-being	−0.100**	0.720**	0.601**	−0.164**	0.765**	0.280**	0.462**	−0.06	0.024	−0.139**	−0.185**	−0.042	−0.149**	1			
15. Academic-life balance	0.489**	−0.204**	−0.191**	0.462**	−0.249**	0.106**	−0.214**	0.415**	0.391**	0.463**	0.089*	0.324**	0.512**	−0.259**	1		
16. Academic efficacy	0.041	0.508**	0.566**	−0.087*	0.680**	0.388**	0.337**	−0.019	0.128**	−0.081*	−0.134**	0.017	0.012	0.588**	−0.175**	1	
17. Academic satisfaction	−0.092*	0.439**	0.473**	−0.029	0.611**	0.178**	0.237**	−0.032	−0.033	−0.214**	−0.134**	−0.016	−0.098**	0.566**	−0.201**	0.589**	1

Two-tailed testing of significance, $N = 756$, *$p < 0.05$; **$p < 0.01$.

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TABLE 2 Hierarchical multiple regression analysis for risk factors of academic-related fatigue.

	β			
	Step 1	**Step 2**	**Step 3**	**Step 4**
Individual difference				
Coping style	0.130***	0.081*	0.082*	0.074*
Self-efficacy	−0.06	−0.032	−0.034	−0.028
Psychological detachment	0.165***	0.045	0.043	0.043
Emotion	0.167***	0.043	0.042	0.044
Lifestyle	−0.151***	−0.131*	−0.131***	−0.094**
Academic characteristics				
Workload	–	0.232***	0.232***	0.198***
Stress	–	0.364***	0.365***	0.359***
Academic source				
Social support	–	–	−0.012	−0.015
Learning environment				
Noise and fumes	–	–	–	0.199***
R^2	0.115	0.323	0.323	0.359
F	19.54***	51.00***	44.59***	46.52***

β, standardized coefficient; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 3 Individual health outcomes under the different levels of academic fatigue.

	Low fatigue		**High fatigue**		***t***
	M	***SD***	***M***	***SD***	
Physical health	3.28	2.11	5.83	2.19	−16.08***
Well-being	6.52	1.76	6.35	1.66	1.32
Academic-life balance	3.78	2.36	5.70	2.324	−11.04***
Academic efficacy	5.58	1.66	5.78	1.80	−1.58
Academic satisfaction	5.25	2.21	4.98	2.30	1.61

***$p < 0.001$.

college students' fatigue feelings, with female college students' fatigue feelings being significantly higher than those of male college students.

Summary

Study 1 was conducted to evaluate the prevalence, risk factors, and adverse outcomes associated with fatigue among Chinese college students. It established the existence of academic fatigue among college students, uncovered the possible influencing factors, and provided some preliminary evidence for the association between academic fatigue and poor sleep quality. Our study revealed that academic fatigue is common and that individual differences, including coping styles and lifestyle, as well as academic characteristics, were found to be significant factors associated with such fatigue. Given that fatigue in college students is closely related to poor physical health, lack of academic-life balance, and poor sleep quality, it is suggested that the aforementioned risk factors require close attention when developing a preventive intervention.

In line with previous studies (Tsai and Li, 2004; Calaguas, 2011; Bani-issa et al., 2018), there were gender differences in academic fatigue and sleep quality among college students in this study, with female college students experiencing higher levels of academic fatigue and poorer sleep quality than males. In the online questionnaire, 57.86% of female college students reported high academic stress compared to 37.81% of male college students; nearly a quarter of female college students reported "poor" (20.07%) or "very poor" (3.34%) sleep quality. The average sleep efficiency of female college students who participated in the exercise intervention was about 80% on the starting day, but according to Hirshkowitz et al. (2015) and Ohayon et al. (2017), healthy individuals should achieve more than 85% sleep efficiency per night. All these phenomena indicate that the academic fatigue status and sleep problems in the female college population cannot be ignored. This provides the basis for our follow-up intervention study.

Study 2

We know from previous studies that females are usually higher than males in terms of fatigue and stress perception (Calaguas, 2011). Also, the quality of sleep is worse in female students compared to male students (Tsai and Li, 2004; Regestein et al., 2010). In addition, based on the results of Study 1, we also found differences in perceived academic fatigue and sleep quality between male and female college students in this study. Specifically, female college students had higher fatigue perceptions than males and poorer sleep quality than males. Thus, on the one hand, we believe that selecting female college students as subjects for the intervention is more effective in showing where the effects of short-term exercise interventions lie, and on the other hand, there have been few studies of exercise interventions for fatigue or sleep that specifically focus on females, and we believe that such a study would provide a more targeted perspective. In summary, we conducted a follow-up intervention study focusing on college women based on the results of Study 1.

In Study 2, participants were taking a short-term exercise intervention for 6 days, and they performed 30 min of physical activity every day with moderate intensity. This study measured the sleep-related indicators using actigraphy and measured the change in the student's perception of academic fatigue before and after the exercise intervention by using an online diary. The main aim of this study was to investigate whether a short-term exercise intervention affected academic fatigue and sleep problems in a typical academic fatigue group of female college students.

TABLE 4 Means, standard deviations, and correlation coefficient matrix for each variable.

	1	2	3	4	5	6	7	8	9
1. Fatigue	1								
2. Subjective sleep quality	0.258**	1							
3. Sleep latency	0.245**	0.445**	1						
4. Sleep duration	0.178**	0.275**	0.161**	1					
5. Sleep efficiency	0.107**	0.171**	0.168**	0.522**	1				
6. Sleep disturbances	0.253**	0.476**	0.415**	0.196**	0.160**	1			
7. Use of sleeping medication	0.066	0.184**	0.129**	0.054	0.003	0.228**	1		
8. Daytime dysfunction	0.323**	0.470**	0.367**	0.243**	0.108**	0.456**	0.139**	1	
9. Overall PSQI score	0.354**	0.718**	0.680**	0.560**	0.498**	0.685**	0.292**	0.725**	1
M	4.98	1.93	0.87	0.41	0.35	0.88	1.06	1.42	6.93
SD	2.45	0.69	0.92	0.64	0.75	0.66	0.35	1.06	3.17

PSQI, Pittsburgh sleep quality index; $^{**}p < 0.01$.

TABLE 5 *T*-test of sleep quality among male and female college students.

	Male		Female		
	M	*SD*	*M*	*SD*	*t*
Sleep quality	1.84	0.679	2.09	0.713	−4.987***

$^{***}p < 0.001$.

TABLE 6 *T*-test of academic fatigue among male and female college students.

	Male		Female		
	M	*SD*	*M*	*SD*	*t*
Academic fatigue	4.68	2.424	5.58	2.373	−6.628***

$^{***}p < 0.001$.

Methods

Participants

We used G*Power to calculate the sample size, effect size $f = 0.25$, $\alpha = 0.05$, $1\text{-}\beta = 0.8$, and calculated the required sample size to be 33. Based on the calculated subject size, 36 female participants were recruited for this study. All of them were (1) female students from the universities in Shenzhen, China, (2) with no previous exercise habits, (3) self-reported academic fatigue as high (7–10 points) in SWELL, and (4) self-reported sleep problems in the Pittsburgh Sleep Questionnaire. During the experiment period, participants were strictly requested to avoid the use of tobacco, alcohol, caffeine and sleep-aiding drugs (sleeping pills, melatonin) to reduce the influence of those factors on the sleep results. Twenty-nine participants completed the experiment, including 21 participants in the exercise intervention group and 8 in the control group.

Sleep measurement

The present study used both subjective and objective measurements of sleep. The subjective measurement used was a sleep diary, while the objective measurement used was Actigraphy (Actigraph wgt3x-bt, United States). The sleep diary, including pre-diary and post-diary, mainly recorded the time they went to bed, subjective feelings about sleep quality, and fatigue before and after sleep.

Actigraphy is a non-invasive tool for monitoring human rest/activity cycles, which can be worn on the wrist. It allows data to be collected over several days in a non-laboratory dynamic environment to examine how sleep changes over time in daily life. Previous studies showed that actigraphy is a valid and reliable method of sleep assessment (Ancoli-Israel, 2003) and has become an accepted tool in sleep research (Sadeh, 2008). The main sleep parameters actigraphy measured in the present study were the total sleep time, sleep efficiency, and length of sleep. The actigraphy algorithm used in this experiment was the Sadeh algorithm (Ancoli-Israel et al., 2003) for young and middle-aged people, as the participants in this study were young college students.

Procedure

After discussing the research objectives and informed consent, participants in the experimental and control groups gave self-reports of academic fatigue and related health indicators. Participants' height, weight, handedness, race, and wearing position were entered into each individual's actigraphy at the beginning of the experiment to ensure accurate and individualized sleep measurements.

A randomized controlled design was used for the experiment. For the exercise intervention group for 6 days (from Sunday of the previous week to Friday of the following week), they were required to perform 30 min of moderate intensity, any type, frequency of physical activity during the day. They were also asked to upload a

screenshot of their exercise time and the exercise program recorded in the mobile app in the "Exercise check-in" group chat by 24:00 each day. The control group was told not to exercise during the day. All participants were asked to wear actigraphy each night before going to bed and to take it off when they woke up the next day. At the end of the experiment, all participants returned the actigraphy and again performed a self-report of academic fatigue and related health indicators. A final data check, data entry and actigraphy initialization were performed for that round.

Statistical analysis

This study mainly used IBM SPSS for Windows, version 25. to analyze the data of the Academic Fatigue Perception Questionnaire and Actigraphy data before and after the experiment. A repeated measures analysis of variance (ANOVA) was used to determine whether the sleep status of female college students improved with the increase of the intervention time during the exercise intervention cycle. Also, to find out whether there were significant differences in academic fatigue perception, academic concentration, and changes in fatigue-induced health indicators (dizziness and headache, back pain) before and after exercise in the exercise intervention group of female college students. Finally, the independent samples *t*-test was used to analyze whether there was a significant difference in the degree of academic fatigue perception between female college students in the exercise intervention group and the control group.

Results

Actigraphy data analysis

As shown by the between-group effect, $F = 34.166$, $p < 0.001$ in Table 7, there was a significant difference between the exercise intervention group and the control group in the length of time spent asleep. The within-group effect, $F = 12.444$, $p < 0.001$, indicated that there was a significant difference in the length of sleep measured at different times. The interaction effect, $F = 15.9$, $p < 0.001$, shows that there was a significant interaction between exercise intervention and time on the length of time spent asleep.

The mean values of total sleep duration for the exercise intervention and control groups within each intervention day are shown in Figure 1. The overall mean value of the length of sleep in the exercise intervention group decreased gradually over the duration of the intervention, while there was no significant change in the control group. There was a significant difference in the length of time to fall asleep between female university students who had the exercise intervention and those who did not have any intervention, with students who had the exercise intervention falling asleep for a shorter period compared to those who did not have any intervention, and the length of time to fall asleep for female university students tended to decrease as the duration of the intervention increased in the exercise intervention condition.

TABLE 7 Repeated measures analysis of variance for the length of sleep.

		MS	*df*	*F*	*p*
Between-group effects	Group	49000.938	1	34.166	0.000***
Within-group effects	Time	4250.221	3.315	12.444	0.000***
Interaction effects	Group* Time	5430.571	3.315	15.9	0.000***

MS, mean square; ***$p < 0.001$.

As shown in Table 8, on the between-group effect, $F = 6.121$, $p < 0.05$, there was a significant difference between the exercise intervention group and the control group for total sleep duration. For the within-group effect, $F = 4.651$, $p < 0.05$, there was a significant difference in total sleep duration measured at different times. On the interaction effect, $F = 1.244$, $p > 0.05$, it can be seen that there was no significant interaction effect between exercise intervention and time for total sleep duration.

The mean values of total sleep duration for the exercise intervention group and the control group within each intervention day are shown in Figure 2. The overall mean value of total sleep duration for the exercise intervention group gradually increased over time, while the control group showed fluctuations, with a small overall mean increase compared to the first day. There was a significant difference in total sleep duration between female university students who underwent the exercise intervention and those who did not undergo any intervention, with longer total sleep duration for the exercise intervention compared to those who did not undergo any intervention and an increasing trend in total sleep duration for those who underwent the exercise intervention as the duration of the intervention increased.

As shown in Table 9, for the between-group effect, $F = 24.796$, $p < 0.001$, it can be seen that there was a significant difference between the exercise intervention group and the control group for sleep efficiency. The within-group effect, $F = 3.218$, $p < 0.05$, shows a significant difference in sleep efficiency measured at different times. The interaction effect, $F = 11.971$, $p < 0.001$, between the exercise intervention and time, was significant for sleep efficiency.

The mean values for sleep efficiency for the exercise intervention group and the control group within each intervention day are shown in Figure 3. The overall mean value of sleep efficiency for the exercise intervention group gradually increased with the duration of the intervention, while the control group showed fluctuations and a certain decrease compared to the overall mean value on the first day. There was a significant difference in sleep efficiency between the female university students who had the exercise intervention and those who did not have any intervention, with higher sleep efficiency in the exercise intervention compared to those who did not have any intervention and an increasing trend of greater improvement in sleep efficiency in the exercise intervention condition as the duration of the intervention increased.

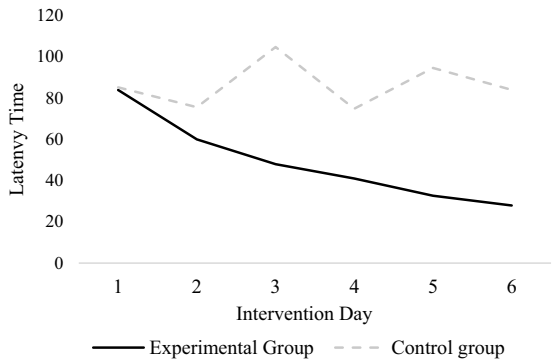

FIGURE 1
Comparison of the overall mean of the length of sleep in the experimental and control group.

TABLE 8 Repeated measures analysis of variance for total sleep time.

		MS	*df*	*F*	*p*
Between-group effects	Group	25475.148	1	6.121	0.02*
Within-group effects	Time	11210.765	3.652	4.651	0.002**
Interaction effects	Group* Time	2997.358	3.652	1.244	0.298

MS, mean square; *$p < 0.05$, **$p < 0.01$.

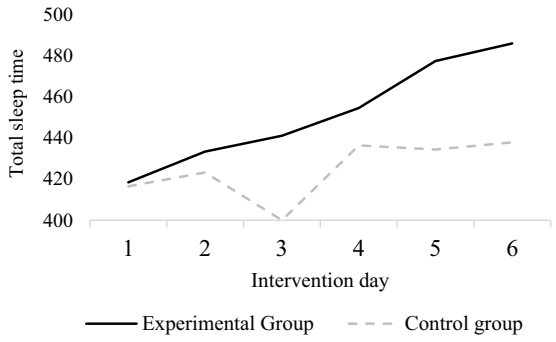

FIGURE 2
Comparison of the overall mean of total sleep time in the experimental and control groups.

Academic fatigue before and after the intervention

As shown in Table 10, the repeated measures ANOVA showed that there was a significant difference in the perception of academic fatigue before and after the experiment, $F = 40.888$, $p < 0.001$. There was also a significant difference in the dizziness and headache variable, $F = 38.979$, $p < 0.001$, and the back pain rating ($F = 26.385$, $p < 0.001$). In contrast, there was no significant difference in academic concentration before and after the experiment.

TABLE 9 Repeated measures analysis of variance for sleep efficiency.

		MS	*df*	*F*	*p*
Between-group effects	Group	1887.798	1	24.796	0.000***
Within-group effects	Time	96.838	3.417	3.218	0.021*
Interaction effects	Group* Time	360.193	3.417	11.971	0.000***

MS, mean square; *$p < 0.05$, ***$p < 0.001$.

The results (see Table 11) indicated that for the female college subjects who underwent the exercise intervention, the pre-experimental fatigue was significantly higher than the post-experimental fatigue. In addition, the positive effect of the exercise intervention may be accompanied by a reduction in the feelings of academic-induced dizziness and headache and back pain. However, there was no significant change in the improvement of academic concentration before and after the exercise intervention.

The results showed that there was no significant difference in the degree of academic fatigue felt by the female college subjects who underwent exercise intervention and those who did not undergo any intervention at the end of the experiment (see Table 12).

Summary

Study 2 specifically examined the effects of an exercise intervention on academic-related fatigue and sleep problems in female university students and analyzed the effects of a short-term exercise intervention using sleep measures and measures of perceived academic fatigue. The results showed that after 6 days of moderate intensity, any form of daily cumulative 30 min of exercise, these female college students with high levels of fatigue and sleep problems showed more significant improvements in the two indicators of sleep latency and sleep efficiency. In terms of fatigue perception, subjective reports indicated that the participants' fatigue perception was reduced to some extent. Overall, the short-term exercise intervention resulted in a significant improvement in sleep quality and a decrease in perceived academic fatigue in female college participants.

Discussion

In light of intense competition for employment, Study 1 investigated if fatigue is common and severe in emerging adulthood and, more specifically, in a sample of college students. The college stage is a critical period in life for development, and the healthy growth of young people meant much to individuals, families, and society. An enhanced understanding of the prevalence and predictors of academic fatigue among college students will help guide intervention development.

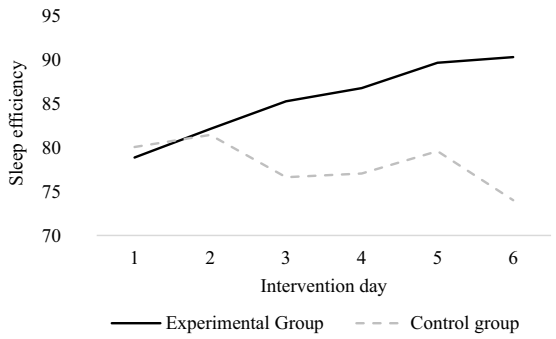

FIGURE 3
Comparison of the overall mean of the sleep efficiency of the experimental and control groups.

TABLE 10 Repeated measures ANOVA of fatigue perception, concentration, dizziness and headache, and back pain of participants in the intervention group before and after the experiment.

		MS	*F*	*p*
Within-group effects	Feelings of fatigue	127.841	40.888	0.000***
	Concentration	0.023	0.004	0.948
	Dizziness and headache	192.364	38.979	0.000***
	Back pain	111.364	26.385	0.000***

MS, mean square; ***$p < 0.001$.

Consistent with previous research (e.g., Schaufeli et al., 2002), the current study found a moderate level of fatigue in college students, and two in five of this sample reported high fatigue. The results showed that applications for studying abroad, postgraduate entrance exams, and graduation thesis were the most important causes of academic fatigue. In general, all these situations are time-limited and require a great deal of energy and time, thereby creating great challenges for college students. Those who aspire to high achievements must exert a lot of effort, depleting themselves in a short time and causing inevitable fatigue. Moreover, most students surveyed rated themselves as having negative personalities, and about half thought they had an unhealthy lifestyle. The links between an unhealthy lifestyle and fatigue have been reported extensively in the literature (e.g., Bültmann et al., 2002; Lee et al., 2007), and this result paves the way for future intervention research.

Second, we analyzed the risk factors associated with academic fatigue among college students. In line with previous workplace research (Mark and Smith, 2011, 2012; Fan and Smith, 2020), the results suggest that most of these factors were positively associated with fatigue. We used hierarchical multiple regressions to confirm the factors that shape academic fatigue. Our results suggest that individual differences, academic characteristics, and learning environment interact to affect fatigue, and academic characteristics account for most of the effect, while the learning environment accounts for the least. In this way, we suggested that modifiable factors (e.g., lifestyle) should be emphasized when developing a preventive intervention. For example, encourage students to exercise more to reduce sedentary time, thereby reducing academic fatigue. It should be noted that the association between social support and fatigue in this study was significant, but it did not play a decisive role. Young adults in college may be relatively independent, and the lack of gain of social support has a relatively small impact.

Finally, the adverse consequences associated with fatigue were evaluated, and consistent with previous studies, it was found that higher academic fatigue leads to poor physical health and a lack of academic-life balance. Surprisingly, there was no significant effect on well-being, academic efficacy, or academic satisfaction in our study. A possible explanation is that Chinese students regard their academic events as their affairs and feel that the fatigue brought upon them will not affect their academic satisfaction. Presumably, the lack of academic-life balance, meaning that too much time was spent on academic events, does not affect academic efficiency. Of the many health outcomes that are associated with fatigue (Dawson et al., 2021), sleep quality deserves particular attention as sleep issues may impact individuals with externalizing psychopathology, as well as increase the potential for antisocial behavior (Taub and John, 1977; Kamphuis et al., 2012; Buysse, 2014). The assessment of the PSQI allowed us to examine whether fatigue would have an impact on sleep. In general, apart from the sleep efficiency and sleeping medications utilized, fatigue was associated with both the subscale and the overall score of PSQI. Even though there is now a longstanding body of research highlighting that insufficient sleep causes fatigue (Angus and Heslegrave, 1985), the current study, in line with many studies focused on fatigue-related impairment (Åkerstedt et al., 2002; Rodrigue et al., 2010), revealed that fatigue is in turn associated with poor sleep quality. This finding partially supported the perspective that poor sleep quality is closely related to both subjective cognitive decline and subjective cognitive decline-related functional limitations (Bradley et al., 2019).

Female college students were selected from Study 1 to participate in an exercise intervention to reduce their academic fatigue and improve their sleep quality. The results demonstrated that a short-term, arbitrary intensity and form of exercise intervention was effective in reducing academic fatigue and improving sleep quality among college students. This is a very efficient way for students with busy academic schedules. Previous studies have shown that balance training and yoga training have been shown to have a moderate alleviating effect on low back pain in people (Nambi et al., 2014; Brämberg et al., 2017; Susan and Wieland, 2017). In the present study, female university students often chose to use forms of exercise such as Pamela's dance exercises and elliptical machines, which are effective in stretching the whole body and improving limb balance, and were, therefore, more likely to report a reduction in low back pain at the end of the experiment. In addition, exercise was shown to have a positive effect on sleep, with significant improvements in length of sleep and sleep efficiency. In line with established research (Li and Liu, 2011), improving sleep quality was associated with an increase in

TABLE 11 Comparison of fatigue feeling, concentration, dizziness and headache, and back pain in the experimental group before and after the intervention.

		M	*SD*
Feelings of fatigue	Before	8.48	1.184
	After	5.45	2.197
Concentration	Before	5.79	1.859
	After	5.86	1.846
Dizziness and headache	Before	5.62	2.871
	After	4.34	2.511
Back pain	Before	7.59	2.413
	After	6.03	2.528

TABLE 12 Independent samples *t*-test between experimental and control groups on fatigue perception.

		F	Sig.	*t*	*df*	*p*
Fatigue perception	Assuming equal variance	0.027	0.87	−0.757	27	0.456
	Not assuming the isotropic variance			−0.77	10.413	0.459

average daily activity, and this study suggests that a short-term exercise intervention was effective in reducing the length of sleep and improving sleep efficiency in female university students. At the end of the experiment, the difference in mean sleep efficiency between the experimental and control groups was around 15%, and the difference in sleep duration was around 40 min, demonstrating the effectiveness of the short-term exercise intervention.

But some of the results obtained in this study differ from established research, and this needs further discussion. Firstly, the reduction in academic fatigue in the exercise intervention group was not necessarily solely caused by exercise, and other influences may have been present. The study has shown that the perception of stress-induced fatigue in the daily lives of university students fluctuates over time as life events unfold (Chen-Ling, 2002), and therefore academic fatigue may also change over time. Due to the lengthy and extensive process of the experiment, a total of 3 months elapsed between the online questionnaire and the conduct of the exercise intervention experiment. It is possible that during these 3 months, there was a change in the participant's academic fatigue due to changes in academic tasks, and this unavoidable phenomenon may have influenced the results.

Similarly, the increase in total sleep time may have been caused by other factors. For example, due to the phenomenon of 'social jet lag', common among students (Castilhos Beauvalet et al., 2017), where sleep patterns between weekdays and weekends do not coincide, subjects sleep longer on Friday nights; research suggests that school hours limit adolescents' weekday sleep (Elfering et al., 2020) and that subjects may have early classes on weekdays. The participants may have early morning classes scheduled on weekdays or may not have classes throughout the morning; therefore, this situation may have a greater impact on the subjects' total sleep duration.

The present study also focused on aspects that have been less addressed in previous studies, providing a novel perspective on how exercise interventions are delivered and how sleep is measured. It is worth noting that most previous studies have focused on exercise interventions of more than 6 months compared to short-term exercise interventions of 6 days (Fernandes et al., 2006; Li and Liu, 2011), and this study demonstrates the feasibility of short-term exercise interventions as a quick and effective way to improve sleep quality and reduce feelings of fatigue in female university students. In this experiment, the exercise intervention was based on "30 min of moderate intensity, any type of physical activity per day," and the volunteers mostly used the school gym, school field, playground running, and dormitory gymnastics as exercise punch cards. These forms of exercise are not restricted by location and can make full use of free and fragmented time. Therefore, this type of exercise intervention is more operational for university students with a large academic load and is more likely to help them develop exercise habits that will lead to lasting improvements in their physical and mental health. In addition, actigraphy was used in this study to continuously monitor the sleep of female university students over 6 days, which provided an important safeguard for obtaining accurate sleep data for this study. As an ambulatory, non-invasive sleep measurement instrument (Sadeh, 2011), the actigraphy helps to increase the ecological validity of the results, and the experiment with the actigraphy in this study provides a reference for research ideas for its further dissemination in China.

Limitations and future study

Previous fatigue studies have been mainly conducted in workplaces. This study assessed the fatigue status among university students and identified factors that influenced it from a more comprehensive perspective. In addition, the effects of daily academic fatigue on youth's health were analyzed, especially those associated with sleep quality. The findings extend the understanding of fatigue, its risk factors, and its associations with sleep and health problems in Chinese young adults. It also provides a simple and efficient way for Chinese university students to relieve fatigue and improve sleep quality.

However, the studies had several limitations. First, all measures used in Study 1 were self-reported questionnaires, which may lead to an overestimation or underestimation of the sense of fatigue. However, before the study, all the participants were told to answer the questionnaires as accurately as possible and to avoid thinking too much about their answers. Secondly, participants in this study included only students living in the south of China, and

the education and academic ability levels may be different in other regions. Therefore, the generalization of our conclusions to all university students should be made with caution. How these results might vary across countries could be determined in further study. Finally, Study 1 was a cross-sectional design performed over a month, which makes it hard to establish causality. Additional studies are necessary to further explore these questions of causality by using a longitudinal design.

Meanwhile, although Study 2 provides a new perspective on the approach to exercise intervention and sleep measurement and focuses on a typical group of female college students, there are some shortcomings in this study as well. First, one of the more obvious problems is the small sample size. Due to the limited experimental period and the limited number of eligible subjects screened by the online questionnaire, there were 36 female college subjects in the exercise intervention experiment, and after removing invalid data from 7 subjects, a total of 29 subjects' data were involved in the data analysis, and the smaller sample size limited the effect size of certain statistics (Heidel, 2016).

In addition, as a social experiment, Study 2 used several methods in supervising volunteers, but it was still difficult to ensure complete control of irrelevant variables. First, before the start of the intervention experiment, the experimenter demonstrated how to wear the actiwatch and created detailed instructions for the experiment, and created an "exercise check-in group" for each experimental period, where daily exercise punch cards were monitored, and reminders were given to wear the actiwatch before sleep. Despite this, seven participants failed the data collection due to wearing errors or forgetting to wear the actiwatch on one night. Secondly, although the experimental instructions clearly stated that the use of alcohol, tobacco, stimulant drinks, and sleep-aid drugs was strictly prohibited, it was difficult to guarantee that participants would not drink or smoke in private. Thirdly, there are additional factors affecting the sleep duration of college students that are not found in typical occupational fatigue groups. The phenomenon of "social jet lag" mentioned in previous studies (Castilhos Beauvalet et al., 2017) suggests that the frequent use of electronic devices and the abundance of social activities contribute to the unstable sleep patterns of students. In the present experiment, individuals also reported excessive night-time cell phone use up to 3:00 a.m., club activities and dinners leading to an early morning return to the dormitory. Fourthly, the schedule of weekday morning classes also had an impact on their total sleep time; for example, those who needed to attend one or two-morning classes had a restricted total sleep time. In summary, although the study had many factors that are difficult to control, the interaction of these factors with the study variables also increases the ecological validity of the experiment, and this is one of the characteristics of social experiments.

Finally, there are some limitations of sleep measurement through actigraphy. On the one hand, although actigraphy is widely used in sleep measurement as an accurate sleep instrument (Sadeh, 2008), it still has some limitations. First, actigraphy is an indirect measurement that estimates sleep–wake time mainly by measuring the activity of the body and, therefore, may have some errors. Second, actigraphy cannot capture some important sleep parameters, such as the percentage of time spent in light sleep, deep sleep, and REM sleep, which are good indicators of sleep to distinguish the experimental and intervention groups (Kobayashi et al., 2007). In addition, the sleep measurement cycle conducted in this experiment was 6 days, and the short measurement time makes it difficult to identify the complete and stable sleep cycle of the volunteers, thus making it difficult to fully grasp the changes in the individual's stable sleep profile, as well as to understand the bi-directional relationship between fatigue and sleep.

Future research can be further improved based on this experiment. First, one could consider doubling the sample size, which will not only make the results more reliable but also make the validity of the study higher. If the sample size was larger, one could also consider classifying the exercise intervention group more carefully, such as whether they need to attend morning classes or not and whether they often participate in club activities or study groups during the experimental cycle or not. In addition, the practical operation of the actigraphy in Study 2 also requires attention to address possible problems such as wearing it incorrectly or forgetting to wear it, and future studies could write more specific and focused experimental instructions and adopt stricter monitoring measures to improve the data collection rate. In addition, previous studies have found that sleep is closely related to the respiratory activity and electrocardiographic activity (Ichikawa et al., 2008; Long et al., 2014). Therefore, it is possible to consider supplementing the actigraphy measurements with respiratory and electrocardiographic measurements to improve the accuracy of the data. In addition, to capture a more stable sleep cycle and to improve the overall understanding of the changes in individual sleep conditions, future studies may consider appropriately extending the duration of short-term exercise interventions. Finally, for subjective measures of academic fatigue, there may be a tendency for participants to give a biased view of themselves. Therefore, a combination of subjective and objective methods should be used in the future to reduce errors.

Conclusion

This study was divided into two parts to explore academic-related fatigue and sleep problems among female college students. Study 1 explored gender differences in academic fatigue perceptions and sleep problems among male and female college students and concluded that female college students had higher academic fatigue perceptions than male college students and that female college students had higher rates of poor sleep caused by academic stress than male college students. Study 2 explored the effects of an exercise intervention

on the perception of academic fatigue and sleep problems in female college students and showed that a short-term exercise intervention could help improve academic fatigue and sleep problems in female college students. This study focused on a group of female college students who have received less attention in fatigue studies so far, used actigraphy, which is not yet popular in China, to measure sleep-related indicators, and verified the feasibility of a short-term exercise intervention. Therefore, this study provides a feasible and convenient way for female college students to reduce academic fatigue and improve sleep.

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 Shenzhen University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

JF formulated the research question and designed the study. JC conducted the data collection. WL and ML performed the data analysis and interpretation. WL drafted the manuscript. AS and JF provided critical revisions. All authors approved the final version of the manuscript for submission.

Conflict of interest

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

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Association of daily and time-segmented physical activity and sedentary behaviour with mental health of school children and adolescents from rural Northeastern Ontario, Canada

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Physical activity (PA) and sedentary behaviour (SED) have been linked to the mental health of children and adolescents, yet the timing of behaviours may play a role in this relationship and clarifying this could inform interventions. We explored cross-sectional associations of PA and SED in varying time segments throughout the school day with the mental health of school-aged children and adolescents from rural Northeastern Ontario, Canada. A total of 161 students (56% female, M=10.3 years old) wore accelerometers for 8 days (7 nights) and completed a self-report survey (parent reported for children younger than 11). Mental health was measured using the Strengths and Difficulties Questionnaire. Accelerometer-measured SED, light PA (LPA), and moderate and vigorous PA (MVPA) were estimated in the time-segments before school (06:00–08:44), school time (08:45–15:04), after school (15:05–16:59), and evenings (17:00–21:59). Associations were tested with multilevel linear regressions while adjusting for confounding factors. Students spent 72.6 min in MVPA, 209.0 min in LPA, and 621.0 min in SED per day. Daily SED was associated with less conduct problems (β=−0.27, p<0.05). Evening LPA was inversely associated with hyperactivity (β=−1.45, p<0.05), while SED was associated with hyperactivity and with peer problems before school (β=1.70 and β=1.01, respectively, p<0.05), and during school (β=−0.83 and β=−0.57, respectively, p<0.05). No associations were observed for MVPA, emotional symptoms, or prosocial behaviour. In conclusion, displacing SED with LPA in some specific periods of the day may benefit the mental health of students; taking this into account could strengthen interventions.

KEYWORDS

mental health, motor activity, public health, sedentary lifestyles, accelerometer

Background

The mental health of children and adolescents has recently received increased attention in the scientific literature (Costello et al., 2005; Thapar et al., 2012), given a worrying increase in depressive symptoms and other indicators of mental ill-health in recent years. Unfortunately, an even worse scenario is projected by 2030, where depressive disorders are estimated to be the leading cause of burden of disease worldwide (World Health Organization, 2004). Among adolescents, depression is the major cause of disability across the globe and a strong risk factor for early mortality (Thapar et al., 2012; Petito et al., 2020; World Health Organization, 2021), and its onset during childhood and adolescence also predicts elevated risk of mental disorders in adulthood (Thapar et al., 2012; Mulraney et al., 2021). Mental health is multifactorial and although some of its biological risk factors are hard to change (Thapar et al., 2012), modifiable environmental (e.g., access to green space) and behavioural (e.g., physical activity, screen time) factors may be related with increased risk or protection (Schuch et al., 2018). Investigating modifiable risk factors associated with children and adolescents' mental health is urgent, as interventions and policies to mitigate mental health problems must be informed by strong scientific evidence (Thapar et al., 2012).

There is an abundance of evidence showing that the maintenance of adequate levels of physical activity (PA) provides health benefits for pediatric populations (Janssen and Leblanc, 2010; Biddle and Asare, 2011; Rasberry et al., 2011; Poitras et al., 2016; Bidzan-Bluma and Lipowska, 2018; Whooten et al., 2019; Chaput et al., 2020), including the prevention of non-communicable diseases, improvement of mental health and academic performance, and ultimately better quality of life. Similarly, evidence has shown that sedentary behaviour (SED), or behaviours undertaken in a sitting or reclined position with low energy expenditure (Tremblay et al., 2017) have been linked to worse metabolic health, mental health, cognitive health, physical fitness, body composition, and holistic measures of health of children and adolescents (Tremblay et al., 2010, 2011; Chinapaw et al., 2011; Carson et al., 2016; Ekris et al., 2016; Biddle et al., 2017; Boberska et al., 2018), and should be avoided in excess. However, recent studies have shown that not all types of PA and SED are equal, and contextual factors may play an important role in their impact on health (Schmidt et al., 2017). Information about where each behaviour happens (e.g., in a park or at home), the types and contents of each behaviour (e.g., studying using a computer or using social media), and the timing of behaviours (e.g., during school hours or in the evening) are examples of contextual factors that may play a role in the relationship of PA and SED with mental health (Carson et al., 2016; Schmidt et al., 2017; da Costa et al., 2022a; Zou et al., 2022), and they have received little attention in scientific literature, possibly because of methodological challenges of measuring contextual factors, such as assessing time-stamped PA and SED. Although the role of different types of PA and SED in relation to mental health has been recently explored in the scientific literature, fewer studies have examined the timing of behaviour (i.e., when behaviour is happening) into account when analysing the relationship of PA and SED with mental health. A recent review with adults has found only three studies investigating the timing of PA and mental health, with two studies testing the impact of exercise in different periods of the day on mental health indicators of older adults, with one observing improvement in mood with exercise in the afternoon, and the other showing similar results between morning and evening exercises on mood; and one study comparing PA patterns between individuals with Alzheimer's disease and healthy controls, observing significant differences in PA engagement in the morning (Janssen et al., 2022). Even less is known about how PA and SED in different time segments of the day relate to mental health of youth.

Previous studies found different associations between PA and SED participation and different domains of psychological difficulties measured by the Strengths and Difficulties Questionnaire (SDQ; Stone et al., 2015). Ahn et al. (2018) explored the relationship of accelerometer-measured PA and SED with SDQ-measured outcomes in school-aged children and found evidence that PA was inversely related to peer problems, and positively related to conduct problems and hyperactivity, whereas SED was positively related to peer problems and inversely related to hyperactivity scores (Ahn et al., 2018). In another study, self-reported PA was associated with increased prosocial behaviour and lower peer problems among boys and girls from London, United Kingdom (Brodersen et al., 2005), while SED was associated with increased conduct problems, hyperactivity, and emotional symptoms (Brodersen et al., 2005). Yet, these studies did not investigate the role of behaviours at different times of the day in relation to mental health.

Data derived from wrist-worn accelerometers provide a temporal record of PA that can be used to determine how SED and PA behaviours are distributed throughout the day (Sasaki et al., 2016), providing more contextual information such as how children spend their time before, during, and after attending school. However, it is unclear if the timing of behaviours is an important factor in the relationship between PA and SED with mental, social, or emotional health indicators. A study with Brazilian students (12.9 ± 5.3 years old) found no association between peer support for PA with PA of any intensity during school time, recess, or PE classes (da Costa et al., 2019a), but found a significant inverse relationship with SED during school time, suggesting that peer interactions such as encouragement and playing together are related to SED in this specific context (da Costa et al., 2019b). However, it is unclear if PA and SED during different periods of the day relate differently to conduct problems, peer problems, hyperactivity, emotional symptoms, and/or prosocial behaviour. Investigating how time-segmented PA and SED relate to different measures of mental health could inform interventions that specifically target PA and SED levels in one particular period of the day to maximize its impact on mental health indicators. Given the limited information on the relationship between accelerometer-derived data and different

mental health outcomes among children and adolescents, the present cross-sectional study aimed to analyze the associations of PA and SED in different time-segments of the school day with mental health indicators in a sample of school children from Northeastern Ontario.

Materials and methods

Participants and procedure

Children and adolescents aged 5–14 were recruited from 3 rural elementary schools (K-8) in Northeastern Ontario (Canada) in May–June 2019 and January–February 2020, before it was interrupted by the COVID-19 pandemic. Following school board approval, an invitation to participate in the study was distributed by the school board to principals of rural schools within the board. The research team met with interested principals and school health promoters to explain the study. Upon agreement, study information was shared with teachers, and students were invited to participate. Each student received a package containing the study description, consent forms, and a survey link for their parents/guardians. Written informed consent was obtained from the participants' legal guardians, and verbal assent was provided by each participant. The procedures of the study were approved by two local school boards and the Nipissing University Research Ethics Board.

Measures

Physical activity and sedentary behaviour

Participants wore GENEActiv accelerometers (ActivInsights Ltd., Kimbolton, Cambridgeshire, United Kingdom) on their non-dominant wrist for 24-h across 8 days (7 nights). The GENEActiv is a small device (4.3 × 4.0 × 1.3 cm, 16 g) that resembles a wristwatch and measures acceleration between −8 g and 8 g across 3 axes (*x*, *y*, and *z*) with an 85.7 Hz sampling rate. After the data collection period, devices were retrieved by the research team, and data were downloaded using proprietary software (i.e., GENEActiv personal computer software version 3.2.). Raw accelerometer data were analyzed using the package GGIR (Migueles et al., 2019), according to the following steps: (1) autocalibration using local gravity as a reference (van Hees et al., 2014); (2) detection of sustained abnormally high values; (3) non-wear detection; and (4) calculation of the average magnitude of dynamic acceleration (Rowlands et al., 2016). The Euclidian norm minus one (ENMO) metric was the chosen data reduction method, using an epoch length of 5 s (van Hees et al., 2013).

ENMO thresholds validated for the pediatric population by Hildebrand and colleagues were used to calculate inactive (or stationary) behaviour (proxy of SED), and PA of light (LPA), and moderate-and-vigorous intensity (MVPA; Hildebrand et al., 2014, 2017). Quantification of SED and PA within predetermined time-segments of the day were calculated using a custom script written in MATLAB (MathWorks, Natick, MA, United States), using a daily class schedule provided by the schoolteachers. Time segments for waking behaviours were operationalized as Before school (06:00:00–08:44:55); School time (08:45:00–15:04:55); After School (15:05:00–16:59:55); and Evening (17:00:00–21:59:55). One of the three schools followed a balanced day schedule instead of traditional day schedule, with learning blocks organized in three periods of 100 min separated by two 40-min breaks for nutrition and play. The other two schools followed the traditional day schedule, with two shorter breaks in the morning and afternoon and a longer lunch break dividing the learning periods. For the balanced day school, the school time segment lasted 10 min longer, which was adjusted based on the threshold of the after-school period (i.e., the transition between the "School time" and "After School" segments was 15:15:00 instead of 15:05:00). Using the daily school schedule provided by the teachers, behaviours in physical and health education (PHE) classes, learning time, and recesses/breaks were also calculated. Data from holidays, school absences, and days when the school was closed due to inclement weather were not analyzed.

Accelerometer non-wear time was identified based on the standard deviation and value range of each axis being less than 13 and 50 mg, respectively (van Hees et al., 2013). Thus, the minimal accelerometer wear-time for inclusion in the data analyses was set at four valid days, with a valid day being defined as at least 16 h of accelerometer wear-time in the midnight-to-midnight period. For days with more than 16 h but less than 24 h of wear time, the difference was imputed using data from similar days. For the time-segmented analysis, a valid time segment was one in which at least 66% of its duration was classified as wear-time. All participants had to provide two or more valid segments to be included in the analyses of time-segmented data. The only exception was PHE classes, where the minimum number of valid PHE classes recorded was one, as some classes only had one PHE class per week. The median number of valid time segments per participant was 5 or above for all except PHE classes (median = 3).

Mental health

The SDQ (Goodman, 2001), a 25-item questionnaire, was used to measure five constructs of mental health: peer problems, hyperactivity, emotional problems, conduct problems, and prosocial behaviour. The SDQ was used in several previous studies with children and adolescents and its psychometric properties are considered strong in a review of validation studies, with a weighted (n = 53,691) mean internal consistency ranging from 0.53 to 0.81 across its multiple constructs for the parent-reported version and validated and confirmed factor structure (Goodman, 2001; Stone et al., 2010, 2015). Parents of children younger than 11 answered the SDQ for them, while children 11 and older self-reported. For each construct, the resulting scores range from 0–10 where higher values are unfavourable, except for prosocial behaviour, which is inverted (i.e., 10 means the worst score for conduct problems, but the best for prosocial behaviour).

Sociodemographic

Sex and date of birth were reported by the respondents (i.e., children or parents). Age was calculated. Both variables were used as covariates in statistical analyses.

Analyses

Data were described using means and standard deviations. The internal consistency of latent variables measured with the SDQ was calculated using Cronbach's Alpha and is presented in Supplementary Table 1.

To test the association of SED, LPA, and MVPA with mental health indicators, multilevel linear regression models were used. Since PA and SED within the same time segment are collinear (i.e., they must add up to the duration of a given class), models for SED, LPA, and MVPA were fit separately. For time-segmented data, a model was fit for each outcome and each behaviour but was mutually adjusted for the same behaviour in other time segments. For example, the association between MVPA and conduct problems included MVPA levels before school, at school, after school, and during the evening. This model structure was chosen since MVPA in different time segments are not necessarily collinear, but there may be some compensation, and thus were mutually adjusted (e.g., less MVPA in one segment due to higher MVPA in another). The data collection happened across different schools, grades, and different teachers and schedules, all of which are factors that can influence PA and SED levels. Thus, to address this variability, we used a multilevel structure with a random intercept for classes in which children are nested. Further, all models were adjusted for age and sex. Model residuals were inspected for heteroscedasticity, normality, and the effects of possible outliers. No transformations were made, or observations excluded.

The descriptive and inferential analyses were conducted in R, version 4.2.1 for Windows (R Foundation for Statistical Computing, Vienna, Austria). Statistical significance was set at $p < 0.05$ (two-tailed).

Sensitivity analyses

The SDQ outcomes can also be expressed in summary measures of externalizing, internalizing, and total difficulties. Externalizing is the combination of the conduct and hyperactivity scales. Internalizing is the combination of emotional and peer problem constructs, and both range from 0 to 20 with 20 being the worst score possible. The total difficulties scale combines all constructs except for prosocial behaviour and varies between 0 and 40, also with the highest scores meaning more difficulties. As a sensitivity analyses, we also investigated of the associations of daily and time-segmented SED, LPA, and MVPA with internalizing, externalizing, and total difficulties, and the results are presented in Supplementary Tables 2, 3.

Results

A total of 483 children and adolescents were invited to participate, and 279 (57.7%) were authorized by their guardians to participate. Of those, 161 (33.3% of the total invited) answered the survey questionnaire and provided valid accelerometer measures to be included in the analytic sample. The characteristics of the participants are described in Table 1. Participants were mostly female (approximately 56%), and were on average, 10.2 years old.

The time in minutes spent on MVPA, LPA, and SED on a habitual day and time segments of a school day are displayed in Table 2. Participants engage, on average, in 72.6 min of MVPA, 209.0 min of LPA, and 621.0 min of SED per day. In absolute terms, most of the daily MVPA was accumulated in the school time (43 min, on average), and participants spent approximately 20% of recesses and 23% of PHE in MVPA.

The association of daily PA and SED with emotional symptoms, conduct problems, hyperactivity-inattention, peer problems, and prosocial behaviours is shown in Table 3. A significant inverse association was observed only between SED with conduct problems (Coefficient: −0.27, 95% CI −0.49, −0.04).

The associations of time-segmented SED, LPA, and MVPA with emotional symptoms, conduct problems, hyperactivity-inattention,

TABLE 1 Characteristics of the participants.

	Overall ($n = 161$)	Females ($n = 90$)	Males ($n = 71$)
	Mean (SD)	Mean (SD)	Mean (SD)
Age (years)	10.2 (2.30)	10.4 (2.14)	9.89 (2.48)
SDQ variables			
Emotional symptoms [0–10]	3.34 (2.43)	3.66 (2.43)	2.94 (2.39)
Conduct problems [0–10]	2.30 (1.65)	2.11 (1.46)	2.55 (1.84)
Hyperactivity-inattention [0–10]	4.89 (2.16)	4.88 (2.08)	4.90 (2.28)
Peer problems [0–10]	3.72 (1.45)	3.69 (1.47)	3.76 (1.44)
Prosocial behaviour [0–10]*	8.09 (1.80)	8.31 (1.72)	7.82 (1.87)
Total difficulties [0–40]	14.3 (5.74)	14.3 (5.56)	14.2 (6.00)

*Higher scores of prosocial behaviours are favourable.
SD, standard deviation; SDQ, strengths and difficulties questionnaire.

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TABLE 2 Participant's daily and time-segmented levels of SED, LPA, and MVPA (n =161).

	Time segment	MVPA	LPA	SED
		Mean (SD)	Mean (SD)	Mean (SD)
Overall	Habitual day	72.6 (30.6)	209 (43.0)	621 (79.9)
	Daily time-segments (minutes/segment)			
	Before school (06:00–08:44)	9.15 (8.12)	24.9 (17.1)	135 (20.4)
	School time (08:45–15:04)	43.0 (17.1)	77.2 (20.0)	226 (40.9)
	After School (15:05–16:59)	16.6 (10.6)	31.5 (9.30)	73.2 (14.2)
	Evening (17:00–21:59)	30.9 (18.6)	55.8 (18.6)	161 (32.2)
	School time-segments (%/segment)			
	Recess time	0.197 (0.117)	0.263 (0.0630)	0.540 (0.155)
	PHE time	0.231 (0.145)	0.225 (0.0749)	0.545 (0.182)
Males	Habitual day	76.2 (30.1)	200 (42.9)	626 (76.0)
	Daily time-segments (minutes/segment)			
	Before school (06:00–08:44)	11.3 (9.28)	25.2 (15.9)	133 (19.5)
	School time (08:45–15:04)	45.6 (16.2)	76.0 (18.6)	223 (38.8)
	After School (15:05–16:59)	18.0 (10.3)	31.2 (9.56)	72.8 (14.0)
	Evening (17:00–21:59)	32.1 (19.3)	53.1 (19.1)	164 (34.2)
	School time-segments (%/segment)			
	Recess time	0.220 (0.118)	0.263 (0.0551)	0.517 (0.146)
	PHE time	0.246 (0.135)	0.219 (0.0677)	0.535 (0.165)
Females	Habitual day	69.7 (30.9)	216 (42.0)	618 (83.1)
	Daily time-segments (minutes/segment)			
	Before school (06:00–08:44)	7.45 (6.68)	24.6 (18.1)	136 (21.1)
	School time (08:45–15:04)	41.1 (17.7)	78.2 (21.0)	229 (42.5)
	After School (15:05–16:59)	15.6 (10.8)	31.8 (9.14)	73.6 (14.4)
	Evening (17:00–21:59)	30.0 (18.1)	58.0 (17.9)	159 (30.7)
	School time-segments (%/segment)			
	Recess time	0.179 (0.113)	0.262 (0.0688)	0.559 (0.161)
	PHE time	0.219 (0.153)	0.230 (0.0801)	0.552 (0.194)

MVPA, moderate-to-vigorous intensity physical activity; LPA, light-intensity physical activity; SED, sedentary behaviour; SD, standard deviation; PHE, physical and health education.

TABLE 3 Association of daily levels of SED, LPA, and MVPA with mental health indicators (n =161).

	Emotional symptoms [0–10]	Conduct problems [0–10]	Hyperactivity-inattention [0–10]	Peer problems [0–10]	Prosocial behaviour [0–10]†
	Coefficient (95% CI)*	Coefficient (95% CI)*	Coefficient (95% CI)*	Coefficient (95% CI)*	Coefficient (95% CI)*
MVPA (h/day)	0.06 (−0.73, 0.84)	0.24 (−0.28, 0.76)	−0.21 (−0.96, 0.54)	0.10 (−0.38, 0.58)	−0.01 (−0.57, 0.56)
LPA (h/day)	0.18 (−0.39, 0.74)	0.09 (−0.28, 0.46)	−0.36 (−0.88, 0.16)	0.12 (−0.22, 0.46)	0.01 (−0.40, 0.41)
SED (h/day)	0.06 (−0.27, 0.39)	**−0.27 (−0.49, −0.04)**	0.05 (−0.27, 0.36)	−0.03 (−0.23, 0.18)	0.14 (−0.10, 0.37)

*Unstandardized coefficients and 95% CI.

†The score for prosocial behaviour is inverted, and 10 is the best prosocial behaviour score possible.

MVPA, moderate-to-vigorous intensity physical activity; LPA, light-intensity physical activity; SED, sedentary behaviour.

Values in bold indicate statistically significant associations at $p < 0.05$.

Models were adjusted for sex and age.

peer problems, and prosocial behaviours can be observed in Table 4. MVPA was not significantly associated with the outcomes. LPA during the evening was inversely related to hyperactivity-inattention (Coefficient: −1.45, 95% CI −2.81, −0.09). SED before school was related to increased hyperactivity-inattention (Coefficient: 1.70, 95% CI 0.16, 3.24) and increased peer problems (Coefficient: 1.01, 95% CI 0.02, 2.00), and was related to the same indicators during school time, but in the opposite direction (Coefficient: −0.83, 95% CI −1.56, −0.10; and Coefficient: −0.57, 95% CI −1.05, −0.09, respectively). In addition, an increased proportion of time spent on SED during PHE classes was also associated with fewer conduct problems

TABLE 4 Association of time-segmented SED, LPA, and MVPA with mental health indicators (n =161).

	Emotional symptoms [0–10]	Conduct problems [0–10]	Hyperactivity-inattention [0–10]	Peer problems [0–10]	Prosocial behaviour [0–10]†
	Coefficient (95% CI)*	Coefficient (95% CI)*	Coefficient (95% CI)*	Coefficient (95% CI)*	Coefficient (95% CI)*
Before school (06:00–08:44)					
MVPA (h/segment)	−0.97 (−4.57, 2.64)	−1.07 (−3.37, 1.24)	−2.36 (−5.81, 1.09)	−0.82 (−2.91, 1.28)	0.09 (−1.15, 1.32)
LPA (h/segment)	−0.81 (−2.46, 0.85)	−0.38 (−1.41, 0.65)	−0.89 (−2.49, 0.71)	−0.32 (−1.24, 0.59)	−0.10 (−1.25, 1.05)
SED (h/segment)	0.58 (−1.10, 2.25)	0.52 (−0.65, 1.69)	**1.70 (0.16, 3.24)**	**1.01 (0.02, 2.00)**	−0.38 (−1.58, 0.82)
School time (08:45–15:04)					
MVPA (h/segment)	0.04 (−1.68, 1.76)	0.11 (−1.11, 1.32)	1.08 (−0.53, 2.69)	0.47 (−0.59, 1.53)	−1.71 (−3.55, 0.14)
LPA (h/segment)	−0.10 (−1.57, 1.36)	0.11 (−0.88, 1.11)	1.02 (−0.34, 2.38)	0.18 (−0.69, 1.06)	0.02 (−1.04, 1.08)
SED (h/segment)	−0.09 (−0.87, 0.70)	−0.19 (−0.76, 0.37)	**−0.83 (−1.56, −0.10)**	**−0.57 (−1.05, −0.09)**	0.17 (−0.39, 0.74)
After School (15:05–16:59)					
MVPA (h/segment)	−0.01 (−2.57, 2.56)	1.43 (−0.38, 3.25)	0.09 (−2.29, 2.47)	0.07 (−1.51, 1.65)	0.63 (−0.45, 1.71)
LPA (h/segment)	−0.32 (−3.19, 2.55)	1.08 (−0.98, 3.15)	2.00 (−0.66, 4.67)	0.61 (−1.17, 2.39)	−0.96 (−3.06, 1.13)
SED (h/segment)	0.34 (−1.71, 2.38)	−0.65 (−2.10, 0.80)	−0.79 (−2.65, 1.07)	−0.38 (−1.62, 0.86)	0.99 (−0.50, 2.47)
Evening (17:00–21:59)					
MVPA (h/segment)	0.45 (−1.06, 1.96)	−0.03 (−1.09, 1.03)	−0.77 (−2.19, 0.64)	−0.24 (−1.16, 0.69)	−0.63 (−0.45, 1.71)
LPA (h/segment)	0.88 (−0.57, 2.33)	0.00 (−1.04, 1.03)	**−1.45 (−2.81, −0.09)**	0.09 (−0.81, 0.99)	0.50 (−0.56, 1.56)
SED (h/segment)	−0.42 (−1.32, 0.49)	−0.13 (−0.76, 0.50)	0.82 (0.00, 1.64)	0.15 (−0.39, 0.69)	−0.41 (−1.07, 0.25)
Recess time					
MVPA (% of time)	- 2.06 (−5.31, 1.19)	−1.59 (−3.85, 0.68)	−1.49 (−4.69, 1.72)	0.36 (−1.64, 2.36)	0.06 (−2.35, 2.47)
LPA (% of time)	−3.42 (−9.44, 2.61)	−0.94 (−5.24, 3.36)	−1.27 (−4.69, 1.72)	1.14 (−2.59, 4.87)	−1.16 (−5.59, 3.26)
SED (% of time)	1.79 (−0.69, 4.28)	1.09 (−0.65, 2.83)	1.10 (−1.34, 3.55)	−0.41 (−1.94, 1.13)	0.17 (−1.68, 2.02)
PHE time					
MVPA (% of time)	0.20 (−2.61, 3.01)	1.61 (−0.24, 3.45)	0.47 (−2.13, 3.05)	0.25 (−1.44, 1.95)	−2.06 (−4.18, 0.07)
LPA (% of time)	2.50 (−2.58, 7.58)	2.81 (−0.64, 6.26)	2.64 (−1.96, 7.24)	1.90 (−1.19, 4.98)	−2.95 (−6.74, 0.84)
SED (% of time)	−0.60 (−2.79, 1.60)	**−1.55 (−3.02, −0.08)**	−0.77 (−2.78, 1.23)	−0.50 (−1.83, 0.82)	**1.84 (0.19, 3.50)**

*Unstandardized coefficients and 95% confidence intervals. Values where there is a significant association should be indicated by bold face.
†The score for prosocial behaviour is inverted, and 10 is the best prosocial behaviour score possible.
MVPA, moderate-to-vigorous intensity physical activity; LPA, light-intensity physical activity; SED, sedentary behaviour.

(Coefficient: −1.55, 95% CI −3.02, −0.08) and more prosocial behaviour (Coefficient: 1.84, 95% CI 0.19, 3.50).

Discussion

The present study aimed to analyze the associations of daily and time-segmented PA and SED with mental health indicators in a sample of school children and adolescents from rural Northeastern Ontario. In contrast to previous literature (Brodersen et al., 2005; Ahn et al., 2018; Bell et al., 2019), we only observed significant associations between daily SED and conduct problems. When time-segmented behaviours were investigated, SED was associated with hyperactivity, peer problems, prosocial behaviour, and conduct problems in specific segments, with some of these associations differing in direction depending on the time-segment analyzed. LPA was inversely associated with hyperactivity on the evening segment, and MVPA was not significantly associated with SDQ outcomes in any of the analyses.

Emotional symptoms were not related to SED, LPA, or MVPA for daily or time-segmented indicators in the present study, which contrasts with findings from previous studies (Brodersen et al., 2005; Bell et al., 2019). There are several potential explanations for this observed result, and a more recent study that used device-measured behaviours also found no association between PA and SED indicators with emotional symptoms among children (Ahn et al., 2018). Specifically for emotional symptoms, intrinsic values and experiences may be more relevant than the duration, intensity, and timing of PA and SED. Previous research shows that some specific types of PA may be more beneficial for quality of life; for example, sports may offer greater benefits than non-sports (da Costa et al., 2020a). Further, team sports may be more beneficial than individual sports for reducing the risk of anxiety and depression (Pluhar et al., 2019; Matias et al., 2022). Similarly, social media seems to be more detrimental to mental health compared to other types of screen-based SED (Boers et al., 2019; da Costa et al., 2022a). For other screen-based behaviours, such as watching videos or playing videogames, content related to violence can have a negative impact compared to other contents (Christakis and Zimmerman, 2007). Future research should consider both timing and the wider context of these behaviours to better understand children's emotional wellbeing.

Only SED was significantly related to conduct problems, prosocial behaviour, and peer problems, while LPA during the evening was negatively associated with hyperactivity. An unanticipated finding was that the direction of the relationship of SED with hyperactivity and peer problems differed between the before-school and school time segments. While more SED before school was related to more peer problems and hyperactivity, SED also related to less problems when at school. The inverse relationship between SED at school and hyperactivity seems to be intuitive, as this relation was observed with a simultaneous positive relationship between PA and hyperactivity among children in a previous study (Ahn et al., 2018). Therefore, we expected to observe significant relationships of PA and SED with hyperactivity in different directions, but only the relationship with SED was observed. This is counterintuitive, as it was hypothesized that hyperactive children would be moving around more instead of being sedentary. Concerning both peer problems and hyperactivity, it is also unclear why the direction of their association with SED changed from before to during school. One possibility is that when children are more hyperactive, teachers may try to manage their behaviour by making the students stay in during recesses, and/or get sent to the office. In relation to peer problems, increased SED during school periods could be reflective of less physical interactions with peers or engagements that could escalate to conflicts, which sometimes happen during active play (da Costa et al., 2020b). Interactions and social dynamics during active play, class time and management, and commuting to school with peers may provide hints to why these relationships were segment-specific as well, and should be explored in future studies, as they have the potential to be changed to favour better mental health.

Children who spent more time on SED during PHE classes had less conduct problems and more prosocial behaviour. Considering that during physical activities such as teams sports and active play, interactions could include rough play and sometimes even conflicts (da Costa et al., 2020b), students who spend more time sedentary may be less exposed to such situations, resulting in less conduct problems and better prosocial behaviours. Furthermore, higher SED during PHE classes could also reflect the behaviours of students who are more compliant with teachers' instructions and class management, compared to disruptive students, who may engage in lower prosocial behaviour and more conduct problems in this particular setting. However, considering that PHE is structured and guided by teachers, other factors such as social climate and norms may play a role in the interactions between peers and how it reflects on their behaviours and mental health (Morton et al., 2016). Some of these results might be also related to how some students respond to class management at the gym as opposed to the classroom, yet, our data does not allow for testing such hypotheses. Studies testing active interventions featuring martial arts have been shown to successfully reduce conduct problems, conflicts, and aggression in PHE classes (Carraro et al., 2014), suggesting that teacher training and changes in class may have the potential to improve the relations between students while also promoting PA. Combining direct observation and/or qualitative methods may also provide new insights into how to increase PA levels and promote mental health simultaneously in PHE classes.

Overall, high levels of MVPA were observed in the present study. Although children are normally depicted with low PA levels in large, survey-based studies (Hallal et al., 2012; Aubert et al., 2018; Guthold et al., 2020), research with accelerometry has also observed MVPA levels above 60 min per day among pediatric populations (Camiletti-Moirón et al., 2020; Ávila-García et al., 2021, Llorente-Cantarero et al., 2021; Padmapriya et al., 2021), which reflect the average recommended engagement in MVPA for children and adolescents according to the most recent World Health Organization guidelines and several international PA guidelines (Chaput et al., 2020; Parrish et al., 2020). We believe this to be a positive finding, considering the many health benefits that result from maintaining high levels of PA (Poitras et al., 2016; Chaput et al., 2020). However, we also recognize that high levels of PA in research with children and adolescents are often attributable to methodological decisions (Kim et al., 2017; Llorente-Cantarero et al., 2021; Leppänen et al., 2022). We have used standardized protocols and recommended acceleration cut-off points for the age-group of our sample (Migueles et al., 2017, 2019), and thereby, our results are comparable to several studies that used the same methods.

Although accelerometers excel at capturing intensity, duration, frequency, and timing of movement behaviours (Sasaki et al., 2016), which are robust predictors of several health outcomes such as cardiometabolic risk, body composition, and physical fitness (Poitras et al., 2016), they do not capture other contextual information that may be relevant for the mental health of children, such as types of physical activities/SED, with whom they are engaged, and aspects of the built, social, and political environments. Previous studies have shown that the relationship between PA and SED with mental health can change according to the measures of PA and SED (e.g., self-report versus accelerometers; Carson et al., 2016; Schmidt et al., 2017; da Costa et al., 2022a; Matias et al., 2022), as well as the correlates of accelerometer-measured PA and SED also differ according to the method of measurement (da Costa et al., 2021a,b). Self-reported instruments such as diaries are capable of investigating types of behaviours and other contextual information that may be more relevant for mental health and other subjective outcomes compared to intensity and duration (Piggin, 2020; da Costa et al., 2022a; Matias et al., 2022) that are stronger predictors of cardiometabolic and fitness outcomes (Poitras et al., 2016). The use of temporally resolved accelerometry data permits further analysis into how behaviours which occur at different times of the day are related to indicators of mental health. However, different activities that share similar intensities and postures may still affect mental health differently, such as playing videogames or using social media (da Costa et al., 2022b), or engaging in team or individual sports or other types of PA (Pluhar et al., 2019; da Costa et al., 2020a), or playing cooperatively or aggressively during recesses or during school time. Novel research methods such as

combining wearable cameras and accelerometers may be needed to adequately assess intensity and duration of PA and SED while also collecting objective contextual information that can be used to further understand how they relate to mental health (Andriyani et al., 2022; Thomas et al., 2022).

The findings of the present study should be interpreted in light of potential limitations. First, the cross-sectional design of the study precludes causality of the associations observed. Although accelerometer-measured variables are time-stamped, the variability of mental health measures throughout the time-segments of day, which would allow for longitudinal analyses, are harder to assess. A second limitation is that the sample, which was selected by convenience, and whose size does not allow for more complex statistical techniques such as structural equation models. However, this sample represents an understudied population of school children and adolescents from rural northeastern Ontario, which differs from studies with samples from dense urban environments. Third, given that SED is commonly defined as any waking behaviour characterized by an energy expenditure less than or equal to 1.5 metabolic equivalents (METs) while in a sitting, reclining, or lying position, the accelerometry derived estimate of SED (i.e., stationary behaviour) in this study cannot be considered true SED, as it does not consider the posture component. However, stationary behaviour is highly correlated with SED, often being used as a proxy of it in studies with wrist-worn accelerometers. Notwithstanding the above, the strengths of the present study include the use of accelerometer-measured PA and SED, which are recommended among school-aged populations, and the use of a standardized comprehensive measure of mental health across different indicators.

Conclusion

When overall behaviour levels were analyzed, only SED was associated inversely to conduct problems, yet LPA and SED in different time-segments of the school day were related to various indicators of mental health. In the evening LPA was favourably associated with hyperactivity, and SED was unfavourably associated with some indicators and favourably with others depending on the time of the day. MVPA was not associated with any mental health indicator, and emotional symptoms were not associated with any indicator of PA or SED. Taken together, displacing SED and PA in some periods of the day may be more beneficial for the mental health of students, yet future studies need to clarify other contextual information that may support creating welcoming and healthy engagement in different behaviours.

Data availability statement

The datasets presented in this article are not readily available because authors are not authorized to share participants' data. Requests to access the datasets should be directed to Dr. Barbi Law, barbil@nipissingu.ca.

Author contributions

BGGC, BB, SMSB, and BL conceptualized the study. BB and BL secured funding for the study. BGGC, BB, BL, and GHR prepared the data and performed statistical analyses. BGGC, BB, and BL wrote the initial draft. All authors critically revised the manuscript. J-PC, TM, GR, JR-W, and TJS have equally contributed to this paper. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.1025444/full#supplementary-material

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Promoting participatory research in chronicity: The ESPRIMO biopsychosocial intervention for young adults with multiple sclerosis

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Background: Co-creation allows to develop tailored interventions in chronicity and to increase patients' engagement. Considering the interacting nature of physical, psychological, and social domains in multiple sclerosis (MS), a biopsychosocial approach to care is crucial.

Aims: This paper aims to present (i) an example of a co-creation process in the context of chronic diseases (ii) preferences and perspectives of young adults with multiple sclerosis (YawMS; aged 18–45) and healthcare professionals (HCPs) on the relevance, objectives, and modalities of a biopsychosocial intervention (named ESPRIMO) and on strategies/barriers to participation.

Methods: A participatory mixed-method approach in three consecutive steps was implemented: online surveys with YawMS (n=121) and HCPs (n=43), online focus groups (FGs) with YawMS, consultation with an advisory board (AB) composed by YawMS, HCPs and researchers. For the survey, descriptive statistics and inductive content analysis have been used for quantitative and qualitative analysis, respectively. FGs and AB were used to deepen the understanding of the survey's results.

Results: An integrated intervention is extremely relevant according to the perspectives of the main stakeholders. Helping disease acceptance, providing stress management strategies, and supporting emotional expression emerged as the most relevant psychological objectives according to participants. Having tangible benefits, being tailored, and fostering interpersonal relationships emerged as the main preferred characteristics of physical activity. Preferences emerged on the modalities and timing of the intervention, with a venue unrelated to the disease strongly supported. Both HCPs and YawMS highlighted as the most valuable advantages of conducting the intervention online the increased accessibility, while the main limit was the restriction to social

interaction (recognized as already limited during the COVID-19 pandemic). Accessibility and lack of time resulted as the main barriers to participation.

Conclusion: The co-creation process gave valuable information on preferences and perspectives of main stakeholders on objectives, modalities, and strategies to improve participation which has been used in the design of the ESPRIMO biopsychosocial intervention. Those results might inform future intervention development in the field of chronicity. The current paper outlined a co-creation methodology which might be replicated in future research on other conditions of vulnerability.

KEYWORDS

clinical psychology and health, multiple sclerosis, co-creation, health related quality of life, participatory research, biopsychosocial (BPS) model, patient engagement, chronic disease

Introduction

Interventions for patients with chronic disease (CD) are usually developed using a top-down approach: patients are passive users of the intervention that has been designed based on literature evidence and researchers' experiences and perspectives. Recently participative approaches are becoming more popular and community-academic partnership is becoming a widely accepted methodology in healthcare research and in the design of interventions for health-related quality of life (HRQoL; Bensing et al., 2013). Participatory research can be defined as an umbrella term for research designs and approaches that "use systematic inquiry with the collaboration of those affected by the issue being studied, for purposes of education and taking action or effecting change" (Green et al., 1995). Research partnership is a promising approach that aims to shift the research paradigm from one in which the researcher is the sole expert and the stakeholders are passive subjects of research to one in which researchers and stakeholders collectively integrate their expertise, knowledge and skills (Hoekstra et al., 2020). The role of the stakeholders might vary ranging from the traditional model where the researcher design all the elements of the product, to meta-design where the end-user controls the majority of the process (Leask et al., 2019). Co-creation is in the middle of this continuum and, even if it has not been uniquely defined yet, it can be described as a collaborative generation of knowledge by academics working alongside stakeholders (Greenhalgh et al., 2016). Co-creation is a promising approach for developing tailored intervention in healthcare and it has the advantage to increase adherence and effectiveness (Leask et al., 2019) which represent key elements in the management of chronic conditions. The evidence and best practices about how to implement the co-creation of knowledge and how to involve end-user in health systems are currently being built (Gagliardi et al., 2015; Jull et al., 2017). However, even if co-creation can be achieved using different methodologies (Drahota et al., 2016) and a clear consensus on how to plan and develop co-created research is far from being reached (Leask et al., 2019), the main principle guiding this paradigm are building a relationship between researchers and stakeholders, co-producing knowledge, engaging stakeholder, building resources and fostering support (Hoekstra et al., 2020).

A biopsychosocial approach to effectively face chronicity

A second core element strictly related to the management and quality of care in chronicity is the adoption of integrated models that recognizes the reciprocal impact and mediating role of different dimensions on illness beside the biological level, such as psychological and social factors. These domains compose the various dimensions that are affected by illness and that can also play a mediating role in the expression of symptomatology and more in general in the acceptance and adaptation to illness. Adjustment to chronicity requires resources in psychological and social domains as well as in the physical/rehabilitative one to maintain and/or promote an adequate HRQoL. Thus, adopting a biopsychosocial approach is highly important (Wade and Halligan, 2017).

However, literature on the development of integrated interventions for CDs targeting all such different domains at the same time seems still scattered. Some efforts have been made on different CDs such as, for example, chronic low back pain (Kamper et al., 2014), stroke care (Kontou et al., 2022) and diabetes mellitus (Suhaimi et al., 2020). More extensive research is needed to tackle the burden of CDs, especially in a neurodegenerative life-limiting chronic condition such as multiple sclerosis (MS), a field in which, to the best of our knowledge, biopsychosocial interventions have not been developed yet.

The ESPRIMO project: Supporting young adults with multiple sclerosis through a biopsychosocial intervention

MS is usually first diagnosed at the age of 20–40 years (Oh et al., 2018). MS is considered the most common neurological

disease that causes disability in young adults (Koch-Henriksen and Sørensen, 2010) with an impact on different personal areas as it interferes with physical (such as gait, vision, and sensory abilities) and cognitive function. Moreover, patients with MS may experience psychological symptoms (such as anxiety and depression; Gajofatto et al., 2019). Having to adapt to a CD with an unpredictable clinical course often have an impact on social dimensions (such as interpersonal relations).

Considering that these aspects interact one with another, a biopsychosocial approach in intervention dedicated to people with MS is needed. With the aim to fill the literature gap on integrated intervention for MS, the ESPRIMO project (Explore, Support, and Promote Resilience In young adults with Multiple sclerOsis) started in 2019 offering a biopsychosocial approach (i.e., ESPRIMO intervention) for young adults with MS (YawMS) aimed at improving HRQoL (Poli et al., 2021; Donisi et al., 2021a,b). The project uses a co-creation approach, thus filling a further gap considering the limited experience with participatory approaches in the MS research field (Giovannetti et al., 2020). The co-creation approach aimed at adjusting and modifying ESPRIMO's theoretical framework (Donisi et al., 2021a), developed based on a literature review, and to inform the content and the modalities of the intervention based on the experience, preferences and needs of the main MS stakeholders.

Considering this background, the aims of the present article are:

i. to present the approaches for the co-creation of a biopsychosocial intervention in the context of chronicity and, in particular, of multiple sclerosis;
ii. to report the preferences and perspectives of young adults with multiple sclerosis and healthcare professionals on a biopsychosocial intervention.

Materials and methods

The co-creation was implemented using a participatory mixed-methods research process (Ivankova and Wingo, 2018; DeJonckheere et al., 2019; Olson et al., 2019) including quantitative and qualitative methods and investigating stakeholders' perspectives, preferences, and suggestions. As part of the project "ESPRIMO," the present study has been approved by the Ethical Committee of the Verona Hospital (Prog 2676CESC) and registered on ClinicalTrials (NCT04431323). Informed consent was obtained from all subjects involved in the study.

Participants

Young adults with a diagnosis of multiple sclerosis (YawMS) and healthcare professionals (HCPs) with different backgrounds in healthcare setting were involved in the co-creation of the intervention together with the ESPRIMO team of researchers and clinicians (i.e., neurologists, psychologists, statisticians, neuropsychologists).

An advisory board (AB) has been established at the beginning and consulted throughout the project.

Procedures

The co-creation consisted of three consecutive steps (Figure 1): surveys, focus groups and consultation with the AB.

Step 1: Surveys

Two web-based, anonymous surveys were implemented using the software LimeSurvey and administered between October and December 2020 (Appendix 1).

The first survey was designed for YawMS meeting the following inclusion criteria: age 18–45 years, MS diagnosis, Italian speaker, and electronic informed consent. The survey was composed of closed and open questions divided into three sections aiming to collect: (section one) socio-demographic and clinical information, (section two) patients' perspectives and preferences about the intervention, and (section three) suggestions about possible barriers/solutions to intervention participation. In section two, participants were asked to rate on a Likert scale ranging from 1 (not important) to 10 (very important) how important is that "an intervention is based on an integrated vision of mind and body" and that "an intervention aims to improve psychological and physical well-being at the same time" and on a Likert scale ranging from 1 (not at all) to 10 (much), and "how much lifestyle can affect the disease." Participants were then asked to choose a maximum of options among a list (multiple choice with the possibility to give other suggestions if they felt something was missing) about: (i) the main objectives on which an intervention should focus to promote psychological well-being and (ii) the main characteristics of an activity to promote physical well-being Additionally, multiple choice questions with one possible answer were used to investigate the ideal frequency, the ideal venue for psychological and physical activities. Two further open questions explored the limits and advantages of conducting the intervention through online modalities Section three contained two open questions asking about possible barriers to participation and possible solutions.

The same rationale was used to develop the second survey designed for HCPs (Appendix 2), with profession and years of experience with MS collected in the first section and two additional questions (in section two) asking (i) how beneficial an integrated biopsychosocial intervention can be for the care process (on a Likert scale from 1 = not at all to 10 = much) and (ii) the perceived benefits of a biopsychosocial integrated intervention (open question). The following inclusion criteria for HCPs have been considered: being a healthcare professional working with MS patients; Italian speakers; electronic informed consent.

YawMS were recruited using social media (e.g., online groups of YawMS on Facebook, and Instagram), while for HCPs email

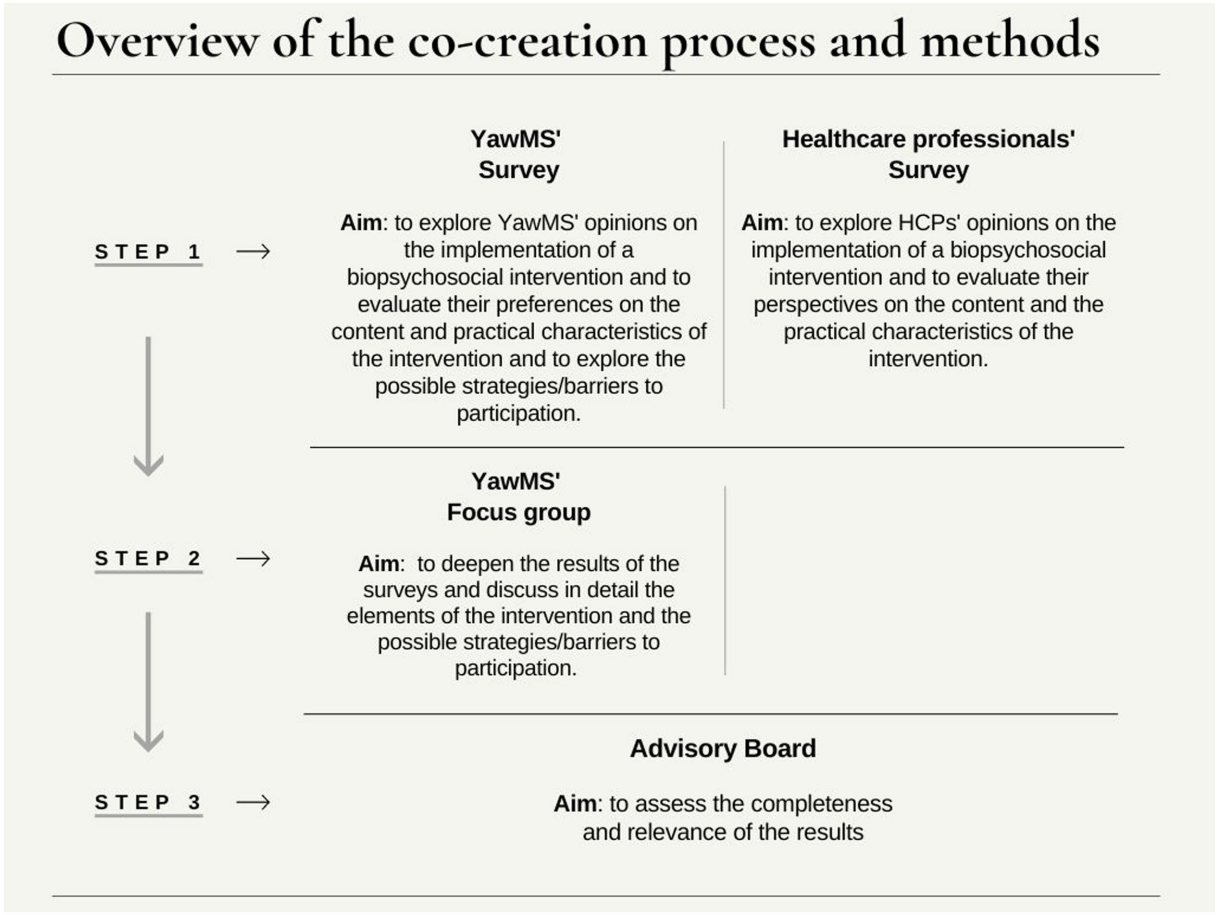

FIGURE 1
Overview of the co-creation process.

invitations to take part in the survey were sent *via* email through the MS Hub and SPOKE network of Verona Province with the request of sending the survey to other colleagues (snowball recruitment). Considering that the surveys are part of a larger mixed-method data collection and according to the relevant literature in qualitative research (van Rijnsoever, 2017; Moser and Korstjens, 2018), a sample of at least 50 YawMS and 25 HCPs were estimated sufficient for this step.

Step 2: Focus group

The focus group topic guide was developed to gain additional information on preferences and needs regarding psychological and physical activities, and on potential strategies to reduce barriers to participation. Aspects connected to the socio-relational contents of the intervention have been investigated. Two FGs were held in March 2021 and, applying the criteria of data saturation (Onwuegbuzie et al., 2009), were considered sufficient to explore all the relevant topics (Donisi et al., 2021a).

Patients have been recruited at the MS Center of Borgo Roma Hospital in Verona (MS Hub Center, northeast of Italy) by the treating neurologist according to the following inclusion criteria: age 18–45 years, MS diagnosis, Italian speakers, and electronic informed consent. Before participating, the participants have to fill out a brief online questionnaire to collect socio-demographic and clinical information. Focus groups have been conducted online (using Zoom) and video recorded; after the completion recordings have been transcribed *verbatim*.

Step 3: Consultation with the advisory board

The Advisory Board is composed of a clinical psychologist, a neurologist, a movement scientist, a health sociologist and four YawMS.

The presentation of the ESPRIMO project and the results of the quantitative and qualitative parts to the AB were held online by the ESPRIMO researchers. Contradictory results from the surveys and the FGs or further suggestions or critical points raised by the AB were examined in an open discussion. One researcher of the team took notes of the exchanges. A final report was sent to all the members of the AB to check for completeness and correctness of the data collected.

TABLE 1 Survey with young adults with MS and with healthcare professionals: opinions regarding relevance and usefulness of a bio-psycho-social intervention.

Questions	YawMS				Healthcare professionals			
	n	mean	SD	range	*n*	mean	SD	range
How important is it that an intervention is based on an integrated vision of mind and body?	101	8.9	1.3	5–10	43	8.7	1.7	4–10
How important is it for an intervention to aim to improve psychological well-being and physical well-being at the same time?	102	9.3	1.1	5–10	43	8.9	1.4	5–10
How much can lifestyle affect the disease?	102	7.7	1.9	1–10	43	7.7	1.5	3–10
How beneficial an integrated biopsychosocial intervention can be for the care process?*					43	8.4	1.6	3–10

*Question included only in the survey for HCPs.

Data analysis

The quantitate results of the survey have been analyzed using descriptive statistics. An inductive content analysis has been applied to analyze the qualitative results of the open questions. In particular, the participants' answers have been reported in an Excel file, and two researchers have analyzed the text and elaborated possible labels in line with the guidelines (Moretti et al., 2011). As a final step, all answers have been coded using the finalized labels, and the frequency distributions have been calculated.

Results of the FGs and the advisory board were used to deepen the understanding of the survey's results and the information on the relevant topic. Each main topic was checked against the results of the survey to see if there was agreement or not and to highlight specifications.

Results

Step 1: Surveys

The surveys reached a sample of 121 YawMS and 43 HCPs. The majority of YawMS who responded were female and had a (self-reported) diagnosis of relapsing–remitting multiple sclerosis; the mean age was 33 ± 7 years.

Neurologists (53%), psychologists (23%), physiatrists (14%), physiotherapists (5%), and nurses (5%) filled out the survey dedicated to HCPs; the mean age was 40 ± 10 years.

Appendix 3 presents detailed characteristics of the participants, while the survey results have been reported in the following paragraphs.

Relevance and usefulness of a biopsychosocial intervention

Most of the participants thought that an intervention based on an integrated mind–body vision is extremely relevant (YawMS: mean 8.9 ± 1.3; HCPs: mean 8.7 ± 1.6), and that is highly important to simultaneously improve psychological and physical well-being (YawMS: mean 9.3 ± 1.1; HCPs: mean 8.9 ± 1.4; Table 1).

When specifically asked how beneficial an integrated biopsychosocial intervention can be for the care process, HCPs answered positively (mean 8.4 ± 1.6). Moreover, the following perceived benefits were added: *benefits in the care path* (*N* = 17), *psychological benefits* (*N* = 14), *adjustment to the disease* (*N* = 7), *social benefits* (*N* = 7), *global benefits* (*N* = 6), and *physical benefits* (*N* = 2).

As regards the *benefits in the care path,* HCPs hypothesized an improved treatment adherence, more realistic expectations regarding treatments, and enhanced HCPs-patients relationships and trust. In the words of a participant "*putting the person at the center with their specific physical, emotional, cultural, and social characteristics allows the doctor to better understand their needs and to establish a more effective care relationship*." Regarding the *adjustment to the disease*, HCPs highlighted that an integrated intervention might foster a better understanding of the symptoms, an acceptance of MS and promote a more favorable concept of disability also improving its acceptance within the family. According to HCPs, an integrated intervention might reduce the risk of relapses (*physical benefits*) and could improve interpersonal relationships and foster social inclusion and stigma reduction (*social benefits*). *Global benefits* are also expected (e.g., a better quality of life). As far as *psychological benefits*, HCPs considered an improvement in mood and self-efficacy and reduction of stress, increased awareness of one's functioning, increased ability to cope with difficulties and disability, all of which might also have a positive impact on relapses.

Psychological objective of the intervention

Regarding the main objectives to promote psychological well-being, among the listed options the most rated both by YawMS and HCPs were helping to accept the disease and providing stress management strategies. The third most rated by YawMS was supporting the expression of emotions and concerns, while the HCPs indicated "increase self-efficacy in managing the disease" (Table 2).

Thirty-one YawMS indicated other potentially relevant objectives; the following are the main categories emerged: increase independence, manage anger and negative emotions, develop a positive approach, help to go back to normal life, work on self-esteem, coping with difficulties, receiving support in a delicate period of time (e.g., motherhood), handling the psychological effects of taking medications, understanding how to communicate

TABLE 2 Survey with young adults with MS (*N*=121) and with healthcare professionals (*N*=43): needs and preferences regarding the main objectives of the psychological activity and the characteristic of the physical activity.

	YawMS	HCPs
a) In your opinion, in order to promote PSYCHOLOGICAL well-being, what are the main objectives on which an intervention should focus? (indicate a maximum of four objectives)		
List of possible answers	Responses, *n* (%)	Responses, *n* (%)
It should help me to accept the disease and its consequences	72 (18.9)	29 (17.9)
It should provide me with advice and stress management strategies	68 (17.8)	29 (17.9)
It should help me to express my emotions and concerns	51 (13.4)	22 (13.6)
It should change the way I see things	48 (12.6)	13 (8)
It should increase my sense of self-efficacy in managing the disease	37 (9.7)	29 (17.9)
It should make me aware of my emotions	35 (9.2)	14 (8.6)
It should motivate me to change	28 (7.3)	14 (8.6)
It should help me to process past traumas	24 (6.3)	0 (0)
It should inform me about the risks of an unhealthy lifestyle	18 (4.7)	12 (7.4)
b) In your opinion, what characteristics should the proposed physical activity have in order to promote PHYSICAL well-being? (indicate a maximum of four characteristics)		
List of possible answers	Responses, *n* (%)	Responses, *n* (%)
It should have tangible benefits for the body	58 (29.3)	10 (9)
It should be adapted to my physical needs	52 (26.3)	34 (30.6)
It should encourage me to continue with physical activity even after the intervention	40 (20.2)	29 (26.1)
It should let me get to know new people	25 (12.6)	26 (23.4)
It should be fun	16 (8.1)	7 (6.3)
It should teach me something new	5 (2.5)	3 (2.7)
It should be a new activity	2 (1)	2 (1.8)

the diagnosis and how to react to judgment, dealing with stigma and feelings of being a burden, sharing experiences with others YawMS.

Physical objective of the intervention

Regarding the preference on the main characteristics of an activity to promote physical well-being, having tangible benefits on the body, being tailored to each individual's physical needs, fostering relationships with others YawMS and encouraging to continue after the intervention were reported more frequently (Table 2).

Other aspects that were added by YawMS ($N = 17$) included: becoming independent, improving balance, and endurance, strengthening the muscles and resistance to fatigue; experimenting dynamic activities; reducing stress. Additionally, one HCP stated that the intervention should improve the perception of one's body, its potentialities, and its limits.

Intervention modalities and timing

As regards practical aspects of the intervention (Table 3) the majority of YawMS preferred one or two meetings per week and a neutral venue not connected to the disease (both for the psychological and physical activities).

Two open questions focused on online delivery (Table 4). The most frequent advantage, both for YawMS and HCPs, of conducting the intervention online would be increased accessibility which might result in higher participation. According to responders, online modalities could lower COVID-19 related risks. The most frequently reported downside of online modalities, both for HCP and YawMS, is the limitation to interpersonal relationships (see more details in Table 4).

Barriers and solutions to foster participation

Table 5 shows the themes, a brief description for specific labels and their frequencies for both YawMS and HCPs on the possible barriers and solutions to foster participation to the intervention. Participants mostly reported accessibility as the main drawback, including distance from the venue, lack of public transport and being dependent on a caregiver for coming to the encounters. As examples of possible solutions to increase accessibility, YawMS and HCPs proposed holding encounters online or selecting an easily accessible venue.

The other most frequent theme regarded psychological barriers. As a possible solution, creating a positive environment was highlighted together with emotional support. Finally, other barriers regarded the practical characteristics of the intervention. Possible solutions reported by participants regards the tailoring of the intervention characteristics to the participants' needs.

Step 2: Focus groups

A total of 31 YawMS took part in the two focus groups (mean age of 32.8 ± 6.6; female 71%; 92.3% diagnosis of

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TABLE 3 Survey with young adults with MS: needs and preferences regarding intervention modalities and timing.

Questions	Levels	*N* (%)
In your opinion, what would be the ideal frequency for meetings?	Two meetings per week	41 (40.2)
	One meeting per week	41 (40.2)
	One meeting per month	3 (2.9)
	One meeting every other week	17 (16.7)
In your opinion, what would be the ideal venue for meetings related to psychological aspects?	My hospital or treatment center	26 (25.5)
	Via telematics (using a videoconferencing platform, e.g., Zoom, skype)	15 (14.7)
	The seat of a patient association	18 (17.6)
	A neutral place not connected to my illness (e.g., gym, social club)	43 (42.2)
In your opinion, what would be the ideal venue for meetings relate to physical activity?	My hospital or treatment center	19 (18.6)
	Via telematics (using a videoconferencing platform, e.g., Zoom, skype)	4 (3.9)
	The seat of a patient association	12 (11.8)
	A neutral place not connected to my illness (e.g., gym, social club)	67 (65.7)

Out of 121 participants in the survey, 102 answered to these questions.

TABLE 4 Survey with YawMS (*N*=121) and with HCPs (*N*=43): qualitative analysis of answer regarding limits and advantages of conducting the intervention through online modalities.

Advantages of online modalities				Limits of online modalities			
Theme	Advantages labels	Frequency		Theme	Limits labels	Frequency	
		YawMS	*HCPs*			*YawMS*	*HCPs*
Accessibility	To reach a wider public; Lower costs for participants; Easiness of participation as there is no need to move or to relay on caregivers; More easily fitted in one own's agenda not having to travel losing time and having the possibility to connect anywhere	28	24				
COVID-19 pandemic	Lower the risk of getting infected (higher safety); Intervention guaranteed even during lockdowns;	8	3				
Organizational aspects	Easiness of organization and management for HCPs	/	3				
				Interpersonal relationships with other participants	Online interactions are different from in-persons and might prevent or limit social connections; Unnatural or difficult communication with lack of paraverbal aspects; Limitation of informal aspects of sociability; Feeling of isolation	30	19
				Limited interactions with HCPs	Limited possibility of motor correction and manipulation; Lower connection and empathy	10	5
Facilitation of expression	Higher comfort in expressing oneself or doing physical activities, overcoming their shyness, anxiety or embarrassment	5	4	*Limitation in expression*	Lower genuineness and comfort in expressing oneself; Lack of privacy and shame of being heard	10	/
Technical advantages	Makes it easy and practical to participates and might give the possibility of recording encounters	1	/	*Technical downsizes*	Costs; Possible malfunctions; Low familiarity with digital tools; Easiness of distraction	6	7
Higher motivation	Higher compliance to the intervention	/	2	*Lower motivation*	Lower motivation in taking part in the intervention; Less involvement and engagement	5	6
*None**		19	2	*None**		5	1
	Total**	64	40			68	39

Please note that limits and advantages have been reported in the same line when they represented conflicting views on the same topic.
*Participants' answers were not relevant to the theme and thus were not categorized in labels, or participant wrote "no answer."
**Some participants reported more than one label.

TABLE 5 Survey with YawMS (*N*=121) and with HCPs (*N*=43): qualitative analysis of barriers for patients to participate in the intervention and possible solutions.

Barrier theme	Barrier labels	Frequency		Possible solutions labels	Frequency	
		YawMS	HCPs		YawMS	HCPs
Accessibility barriers	The venue might be far from home or difficult to reach with public transport; Some participants might not be independent; Fatigue or presence of physical symptoms	21	19	Using online tools, offering intervention at the patients' house, or transport solutions, offering the intervention in different venues, granting possibility to skip some encounter, choosing a venue suitable for the whole group to lessen the distance; Help patients to accept and overcome fatigue	19	9
Example of quote by the participants	*"If the encounters are held far from home, because sometimes I cannot drive for many miles, sometimes I have problems with one eye and while I'm driving it hurts and I have to stop"* [by YawMS]			*"Identification or creation of several structures that are able to offer sports motor activities for people with disabilities, guaranteeing diversified time slots, specific equipment and customization of the proposals"* [by HCP]		
Psychological barriers	Difficulties in talking with others; Fear of judgment from other people, of not being understood, of seeing other people with greater disability, of failure and belief of not being adequate; Low motivation; Not seeing the benefit of a psychological approach	13	22	Proposing activities that are new and entertaining, fostering a welcoming and non-judgmental environment, normalizing symptoms; Helping awareness of one own's emotions, using motivational interview, offering psychological support	3	11
Example of quote by the participants	*"Fear of encountering more serious situations than theirs, and consequently anticipating their own worsening and experiencing a form of threat"* [by HCP]			*"Underline in the communication that the environment is welcoming and non-judgmental"* [by YawMS]; *"Show the feasibility by everyone regardless of their skills"* [by YawMS]		
Characteristics of the intervention	Not having enough time to take part in the encounters due work, family, or personal reason; People in the group might have different ages or different experiences (e.g., different diagnosis)	16	17	Offering encounters later on the evenings or on the weekend, offering different, tailored, and flexible timeframes; Creating small groups with similar ages and physical abilities	9	17
Example of quote by the participants	*"The time to dedicate to it that you have to cut out from other work-related or non-work-related activities"* [by YawMS]			*"Try to detect, through an online questionnaire, what are the difficulties and needs and in which time range they are available"* [by HCP]		
No barriers*		**11**	**1**	No solutions*	**14**	**4**
	Total**	**61**	**59**		**45**	**41**

*Participants' answers were not relevant to the theme and thus were not categorized in labels, or participant wrote "no answer."
**Some participants reported more than one label.

relapsing–remitting MS). No YawMS participating in the FGs had significant limitations, while 23% had partial limitations, and 77% had no limitations.

Psychological objective of the intervention

Regarding the main psychological objectives of the intervention, all participants agreed on the ones most frequently reported in the surveys. Regarding the acceptance of the disease, receiving practical suggestions, for example, on how to deal with a specific symptom or with uncertainty, should be considered in the delivery of the intervention. Having to deal with the disease made YawMS realize their functioning and other difficulties because the disease is connected to all areas of their lives: accepting the disease is the first step that also helps to intervene on other aspects ("*And then [after the diagnosis]at that point many things come out, in short: about you, how you are, what you do, how you act in certain situations and moments or in the workplace*)." As an adjunction, single comments regarded that it is important to: "*let things emerge and think about them*" not to be overwhelmed; increase motivation to act positive change; improve self-efficacy in the management of the disease, because of his personal difficulties in adapting to a new lifestyle.

Physical objective of the intervention

Participants agreed on the main characteristics that emerged in the survey regarding physical activity. For example, a participant stated: "*If we decide to take a walk, [it is important] that I can do it, that I can have fun and that I am able to repeat it even alone and that it is good for me*."

In addition, getting to know people dealing with the same condition and doing physical activities together has been considered a way of increasing motivation. Interaction with other people and music are a way, according to participants, to have fun while also doing something useful for the body ("*Doing [physical*

activity] alone I think that everyone is a little less encouraged"; "*Also that there is a bit of fun and maybe even music*"). Dance has been considered a good way to mix all these elements, also helping to create social connections and prevent social isolation linked to diagnosis. Moreover, dance might help to express oneself in a more effective way, "*allowing to express even emotions*." Nevertheless each individual impairment such as balance should be acknowledged, and one participant suggested to offer different types of dances. One participant cited the possibility to organize evening events based on dance activities.

Socio-relational aspects of the intervention

Participants stated that sharing the common experience of living with MS can foster a feeling of comfort, for example, a participant stated: "*In my opinion, the fact that we are all on the same boat puts us a little more at ease[…] because we all have a lot of things in common on this*." One participant highlighted that after diagnosis people might isolate themselves and, therefore, having the possibility to share concerns and anxieties with people in a similar condition might increase the sense of belongingness.

Working on oneself to acquire social skills and strategies to interact with friends, family, or colleagues has also been cited by participants as a relevant objective in socio-relational domain. Moreover, the discussion focused on the need to sensibilize the general public about the disease using leaflets or designing specific events.

As an additional topic of the FGs, participants discussed whether if, during the physical or phycological activities, they would like to bring friends or family members. In the first focus group, people expressed the wish to have this opportunity to connect different social microcosmos and that this could be a way to let beloved ones see other experiences. However, in the second focus group, all participants agreed that they would prefer not to be accompanied and that, if this might be the case, all patients taking part in the intervention should consent. In fact, the presence of other people without MS might create discomfort in the group. Moreover, referring to their own experience, participants stated that the relationship with their beloved might change in unexpected ways after participating in such encounters and they would not be comfortable in inviting friends. Nevertheless, participants in both groups expressed the wish to be accompanied by a partner or by some member of the family in some dedicated informal encounters.

Intervention modalities and timing

The survey results on the modalities and timing of the intervention have been discussed during the FG, with extensive considerations regarding the barriers and advantages of the online modalities versus the in-person ones. The main contents have been summarized in Table 6.

Barriers and solutions to foster participation

Regarding barriers to participation, as emerged in the surveys, participants in the FGs highlighted that people might find it difficult to have time to take part in the intervention due to work or family commitments. A theme that did not emerged during the survey is the possible interference of therapies with the participation in the intervention during the pandemic: "*Because maybe someone takes immunosuppressants with very low immune defences […]perhaps it is not so convenient to move*."

Step 3: Advisory board

The involvement of YaMS during all phases of the project through a co-creation approach has been appreciated by the Advisory Board. Some specific comments that emerged during the discussion highlighted the strengths of the project and offered ideas for improvement.

In general, the AB confirmed previous results on the usefulness of an intervention that takes into consideration the biopsychosocial domains at the same time. Dance, supported in the FG as a possible ESPRIMO physical activity, was considered positive highlighting the value of music in fostering relationships and improving the enjoyability of the activity. According to the expert in movement sciences some elements of music such as rhythm might enhance motor gains.

The duration of the sessions was discussed along with the suggestion to provide for an additional "booster" session 1 month after the end of the intervention to allow consolidation of the improvements.

The attention to social aspects, has been considered fundamental, as it builds connectedness and allows to share experiences between YawMS: a key element in the process of adjusting to the disease. Regarding the controversial results on online and in-person modalities, the AB stressed the importance of contemplating in-person activity which has been considered the most appropriate way to foster involvement and connectedness, also considering the reduction of social activities due to the COVID-19 pandemic.

Discussion

The relevance of the co-creation process

The co-creation process gave valuable information about stakeholders' perspectives and preferences for the development of a biopsychosocial intervention in the field of MS. Different consecutive steps have been used (surveys, FGs and the AB) in order to enrich and deepen the data collected.

Involving patients in research and valuing their opinion as experts can inform the design of services starting from the experience and needs of people that will use them (Morote et al., 2020). Programs that are designed based on the patients' preferences are more sustainable for participants and more sensitive to the specific context, thus possibly reducing the dropout rate (Lo and Karnon, 2019). The co-creation process has been

TABLE 6 Synthesis of the focus group with YawMS in comparison with the main results of the survey: needs and preferences regarding intervention timing, venue, and modalities.

Topics	Survey main results	Focus group specifications and additional considerations
The ideal frequency	One or two meetings per week	In partial agreement with the survey, participants believed that holding one encounter per week would be a good way to foster participation. In fact, two encounters a week, even if considered useful and appealing might be unsustainable because of having to balance work, family, and personal time (*"Surely one meeting, which I would be able to keep up with, will be less binding; not because I do not like two encounters, but it [one meeting] would be more sustainable"*). Moreover, few people might have difficulties also with one encounter per week (*"For me, even one meeting a week is not exactly that simple"*) with one encounter every other week has been also suggested for the timing of the intervention. Moreover, participants suggested to choose a time in the day during which public transportations are available and one might be more available "[the intervention] *could be implemented at a time of the day when there is public transport available.*"
The ideal venue	A higher percentage of respondents prefer a neutral venue	All participants agreed, in line with the results of the surveys, that a neutral venue not connected to the disease is preferable. This would help to lower the burden of the disease as MS would not be perceived as the only identifying characteristic of the group, but it would be one of the reasons why people meet at the encounters. Moreover, participants suggested a place connected with nature (*"Maybe it can be thought of trying to see each other outdoors, perhaps in a park"*) as it has been suggested to be a good way to relax. According to participants the chosen venue should be easily accessible and served by public transport
The online modalities	A low percentage of respondent prefer the online modalities	Participants confirmed the limits and advantages of conducting the intervention online emerged during the surveys. In fact, the most cited advantage was accessibility as people far away might take part in the intervention and even shy people might be more prone to participate. Moreover, being at home might increase the feeling of comfort (*"It's my home so I feel at ease"*). As the main limit, online modalities might inhibit informal social interactions because *"It misses the physical aspects of getting to know people."* A participant stated that *"In my opinion the online modalities, if you really cannot do without it, that's fine, it is better than nothing However, if I were to talk about multiple sclerosis and had to do activities with these people, I would feel better seeing them in person."*
	Different limits and advantages of conducting the intervention online emerged without a conclusive preference	As a possible solution to increase social interaction, one participant suggested to organize small group activities during online encounters. One person highlighted that since the beginning of the pandemic all activities have been delivered online through smartphones or computers and this modality is becoming tiresome (*"Given that I am tired of online modalities, because I have practically lived in front of my PC for a year for various reasons"*). Some participants stated that, being personal protective equipment available, there is no need to think of an online intervention to prevent the spread of the COVID-19 while two participants said they might feel unsafe or anxious to do group physical activities indoor (*"It happened to me in recent days, of meeting people, of taking all the precautions, but in any case I was hardly able to relax"*). Moreover, face masks, might hamper communication and emotional expression, however a potential solution (as suggested even above regarding venue) could be to meet outdoors.

introduced as a particularly valuable strategy in the current paper for at least two reasons: the particular target of the ESPRIMO intervention (i.e., young adults with MS) and the specific contextual conditions in which ESPRIMO has been developed. Indeed, as a first reason, a diagnosis of MS at this age might be intertwined with the personal and interpersonal goals typical of this phase of life, creating peculiar needs. Accordingly, for example, many barriers to participation discussed in the survey and focus groups results regard the overlap of the intervention time with the daily activities typical of the age. Secondly, the participatory methodology is particularly essential in this historical period of the COVID-19 pandemic that has brought changes and challenges and potentially created new psycho-social needs, especially for young people and for patients with medical frailties (Xiong et al., 2020). Indeed, in a previous Italian study targeting YawMS in the aftermath of the COVID-19 pandemic, psychological distress (even in relation to the change that occurred in treatment and healthcare services) and the need for psychological interventions emerged (Donisi et al., 2021b). As well as reported by participants in the co-creation, during the pandemic, people had to use online tools to socialize and reduce loneliness, both because of government restrictions to social contact both to prevent possible contagion. However, using digital technologies changes the way we connect and interact (Shah et al., 2020); for this reason, understanding social needs and preferences regarding the choice of online or face-to-face modalities was especially useful in the current paper.

The confirmed value of the biopsychosocial approach from the main stakeholders' perspective

The value of the biopsychosocial approach was confirmed by results throughout all steps of the co-creation, with a clear

recommendation, as all parties involved might benefit from it. Specifically, the responses of YawMS and HCPs highlighted the importance of developing interventions using an integrated vision of mind and body, that simultaneously target physical and psychological well-being. HCPs highlighted possible benefits for patients, for the course of the disease and for the general process of care, including the improvement of doctor-patient relationships which represent a valuable aspect according to the literature (Price et al., 2021).

Moreover, the results suggest that each activity should not only target one specific component but that the bio-psycho-social domains are highly integrated. For example, some answers regarding physical activity encompassed themes pertaining social or psychological domains. In fact, according to participants, physical activity should also aim to reduce stress and foster relationships with others YawMS, once again reinforcing the importance of a biopsychosocial approach in the design of the intervention. However, the interaction between different components must be acknowledged all throughout the intervention design and should be targeted as a specific aim and should not be just a collateral result.

Preferences and perspectives on the psychological, physical, and social intervention domains

Regarding the psychological domain, the main objectives highlighted by YawMS, and also supported by HCPs, regarded acceptance of the disease, stress management and emotional expression. This is in line with previous results in which YawMS stressed the importance of reducing unpleasant emotions and promoting strategies to accept MS as the most relevant aim of a psychological intervention (Donisi et al., 2021b) and with the relevance of acceptance principles in the psychological literature in the chronicity field (Giovannetti et al., 2021). People who accept their own illnesses are more optimistic, experience fewer negative emotions related to the disease, and have a higher rate of adherence to recommended treatments (Dymecka et al., 2021; Kołtuniuk and Rosińczuk, 2021). Interestingly, participants added other objectives that they considered important; however, those answers might be seen as more specific topics of the three main reported themes. During the focus group, participants reinforced the importance of working on MS acceptance, also focusing on the relationship between disease and other areas of life. Obtaining these specifications during the co-creation steps was useful for defining the specific contents of the intervention and enriching the examples in the materials proposed.

Regarding the physical activity domain, the main characteristics, according to stakeholders, are that it should have tangible benefits on the body, be tailored to each individual's physical needs, and encourage to continue after the intervention. During the focus group, the main results of the survey in the area of physical activity were confirmed, such as the relevance of an activity that should be beneficial and adapted to the level of the individual. In line with the literature in this field (Wiersma, 2001; El-Sherif, 2016) participants in the FGs prioritized the role of pleasantness, highlighting that doing physical activities together with other YawMS is a way to increase pleasantness and motivation. Dance has been considered a good way to socialize (also offering opportunities to organize events for a broader community) and to incorporate pleasant elements such as music; which is in line with the existing literature on dance activities in MS (Salgado and de Paula Vasconcelos, 2010; Mandelbaum et al., 2016; Ng et al., 2019; Van Geel et al., 2020).

Regarding the socio-relational domain of the intervention, doing the intervention with other young people that share the experience of living with MS emerged as a positive element that can help people to prevent social isolation and to foster meaningful interaction with alike people. Having to share a path with people that can easily comprehend the struggles of living with MS can help to build a positive environment, however, the broader social context should not be forgotten. Indeed, participants highlighted the need to learn specific skills to interact with their personal friends, family, or colleagues and the importance of diminishing stigma-related aspects in the general population. In fact, stigma is a social factor that can affect mental health in MS; however social resources (e.g., social support, sense of belonging) might protect people from stigma's negative consequences (Cadden et al., 2018).

Preferences and perspectives on modalities and timing of the intervention and on fostering participation

The co-creation phase made it possible to inform the choice of the intervention on practical aspects which are fundamental to maximize the results and the feasibility of the intervention.

Regarding the timing, the intervention should have modalities that have low interference on the person's life and be sustainable while also being pleasant and enjoyable for the person. This is particularly relevant considering the target population (young adults) that often works or studies, has low levels of disability and has an active personal (e.g., hobbies and personal interests) and social life (e.g., friends, family) potentially making them busier and also already involved in other psychological, physical or social activities. In general, an intervention dedicated to young adults should fit in their busy daily schedule and should consider strategies to reduce psychological barriers to participation, including different types of fear in interacting with other people (e.g., judgment, not being understood, failure, seeing other people with greater disability).

Linked to the previous aspect, different insights on the limits and advantages of conducting the intervention online emerged and could be considered in future research in this field. To sum up, online modalities could be accessible to a wider public and could lower the risk of COVID-19 infections; however, reduced sense of belonging and social connections (which might be relevant in the aftermath of social restriction during the first year of the pandemic—during which this research was held) and

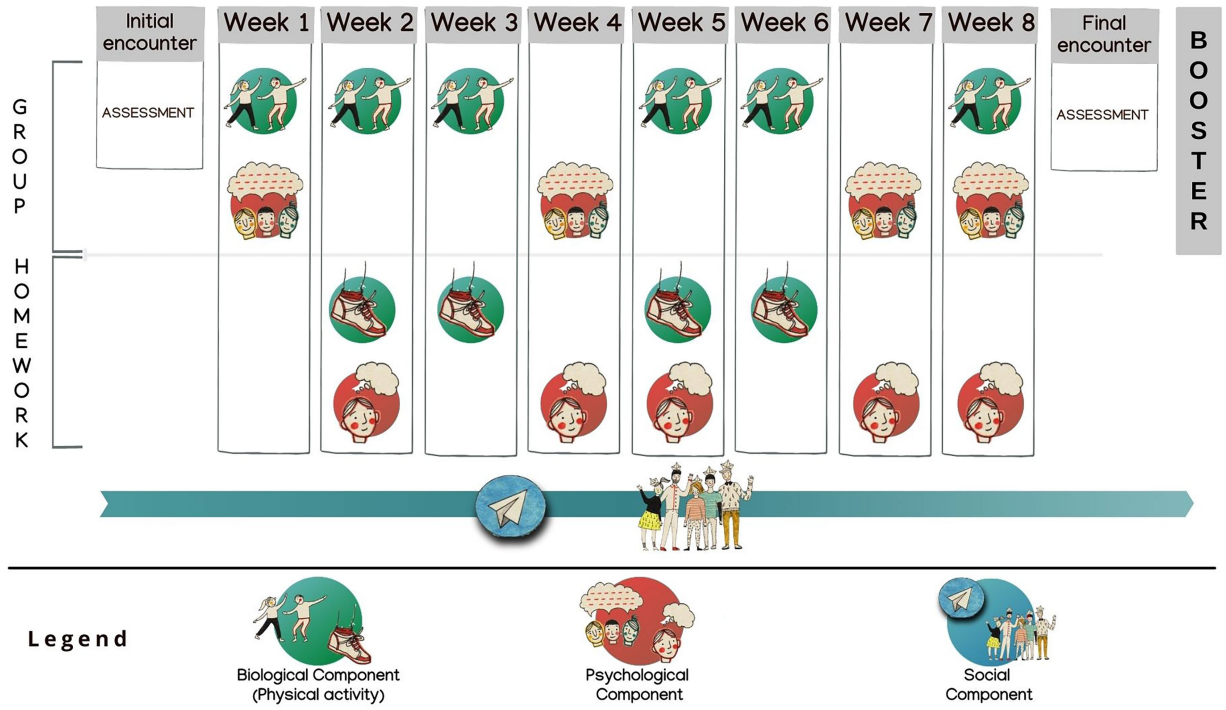

FIGURE 2
Overview of the ESPRIMO bio-psycho-social intervention.

increased feelings of isolation have been stressed as the main limits of this modality. Some aspects regarding the facilitation/limitation in personal expression, the level of motivation and the technical aspects of the online modalities were more controversial; however, a slight prevalence of negative considerations.

In-person encounters should also consider an easily accessible venue. The relevance of a non-medical venue for the intervention was strongly recommended by YawMS. Recent literature supports this suggestion; for example, an external de-medicalized venue was preferred for physical intervention for stroke patients (Young et al., 2021).

An overview of the ESPRIMO intervention: A summary of the co-creation outcome

Based on the suggestions regarding possible barriers to participation, the ESPRIMO program has been designed to maximize the effects on wellbeing while also considering accessibility and people's difficulties in participating in too many encounters due to personal reasons.

Considering also the AB suggestions and previous literature recommendation for incorporation of at least one booster session to extend the length of the intervention to a minimum of 3 months in psychological interventions for adolescents and young adults living with chronic illnesses (Sansom-Daly et al., 2012) the intervention has been designed to last 10 weeks with 12 total encounters (one encounter per week except for the first and last week of intervention that have two encounters each), plus one booster session 1 month after the end of the intervention (see Figure 2 for an overview). The booster included a follow-up psychological session which might enhance retention and memory of intervention concepts consolidating what has been practiced during the intervention through a review of the principal constructs (Lochman et al., 2014). Moreover, based on suggestions collected during the focus group, an informal event that welcomed all participants and their beloved followed the formal part of the booster session.

Three different timeframes (lunch break, afternoon, and evening) have been offered to foster participation. Psychological sessions focused mainly on the preferred objectives that emerged in the co-creation; for the physical activity, swing dance sessions were held by trained specialists that could adapt the activities based on the participants' physical abilities. One psychologist was always present during each session to motivate the participation and to serve as a reference person during the intervention in order to potentially manage the psychological barriers.

Even if contrasting opinions were collected during the different co-creation steps regarding the modalities of the intervention, in-person encounters were chosen given the lifting of preventative measures during the period of the start of the intervention and to account for the desire of human contact after a long period of social distancing. However, personal protective equipment was mandatory during in-person encounters to increase patient safety. Moreover, in addition to the group psychological and physical

group face-to-face activities, to foster independence and give the possibility to practice in the most convenient moment of the day (as suggested by participants), YawMS are invited to do some short psychological and physical exercises that were guided by a manual and videos/audios shared on a dedicated Telegram channel. The Telegram channel also allows for informal communication between participants as a space to share thoughts, doubts, or improvements.

All group activities were held in a neutral venue not connected with the health services: a villa managed by a non-profit association that pursues civic, solidarity and social utility purposes by hosting different projects dedicated to the community, young people, and vulnerable people. The building is surrounded by nature, based on participants' suggestions and the literature on the positive effect of nature on wellbeing (Bratman et al., 2019; Rogerson et al., 2020; Taylor et al., 2022). In order to facilitate accessibility, as suggested by the results of the co-creation, the venue has been selected considering the connection with the city center and its services (e.g., easy parking and disabled access).

Strengths and limits

To the best of our knowledge, no previous study investigated the needs and preferences of YawMS regarding a biopsychosocial intervention and involved those patients in the co-creation process, making the paper particularly innovative in this field. Moreover, due to the COVID-19 scenario, an adaptation of the methods used for the co-creation process has been implemented, with online modalities for the surveys, FGs and AB discussion. As a further strength, representatives for each psychological, physical, and social domain have been included as stakeholders in the different steps of the co-creation process, together with YawMS representatives. Moreover, a representative of MS patients was also involved in the design of the manual and the revision of this manuscript.

The majority of YawMS included in the surveys and focus groups were female, which, however, is in line with the higher frequency of MS diagnosis in females. The paper presents some limits; a relevant limit is that almost all respondents reported a diagnosis of relapsing–remitting MS, and patients with other types of MS and higher disability were less represented. The preferences and perspectives of those patients should be further explored in future research.

Conclusion

The co-creation process described in the current paper allowed to integrate evidence from the literature and the clinical expertise of the researchers from the ESPRIMO project with the perspective of the MS main stakeholders (YawMS and HCPs) and to inform the design of the ESPRIMO intervention. Moreover, engaging patients in a meaningful way and fostering an alliance between researchers and patients (emphasizing active involvement, reciprocity, and mutual learning during co-creation) might have empowered patients and reduced the power imbalance between them and researchers.

Preferences and perspectives of YawMS on the relevance, the objectives, modalities, and timing of the intervention but even on strategies to promote participation have been described and might enrich with insights future interventions development and research in the chronicity field. Moreover, the current paper outlined in detail a participative methodology as a model of co-creation in practice which might be replicated in future research on other CDs.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors upon reasonable request.

Ethics statement

The studies involving human participants were reviewed and approved by the Ethical Committee of the Verona Hospital (Prog 2676CESC). The patients/participants provided their electronic informed consent to participate in this study.

Author contributions

VD and MR: conceptualization. VD, SP, and MR: data collection and curation. VD, SP, MR, FG, and AG: participant recruitment. SP and VD: formal analysis. SP, MR, and VD: methodology and writing—original draft. AG, MM, FG, VB, LP, and FS: writing—review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.1042234/full#supplementary-material

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The impact of built environment on physical activity and subjective well-being of urban residents: A study of core cities in the Yangtze River Delta survey

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Objective: In cities with high population density in China, the impact of built environment on human health is rather complicated. Physical activities are an important factor in promoting people's health. This study is aimed to explore ways of enhancing the residents' intensity of physical activities and psychological health in a limited built environment. For this purpose, this study conducted research on 1875 residents from cities in the Yangtze River Delta in China to clarify the complicated correlations among the residents' physical activities, the multi-dimensional geographic environment characteristics, and subjective well-being.

Methods: First, Neighborhood Environment Walkability Scale (NEWS-A), International Physical Activity Questionnaire Short Form (IPAQ-SF), and Subjective Well-being Scale for Chinese Citizens (SWBS-CC) were used to measure built environment characteristics, intensity of physical activities, and subjective well-being. Second, the correlations among built environment, physical activities, and subjective well-being were analyzed, which reflected different effects of built environment characteristics on physical activities and subjective well-being. Third, physical activities were viewed as a mediating variable in SEM to analyze the influence mechanism of each built environment characteristic on the subjective well-being of residents.

Result: Residents with different individual characteristics may have different levels of perception and usage of built environment. The intensity of physical activities has significant positive correlations with proximity to supporting facilities, accessibility of destinations, and public security, while no significant correlation with overall environmental aesthetics and street connectivity. The residents' subjective well-being has significant positive correlations with accessibility of destinations, overall environmental aesthetics, and public security, while no significant correlation with proximity to supporting facilities and street connectivity. Physical activities not only have a direct effect on subjective well-being, but also a mediating effect on the correlations between subjective well-being and built environment characteristics.

Conclusion: In the future, more research could be conducted on the optimization of correlations between residential built environment characteristics and physical activities as well as subjective well-being, so

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as to gain a deeper understanding about the impact of residential built environment on people's physical and mental health.

KEYWORDS

built environment, physical activities, subjective well-being, mental health, cities of Yangtze River Delta

Introduction

As urbanization expands globally, cities have markedly improved people's health with better medical services and mature infrastructure. However, the fast-speed expansion has also led to problems such as chronic diseases and mental illnesses. A large number of studies have shown that public health is closely related to built environmental factors such as urban land use, development density and transportation system (Lin and Yang, 2015). A good residential environment can not only promote healthy physical activity, reduce the risk of obesity, cardiovascular disease and other chronic diseases, but also provide people with psychological recovery and mental release, thus promoting mental health and improving happiness (Zhao et al., 2022). In 1984, WHO initiated the Healthy Cities Campaign and identified the urban built environment as an important factor affecting public health. Thus, the built environment became an important entry point for human settlements planning to actively intervene in health (Lu and Tan, 2015).

Social ecological model, the theoretical basis of healthy city, believes that people's health status is subject not only to their genes and roles in social and economic lives, but also to the external built environment, social environment, and natural environment (Sallis, 2009). As technologies such as GIS, RS, and GPS get mature, scholars of geographics start to consider built environment characteristics and believe that a positive and friendly urban environment encourages the residents' participation in physical activities and is conducive to human health (Lu and Qin, 2013).

Built environment refers to the sum of physical characteristics that encompass the surroundings, or a spatial combination of various physical environmental characteristics such as land use, transportation system, and infrastructure (Timmermans et al., 2016). In early time, Cervero et al. proposed a 3D conceptual model of built environment, which comprises density, diversity, and urban design (Cervero and Kockelman, 1997). On that basis, Ewing et al. added two more concepts, namely accessibility of destinations and distance to transit, forming a new "5D" model (Ewing and Cervero, 2001). In research on built environment and physical activities by Boarnet and others, environment characteristics such as population density, employment density, distance to transit, and distance to city center exhibit a significant impact on residents' physical activities (Boarnet et al., 2008). The higher the degree of mixed land use, the more convenient it is for people to travel. When the travel distance gets shorter, people are more likely to choose green travel and thus have more physical activities (Saelens and Handy, 2008). Oakes et al. also found that, a compact community of high density could encourage the residents to travel more on foot or by bike, which also means more physical activities (Oakes et al., 2007; Forsyth et al., 2008). Besides, the distance from the residential area to the entertainment area, well-equipped sports courts, well-designed streets, and walkable residential environment also have significant correlations with green travel frequency and physical activities (Koohsari et al., 2015). According to existing literature, the academia has reached a consensus on how destination accessibility and distance influence the residents' physical activities: the higher the accessibility of destinations, the shorter the travel distance, the more likely that people would travel on foot or by bike, and the more physical activities they will have (Heinen et al., 2009). According to Kerr, Galvez, Wendel et al., people's walking is positively correlated to sidewalks connection. A clearer street network helps increase physical activities like walking or biking (Kerr et al., 2006; Wendel-vos et al., 2007; Galvez et al., 2009). Children and teenagers would participate more in outdoor activities when they believe there is a safe and large activity space (Nuno et al., 2010).

Mental health is usually reflected in two aspects, namely positive development and no psychological disorders (Robert, 2012). Positive development means realizing subjective well-being, perceived self-efficacy, autonomy, intelligence, and emotional potentials (World Health Organization, 2001). Subjective well-being is often known as a person's subjective feelings affected by his or her possession of environmental resources during his or her interactions with the external environment and is closely related with subjective behaviors (Pacione, 2003). It could be influenced by various factors, which can be summarized into two aspects: external environment characteristics (e.g., behaviors, social culture, education, economy, geography, life incidents, aesthetics) and individual characteristics (e.g., genetics, cognition, personalities, moral ethics; Steptoe, 2019). Good built environment design can guide the living state of residents and thus affect the subjective well-being. In research on built environment and subjective well-being by Dong and others, a higher degree of mixed land use improves living convenience and thus people's well-being (Dong et al., 2018). Ma and Rao believed that a higher land-use mixing degree may be beneficial to improve residents' happiness due to its convenience (Ma et al., 2020). Neil Harris and Huw Thomas also found that diversified public activity places and perfect entertainment facilities can improve the quality of life and happiness of residents (Harris et al., 2008). Su and Zhou believed that the increase in the number of daily living facilities can

improve residents' subjective well-being (Su et al., 2019). But other studies have found no significant relationship between diversity and happiness (Cao, 2016; Jie and Bindong, 2017). While the correlations between subjective well-being and accessibility of destinations, including accessibility to medical facilities, entertainment, accessible stores, and education institutions, vary in different research regions and groups. However, most existing results show positive relationships between subjective well-being and accessibility of destinations (Brereton et al., 2011; Morrison, 2011). Ambrey and Fleming believed that in the design of urban built environment, green landscape also has a positive effect on people's mental health and well-being (Ambrey and Fleming, 2014). According to Ballas and Tranmer, a good security situation can often improve the subjective well-being of individuals (Ballas and Tranmer, 2012).

From the perspective of behavior studies, human sense of well-being could result from various behaviors for various reasons. In addition to directly affecting people's physical activity and subjective well-being, built environment can also have indirect effects on subjective well-being through sports participation behavior. From the perspective of "social psychology," people's psychological perception should include happiness，which is the unique experiences going through by individuals (Taylor et al., 1997). Sports participation can eliminate mental tension and stress, reduce depression, enhance physical fitness, and thus produce subjective well-being (Donaldson et al., 2011). From the perspective of "social capital," through social interaction and social communication with others in the process of sports participation, individuals can gain social capital like trust or social support (Frey and Stutzer, 2010), which in turn could escalate individual's happiness level (Krause and Wulff, 2005; Dolfsma and Davis, 2009; Growiec and Growiec, 2011). Most of the empirical results also show that sports participation has a certain positive effect on subjective well-being (Liu, 2016; Schmiedeberg and Schröder, 2017). In Craveiro and Erin's research, they pointed out that accessibility to public space like green land and parks not only directly promotes human health but also indirectly by creating opportunities for outdoor physical activities, and increasing social interactions and community participation (Erin et al., 2015; Craveiro, 2017). Florindo studied the relationship between leisure-time walking and the presence of public open spaces such as parks, bike paths and squares, and showed positive correlation between promotion of physical activity among adults and the existence of aforementioned open spaces (Florindo et al., 2017). However, some other scholars found that such effects on health were overestimated. For example, Kawachi and Berkman thought that health-promotion environment may not bring much improvement in public health, while collective community operation, which includes culture and norms, community integration, community support system, etc. turns out to be a more decisive social factor for individual health (Kawachi and Berkman, 2000; Lindstrom et al., 2002).

Urbanization, fast growing population, gathering of industries in big cities have caused huge demands for all type of resources and have led to a series of environmental issues, and they are becoming a great impact on living environments of human being as well as threatening human being's safety and health. As design for healthy living has become a new trend in developed countries, it is important to emphasis public health as a crucial option in urban residential built environment design and construction (Patrick et al., 2005). Although many scholars from highly urbanized countries have found significant correlations between built environment, physical activities, and subjective well-being in their research. However, the impact mechanism of the built environment on people's physical and mental health is very complex, due to comprehensive impact of cultural, social and economic conditions and personal lifestyle. On the one hand, for the action of built environment on physical activity and subjective well-being, the impact mechanism is still weak, and the impact path is still not clear enough. On the other hand, these results cannot be directly referenced from cities with high population density in developed countries as most of them are in Europe and the US where there is sparse population and advanced economy. The Yangtze River Delta region is the area with the highest degree of urbanization, the densest urban distribution and the fastest population growth in China. It is also the area with rapid growth of urban expansion. The population growth rate is fast and the density is relatively concentrated. The convergence of population, land, and capital in cities had boosted the continuous outward expansion of urban (Huang et al., 2021). Therefore, it is of great significance to study how to build urban residential built environment of the cities in the Yangtze River Delta of China to promote public health during unban expansion. The results could be referenced for other rapidly expanding cities especially cities in those developing countries with similar urban expansion scale as in the Yangtze River Delta of China.

This study, based on the existing research results in domestic and foreign academia and by using the micro research paradigm of individual behaviors, proposed a theoretical framework featuring "built environment – physical activity – subjective well-being" after investigating the complicated correlations among the residents' daily behaviors, the multi-dimensional geographic environment characteristics, and subjective well-being. In this analysis model, individual characteristics are the controlled variables, built environment characteristics are the independent variables, and physical activities and subjective well-being are the dependent variables (Figure 1). Based on the analysis above, three hypotheses are put forward as follows:

> *Hypothesis 1*: Built environment characteristics have a positive effect on the residents' physical activities.
>
> *Hypothesis 2*: Built environment characteristics have a positive effect on the residents' subjective well-being.
>
> *Hypothesis 3*: Physical activities have a mediating effect on the correlations between subjective well-being and built environment characteristics.

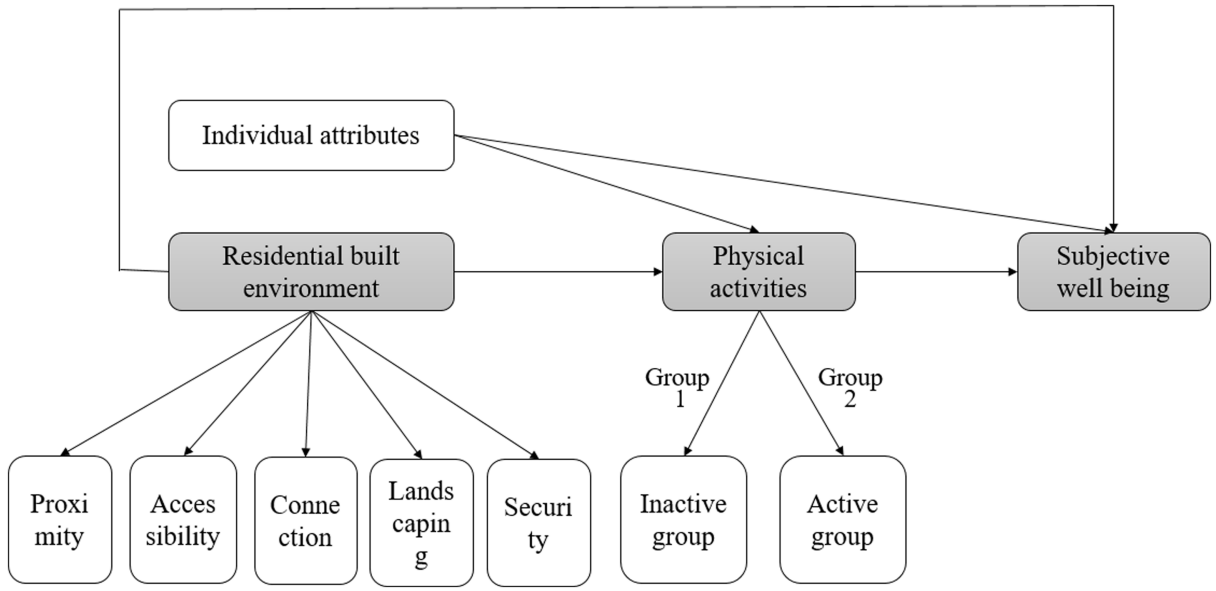

FIGURE 1
Theoretical framework of "Environment-Activity-Health."

Materials and methods

Study area

This study selects the expanding cities in the Yangtze River Delta as the study area. Hereby the expanding cities mainly refer to mega cities, super-large cities, and large cities with urban population over 1 million (Fang, 2014), and they have the potential to have a growing population in the near future. According to the Yangtze River Delta Urban Agglomeration Development Plan approved by the State Council in 2016, the Yangtze River Delta will be built into a world-class urban agglomeration of world-class quality by 2030. In the future, regional population and economic factors will further gather, urban space will further expand, and the environmental impact of urbanization will further intensify. Shanghai, Hangzhou, Nanjing and Hefei, as important cities in the Yangtze River Delta urban agglomeration, have witnessed rapid growth in urbanization rate in recent years. As of 2020, the urbanization rate of Shanghai has reached 89.3%, and the urbanization rate of the other four cities have also been above 80%.

Study design and participants

This study used a cross-sectional survey on the relationship between the environment characteristics in the residential areas in cities of Yangtze River Delta and the residents' physical activities and subjective well-being. Research subjects are urban residents in Shanghai, Hangzhou, Nanjing, Hefei, whose residential areas all present multiple built environment characteristics. This study ran from February to August 2022. Choose different types of communities in each city, such as traditional old communities and modern commercial housing communities. A total of 2,500 questionnaires were randomly distributed through the neighborhood committees of each community. 2,037 samples were recovered with a recovery rate of 81.48%. Respondents aged over 65 were instructed by trained interviewers when filling in the questionnaires. After deleting the invalid answers, the study collected 1875 questionnaires (the effective rate is 91.95%), among which 893 were from male respondents and 982 were from female respondents.

And this study complies with the Declaration and Helsinki, and ethical approval was granted by the Chinese ethics research review board. All respondents agreed to the experimental agreement and signed an informed consent form.

Measures

Measure of residential built environment characteristics

Residential built environment characteristics were measured with the abbreviated form of Neighborhood Environment Walkability Scale (NEWS-A) by Cerin et al. to evaluate the respondents' perception of their residential areas related to physical activities (Cerin et al., 2006). The scale has been verified to be effective when used in Chinese Mainland (Zhou et al., 2011; Yukun et al., 2012). It includes 24 items in 5 dimensions, namely proximity to supporting facilities, accessibility of destinations, street connectivity, overall environmental aesthetics, and public security. Proximity to supporting facilities means whether there are outdoor courts, indoor sports venues, sidewalks or cycling roads nearby and

whether the sports equipment is available, 5 questions in total. Accessibility of destinations refers to the accessibility from the residential area to public areas like sports venues, squares, bus stations, shopping malls, and parks, 6 questions in total. Street connectivity refers to the number of crossroads and streets, and the conditions of street lighting, pavement, and hygiene, which reflect the convenience of accessing public areas like sports venues, shopping malls, and parks, 4 questions in total. Overall environmental aesthetics is the aesthetic attraction of the surrounding natural environment, buildings, greenness, and public green sidewalks, 5 questions in total. And public security is the security level of the residential area and its traffic conditions, 5 questions in total. The scale is designed in five-point style, where 1 stands for "totally disagree," 2 for "disagree a little," 3 for "neutral," 4 for "agree a little," and 5 for "totally agree." The score of each dimension is the average score of all items in each dimension. Higher points indicate higher degrees of satisfaction toward residential built environment (Xie and Peng, 2021). In this measurement: Cronbach's $\alpha = 0.953$, KMO = 0.910, and Bartlett $p < 0.001$. Internal consistency reliability for the 5 dimensions: respectively 0.942, 0.832, 0.868, 0.857, and 0.873, indicating that the scale is of well validity and reliability and is suitable for factor analysis.

Measure of physical activities

The measure of physical activities in this study adopted the International Physical Activity Questionnaire Short Form (IPAQ-SF), which is commonly used in Chinese Mainland and is regarded as a scientific tool for measuring adults' physical activities (Qu and Li, 2004). The questionnaire is composed of seven questions and categorizes activity intensity into three levels, namely low, medium, and high levels (Elahi et al., 2021, 2022). According to the frequency and time of three kinds of physical activities per week, the physical activities level of residents can be calculated and the physical activities participation of residents can be measured. The specific formula is:

$$\text{Physical activities level} = (3.3 \times A \times a) + (4 \times B \times b) + (8 \times C \times c).$$

A, B and C represent the frequency of low, medium and high intensity physical activities. a, b and c represent the average time spent doing low, medium and high intensity physical activities. 3.3, 4, and 8 represent the metabolic equivalent (METs) assignment of each low, medium and high intensity physical activities (Jing and Chunzheng, 2021).

Evaluation standards for different intensity levels of weekly physical activities are shown in Table 1. Research subjects are further divided into two groups, namely the active group and the inactive group based on their intensity of physical activities. The active group include those of high-and medium-level physical activities and the inactive group include those of low-level physical activities.

Measure of subjective well-being

The subjective well-being was measured with the Subjective Well-being Scale for Chinese Citizens (SWBS-CC20) by scholar Xing Zhanjun from Chinese Mainland. With reliability of 0.848 and validity of 0.972, the scale is an effective measurement in research of urban citizens in Chinese Mainland. This scale is a six-level Likert scale. It contains 20 items in 10 dimensions (Each dimension contains two items), including satisfaction and abundance, mental health, confidence towards society, growth and progress, goal and personal value, self-acceptance, physical health, psychological balance, adaptation to interpersonal relations, and family atmosphere (Xin, 2003). Each question in the subjective well-being scale form used in this study adopts a 6-level scoring system, which is divided into "completely disagreed, disagreed, slightly disagreed, slightly agreed, agreed and completely agreed," with 1 to 6 points, respectively. Question number 4, 5, 6, 9, 10, 11, 13, 15, 17, 18, and 20 are scored inversely. The overall well-being score is the average of the total scores of 20 questions. According to Xing, the higher the respondent's score, the happier he is. A score above 4.5 is considered high, and a score below 2.5 is considered low (Xin, 2009). In this measurement: Cronbach's $\alpha = 0.856$, KMO = 0.879, and Bartlett $p < 0.001$, indicating that the scale is of well validity and reliability and is suitable for factor analysis.

Statistical analyses

The statistical analyses were conducted with SPSS 23.0 and Amose23.0. The level of statistical significance was set at $p < 0.05$. The descriptive characteristics were summarized and presented as mean and standard deviation (SD), count and percentages. Firstly, this study used SPSS to conduct descriptive statistics on the differences in the perception of the built environment, physical activity and subjective well-being of residents with different individual characteristics.

Secondly, people may have different levels of perception and usage of built environment due to different individual

TABLE 1 Evaluation standards for different intensity levels of weekly physical activities (Chen et al., 2019).

Intensity levels of physical activities	Evaluation Standards
High-level physical activities (meeting any of the two standards)	(1) Over 3 days of high-level physical activities a week, with 1,500-MET energy consumed in total.
	(2) Seven days of high-or medium-level physical activities a week, with 3,000-MET energy consumed in total.
Medium-level physical activities (meeting any of the three standards)	(3) At least 3 days of high-level physical activities a week, each over 20 min.
	(4) At least 5 days of medium-level physical activities, or walking for over 30 min every day.
	(5) At least 5 days of high-or medium-level physical activities a week, with 600-MET energy consumed in total.
Low-level physical activities	(6) Not meeting the standards of high-or medium-level physical activities.

characteristics (Smith et al., 2012; Wang and Jiao, 2018). Therefore, these individual characteristics were measured at baseline and were incorporated as potential confounders in the regression model. This study first conducted collinearity diagnostics on the variables of individual characteristics (gender, age, educational attainment, income) and built environment (proximity to supporting facilities, accessibility of destinations, street connectivity, overall environmental aesthetics, public security). According to the results, there is no collinearity between built environment and individual characteristics (Sun, 2005). Then, independent sample t-test and one-way ANOVA were used to select controlled variables through the test of the difference between physical activity, subjective well-being and gender, age, educational attainment, and income.

Thirdly, to verify the correlations between physical activities and residential built environment, independent sample t-test was used to compare the perception of built environment of respondents of different intensity levels of physical activities. With variables controlled, the correlations between physical activities and proximity to supporting facilities, accessibility of destinations, street connectivity, overall environmental aesthetics, and public security were tested with binary logistic regression. And to verify the correlations between subjective well-being and residential built environment, with variables controlled, the correlations between subjective well-being and proximity to supporting facilities, accessibility of destinations, street connectivity, overall environmental aesthetics, and public security were tested with linear regression. The results were presented as OR with 95% confidence interval (CI).

Finally, and the study adopted Bootstrap (under 95% CI and sampling for 5,000 times) to figure out whether the physical activities have a mediating effect on the correlations between subjective well-being and residential built environment.

Results

Descriptive analysis results of the variables

Dependent variables are the residents' physical activities and subjective well-being. Independent variables include the 5 dimensions of built environment, namely proximity to supporting facilities, accessibility of destinations, street connectivity, overall environmental aesthetics, and public security. Individual attributes variable refer to Demographic variables, including gender, age, educational attainment, and income. The descriptive analyses were conducted on the physical activities, subjective well-being, and residential built environment characteristics.

As shown in the results, the inactive group has 765 respondents, accounting for 40.80% of the total and the active group has 1,110, accounting for 59.20% of the total. The average score of well-being reached 4.16, which is a relatively high level. Among the perceived scores of the five dimensions of the built environment, public security's > overall environmental aesthetics > accessibility of destination > proximity to supporting facilities > street connectivity (Table 2).

Perception differences of built environment, physical activity, and subject well-being by residents with different individual characteristics

Difference analysis on perception of built environment By residents with different individual characteristics

Firstly, as found in the survey on the perception of built environment conducted on residents with different individual characteristics (Table 3): female residents share the similar scores in four out of five perceptional assessments, except in perception of public safety, where female scored (3.80) slightly lower than male (3.91). For residents age 14–25, they scored the highest, whereas for residents age between 25 and 45, they scored the lowest. Furthermore, for residents with varying educational background, those with high school diploma or below scored the highest. For residents with different financial status, those with middle or high incomes scored higher in general than those with lower incomes.

Difference analysis on physical activity of residents with different individual characteristics

Secondly, as found in the survey regarding physical activities of residents with varying individual characteristics, inactivity is more common among females than males. The study also shows that among residents age 14–25, the inactive rate is the lowest (16.38%), among residents age between 46 and 59, the rate is 40.46%, and among senior residents, the rate is 61.72%. Moreover, the results vary among residents with different educational background: residents with undergraduate degree have the inactive rate of 35.51%, compared to the inactive rate of 52.91% among residents with vocational college degree, and 40.65% with graduate degree or above. The results also suggest that inactivity vary among residents with different financial status. Those with high incomes have the lowest inactive rate (37.19%), those with medium incomes have the rate of 40.48%, and those with low incomes have the highest rate of 46.67%.

Difference analysis on subject well-being of residents with different individual characteristics

Finally, as found in the survey on the subjective well-being of residents with different individual characteristics: women's subjective well-being (4.19) is higher than men's (4.12). For residents of different ages, people aged 46 to 59 have the greatest sense of subjective well-being (4.30). However, people aged 25–45

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TABLE 2 Results of descriptive analyses of the variables.

Variable		Total ($n = 1875$)	M (%)	SD
Dependent variable	**Physical activities**	1875		
	Inactive group	765	40.80	
	Active group	1,110	59.20	
	Subjective well-being	1875	4.16	0.63
Independent variable	**Built environment**	1875		
	Proximity to supporting facilities	1875	3.57	0.89
	Accessibility of destinations	1875	3.59	0.94
	Street connectivity	1875	3.54	1.23
	Overall environmental aesthetics	1875	3.60	0.82
	Public security	1875	3.85	0.81
Individual attributes variable	**Gender**			
	Male	893	47.60	
	Female	982	52.40	
	Age			
	14 < 25	457	24.40	
	25–45	468	25.00	
	46–59	576	30.70	
	≥60	374	19.90	
	Educational attainment			
	High school or less	658	35.10	
	Vocational college	343	18.30	
	Undergraduate degree	673	35.90	
	Graduate degree or above	201	10.70	
	Income			
	<4,000 RMB	444	23.70	
	4,000–8,000 RMB	1,054	56.20	
	>8,000 RMB	377	20.10	

TABLE 3 Perception differences of built environment, physical activity, and subject well-being by residents with different individual characteristics.

Variable	Proximity to supporting facilities	Accessibility of destinations	Street connectivity	Overall environmental aesthetics	Public security	Inactive rate	Subjective well-being
Gender [M (%)]							
Male	3.55	3.59	3.50	3.57	3.91	43.73	4.12
Female	3.59	3.60	3.54	3.61	3.80	39.93	4.19
Age [M (%)]							
14 < 25	3.77	3.88	3.76	3.73	3.97	16.38	4.21
25–45	3.39	3.50	3.28	3.49	3.71	50.18	4.00
46–59	3.58	3.57	3.54	3.61	3.88	40.46	4.30
≥60	3.55	3.40	3.49	3.55	3.85	61.72	4.10
Educational attainment [M (%)]							
High school or less	3.70	3.71	3.64	3.75	4.00	41.83	4.23
Vocational college	3.52	3.28	3.27	3.50	3.73	52.91	4.08
Undergraduate degree	3.48	3.64	3.56	3.53	3.83	35.51	4.07
Graduate degree or above	3.56	3.62	3.41	3.48	3.70	40.65	4.26
Income [M (%)]							
<4,000 RMB	3.55	3.58	3.39	3.59	3.80	46.67	4.02
4,000–8,000 RMB	3.60	3.55	3.56	3.61	3.87	40.48	4.16
>8,000 RMB	3.54	3.73	3.57	3.55	3.88	37.19	4.29

(4.00) and over 60 (4.10) had relatively low subjective well-being. For residents with different levels of educational attainment, the highest score goes to graduate degrees above (4.26). And for residents of different economic statuses, their subjective well-being decreases successively from the high-income group (4.29) to the low-income (4.02).

The impact of the variables of residential built environment on the residents' physical activities and subjective well-being

With a normal distribution of the data, this study further verified the correlations between the residents' physical activities, subjective well-being, and built environment characteristics. According to the results, every two variables are positively correlated with $p < 0.01$, which is of statistical significance. Besides, the results indicate independence of the variables, meaning they are valid for further statistical analyses.

The impact of the variables of residential built environment on the residents' physical activities

Independent sample t-test was used to compare the scores of respondents of different intensity levels of physical activities (the active group and the inactive group). As shown in Table 4, the active group has higher average scores in proximity to supporting facilities, accessibility of destinations, street connectivity, overall environmental aesthetics, and public security than those of the inactive group. All the data in the table have significant difference ($p < 0.01$).

Binary logistic regression was used to analyze the correlations between the residents' physical activities and residential built environment characteristics. Based on above, analyses were conducted with age as the controlled variable, physical activities as the dependent variable, and the five residential built environment characteristics as the independent variables. As the results shown in Table 5, three out of the five environment characteristics, namely proximity to supporting facilities, accessibility of destinations, and public security are of statistical correlations with physical activities, or in other words, have impact on physical activities. More specifically, the residents would have more physical activities when the community is of high security level and has supporting facilities and sports venues that are easy to access. While no significant correlation was discovered between physical activities and street connectivity as well as overall environmental aesthetics.

The impact of the variables of residential built environment on the residents' subjective well-being

In the analysis of the correlations between the residents' subjective well-being and residential built environment characteristics, linear regression was adopted. Based on above, analyses were conducted with age, educational attainment, and income as the controlled variables, subjective well-being as the dependent variable, and the five residential built environment characteristics as the independent variables. The results are shown in Table 6, which presents statistical correlations between subjective well-being and three environment characteristics, namely accessibility of destinations, overall environmental aesthetics, and public security. In other words, residents' subjective well-being could be influenced by these three characteristics.

TABLE 4 Correlation analysis of physical activities and residential built environment characteristics.

Variable	Inactive group ($n = 765$)	Active group ($n = 1{,}110$)	t	p
	M SD	M SD		
Proximity to supporting facilities	3.295 ± 0.900	3.765 ± 0.834	−11.593	0.000
Accessibility of destinations	3.102 ± 0.947	3.933 ± 0.779	−20.791	0.00
Street connectivity	3.222 ± 1.252	3.762 ± 1.182	−9.487	0.00
Overall environmental aesthetics	3.407 ± 0.882	3.729 ± 0.745	−8.534	0.00
Public security	3.633 ± 0.794	4.009 ± 0.800	−10.040	0.00

TABLE 5 Logistic regression analysis of physical activities and residential built environment characteristics.

Variable	B	OR	p	95%CI	
				Lower	Upper
(constant)	−4.583	0.010	0.000		
Proximity to supporting facilities	0.139	1.149	0.030	1.013	1.303
Accessibility of destinations	1.021	2.775	0.000	2.410	3.194
Street connectivity	0.051	1.052	0.298	0.956	1.158
Overall environmental aesthetics	0.132	0.876	0.140	0.735	1.044
Public security	0.339	1.404	0.000	1.193	1.652

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TABLE 6 Regression analysis of subjective well-being and residential built environment characteristics.

Variable	*B*	Beta	*t*	*p*	95%CI	
					Lower	Upper
(constant)	3.066	0	30.631	0.000	2.870	3.262
Proximity to supporting facilities	0.008	0.012	0.393	0.694	−0.033	0.050
Accessibility of destinations	0.040	0.060	2.489	0.013	0.009	0.072
Street connectivity	−0.017	−0.034	−1.369	0.171	−0.042	0.007
Overall environmental aesthetics	0.091	0.117	4.062	0.000	0.047	0.134
Public security	0.174	0.022	8.028	0.000	0.132	0.217

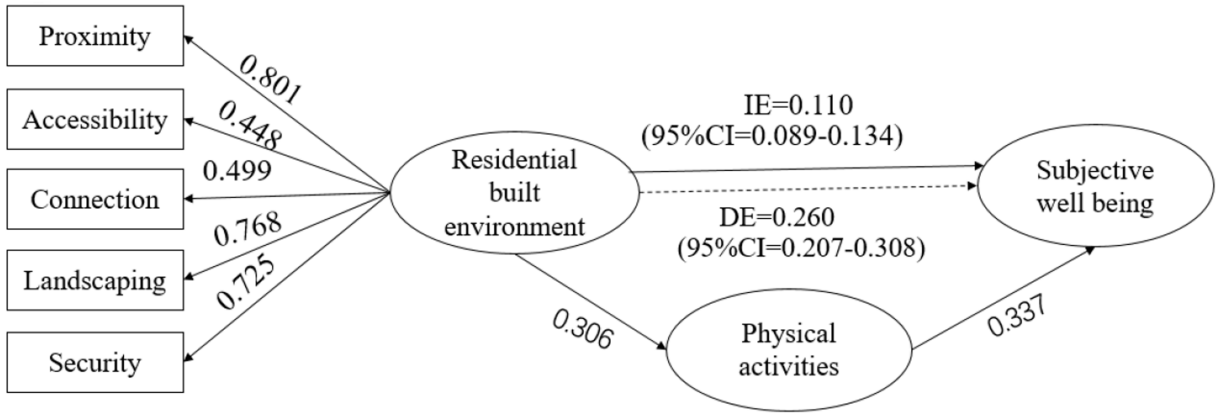

FIGURE 2
Mediator model on residential built environment, physical activities, and subjective well-being.

People would feel happier when there are easy-to-access sports courts, a beautiful environment, and reliable public security. While the rest two environment characteristics, namely proximity to supporting facilities and street connectivity, were found to have no significant correlations with subjective well-being.

Structural equation model on the correlations between residential built environment, physical activities, and subjective well-being

This study constructed a structural equation model (Figure 2) on the correlations between residential built environment, physical activities, and subjective well-being based on the factor analyses on the data collected from the 1875 questionnaires. Table 7 presents the fit indices of the model. With $\chi 2/df = 5.183$, RMSEA = 0.078, GFI (0.952)/AGFI (0.913)/NFI (0.95)/CFI (0.953)/IFI (0.953) > 0.9, and PNFI (0.543)/PCFI (0.545) > 0.5, the fit of the model is within the acceptable range.

From Table 7, Figure 2, it can be inferred that residential built environment has a direct effect on both people's physical activities and subjective well-being, with a path coefficient of 0.306 and 0.244, respectively. Many past research has proved physical activities' function in improving subjective well-being, and their correlations are verified in this study, that is, physical activities have a direct effect on subjective well-being, with a path coefficient of 0.337. Moreover, the loadings of the environment characteristics are, respectively, 0.801 for proximity to supporting facilities, 0.768 for overall environmental aesthetics, 0.725 for public security, 0.499 for street connectivity, and 0.448 for accessibility of destinations.

This study also adopted Bootstrap (under 95% CI and sampling for 5,000 times) to test whether physical activities have a mediating effect on the correlations between subjective well-being and residential built environment. As shown in Table 8, the bias-corrected intervals of physical activities' mediating effect (0.089–0.134) and direct effect (0.207–0.308) are higher than the value of 0, indicating significant effects in both paths, respectively accounting for 29.730 and 70.270%.

This study further uses the intermediary analysis method to test whether physical activity has intermediary effects in the five characteristics of the built environment, and the test is strictly in accordance with the intermediary effect test process provided by Wen and Ye (2014). C represents the total effect when independent variable X corresponds to variable Y; A represents the effect of the independent variable X on M, b represents the effect of the corresponding variable Y of M, and A *b is the mediating effect. C 'represents the direct effect of X on Y after controlling for the mediating variable M. The conclusion of mediating effect are shown in Table 9:Physical activity played a complete mediating

TABLE 7 Path test of residential built environment, physical activities, and subjective well-being.

Path	Non-standard coefficient	Standard coefficient	S.E.	C.R.	P
Built environment——Physical activities	0.253	0.306	0.021	11.992	0.000
Physical activities——Subjective well-being	0.433	0.337	0.028	15.442	0.000
Built environment——Subjective well-being	0.260	0.244	0.026	9.931	0.000

TABLE 8 Total, direct, and mediating effects of physical activities.

Path	Effect value	SE	Bias-corrected 95%CI lower	upper	*p*	Effect percentage (%)
Mediating effect	0.110	0.011	0.089	0.134	0.000	29.730
Direct effect	0.260	0.026	0.207	0.308	0.000	70.270
Total effect	0.370	0.026	0.317	0.419	0.000	

TABLE 9 Mediating effect of intensity of physical activities on built environment characteristics and subjective well-being.

Path	c Total effect	a	b	a*b Mediating effect	a*b (95% boot CI)	c' Direct effect	Conclusion
Proximity to supporting facilities = > Physical activities = > Subjective well-being	0.071**	0.205**	0.490**	0.101	0.128 ~ 0.174	0.03**	Completely Mediator
Accessibility of destinations = > Physical activities = > Subjective well-being	0.008	−0.004	0.490**	−0.002	−0.021 ~ 0.015	0.002	No significant Mediator
Street connectivity = > Physical activities = > Subjective well-being	−0.001	0.011	0.490**	0.005	−0.006 ~ 0.028	−0.007	No significant Mediator
Overall environmental aesthetics = > Physical activities = > Subjective well-being	0.076**	0.023*	0.490**	0.011	0.002 ~ 0.035	0.065**	Partial Mediator
Public security = > Physical activities = > Subjective well-being	0.122**	0.042**	0.490**	0.02	0.002 ~ 0.035	0.101**	Partial Mediator

*$p < 0.05$, **$p < 0.01$.

role in Proximity to supporting facilities and Subjective well-being. Overall environmental aesthetics and Public security not only directly affect residents' subjective well-being, but also have indirect effects on subjective well-being through physical activities. The indirect effect value accounted for 14.73 and 16.75% of the total effect value.

Discussion

Perception features of built environment, physical activity, and subject well-being by residents with different individual characteristics

As China is under rapid development of urbanization, people have raised more diversified and personalized demands for urban lives, which are also reflected in their varying demands towards built environment. This study has proved that residents with different individual characteristics may have different levels of perception and usage of built environment (Smith et al., 2012; Wang and Jiao, 2018). This result is consistent with Cao et al., that compared with men, women are more sensitive in perceiving the microenvironment (Gao et al., 2022). The reason may be that as a vulnerable group, women are also more sensitive to environment security. The research also shows that the young and middle-aged people (25–45 years old) are less satisfied with the overall built environment while the teenagers present the greatest satisfaction. This result is consistent with Wu et al., that it is maybe because the young and middle-aged people bear more pressure and responsibility for work and family. Also, their requirements for built environment may be higher than the teenagers' (Wu et al., 2013). The high-income people show a relatively high level of satisfaction towards built environment and the low-income the least. Probably because people with higher income live in better communities with more convenient public transportation, public services, and facilities such as sports venues.

Individual characteristics including gender, age, educational attainment, and income all have an impact on the residents' participation in physical activities (De and Sallis, 2002; Poggio et al., 2016). This study has proved that people with different individual characteristics have different intensities of physical activities. Most research has concluded that lack of physical activities is more likely to happen to women than to men (Vare et al., 2003), but some attributed that to a regional issue. The study of Qiao show that in some regional men are less physically active than women (Qiao and Wang, 2015). According to analyses of this study, men have fewer physical activities than women. Meanwhile,

among different age groups, those between 46 to 50 years old have more physical activities than others. The reason may partially lie in retirement. Lahti et al. found that men near retirement would increase the time spent on medium-level physical activities by 42 min every week and women by 31 min (Lahti et al., 2011). In France, regardless of gender, people spend 2 more hours in physical activities every week after retirement (Touvier et al., 2010). In China, most women retire at the age of 50 and men at the age of 60. The retired people, especially women who retire much earlier than men, have more spare time for more physical activities. Individual characteristics of educational attainment and income present a non-linear pattern. But overall, people with undergraduate degrees or above tend to have higher intensity of physical activities than those less educated, which may be related to their awareness of the importance of physical activities. This result is consistent with Prochaska et al., that people with higher educational attainment are more likely to engage in mental work or jobs that require little physical strength. Although having fewer chances of commuting by walking or cycling, they would have more leisure physical activities as they know it is important to do so (Prochaska, 2011).

The residents' individual characteristics, namely gender, age, educational attainment, and income also have a significant impact on their subjective well-being (Helliwell and Putnam, 2004; Dolan et al., 2008; Sweet and Kanaroglou, 2016). This study has proved the relevant hypothesis. This result is consistent with the study of Gerdtham, Lin and McBride et al. Compared with men, women are easier to develop a sense of well-being (Gerdtham and Johannesson, 2001). A "U" type correlation, which decreases first and increases later, was found between age and subjective well-being (Lin and Sun, 2017). People with higher educational attainment would have greater subjective well-being. And higher income could also effectively improve subjective well-being (McBride, 2001).

The impact of residential built environment on physical activities

Factors that may influence people's physical activities are complicated and keep changing over time. The socio-ecological model regards residential built environment and public facilities as two of these factors. For example, sufficient convenient public facilities, a beautiful environment, high-level public security, low traffic flow, etc. could encourage the residents to have more physical activities (Cranney et al., 2016; Yang et al., 2017). Therefore, residential built environment is an important influencing factor of physical activities. This study verified the significant correlations between the residents' physical activities and the five residential built environment characteristics, namely proximity to supporting facilities, accessibility of destinations, street connectivity, overall environmental aesthetics, and public security. Also, residential built environment's direct effect on the elderly residents was proved with structural equation model.

Besides, in this study, residents of the active group are more satisfied with factors including proximity to supporting facilities, accessibility of destinations, and public security than those of the inactive group. And it is found that people would have more physical activities when there are sufficient convenient supporting facilities, easy-to-access sports venues, and high public security level. This result is consistent with those concluded by scholars in foreign academia. For example, Jansen et al. concluded that, better public facilities, especially entertainment facilities could increase the adults' physical activities and thus improve their health (Jansen et al., 2016). According to Van and others, safe traffic and convenient public supporting facilities that are easy to access are also conducive to the residents' physical activities (Van et al., 2012). From the above, it can be inferred that a community with good sports facilities, venues, and public areas like parks and squares that are suitable for sports exercises, as well as high public security level and low traffic flow has a certain strength in enhancing people's motivation for sports exercises and improving their status of physical activities.

No significant correlation was found between physical activities and the rest two built environment characteristics, namely overall environmental aesthetics and street connectivity. Though in some research, more streets and better street connectivity could encourage walking or cycling trips as the travel distance gets shorter and people have more choices of traveling routes (Helbich et al., 2016). Some scholars concluded that street connectivity is negatively related to the residents' walking. In an environment of high street connectivity, the elderly would have a reduced sense of security towards public transport and thus spend less time on physical activities every week (Van et al., 2011). It may be because overall environmental aesthetics and street connectivity emphasize more the improvement of urban greenness and sceneries as well as traffic conditions, which are aimed either to enhance the community's ecological and esthetical functions or to reduce its traffic jams and potential traffic danger. Providing more areas for physical activities is not the priority in the planning of overall environmental aesthetics and street connectivity. Instead, it may weaken the residents' enthusiasm for physical activities. Hence, tests on the correlations between physical activities, overall environmental aesthetics and street connectivity could draw different results.

The impact of residential built environment on subjective well-being

Subjective well-being receives multiple influences from both the physical environment and the subjective social environment. The influencing factors could be temporal-special behaviors or the multi-dimensional geographical environment. For example, land use mix, convenience and accessibility of public facilities, traffic connectivity, and the overall environmental aesthetics could improve residential subjective well-being (Ma et al., 2018). Therefore, residential built environment is an important factor that may influence subjective well-being. This study verified the significant correlations between the residents' subjective well-being and the five residential built

environment characteristics, namely proximity to supporting facilities, accessibility of destinations, street connectivity, overall environmental aesthetics, and public security. Also, the direct effect of residential built environment on subjective well-being was proved with structural equation model.

Meanwhile, this study proved that subjective well-being has significant positive correlations with accessibility of destinations, overall environmental aesthetics, and public security. Good accessibility of destinations, which includes accessibility to sports venues, public facilities, parks, green land, etc., a beautiful environment, and high public security level could improve the residents' subjective well-being. This result goes in line with those drawn by scholars in foreign academia. For example, Gao et al. proposed that short distance between destinations in daily travel encourages positive means of transportation and increases interpersonal interactions, which helps improve people's mental health (Gao et al., 2016). Andrew and Dong et al. proposed that in a beautiful environment or a green area where there is more space and opportunities for physical activities and chances to interact with others, people can better improve their interpersonal relationships and mental health (Dannenberg et al., 2011). Frank et al. believe crimes are more likely to happen in an environment with poor public security. When people feel unsafe about the environment, they would bear more mental pressure and would not prefer walking or cycling trips (Frank et al., 2019). That's because, in urban residential built environment, convenient facilities and high public security level are important premises for human interactions and connections. And green landscape inspires people's curiosity and desire for exploration, which enhances residential well-being as well as social interactions and neighborhood unity.

No significant correlation was found between subjective well-being and the rest two built environment characteristics, namely proximity to supporting facilities and street connectivity. Though in some research, a high rate of land use could increase the residents' subjective well-being as it makes the supporting facilities more convenient to use (Ma et al., 2020). Some others believed diversity has no significant relationship with subjective well-being. According to Cao, land used mix provides the residents with diversified destinations but simultaneously makes the community noisy and crowded, so its positive and negative impacts cancel each other out (Cao, 2016; Su et al., 2019). The situation is similar in the case of street connectivity. Although as noted by Leslie et al. research, higher street connectivity and crossroad density encourage walking trips and social interactions and improve mental health by creating a safe walking environment where cars drive much more slowly (Leslie and Cerin, 2008). But some research found street design may restrict residential mental health. For example, according to the research on low-income people in Southeast America by James et al., community walkability is positively correlated to depression, which is particularly true in poor areas. Because areas with high walkability are more likely to have problems like pollution and crimes, which may increase people's mental pressure and thus impair mental health (James et al., 2017). In conclusion, subjective well-being could be influenced by multiple factors such as built environment, social environment, and individual factors. And for different built environment characteristics, their impacts may be multi-dimensional and contradictory. That explains why the research results of correlations between residential built environment characteristics and the residents' subjective well-being vary from one another.

Correlations between residential built environment, physical activities, and subjective well-being

The mediator model of this study found that, physical activities have a direct effect on subjective well-being and a mediating effect on the correlations between subjective well-being and residential built environment. Physical activity played a complete mediating role in Proximity to supporting facilities and Subjective well-being. Overall environmental aesthetics and Public security not only directly affect residents' subjective well-being, but also have indirect effects on subjective well-being through physical activities. It may be because subjective well-being could be influenced by residential built environment through influence on commuting and individual health. This result goes in line with those drawn by scholars in foreign academia. For example, Craveiro and Erin et al. thought that with a higher accessibility of supporting facilities, and shorter commuting distance, the residents are more likely to choose green travel and thus have more physical activities, which in turn improve interpersonal interactions, mental health, and subjective well-being. People would commute more by walking when the community has various parks, squares, and green space, which improves health by creating more physical activities. People would also have enhanced subjective well-being after spending more time on physical activities and social interactions (Liu, 2016; Schmiedeberg and Schröder, 2017). In a beautiful environment or a green area where there is more space and opportunities for physical activities and chances to interact with others, people can better improve their interpersonal relationships and mental health (Dong and Qin, 2017). Meanwhile, a clear street network, safe traffic, and high public security level increase physical activities by encouraging the residents to commute by walking and enhance people's physical and mental health as they feel safe and more comfortable when having sports activities.

Taken together, future planning on the construction of residential built environment in cities can be approached in the following aspects: (Lin and Yang, 2015) Under the backdrop of rapid urbanization, the residential built environment in cities shall try best to satisfy the needs of different social strata, especially the elderly, the female, the low-income, and the less educated groups. We shall maximize the aggregate of happiness by enhancing policy support for the improvement of old urban communities and the optimization of built environment that faces the whole society (Zhao et al., 2022). Supporting facilities for living and physical activities shall be easy to use and access with a diversified functional layout, so as to meet the various needs of the residents (Lu and Tan, 2015). Planning of

activity venues in the residential area shall take full consideration of building practicability, environmental openness, and landscape aesthetics. Space and environment design are not only visual aesthetics for the residents, but also bear the responsibility to realize harmonious coexistence between man and nature. Outdoor built environment would be used more when people perceive a shorter distance to nature (Sallis, 2009). Street connectivity and security shall be improved with reasonable planning of public areas and outdoor activity space such as squares, parks, and green sidewalks. Measures shall be taken to reduce traffic flow and speed of motorized vehicles, so as to create a comfortable and safe environment for walking and cycling. It is also important to set up enough accessible facilities to meet the travelling needs of the vulnerable.

Limitations and future directions

First, the study used a cross-sectional survey to explore the correlations between residential built environment, physical activities, and subjective well-being in cities of Yangtze River Delta. As it did not conduct longitudinal research, the results cannot explain the mutual influence between the variables. Second, this study used subjective measurements. While in future research, more objective research methods shall be considered to produce more objective results, such as GIS for the measure of built environment and accelerometer for physical activities. Third, in the next step, social environment and neighborhood relationship could be researched as another two influencing factors of physical activities and subjective well-being, so as to optimize the correlation model of residential built environment, physical activities, and subjective well-being.

Conclusion

Lin and Yang (2015) residents with different individual characteristics may have different levels of perception and usage of built environment (Zhao et al., 2022). The intensity of physical activities has significant positive correlations with proximity to supporting facilities, accessibility of destinations, and public security ($p < 0.05$), while no significant correlation with overall environmental aesthetics and street connectivity (Lu and Tan, 2015). The residents' subjective well-being has significant positive correlations with accessibility of destinations, overall environmental aesthetics, and public security ($p < 0.05$), while no significant correlation with proximity to supporting facilities and street connectivity (Sallis, 2009). Built environment characteristics have a direct effect on the residents' physical activities and subjective well-being, with an effect value of 0.343 and 0.238, respectively. Physical activities not only have a direct effect on subjective well-being, with an effect value of 0.304, but also a mediating effect on the correlations between subjective well-being and built environment characteristics, which accounts for 30.42% of the total effect (Lu and Qin, 2013). Physical activity played a complete mediating role in Proximity to supporting facilities and Subjective well-being. Overall environmental aesthetics and Public security not only directly affect residents' subjective well-being, but also have indirect effects on subjective well-being through physical activities. The indirect effect value accounted for 14.73 and 16.75% of the total effect value.

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 Human Research Ethics Committee of Shanghai International Studies University. Written informed consent to participate in this study was provided by the participants, and if necessary, their legal guardian/next of kin.

Author contributions

JZ designed the research and wrote the manuscript. YZ undertook the statistical analysis. MY and TW aided in reference collection and summary as well as participated in the manuscript preparation. QMF directed the research process and revised the draft. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

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Effects of physical activity on regulatory emotional self-efficacy, resilience, and emotional intelligence of nurses during the COVID-19 pandemic

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The normalization of epidemic prevention and control has exacerbated nurses' physical and mental stresses. The important role of physical activity in relieving nurses' physical and mental stresses has received extensive attention from researchers in recent years. The purpose of this study was to investigate the influence of physical activity on the regulatory emotional self-efficacy, resilience, and emotional intelligence of nurses and explain their interactions. The present study adopted the cluster sampling method. From April to May 2022, a total of 500 nurses in six municipal hospitals in Changsha City were selected. Finally, 402 valid data samples were obtained. Afterward, AMOS 23.0 (by maximum likelihood estimation) was used to process the collected data and analyze the proposed hypotheses by using 5,000 bootstrap samples to test the mediating effects of the structural equation model. The results demonstrated that there are positive correlations between physical activity and resilience (standardized coefficients = 0.232, p <0.001), resilience and regulatory emotional self-efficacy (standardized coefficients = 0.449, p <0.001), and emotional intelligence and regulatory emotional self-efficacy (standardized coefficients = 0.330, p <0.001). The positive influence of physical activity on emotional regulation self-efficacy is completely mediated by emotional intelligence and resilience (standardized indirect effect = 0.237, p <0.01), and this explanatory power is far higher than any previous study (R^2 = 0.49). The positive emotions generated by an individual's physical activity have an important explanatory role for individuals who want to establish more emotional regulation self-efficacy, emotional intelligence, and psychological resilience.

KEYWORDS

physical activity, regulatory emotional self-efficacy, emotional intelligence, resilience, nurse

Introduction

Although the COVID-19 pandemic is greatly weakening, the nurses who are on the front lines of epidemic prevention have not relaxed. On the contrary, with the normalization of epidemic prevention and control in China, nurses have become the main force in applying epidemic prevention and control (Keshkar et al., 2021). Every time a major holiday begins or ends, hundreds of millions of people return to their hometowns, schools, and jobs. Nurses are often overwhelmed by having to conduct nucleic acid testing on people from all walks of life and constantly having to repeat boring work processes. This pressure was not only reflected in the fact that they needed to complete more than 8 h of work in protective clothing when the outdoor temperature exceeded 30°C (73°F) in summer, it was also reflected in the normalization of epidemic prevention and control likely to be continuing for a long time in the future. This form of work will become their norm. Nurses often suffer from excessive psychological pressures that affect their mental health and cause problems, such as job burnout, decreased happiness, and suicidal tendencies (Hamre et al., 2020). It is therefore important to know how to relieve these excessive psychological pressures on the nurses through certain means in the post-epidemic era to improve their mental health.

In recent years, the relationship between physical activity and individual mental health has received extensive attention from researchers (Chekroud et al., 2018). Research shows that people who are physically active have higher levels of mental health, and they tend to be less susceptible to mental illnesses, such as anxiety, depression, emotional disorders, and insomnia (Stafseth et al., 2022). Physical activity allows people to obtain an emotional experience that liberates them from repressed mental states and then plays a role in eliminating negative emotions (Tamminen and Bennett, 2017). The extended theory of positive emotions believes that an individual's long-term emotional experience will be transformed into an emotional ability (Fredrickson, 1998). When people are in a negative and repressed emotion for a long time, this actually indicates that they are losing the ability to experience positive emotions (Fredrickson, 1998). When in the midst of a positive emotional experience, a positive emotion actually transforms into an ability to experience positive emotions while also enhancing the ability to resist negative emotions (Fredrickson, 2001). Relevant studies have shown that individuals who participate in physical activity for a long time have higher emotional intelligence, and their perceptions and control of emotions will be significantly enhanced (Frazier and Nagy, 1989). Physical activity can make people gain a sense of positive emotional experiences so that an individual's emotions can be released and relaxed during exercise, thereby reducing or eliminating the impact of negative emotions on the individual's mental health (Wang et al., 2020).

For the nurses, their occupational characteristics cause their mental health to be affected by more uncertain factors than the general population, such as doctor–patient relationship, working environment, work and rest time, especially in the context of the normalization of epidemic prevention and control, The dull and single work process and severe work environment have led to the accumulation of nurses' negative emotions (Jeung et al., 2018; Alsaqri et al., 2021). When the long-term accumulated psychological pressure cannot be effectively relieved, it will increase the risk of individuals suffering from mental illness (Lorente et al., 2021). Although the psychological pressure generated by the external environment exists objectively, the ability of individuals to resist negative emotions varies from person to person and is affected by many factors, such as emotional regulation, emotional intelligence, and psychological resiliency (Labrague and De los Santos, 2020). It is worth noting that most of the previous studies focused on the descriptive level of the relationship between physical activity and individual mental health, but few studies have paid attention to how physical activity affects individuals' mental health.

Emotional regulation of self-efficacy, emotional intelligence, and resilience has been regarded as the major predictor of individual mental health in recent years (Young et al., 2011). An individual's ability to regulate emotions was once considered to be an important channel for stress relief (McEwen et al., 2015). Emotion regulation, resilience, and social support play a combined and important role in the maintenance of the mental health of frontline health-care workers during the COVID-19 pandemic (Fino et al., 2021). Regulatory emotional self-efficacy, as an important predictor of individual emotional regulation ability, has received extensive attention from researchers in recent years. Studies have shown that regulatory emotional self-efficacy is significantly related to prosocial behavior, mental health, self-esteem, subjective well-being, and other factors (Bandura et al., 2003). Other studies have shown that emotional regulation self-efficacy, emotional intelligence, and resilience can significantly affect individual mental health, and physical activity has an important role in promoting individuals' mental health, but little attention has been paid to how physical activity affects emotional regulation self-efficacy, emotional intelligence, and resilience, and how they interact to promote an individual's mental health (Paluska and Schwenk, 2000).

This study attempts to achieve the following objectives: (1) to investigate the effects of nurses' physical activity on their emotional intelligence, resilience, and regulatory emotional self-efficacy; (2) to explore the impact mechanism of physical activity on emotional intelligence, resilience, and regulatory emotional self-efficacy; (3) to explore whether and how emotional intelligence, resilience, and regulatory emotional self-efficacy interact with each other; and (4) to propose suggestions for improving the physical activity of nurses.

The contributions of this study are as follows: First, by exploring the effect of physical activity on emotional intelligence, psychological resilience, and regulatory emotional self-efficacy, the research on the influence mechanism of physical exercise on individual mental health was expanded. Second, this study adopted the extended broaden-and-build theory of positive emotions, which highlighted the important explanatory role of

positive emotions generated by individuals participating in physical activities to build more regulatory emotional self-efficacy, intelligence, and resilience. Third, this study expanded the research on the micro-influence mechanism of emotional regulation self-efficacy. As in previous studies, regulatory emotional self-efficacy is usually used as a mediator and moderator variable affecting the results of the study, but in this study, regulatory emotional self-efficacy will be the target variable.

Literature interviews and hypotheses development

Broaden-and-build theory of positive emotions

Fredrickson (1998). proposed the broaden-and-build theory of positive emotions. Through the research on the four positive emotions of happiness, interest, satisfaction, and love Fredrickson (2001) believed that positive emotions could broaden the thought-action ability of individuals. Fredrickson pointed out that positive emotions can effectively expand the individual's attention span, creative thinking, and cognitive ability.

In subsequent research, Tugade and Fredrickson (2004). proved that positive emotions play a positive role in relieving negative emotions, improving resilience, and promoting emotional health. Relevant studies showed that physical activity plays an important role in promoting an individual's physical and mental health and creating positive emotions (Bouchard et al., 1994; Gehlhar et al., 2022). Based on the extended broaden-and-build theory of positive emotions, this study attempts to discuss how physical activity affects emotional intelligence, resilience, and regulatory emotional self-efficacy.

Physical activity and resilience

In recent years, there has been a prevailing view in the mass media and academia that the psychological benefits of physical activity may equal or even exceed the physical benefits (Smith et al., 1996). Specifically, first, people who regularly participate in sports have higher levels of mental health and are less susceptible to negative emotions such as depression, anxiety, and stress (Scully et al., 1998). Second, exercise can enhance an individual's emotional state. People who regularly participate in sports have a more optimistic attitude, a higher cognitive level, and a more positive emotional experience (Frazier and Nagy, 1989). Third, exercise can effectively shape personality, and studies have shown that physical activity is positively correlated with self-esteem, emotional intelligence, and self-efficacy (Wang et al., 2020; Aouani et al., 2022; Liu and Qiang, 2022).

Resilience, as a personality trait, reflects an individual's ability to cope successfully or adapt well in the face of adversity (Masten, 2001). Individuals with high resilience have a more optimistic attitude and more positive emotions. They are often able to face problems head-on and are good at using positive emotions, so they also have a higher sense of well-being, a higher level of mental health, and a stronger ability to deal with emergencies (Chan et al., 2013). In the formation and development of resilience, the consensus view is that resilience is affected by protective factors and risk factors (Kumpfer, 2002). Protective factors include individual factors, such as self-efficacy, intellectual function, attribution style, and self-esteem, as well as non-individual factors such as family environment and social support (Masten and Coatsworth, 1998). When an individual encounters adversity, the body responds quickly to the current environment through protective factors, so that the body can adapt well to the current environment or quickly recover from the traumatic state. Risk factors refer to certain biological, psychological, cognitive, or external environmental factors that hinder the normal development of an individual, such as poverty, physical illness, and the crisis of abuse and violence.

To sum up, there are the following connections between physical activity and resilience: First, both physical activity and resilience are important promoting factors for individuals' mental health. Second, physical activity appears to promote protective factors of resilience such as self-esteem and self-efficacy, while physical activity enhances social support by building wider social networks. Third, individuals enhance their physical, psychological, cognitive, and other abilities by participating in sports, thus reducing the impact of risk factors on psychological resilience. Based on this, this study proposes the following hypotheses:

> *Hypothesis* 1 *(H1)*: Physical activity has a positive impact on resilience.

Emotional intelligence, resilience, and regulatory emotional self-efficacy

According to the emotional intelligence competency model of Mayer et al. (1999)., emotional intelligence is mainly composed of accurately perceiving emotions in oneself and others, using emotions to facilitate thinking, understanding emotional meanings, and managing emotions. Related research suggests that people with high emotional intelligence may have better levels of mental health and well-being because they have a better ability to regulate stress and flexibility to improve the effects of negative emotions (Ciarrochi et al., 2002). People with high emotional intelligence have a better ability to understand, control, and manage emotions, and they seem to be more successful at avoiding interpersonal squabbles and fights, and thus have better social support and relationships (Ciarrochi et al., 2002). People with high emotional intelligence have a better ability to perceive and use emotions, as they are good at regulating their emotions, and thus they have a more positive emotional state (Salovey et al., 2009; Sharma et al., 2016).

As a branch of self-efficacy, regulatory emotional self-efficacy refers to a degree of self-confidence of individuals in their emotion regulation ability, which affects the process of emotion regulation and is the basis of emotional competence (Bandura et al., 2003). In other words, regulatory emotional self-efficacy is the expectation of behavioral subjects on their emotional regulation ability, which is based on self-evaluation and represents a cognitive state of one's ability. Research by Kavanagh and Bower (1985). showed that positive emotions are a significant predictor of self-efficacy. Research by Caprara et al. (2003). pointed out that individuals with higher self-efficacy in regulating negative emotions have higher levels of emotional stability.

Taken together, emotional intelligence, resilience, and regulatory emotional self-efficacy appear to be highly correlated in theory. On the one hand, emotional intelligence is the individual's ability to control emotions. To a certain extent, emotional intelligence provides a cognitive judgment for regulatory emotional self-efficacy and is the basis for regulatory emotional self-efficacy. While regulatory emotional self-efficacy seems to be predicted by positive emotions, higher emotional intelligence also seems to predict higher positive emotions. Emotional intelligence seems to be a predictor of regulatory emotional self-efficacy. On the other hand, according to the related definition of resilience, self-efficacy is one of the protective factors in resilience, and higher resilience predicts higher positive emotions (Kumpfer, 2002). Therefore, regulatory emotional self-efficacy, which is also affected by positive emotions, seems to be related to psychological resilience. In addition, a significant positive correlation between emotional intelligence and resilience has been demonstrated (Akbari and Khormaiee, 2015; Jayalakshmi and Magdalin, 2015). Based on this, this study proposes the following hypotheses:

> *Hypothesis* 2 *(H2)*: Resilience has a positive impact on regulatory emotional self-efficacy.
>
> *Hypothesis* 3 *(H3)*: Emotional intelligence has a positive impact on regulatory emotional self-efficacy.

The mediating roles of emotional intelligence and resilience

According to the broaden-and-build theory of positive emotions, positive emotions promote the establishment of various personal resources (e.g., material, intellectual, and social resources) by broadening the individual's ability to think and act, and then have an impact on the formation and development of an individual's personality (Fredrickson, 1998). It should be pointed out that Fredrickson's previous research only clarified that positive emotions can have an impact on individual elements of an individual's personality such as creative thinking, cognitive ability, and resilience. But Fredrickson did not explain whether these factors interacted under the influence of positive emotions. Previous research has demonstrated that emotional intelligence, resilience, and regulatory emotional self-efficacy may be affected by positive emotions (Fredrickson, 2001). Based on this, it is the focus of this study to explore how they are affected by positive emotions and how they interact with each other.

Relevant studies have demonstrated that physical activity could promote positive emotions in individuals, as there is a significant relationship between physical activity and emotional intelligence and a significant relationship between emotional intelligence and resilience (Jayalakshmi and Magdalin, 2015; Wang et al., 2020). Thus, physical activity can have an impact on resilience through emotional intelligence. If there is a significant relationship between resilience and regulatory emotional self-efficacy, can emotional intelligence affect regulatory emotional self-efficacy? Assuming that physical activity, emotional intelligence, resilience, and regulatory emotional self-efficacy are all directly linked, can emotional intelligence and resilience mediate the relationship between physical activity and regulatory emotional self-efficacy? Based on this, this study proposes the following hypotheses:

> *Hypothesis* 4 *(H4)*: Emotional intelligence mediates the relationship between physical activity and resilience.
>
> *Hypothesis* 5 *(H5)*: Resilience mediates the relationship between emotional intelligence and regulatory emotional self-efficacy.
>
> *Hypothesis* 6 *(H6)*: Emotional intelligence and resilience mediate the relationship between physical activity and regulatory emotional self-efficacy.

A summary of all the hypotheses in this study is shown in Figure 1.

Materials and methods

Procedure

In this study, the cluster sampling method was adopted, and the samples were drawn from the groups as the sampling unit, and each group was required to have good representativeness. According to the geographical distribution of the six municipal districts of Changsha, the researchers randomly selected one municipal hospital in each municipal district and finally took the nurses at the six municipal hospitals as the research objects. From April to May 2022, the researchers received the help of the relevant management personnel of the hospital's medical department, and through them, the nurses in each department were given the task of filling out the online questionnaire. In the end, a total of 500 questionnaires were distributed and 402 valid questionnaires were recovered for a recovery rate of 80.4%.

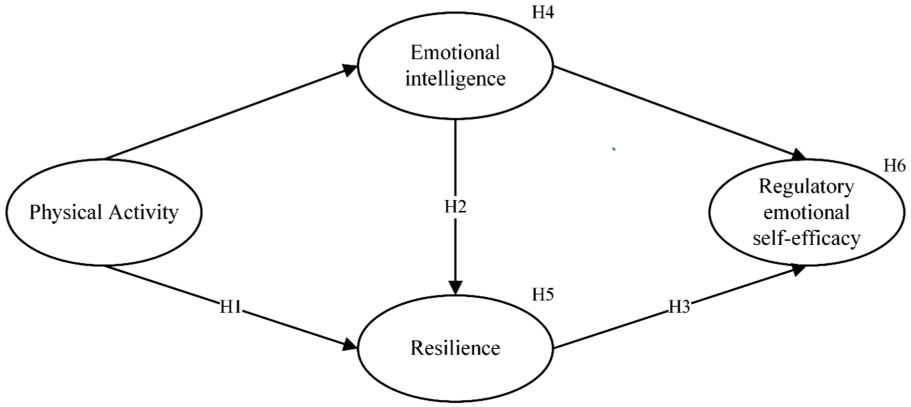

FIGURE 1
The hypothesized model.

Measures

This study measured physical activity by using three items on the scale of Andersen et al. (2010). and measured resilience by using six items on the scale of Campbell-Sills and Stein (2007). Emotional intelligence was measured using six items on the Law et al. (2004) scale, originally developed to measure the emotional intelligence of respondents in Eastern countries. Four items were selected from the study by Caprara et al. (2008) to measure regulatory emotional self-efficacy. These four scales were all measured using a five-point Likert scale, where responses ranged from 1 (i.e., strongly disagree) to 5 (i.e., strongly agree). All items are shown in Table 1.

To adapt to the specific research field and Chinese cultural background, the researchers made certain adjustments to the items of the scales. A pilot test was used to ensure the reliability of the adjusted scale (Kimberlin and Winterstein, 2008). Taking the nurses of a municipal hospital as the survey object, the researchers distributed 60 questionnaires using the convenience sampling method and recovered 54 valid questionnaires. The results showed that Cronbach's alpha coefficients were all greater than 0.8, indicating that the measuring instruments had good internal consistency (Fornell and Larcker, 1981).

Reliability and validity

Reliability is measured by Cronbach's α coefficient and composite reliability (CR) coefficient, recommended by Fornell and Larcker (1981). As shown in Table 2, the lowest value of Cronbach's α coefficient in all variables is 0.792, which is above the minimum value of 0.7 recommended by Hair et al. (2012). Therefore, the reliability of all variables is ideal. The convergent validity was evaluated by two indicators' factor loading and average variance extracted (AVE; Fornell and Larcker, 1981). Table 2 shows that the lowest values of factor loading and AVE in all measurement items are 0.544 and 0.555, respectively, both of which are higher than the recommended value of 0.5 suggested by Fornell and Larcker (1981). Therefore, all variables have high convergent validity. Finally, the discriminant validity is verified by comparing the square root of AVE and the correlation coefficient of each variable. The results from Table 3 show that the square root of the AVE of each construct is greater than the correlation coefficients, which meets the requirement for the existence of discriminant validity suggested by Fornell and Larcker (1981).

Data analysis

This study used structural equation modeling (SEM) with AMOS 23.0 to analyze the proposed model. SEM is often used to evaluate latent variables on measurement models and to test hypotheses between latent variables on structural models (Hair et al., 2012). This study adopted the two-step modeling approach proposed by Anderson and Gerbing (1988). First, the researchers tested the reliability and effectiveness of the instrument as shown in "Reliability and validity", and the average value of the Cronbach α coefficient in all variables was 0.792, indicating good reliability and effectiveness of the instrument. Second, the researchers used the maximum likelihood estimation method to verify the significant relationship between physical activity, regulatory emotional self-efficacy, resilience, and emotional intelligence as independent variables. Third, the researchers used 5,000 bootstrap samples to test the indirect effects between physical activity and regulatory emotional self-efficacy. Finally, evaluated the validity of the model, and measure the fit coefficients and path coefficients of the hypothetical model.

Results

Participants

Table 1 lists the demographic characteristics of the 402 respondents: (1) In terms of age, 63.5% were 18–35 years old, and

TABLE 1 Reliability and validity tests.

Items	Loadings	Cα	AVE	CR
Physical activity (PA)		0.792	0.561	0.792
PA1: In your leisure time, how often do you spend per week doing light physical activity such as walking, light cleaning, and yoga?	0.824			
PA2: In your leisure time, how often per week do you engage in gardening, carrying loads upstairs, or doing moderately strenuous sports week doing light physical activity?	0.729			
PA3: In your leisure time, how often per week do you engage in strenuous sports and conditioning exercises such as running, jogging, soccer, tennis, or similar activities?	0.687			
Resilience (RE)		0.893	0.584	0.893
RE1: I am not easily discouraged by failure.	0.766			
RE2: I can stay focused under pressure.	0.752			
RE3: I can achieve goals despite obstacles.	0.812			
RE4: I tend to bounce back after illness or hardship.	0.754			
RE5: Coping with stress can strengthen me.	0.727			
RE6: I can deal with whatever comes.	0.771			
Emotional intelligence (EI)		0.792	0.574	0.800
EI1: I have good control of my own emotions.	0.798			
EI2: I can control my temper so that I can handle difficulties rationally.	0.823			
EI3: I am a self-motivating person.	0.639			
Regulatory emotional self-efficacy (RES)		0.825	0.555	0.830
RES1: I can try to avoid negative experiences because I fail to achieve my goals.	0.806			
RES2: I can reduce the upset when I do not get the appreciation, I feel I deserve.	0.786			
RES3: I can avoid getting upset when others keep giving me a hard time.	0.809			
RES4: I feel gratified about overachieving what I set out to do.	0.544			

All standardized loadings are significant at the 0.001 level.

TABLE 2 Discriminant validity test.

Construct	PA	RE	EI	RES
PA	**(0.749)**			
RE	0.386**	**(0.764)**		
EI	0.262**	0.676**	**(0.758)**	
RES	0.180**	0.570**	0.524**	**(0.745)**

The square root of the average variance extracted (AVE) is in diagonals (bold); off diagonals are Pearson's correlations of constructs. $^{**}p < 0.01$.

TABLE 3 Participant profile (N=402).

Profiles	Survey	2020 Statistical bulletin of China's health development[a]
Respondent age (%)		
18–25	10.6	
26–35	52.9	
36–45	24.2	
≥ 45	12.3	
Respondent gender (%)		
Male	4.3	3.6
Female	95.7	96.4
Respondent education level (%)		
Below high school	2.1	1.0
High school/Vocational school	10.8	13.8
College/University	79.3	85.2
Master or Ph.D.	7.8	

[a]National Health Commission (2022).

the entire sample tends to be younger in age; (2) In terms of gender, the proportion of males was 4.3%, female accounted for 95.7%; (3) In terms of education level, the majority of respondents were college graduates (79.3%). The survey results were close to the 2020 Statistical Bulletin of China's Health Development (National Health Commission, 2022).

Structural path model

Referring to the test parameters commonly used in previous studies (Jackson et al., 2009). and the suggested values of Hair et al. (2012). the results show that the data ($\chi^2/df = 2.433$, GFI = 0.934, NFI = 0.928, CFI = 0.956, TLI = 0.946, IFI = 0.956, RMSEA = 0.060) has a good fit with the structural model. The results of the structural path model are shown in Figure 2. There are positive correlations between physical activity and resilience (standardized coefficients = 0.232, $p < 0.001$), resilience and regulatory emotional self-efficacy (standardized coefficients = 0.449, $p < 0.001$), and emotional intelligence and regulatory emotional self-efficacy (standardized coefficients = 0.330,

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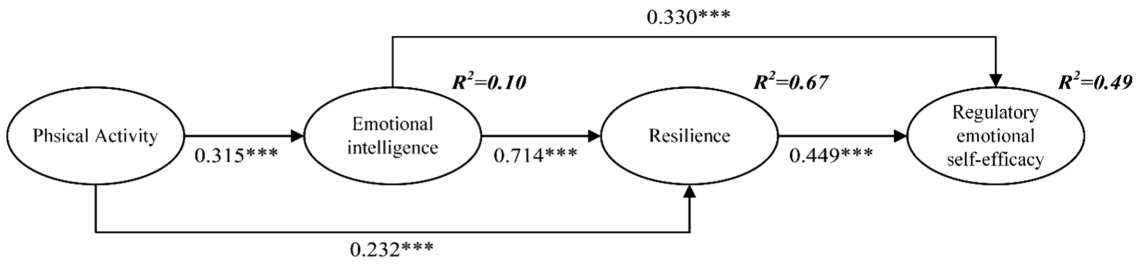

FIGURE 2
Structural path model. ***p<0.001. Standardized coefficients are reported.

TABLE 4 Standardized direct, indirect, and total effects.

	Point Estimate	Product of coefficients		Bootstrapping				
				Percentile 95% CI		Bias-corrected 95% CI		Two-tailed significance
		SE	Z	Lower	Upper	Lower	Upper	
Direct effects								
PA → RE	0.171	0.038	4.500	0.095	0.245	0.102	0.249	0.000(***)
EI → RES	0.348	0.112	3.107	0.142	0.584	0.135	0.577	0.002(**)
Indirect effects								
PA → RE	0.165	0.039	4.231	0.093	0.245	0.095	0.251	0.000(***)
PA → RES	0.237	0.046	5.152	0.152	0.335	0.157	0.341	0.000(***)
EI → RES	0.338	0.092	3.674	0.162	0.518	0.172	0.531	0.002(**)
Total effects								
PA → RE	0.336	0.048	7.000	0.244	0.430	0.248	0.435	0.000(***)
PA → RES	0.229	0.049	4.673	0.060	0.253	0.064	0.256	0.002(***)
EI → RES	0.686	0.065	10.554	0.566	0.821	0.568	0.823	0.000(***)

Standardized estimation of 5,000 bootstrap samples; **p < 0.01, ***p < 0.001.

p < 0.001) and all are statistically significant, so H1, H2, and H3 were supported. The relationship of physical activity to resilience, emotional intelligence, and regulatory emotional self-efficacy appeared to be mediated by emotional intelligence and resilience. Although the effect of physical activity on regulatory emotional self-efficacy was not statistically significant, the effect of physical activity on regulatory emotional self-efficacy appeared to be mediated by emotional intelligence and resilience.

Mediation test

For testing the mediation effect, this study followed the suggestion of Bollen and Stine (1990)., and the bootstrapping method was used. The 95% confidence interval results for the 5,000 bootstrap samples are shown in Table 4. All Z values are greater than 1.96, and there is no zero value in the 95% confidence interval. There was a significant mediating effect between physical activity and resilience through emotional intelligence (standardized indirect effect = 0.165, p < 0.001), and H4 was supported. There was a significant mediating effect between emotional intelligence and regulatory emotional self-efficacy through resilience (standardized indirect effect = 0.338, p < 0.001), and H5 was supported. There was a significant mediating effect between physical activity and regulatory emotional self-efficacy through resilience and emotional intelligence (standardized indirect effect = 0.237, p < 0.01), and H6 was supported.

Discussion

Contributions

This study makes the following contributions to the study of regulatory emotional self-efficacy. It explores the effect of physical activity on the regulatory emotional self-efficacy of nurses. At the same time, emotional intelligence and psychological resilience were added as mediators providing a clearer path for the impact of physical activity on regulatory emotional self-efficacy. The findings showed that the positive effect of physical activity on regulatory emotional self-efficacy was mediated by emotional intelligence and resilience. This explains 49% of the variance in regulatory emotional self-efficacy, which was much higher than

the 27% explanatory power of previous studies (Chan, 2004). According to previous research, scholars defined regulatory emotional self-efficacy as a cognitive judgment of one's emotion regulation ability. From this perspective, both the individual's internal cognitive ability and the influence of the external environment will affect the individual's cognitive state. Emotional intelligence, as the ability to perceive, use, understand and manage emotions, essentially exerts an influence on self-efficacy in emotion regulation by changing the individual's intrinsic cognitive ability to emotions. Mayer (2015). sees emotional intelligence as a mental ability, which is exactly in line with this point of view; while resilience affects regulatory emotional self-efficacy through an experiential environment from the outside world.

Previous studies on resilience found that individual resilience needs to be improved in the face of constant adversity, which is manifested as an empirical adaptation process. In other words, when different individuals face the same situation, individuals with similar experiences tend to have higher regulatory emotional self-efficacy. This study attempts to use an extended broaden-and-build theory of positive emotions to explain the effects of physical activity on emotional intelligence, resilience, and regulatory emotional self-efficacy. Positive emotions can motivate individuals to act to promote individuals to build material, intellectual, social, and other resources, among which intellectual resources are the focus of this research (Fredrickson, 1998). Positive emotions can promote the establishment of individual intellectual resources. From this point of view, emotional intelligence, resilience, and regulatory emotional self-efficacy, as important individual intellectual resources, may also be affected by positive emotions. Fredrickson's (2001) subsequent research confirmed this view by studying the impact of positive emotions on individual intellectual factors such as creative thinking, resilience, and cognitive ability. Based on this, this study used the extended broaden-and-build theory of positive emotions to explain the theoretical presuppositions among physical activity, emotional intelligence, resilience, and regulatory emotional self-efficacy.

Practical implications

Studies have showed that regulatory emotional self-efficacy is strongly associated with prosocial behaviors, low aggressive behavior problems, and low anxiety and depression problems (Caprara et al., 2008). This is very consistent with previous studies. The study by Sui et al. (2021). has showed that regulatory emotional self-efficacy is an important mediator explaining the impact of nurses' personalities on COVID-19 pandemic-related negative emotions. However, unlike previous studies showing that physical activity can have a direct positive impact on self-efficacy, the positive effects of physical activity on emotion-regulating self-efficacy in this study need to be mediated entirely by mental resilience and emotional intelligence. This further demonstrates the importance of positive emotions for the establishment of an individual's emotional capacity; building an individual's emotional competence requires a process, and the positive impact of physical activity on an individual's dynamic ability needs to be transmitted through positive emotions, rather than directly affected by subjective feelings. This study demonstrates the positive effect of nurses' physical activity on regulatory emotional self-efficacy and the mechanism of action in the process. Therefore, the broader promotional effect of physical activity on an individual's physical and psychological levels deserves attention. For example, in the early days of COVID-19, in Wuhan, China, the epicenter of the outbreak, nurses and patients in field hospitals used exercise to reduce fatigue and enhance health. During the COVID-19 pandemic in Shanghai in the spring of 2022, exercise was also widely used by nurses and patients in various field hospitals. During the COVID-19 pandemic, nurses are often under tremendous physical and mental pressure as frontline workers in epidemic prevention and control. On the one hand, changes in the work environment and increased workload often make it difficult for them to adapt in a short period, which in turn creates physical and psychological stress (Alsaqri et al., 2021). On the other hand, as mentioned above, the COVID-19 pandemic has changed nurses' work content, and the daily repetitive nucleic acid testing work has become their daily work. The dull and single-work content cannot give them get fun and a sense of achievement from their work. Meanwhile, alleviating the public's anxiety about the COVID-19 pandemic often requires a lot of emotional labor. These factors make nurses prone to mental fatigue, which increases the risk of mental illness (Soylu et al., 2021). From the results obtained, the physical benefits obtained by physical exercise in the nurse group also positively impacted the mental health of the nurse group. On the one hand, a muscular physique helps improve the individual's work and quality of life, and work and quality of life are the premises of ensuring the individual's mental health. On the other hand, the positive emotional experience obtained by the individual in physical activity can effectively relieve the emotional pressure generated by the individual, and the individual can enhance the emotional ability in the long-term positive emotional experience, which represents the enhancement of the individual's resistance to negative emotions, thereby improving the individual's mental health.

However, despite the proven benefits of participating in physical activity, the level of physical participation of the public and special health-care workers is actually not high. This result can be attributed to the following reasons. The public does not have a clear understanding of the benefits of sports participation. The conditions for providing public participation in sports activities, including venues, time, and sports instructors, are not sufficient. The atmosphere of public participation in sports is not strong enough. Based on this, this study puts forward the following suggestions for the nurses. To improve the awareness of nurses' participation in sports, the government and hospital management departments should carry out more publicity

activities about the public's participation in sports activities (including the benefits of sports, exercise tips, exercise precautions). Hospitals should encourage nurses to develop the habit of participating in sports every day and provide conditions such as venue and time for nurses to participate in sports activities. Sports activities should be regarded by hospitals as one of the most important components of cultural construction, and the purpose of improving nurses' participation in sports atmosphere is achieved by regularly organizing collective sports activities.

Limitations

There are certain limitations to this study. This study only selected two mediating variables, emotional intelligence, and resilience, to explore the impact mechanism of physical activity on regulatory emotional self-efficacy. More variables should be involved in future research. Different ages and genders have different performances on regulatory emotional self-efficacy, and future research can subdivide the effect of physical activity on regulatory emotional self-efficacy on age and gender.

Conclusion

This study confirmed the positive effect of physical activity on the regulatory emotional self-efficacy of nurses. Specifically, the effect of physical activity on regulatory emotional self-efficacy was mediated by two variables: emotional intelligence and resilience. In the face of the severe pandemic in the world, nurses are often the type of group that suffers from greater physical and mental pressures. Considering that the current level of nurses' participation in sports is low, the government and hospital management departments should take corresponding measures to increase the level of physical activity of nurses.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the study was approved by the Ethics Committee of the School of Physical Education of Hunan University of Science and Technology (No. ECSPEHUST 2022/0010). The patients/participants provided their written informed consent to participate in this study.

Author contributions

RW and HW contributed to conception and design of the study. RW and LJ organized the database. RW and JY performed the statistical analysis. RW wrote the first draft of the manuscript. LJ, YL, HW, and JY wrote sections of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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Association between physical activity and online sexual objectification experience: The mediating role of body-image depression

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Objective: With the popularization and development of online media technology, more and more women are paying attention to their body image and physical behavior. The purpose of this study was to investigate the effect of online sexual objectification experience on the physical activity of female college students and verify the mediating role of body-image depression between them.

Methods: A cross-sectional convenient sample of 882 female college students from four universities in Hubei Province completed an online survey, and the Online Sexual Objectification Experience Scale (OSOES), the Body-Image Depression Questionnaire, and the Physical Activity Rating Scale (PARS) were used to collect the data. The mediating effect of the association between online sexual objectification experience and physical activity, was examined using the process procedure in SPSS and the bootstrap method.

Results: Online sexual objectification experience was significantly positively correlated with physical activity ($r = 0.420$, $p < 0.01$). Body-image depression was significantly negatively correlated with online sexual objectification experience and physical activity ($r = -0.484$, $p < 0.01$; $r = -0.569$, $p < 0.01$). Online sexual objectification experience can affect physical activity directly ($\beta = 6.49$, $p < 0.001$, effect value 44.97%) and also indirectly through body-image depression ($\beta = 7.95$, $p < 0.001$, effect value 55.03%); there were significant differences between major and education-level categories in body-image depression and physical activity.

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Conclusion: Both online sexual objectification experience and body-image depression can promote physical activity among female college students, and body-image depression has a mediating effect between online sexual objectification experience and physical activity.

KEYWORDS

mental health, online sexual objectification experience, body-image depression, physical activity, female college students, mediating role

Introduction

With the popularization and development of online media technology, social media is used to widely promote photos or short videos containing slimming, beauty, and body appearance content. Female college students, who are in an important period of physiological development and are more sensitive to their physical appearance, are prone to excessive self-objectification, such as posting selfies or being exposed to others' beautified photos and giving feedback (likes and comments) anytime and anywhere (de Valle et al., 2021). Previous research has found that self-objectification is more prevalent in young women and can trigger a range of physical and mental health problems, such as inducing external manifestations of disordered eating behaviors, excessive body monitoring, and body shame (Fredrickson et al., 1998; Zhang et al., 2021). However, the experience of online sexual objectification is a common form of self-objectification experience, specifically an experience of extensive attention to the appearance on social media that encompasses both media and interpersonal approaches to objectification and can significantly predict others' sense of objectification (Luo, 2017). A growing body of research suggests that social media provides opportunities to objectify women because it often displays idealized and inauthentic images of glamor, which can easily trigger the internalization of thinness ideals and social comparisons (Saiphoo and Vahedi, 2019). A previous meta-analysis found that women have a richer experience of objectification than men and that younger women are more likely to be troubled by online sexual objectification and body image problems than older women (Mingoia et al., 2017). The general population is more likely to compare themselves to people at similar levels, rather than models and celebrities, and a recent study found that body image comparisons between peers were more helpful in reinforcing female college students' online sexual objectification experience (Tiggemann et al., 2018) and that such comparisons tended to provide more valid evaluative information (Festinger, 1954). In addition, we found that with the increased use of appearance-focused social media (e.g., Tik Tok and Facebook), the effect on women's online sexual objectification and body image problems was stronger (Huang et al., 2021). Therefore, exploring online sexual objectification is important for promoting the mental health of female college students.

Physical activity has now been identified as a "meaningful" activity that enhances body self-concept, body self-esteem, and body satisfaction (Richman and Shaffer, 2000; Babic et al., 2014). The World Health Organization (WHO) defines physical activity as any physical activity produced by skeletal muscles that requires energy expenditure higher than that at the metabolic level at rest (Guthold et al., 2020). Studies have shown that regular participation in physical activity can be beneficial for moderate weight loss and shaping in exercising populations (Tucker and Mortell, 1993), and can contribute to the prevention of mental health problems such as anxiety, depression, and eating disorders (Dale et al., 2019; Mathisen et al., 2021). A review of the literature found that self-objectification promotes physical activity, health quality, and body confidence in women (Ginis et al., 2012). Although it has been well documented that self-objectification positively predicts female physical activity, the relationship between online sexual objectification through social media and female college students' physical activity has not been established. Thus, this article explores the relationship between physical activity and online sexual objectification experience for female college students.

However, research on online sexual objectification experience and physical activity has mainly focused on whether objectification positively affects physical activity, and there is a paucity of research on how it alters the effects of physical activity and through what paths it leads individuals to increase their physical activity. In particular, the frequency of body image comparison (mutual evaluation) on social media, users uploading messages, the sharing of photos, and other inter-individual comparisons have led to young women being overly concerned with their body image, having a strong desire to improve their bodies, and having negative emotional experiences. Many studies have confirmed that young women have higher negative body image awareness and face stronger body image pressure than men, and female college students, as an important representative group of young women, are characterized by rapid physiological development and a high level of body image concern (Smolak, 2009) and are prone to symptoms of body-image depression such as appearance

anxiety. Body image is also known as body imagery, and body-image depression is a kind of abnormal body image psychology caused by the deviation of an individual's perception of the real body image and ideal body image (Liang et al., 2017). Recent studies show that body-image depression is growing more common in the world, with a detection rate of body-image depression among female college students in China of 28.7% (Zhang and Liu, 2019) and an incidence of body image disturbance in Korea of 51.8% (Hyun et al., 2014). This is especially prominent in Western countries, where 80% of female college students report dissatisfaction with their bodies (Myers and Crowther, 2009). If an individual has severe body-image depression, it can affect their social life, interpersonal relationships, studies, and mood, and long-term body-image depression can also lead to a series of mental health problems such as low self-esteem (Gao et al., 2006), eating disorders (Thomas et al., 2010; Stice et al., 2011), and depression (Rierdan and Koff, 1997; Jones and Griffiths, 2015). Fredrickson's objectification theory suggests that women who objectify themselves are prone to body shame, appearance anxiety, etc., and are motivated to improve their body image and have a good body experience, thus actively engaging in physical activity (Fredrickson and Roberts, 1997). Therefore, the body-image depression of female college students should also be considered. Based on these findings, this study aims to clarify the relationship between online sexual objectification experience, physical activity, and body-image depression among female college students, as well as their internal mechanisms, in order to provide a reference for promoting psychological well-being interventions among female college students.

Literature review and research hypothesis

Direct effects of online sexual objectification and physical activity

The self-objectification theory suggests that the experience of objectification can cause women to habitually apply a third-party perspective to themselves, engage in frequent self-monitoring of their appearance, be more sensitive to body-related information, and be more likely to feel dissatisfied with their body image, which can put women at risk of psychological disorders related to appearance anxiety, body dissatisfaction, and a reduced experience of flow states (Fredrickson and Roberts, 1997). A review of the literature found that participation in two physical activities or longer periods of physical activity predicted lower levels of self-objectification in women compared with women who did not participate in physical activity (Slater and Tiggemann, 2011, 2012). A recent cross-sectional study explained the mechanism of self-objectification by suggesting that participation in physical activity moderates the association between the internalization of the thinness ideal and self-objectification. This may be due to the importance of internal focus during physical activity, which allows for a better respect and appreciation of one's body, thus reducing the frequency of self-objectification and negative emotional experiences, and helping women to regain confidence in their appearance (Jankauskiene and Baceviciene, 2022). This finding provides evidence to support that self-objectifying women engage in more physical activity. In addition, Parsons and Betz (2001) found that women with different levels of objectification tended to choose different exercise programs to alleviate their self-objectification, and that this also had a significant influence on the environment and effects of physical activity (Dimas et al., 2021). Accordingly, we propose research hypothesis H1: online sexual objectification experience positively influence physical activity among female college students.

Indirect effects of online sexual objectification and physical activity

Based on objectification and social comparison theories, objectified women continuously monitor their bodies and habitually compare their bodies to popular societal aesthetic standards (upward comparison), which makes them prone to body-image depression and dissatisfaction with their bodies (Zhao et al., 2021). Previous evidence suggests that social media environments with a richer online sexual objectification experience compared with traditional media are associated with higher levels of body-image depression among female college students (Cohen and Blaszczynski, 2015). This may be because social media creates ample conditions for online sexual objectification experience to occur, and women are more worried about when and how their bodies will be exposed to social media; this uncertainty dramatically increases rates of body-image depression in women (Mingoia et al., 2017). One study found that online sexual objectification is potentially harmful to individuals and is a risk factor for body-image depression (Fardouly and Vartanian, 2016). In addition, female college students with high levels of self-objectification not only reinforce self-objectification but also objectify others, forming a "cycle of objectification" mechanism that increases female college students' body-image depression (Strelan and Hargreaves, 2005). We propose research hypothesis H2: online sexual objectification experience can positively predict female college students' body-image depression.

In addition, many studies have confirmed that better body image is associated with physical activity; for example, Kirkcaldy et al. (2002) found that regular physical activity was associated with higher body satisfaction, possibly because physical activity can improve one's body shape or appearance to some extent, enhancing individual self-efficacy and confidence in the control

of one's appearance, thus alleviating body-image depression (Abbott and Barber, 2011). It was found that athletes who regularly participated in physical activity had a more positive body image than non-athletes (Soulliard et al., 2019). The results of two other meta-analyses consistently concluded that body image was positively associated with physical activity and confirmed a slight to moderate effect on body image improvement (Campbell and Hausenblas, 2009; Bassett-Gunter et al., 2017). Indeed, in addition to altering one's appearance, physical activity may also have a potential effect on body image perception, although this relationship may be more complex due to its association with health promotion and physical strength (Li et al., 2016). A previous review found that physical activity may have a positive effect on body image perception (Sabiston et al., 2019). A recent study similarly confirmed this finding, particularly that moderate and vigorous physical activity was strongly associated with body image problems in young women and adolescents (Miranda et al., 2021). Thus, for individuals with body-image depression, participation in physical activity can be an effective way to manage weight and improve body satisfaction (Bray et al., 2016). However, it is worth noting that physical activity is a "double-edged sword" for improving body image and that the excessive or prolonged misuse of physical activity can also have adverse physical and psychological health consequences (Lichtenstein et al., 2017). Physical consequences mainly manifest in long-term risks such as pain, physical deformities, and repetitive injuries (Tod et al., 2016). Psychological impairment is usually manifested as a range of negative emotional and physical symptoms, such as anxiety, depression, irritability, and mood changes that can induce psychological problems such as social disorders and eating disorders (Weinstein et al., 2015). The close association with eating disorders, in particular, is a common feature, with nearly 80% of patients with eating disorders exhibiting excessive physical activity (Bewell-Weiss and Carter, 2010; Bratland-Sanda et al., 2010). Accordingly, we propose research hypothesis H3: body-image depression is an intermediate variable between online sexual objectification experience and physical activity.

As can be seen, there are a number of domestic and international studies focusing on the relationship between online sexual objectification experience and physical activity among female college students, and some literature has also explored the interaction between body-image depression, body dissatisfaction, and physical activity; however, there is little in-depth exploration of the predictive role of the three, especially using body-image depression as a mediating variable to verify the effect of online sexual objectification experience on physical activity. This field of research is still in its infancy in China, and systematic studies focusing on this topic are lacking. To sum up the above analysis, based on objectification theory, social comparison theory, and the triple-factor model of socio-cultural influence on individual body image proposed by Thompson et al. (1999), this study constructs a theoretical relationship between online sexual objectification experience, body-image depression, and physical activity among female college students, and integrates hypotheses H1, H2, and H3 to form a research structure (**Figure 1**). In addition, it was found in previous studies that major, education, place of birth, and being an only child may have different degrees of influence on the three research variables, so they were included in this study as covariates in the model to compare the differences in online sexual objectification experience, body-image depression, and physical activity scores. Given that college and university is an important time for the physical and mental health development of college students, and considering the prevalence of social media use among female college students, it is necessary to examine the online sexual objectification experience of female college students. Based on the existing theories and literature studies, this study analyses the correlation between the three factors and tries to explain the mechanism at the structural level, aiming to provide theoretical support and guidance for female college students to enhance their well-being, and provide a reference for relevant departments to make decisions.

Research methods

Participants

A total of 882 female college students from four universities in Hubei Province were selected by convenient sampling method. In order to ensure the quality of the test, the test was conducted in class under the coordination of the head teacher and teachers. The subjects were given instructions before distributing the questionnaire, and all the subjects participated voluntarily after understanding the purpose of the study. At first, 18 female college students said they did not intend to take the test. After the end of the test time, 24 female students did not take the test at all. According to the questionnaire recovery standard, they answered all the questions of the questionnaire within the prescribed time as required, and 858 questionnaires were collected on site. According to the principle of obviously wrong answers, random filling or incomplete, a total of 28 invalid questionnaires were excluded and 830 valid questionnaires were retained, with an efficiency rate of 96.7%, according to the principle of obvious misfiring, omission, or random filling of answers. The age range of the subjects was between 17 and 28 years old, with an average age of 21.17 $\pm$ 2.03 years; there are 394 undergraduates and 436 postgraduates, 190 in science and technology categories, 481 in arts categories, and 159 in arts and sports categories. The inclusion criteria of the participants in this study were healthy female college students who passed the entrance physical examination, consented, and volunteered to participate. The exclusion criteria were that they could not complete the questionnaire within the deadline and unwillingness to accept

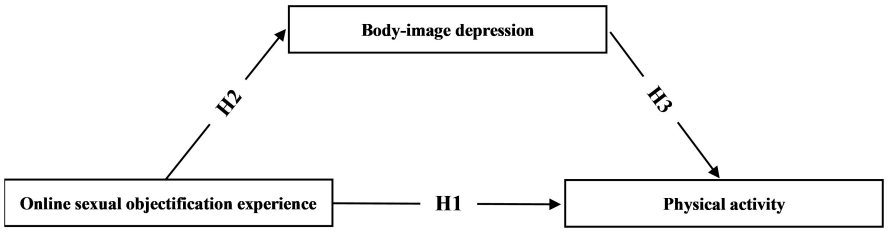

FIGURE 1
Research theoretical model.

the survey. A few points need to be clarified: (1) All female university students participated in the test voluntarily, and the questionnaire was answered online and collected on the spot, with a filling time of 4 min. (2) Before the test, training was conducted for the test group composed of 10 psychology graduate students. (3) In order to avoid the disadvantages of self-reporting, the test was scored in a positive and negative way and anonymously. (4) All procedures were in accordance with the Declaration of Helsinki. (5) The study was authorized by the local Ministry of Education Institutional Review Board (102772021RT072), which is responsible for evaluating studies conducted at schools.

Research tools and procedures

Online sexual objectification experience scale

The online sexual objectification experience scale developed by Luo (2017). was used to investigate female college students, which has a total of 6 questions and uses 5-point Likert scoring, using 5 levels, with a score of 1–5, respectively; the higher the score, the richer the individual's online sexual objectification experience. In this study, Cronbach's alpha coefficient of the scale was 0.883, and the index met the psychometric requirements.

Body-image depression questionnaire

The body-image depression questionnaire developed by Gao et al. (2005). was used to investigate body-image depression of female college students in four dimensions: body-shape depression, gender depression, sexual-organ depression, and appearance depression. The questionnaire consists of 25 items, including 8 items on body-shape depression, 4 items each on gender depression and sexual-organ depression, and 9 items on appearance depression, which has been widely validated in the female university student population (Zhang and Liu, 2019; Zhao et al., 2021). And the questionnaire was scored on a 3-point scale, i.e., 1 point for conformity, 2 points for non-controversial, and 3 points for non-conformity. The lower the score, the higher the level of body-image depression; conversely, the higher the score, the lower the level of body-image depression. A score of <2 for a single dimension indicates the presence of such worries and ≥ 2 indicates the absence of such worries (Luo et al., 2005). The Cronbach's alpha scores ranged from 0.816 to 0.91 for each factor and 0.93 for the whole scale, demonstrating sufficient internal consistency.

Physical activity rating scale

The physical activity of female university students was measured using the Physical Activity Rating Scale developed by Hashimoto (1990), which was localized to take into account our national conditions. There are three questions in the scale to examine the amount of physical activity in terms of intensity, time, and frequency of physical activity, and each dimension is scored on a 5-point Likert scale. Exercise volume = intensity × time × frequency; exercise intensity, and exercise frequency, from 1 to 5 levels, scored 1–5 points; and exercise time from 1 to 5 levels, scored 0–4 points. The lowest score was 0 points, the highest score was 100 points, the higher the score indicating a greater amount of physical activity and the higher the level. The Cronbach's alpha coefficient of PARS was 0.846, and the index met the psychometric requirements.

Statistical analysis

After eliminating the unqualified questionnaires, the questionnaire numbers were entered into SPSS 25.0. An independent sample *t*-test was used to compare the differences in indicators of education-level categories, place of birth, and whether they were only children; one-way ANOVA was used to compare the differences in indicators between students of different majors; Pearson correlation analysis was used to explore the correlations between online sexual objectification experience, body-image depression, and physical activity among female college students; Harman one-factor test and validation factor analysis were used to test for common method bias. The procedure developed by Hayes was used to select model 4, test the mediating effect between online sexual objectification experience and physical activity of body-image depression, and

adopt the bias-corrected bootstrap method (5,000 repetitions of sampling) to estimate 95% confidence intervals (CI) to further validate the mediating effect in order to achieve the study needs.

Results

Demographic results

A total of 830 female college students were included in this study, with online sexual objectification experience scores of 2.12 ± 0.55, body-image depression scores of 2.25 ± 0.34, and physical activity scores of 20.80 ± 18.91. The highest physical activity scores were (25.08 ± 20.68) for arts and sports students, and higher for arts (20.42 ± 18.89) than for science and technology (18.17 ± 16.83).

Common method deviation control and inspection

Harman's one-factor method was used to test for common method bias, and all question items about online sexual objectification experience, body-image depression, and physical activity were subjected to unrotated exploratory factor analysis; a total of six common factors with eigenvalues greater than 1 were extracted, and the maximum factor explained 34.954% of the total variance, which was less than 40% of the judgment criterion (Podsakoff et al., 2003). In addition, the validation factor analysis revealed that the one-factor model fit was poor (X^2/df = 11.156, CFI = 0.637, TLI = 0.637, IFI = 0.638, RMSEA = 0.111), further indicating that there was no serious common method bias in this study and that statistical requirements had been met.

Demographic variance analysis

From the *t*-test and one-way ANOVA results (**Table 1**), the online sexual objectification experience, body-image depression (including body-shape depression and appearance depression), and physical activity of female college students with different majors were significantly different, but gender depression and sexual-organ depression were not significantly different. Online sexual objectification experience, body-image depression, and physical activity were higher in arts and sports categories than in arts categories, and were higher in arts categories than in science and technology categories. There were significant differences in body-image depression (including body-shape depression and appearance depression) between female college students with different education levels categories, undergraduate students scored more highly than graduate students; however, there were no significant differences between these groups in online sexual objectification experience and physical activity. There were no significant differences in online sexual objectification experience, body-image depression, and physical activity between different birth sources or whether or not respondents were only children.

Correlation analysis

Pearson's correlation analysis of online sexual objectification experience, body-image depression, and physical activity, shown in **Table 2**, revealed that online sexual objectification experience was negatively correlated with body-image depression ($r = -0.484$, $P < 0.01$), body-image depression was negatively correlated with physical activity ($r = -0.569$, $P < 0.01$), and online sexual objectification experience was positively correlated with physical activity ($r = 0.420$, $P < 0.01$).

Body-image depression mediating-effect test

A multivariate hierarchical regression analysis using Process, an SPSS macro program developed by Hayes (2013), was used to test for mediating effects. After controlling for major and education level categories, regression analysis revealed that online sexual objectification experience significantly positively predicted physical activity (β = 14.229, $p < 0.001$) and significantly positively predicted body-image depression (β = −0.293, $p < 0.001$) giving support for H1 and H2. When both online sexual objectification experience and body-image depression predicted physical activity among female college students, the positive predictive effect of online sexual objectification experience on physical activity was still significant (β = 6.448, $P < 0.001$). Therefore, body-image depression played a partial mediating role between online sexual objectification experience and physical activity, as shown in **Table 3**.

The mediation effect was further tested using the bootstrap method with 5,000 random samples; if the confidence interval does not include 0, it indicates a significant mediation effect. The test results showed that the confidence interval of the mediating effect of body-image depression was [6.610, 9.380], excluding 0, indicating that body-image depression mediated the effect of online sexual objectification experience on physical activity of female college students. The total effect of online sexual objectification experience on physical activity was 14.44, of which the direct effect was 6.49 (accounting for 44.97% of the total effect), and the indirect effect through body-image depression was 7.95 (accounting for 55.03% of the total effect), this supports H3 in this study (**Table 4**).

TABLE 1 Demographic characteristics of the sample.

Variables		*n*	Statistics	OSOE	BID	Body-shape depression	Gender depression	Sexual-organ depression	Appearance depression	PA
M	STC	190		2.05 (0.51)	2.30 (0.35)	2.27 (0.41)	2.28 (0.48)	2.27 (0.47)	2.35 (0.44)	18.17 (16.83)
	AC	481		2.09 (0.55)	2.26 (0.34)	2.21 (0.43)	2.26 (0.47)	2.31 (0.44)	2.30 (0.42)	20.42 (18.89)
	ASC	159		2.29 (0.56)	2.16 (0.33)	2.06 (0.38)	2.25 (0.43)	2.27 (0.43)	2.15 (0.44)	25.08 (20.68)
			F	10.322	8.765	12.571	0.113	0.786	10.476	6.064
			p	**	**	**	0.893	0.456	**	**
ELC	Undergraduates	394		2.09 (0.55)	2.28 (0.34)	2.23 (0.41)	2.26 (0.45)	2.28 (0.45)	2.33 (0.43)	21.46 (19.20)
	Graduates	436		2.15 (0.55)	2.23 (0.35)	2.17 (0.43)	2.27 (0.47)	2.30 (0.44)	2.23 (0.43)	20.19 (18.65)
			t	−1.353	2.138	2.250	−0.369	−0.536	3.306	0.966
			p	0.177	*	*	0.712	0.592	***	0.335
POB	Rural	427		2.16 (0.55)	2.26 (0.35)	2.20 (0.41)	2.27 (0.47)	2.29 (0.44)	2.29 (0.44)	19.68 (17.86)
	City	403		2.08 (0.55)	2.25 (0.34)	2.21 (0.42)	2.26 (0.46)	2.29 (0.45)	2.27 (0.43)	21.99 (19.92)
			t	1.870	0.249	0.023	0.200	0.084	0.421	−1.759
			p	0.062	0.803	0.832	0.842	0.933	0.674	0.079
OC	Yes	384		2.09 (0.56)	2.26 (0.35)	2.21 (0.43)	2.27 (0.46)	2.28 (0.46)	2.29 (0.43)	20.23 (18.99)
	No	446		2.15 (0.54)	2.24 (0.34)	2.19 (0.41)	2.25 (0.47)	2.29 (0.43)	2.27 (0.44)	21.28 (18.85)
			t	−1.391	0.951	0.744	0.628	−0.281	0.465	−0.800
			p	0.164	0.342	0.457	0.530	0.778	0.642	0.424

OSOE, online sexual objectification experience; BID, body-image depression; PA, physical activity; M, major; ELC, education-level categories; POB, place of birth; OC, only children; STC, science and technology categories; AC, arts categories; ASC, arts and sports categories. *$P < 0.05$; **$p < 0.01$; ***$p < 0.001$.

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TABLE 2 Descriptive statistics and correlation analysis of all the variables.

Variables	Mean	SD	1	2	3
(1) Online sexual objectification experience	2.12	0.55	1		
(2) Body-image depression	2.25	0.34	−0.484**	1	
(3) Physical activity	20.80	18.91	0.420**	−0.569**	1

**$P < 0.01$.

Discussion

The findings of this study showed that there was a significant correlation between online sexual objectification experience, body-image depression, and physical activity among female college students. The results proved that the richer the online sexual objectification experience of female college students, the more serious body-image depression and the more active the participation in physical activity. Further analysis revealed that the differences between online sexual objectification experience, body-image depression, including body-shape depression and appearance depression, and physical activity were significant between different majors. The differences between education level categories in body-image depression, body-shape depression, and appearance depression were significant, and the differences in online sexual objectification experience and in physical activity were not significant. The online sexual objectification experience and physical activity scores of arts and sports categories are higher than those of arts categories, and the scores of arts categories are higher than those of science and technology categories. This may be due to the characteristics of the majors, as art students have a strong aesthetic awareness, are more sensitive to their own body image, and often look at the bodies of others and themselves from an objectification perspective, resulting in a richer objectification experience compared to the other two categories of body-image comparison frequency; physical education students have formed a good awareness of physical activity and developed physical activity habits, and their attitudes and behaviors are both significantly higher than those of other majors (Moreno et al., 2014).

Hypothesis one of this study was verified. This study found that a certain level of online sexual objectification can positively predict physical activity. A study based on American women also confirmed this result, showing that self-objectification is an important predictor of physical activity in both young and older women (Rose, 2008). Self-objectified individuals have higher expectations for improving their appearance through physical activity, which leads women to choose physical activity to improve body satisfaction when comparing them to ideal beauty. Individuals with different levels of self-objectification also differ in the type of physical activity, motivation, and choice of environment for physical activity (Harper and Tiggemann, 2008). For example, individuals with high levels of self-objectification are more likely to choose appearance-oriented physical activity and also prefer fitness centers to sites outside fitness centers in terms of environment choice (Prichard and Tiggemann, 2008).

Hypothesis two of this study was verified. According to the study, the higher the level of online sexual objectification, the more serious the body-image depression, which is consistent with previous studies (Grippo and Hill, 2008). Social media is more popular than traditional media among female college students (Bair et al., 2012). Users in social media are both creators and receivers, and can post content as well as comment and agree with their companions (Prieler and Choi, 2014), this greatly enriches the online sexual objectification experience, and combined with the over-promotion of idealized female bodies inherent in the social media environment, creates fertile conditions for body-image depression among female college students.

Correlation and regression analyses showed a negative correlation between body-image depression and physical activity, that is, body-image depression promoted physical activity participation, indicating that when female college students have body-image depression, they may show more physical activity due to stimulation, hoping to build their body shape and improve their body image through active participation in physical activity. This is consistent with the results of the cross-sectional study of Gaspar et al. (2011). Numerous studies have shown that moderate physical activity can improve an individual's body image, and most people participate in physical activity for the purpose of changing and maintaining their body shape and obtaining an attractive body shape (Furnham and Greaves, 1994). The study also found that individuals' self-body image cognition is also one of the important factors affecting physical activity, which will not only affect physical activity behavior but also affect the emotion and attitude during physical activity (Hausenblas and Fallon, 2006). Physical activity can reduce the experience of objectification and alleviate body-image depression. First, because it is the most convenient and effective means of promoting the physical and mental health of college students. Physiological analysis suggests that weight loss and shape change is influenced by a negative energy balance. Adherence to exercise can directly promote metabolism, stimulating sugar and fat consumption, and thus reduce body weight. At the same time with diet control, take the form of dynamic and static combination effect is better (Jakicic and Davis, 2011). It is worth noting that exercise to improve body shape is a long-term physiological adaptation process, to achieve gradual and consistent progress, participants should choose the appropriate exercise program from their own situation; this should involve reasonable degrees

TABLE 3 Regression analysis of the mediation model.

Result variables	Predictive variables	R^2	ΔR^2	F	β	t
PA	Major	0.183	0.179	46.145***	−2.036	−1.702
	STC					
	AC				1.468	0.997
	ASC				3.443	1.850
	OSOE				14.229	12.986***
BID	Major	0.241	0.238	65.658***	−0.035	−1.661
	STC					
	AC				−0.027	−1.056
	ASC				−0.074	−2.273**
	OSOE				−0.293	−15.322***
PA	Major	0.358	0.354	92.049***	−2.956	−2.783**
	STC					
	AC				0.748	0.572
	ASC				1.482	0.895
	OSOE				6.448	5.855***
	BID				−26.541	−15.015***

OSOE, online sexual objectification experience; BID, body-image depression; PA, physical activity; STC, science and technology categories; AC, arts categories; ASC, arts and sports categories. *$P < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 4 Bootstrap analyses of the mediation effect.

Effect	Effect value	95% confidence interval		Effect of the amount
		Lower limit	Upper limit	
Total effect	14.44	12.312	16.566	
Direct effect	6.49	4.335	8.651	44.97%
Intermediary effect	7.95	6.610	9.380	55.03%

of intensity, time, and frequency, preferably under the guidance of professional sports instructors in order to develop a scientific exercise prescription. Second, active participation in physical activity can effectively enhance self-efficacy and self-esteem levels and promote the development of human socialization (Ouyang et al., 2019). Physical activity can strengthen body perception and movement perception, and good proprioception not only helps college students better recognize their self-image, so reducing cognitive bias, but also allows them to fully immerse themselves in the fun of sports, thus enhancing individual self-confidence. Previous studies have found that individuals with different objectification levels tend to choose different types of sports, probably because individuals with high self-objectification are more likely to be driven by body-image comparisons, tend to be associated with more negative body-image outcomes, and are more involved in appearance-oriented sports; individuals with low self-objectification are more likely to be involved in health-oriented sports (Prichard and Tiggemann, 2008). Third, self-objectifying individuals believe that by being physically active they may achieve socially promoted standards of beauty, enhance friendships among peers, family, and other interacting groups, and reduce the risk of interpersonal objectification occurring. However, there is also an alternative argument that self-objectifying individuals reduce physical activity in order to avoid showing their "imperfect" bodies as much as possible (Leary, 1992). It remains to be studied which of the two opposing effects is stronger and which is weaker.

Hypothesis three of this study was tested. The findings suggest that online sexual objectification experience influence physical activity by affecting body-image depression. Online sexual objectification experience was a predictor of body-image depression (Bassett-Gunter et al., 2017), higher levels of online sexual objectification were associated with more severe body-image depression, and individuals with body-image depression

may achieve their desired body image through physical activity (Campbell and Hausenblas, 2009).

The survey shows that the online sexual objectification experience score of female graduate students is higher than that of undergraduate students, but the level of body-image depression is lower than that of undergraduate students, which indicates that graduate students have more mature coping mechanisms when facing body-image depression. There may be several reasons for this phenomenon: First, compared with undergraduates, graduate students bear a greater psychological burden; the heavy academic and employment pressures directly lead to shorter exposure to social media. Research has found that reduced social media use time predicts lower body-image depression (Marengo et al., 2018). Therefore, the risk of body-image depression for graduate students is reduced. Second, the wide variety of sexualized images that flood social media is a significant contributor to body dissatisfaction among adolescent girls, and these images have a more negative impact on how undergraduate students in early and mid-adolescence view their bodies compared to the graduate student population in late adolescence (Tiggemann and Lynch, 2001). Third, graduate students are older and have richer experiences, have a deeper understanding of their body image, and have been able to internalize a more stable body image of themselves. So, they can respond in a positive way to the sexualized images in social media and reduce the frequency of appearance comparisons to reduce body-image depression (Tatangelo and Ricciardelli, 2017).

Research limitations and prospects

The contribution of this study is mainly reflected in two aspects. Firstly, it reveals a clear and systematic structure that links online sexual objectification experience, body-image depression, and physical activity, and explores the mediating role of online sexual objectification experience and physical activity of body-image depression. Secondly, this study included an older group of graduate students than the previous group of college students. However, whether the current findings apply to women of other ages needs further research.

This study has the following limitations. Firstly, only a cross-sectional study was used and a follow-up survey is lacking, so the causal relationship could not be verified. It is hoped that follow-up research methods can be used in the future to further support the results of this study. Secondly, the sample of this study consisted of female college students, and future survey respondents should include diverse groups of young women including athletes, etc. The study found that female athletes have lower body satisfaction than non-athletes (Varnes et al., 2013). People are more concerned about female athletes' body image and temperament rather than athletic performance (Fink, 2015), and female athletes are often promoted as attractive and sexy in the media environment, leading female athletes to over-surveil their body image and be more susceptible to body-image depression (Bissell, 2004). In addition, the data sources are all self-reported, and the subjects may be forced by social and cultural pressures to report better results than the actual results. Finally, although women experience objectification more than men, the impact of objectification on men cannot be ignored, and studies have found that men's levels of objectification may be increasing in today's media environment (Farquhar and Wasylkiw, 2007; Hatton and Trautner, 2011). Therefore, this study also needs to expand the sample to males in order to provide a theoretical basis for the relevant departments to scientifically formulate countermeasures, and promote the physical and mental health development of all college students. The physical activity measurement method of this study needs to be improved. A physical activity recorder should be used in the future to provide precise and real-time monitoring of physical activity data. Although further research is needed, existing studies have confirmed that self-objectification and body-image depression are important factors affecting the physical and mental health of contemporary college students. Future health studies should pay attention to this topic, and reduce the negative effects of self-objectification and body-image depression from the aspects of effective physical activity and improving the cognition of self-body image, so as to improve the mental health level of college students.

Conclusion

This study found that major and educational level categories had significant effects on female college students' online sexual objectification experience, body-image depression (body-shape depression, appearance depression) and physical activity. Online sexual objectification experience and body-image depression can positively predict the physical activity of female college students, and body-image depression has a significant mediating effect between online sexual objectification experience and physical activity.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the local Ministry of Education

Institutional Review Board (102772021RT072). The patients/participants provided their written informed consent to participate in this study.

Author contributions

X-YD, LW, and RM contributed to the design of the questionnaire. QW and Y-FZ organized and analyzed the database. X-YD, LW, and Y-LQ contributed to writing the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

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A cross-sectional analysis of yoga experience on variables associated with psychological well-being

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Introduction: Previous research has identified numerous physical, psychological, and spiritual benefits associated with the practice of yoga. Indeed, yoga has been linked with improved quality of life, reduced stress, and numerous markers of psychological well-being. In the current research, a cross-sectional design was used to examine whether the psychological benefits associated with yoga only apply to long-term practitioners or whether more "casual," intermittent yoga experience could produce positive outcomes.

Methods: An American population of long-term practitioners (n=129), intermittent practitioners (n=161), and non-practitioners (n=164) completed online self-report measures of emotional regulation, trait mindfulness, self-compassion, interoceptive awareness, and spiritual intelligence variables.

Results: The results indicated that long-term (LT) practitioners scored higher than intermittent experience (IE) practitioners on measures of mindfulness (M_{LT}=137.3; M_{IE}=127.6), interoceptive awareness (M_{LT}=3.4; M_{IE}=3.1), self-compassion (M_{LT}=3.4; M_{IE}=3.1), and spiritual intelligence (M_{LT}=63.5; M_{IE}=55.5; all p-value < 0.05). Intermittent practitioners scored higher than no-experience (NE) group on interoceptive awareness (M_{IE}=3.1; M_{NE}=2.7) and spiritual intelligence (M_{IE}=55.5; M_{NE}=46.6; both p-value < 0.05). Contrary to our hypotheses, yoga experience had no effect on depression, anxiety, or stress levels. Separate mediation analyses demonstrated that interoceptive awareness, spiritual intelligence, mindfulness, and self-compassion each mediated the relationship between yoga experience and emotion dysregulation. Furthermore, emotion dysregulation mediated the relationship between yoga experience and depression, anxiety, and stress.

Discussion: Taken together, the results of this study suggest that long-term practitioners experience more benefits compared to intermittent and non-practitioners, and that the mechanisms underlying these benefits are multi-faceted.

KEYWORDS

yoga, emotional regulation, mindfulness, self-compassion, interoception, spiritual intelligence

1. Introduction

Yoga originated in India over 5,000 years ago and has evolved into a popular activity that is practiced worldwide for a variety of physical, psychological, and spiritual purposes (Feuerstein, 2003; Pandurangi et al., 2017). Although yoga was originally performed in order to achieve a state of self-realization representing one's greatest potential (Feuerstein, 2003), the primary focus of present-day yoga is on the numerous physical and emotional benefits that result from its practice (see Büssing

et al., 2012, for a review). For example, yoga has been associated with improvements in self-reported quality of life (Birdee et al., 2017), well-being (Cartwright et al., 2020), and sleep quality (Sloan and Kanchibhotla, 2021). It has also been linked with more objective measures of physical health such as a lower waist/hip ratio and body mass index (see Lauche et al., 2016, for a review). Other research has demonstrated that yoga may enhance psychological well-being; yoga practitioners frequently score lower than non-practitioners on measures of perceived stress (Cartwright et al., 2020) and depression (Forseth et al., 2021; Sahni et al., 2021). However, although a rapidly expanding body of research has consistently highlighted the numerous potential benefits of yoga, few studies have included length of yoga practice as a variable of interest. As a result, it is unclear whether the benefits associated with yoga appear with intermittent practice (as would occur for "casual" practitioners) or if longer-term practice is required. The goal of the current research is to examine whether length of yoga practice is related to multiple measures of psychological health. For the purpose of this study, yoga is defined as a practice involving any combination of the following components or "limbs": physical postures (Sanskrit: *asanas*), breathing techniques (*pranayama*), meditation, and/or ethical living toward oneself and others. These limbs may be practiced independently or in a classroom format with a certified instructor. In order to improve clarity, the term "yoga practice" is used to contrast individuals who performed yoga and those who have not; "yoga experience" refers to the length of time—typically months or years—that an individual has performed yoga.

A key component of yoga's long-term psychological benefits appears to be its positive effects on emotional regulation (Gothe et al., 2019). Evidence from neuroimaging studies points to the fact that long-term yoga practice can have neuroplastic effects in areas related to emotional experiences and their regulation (van Aalst et al., 2020). For example, researchers have reported that yoga experience is associated with greater gray matter volume in multiple cortical regions—including the prefrontal cortex—as well as the cerebellum (Froeliger et al., 2012; Villemure et al., 2015; Afonso et al., 2017). This increased cortical volume is similar to that observed in previous studies of mindfulness meditation (Lazar et al., 2005; Tang et al., 2007) and suggests that long-term yoga practice may enhance executive control processes (Gothe et al., 2019). These yoga-related changes in the prefrontal cortex are particularly beneficial to older practitioners; changes in cortical thickness were negatively correlated with scores on the Cognitive Failures Questionnaire (Froeliger et al., 2012). Another volumetric brain-imaging study found that the volume of the right amygdala and left hippocampus were *smaller* in yoga practitioners (Gotnik et al., 2018). The fact that yoga decreases the volume of limbic structures related to emotional responses while also increasing the volume of brain areas involved with emotional regulation may explain the superior emotional regulation abilities reported in previous studies of yoga practitioners (e.g., Gothe et al., 2019).

Although both self-report and neuroimaging studies demonstrate the benefits of long-term yoga practice, there are still many questions that remain unanswered. For example, while yoga is associated with improvements in a number of negative emotional states, less is known about the interoceptive mechanisms that might mediate these effects. Additionally, it is currently unclear whether the benefits of yoga found in long-term practitioners would also be detected in individuals who take yoga classes in a less consistent manner (e.g., people who take yoga classes for some parts of the year but then have periods of time without practicing yoga). Addressing the first question would provide new insights into the factors underlying yoga's benefits. Examining the second question would clarify whether the positive outcomes associated with yoga only apply to dedicated practitioners—or could be relevant to the more casual practitioner. It is important to note that we do not define dedicated practitioners as "experts" in this study. This study also aims to acknowledge traditional Eastern philosophy suggesting that humility and a beginner's mind (*shoshin*) are important in a yoga practice in order to obtain benefits, particularly those of a spiritual nature, as a practitioner.

The current study used a cross-sectional design to investigate whether different measures of emotional well-being and three potential mediating mechanisms differ between individuals with no yoga experience, those with intermittent experience, and long-term yoga practitioners. Emotional well-being was quantified by using questionnaires that measured depression, anxiety, stress, and emotion dysregulation (Lovibond and Lovibond, 1995; Gratz and Roemer, 2004). To assess potential mechanisms of these changes, participants also completed self-report measures associated with mindfulness (Baer et al., 2006), interoceptive awareness (Mehling et al., 2012), and self-compassion (Neff, 2003). These specific variables were included because they are relevant to key components of yoga: physical postures (Sanskrit: *asanas*), breath regulation (*pranayama*), and meditation. Specifically, mindfulness and self-compassion relate to the meditative component of yoga whereas interoceptive awareness is related to the postural, breath regulation, and, sometimes, to the meditative elements of yoga. A measure of spiritual intelligence (King, 2008) was also included for exploratory purposes because many individuals report a spiritual motivation for practicing yoga (Park et al., 2016).

Our initial analyses examined whether there were differences between long-term practitioners, intermittent practitioners, and yoga on measures of psychological well-being. These analyses allowed us to compare our results with previous research; they also demonstrated that there were group differences that could be investigated with more sophisticated statistical analyses. Several mediation analyses were then performed in order to determine how *the relationships between these factors* vary as a function of yoga experience. Separate analyses were performed to test the hypotheses that mindfulness, self-compassion, and interoceptive awareness would each act as mediators underlying yoga's beneficial effects on emotional dysregulation. We also predicted that mindfulness and self-compassion would act concurrently as mediators in the relationship between yoga experience and emotional regulation due to the top-down nature of these processes. Our final analyses examined whether emotional dysregulation could act as both an outcome variable (as noted above) *and* as a mediator of other effects. Specifically, we hypothesized that emotional dysregulation would mediate the relationship between yoga experience and depression, anxiety, and stress.

2. Materials and methods

2.1. Participants

The sample size for this study was determined using G*Power for effect size = 0.15, power = 0.80, and $\alpha = 0.05$ for three groups. An estimate of 432 was provided, although more data were collected in the event of inaccurate reporting. A total of 492 participants completed the current study. Participants were recruited through the Qualtrics Online Market Research Panel (Qualtrics, Inc., Provo, UT) between April and August 2021. Participants were at least 18 years of age and fell into one of three groups: individuals with no experience practicing yoga in their lifetime, individuals who practiced yoga intermittently, or individuals who engaged in a dedicated yoga practice. Participants were provided with these options in multiple-choice format. Intermittent yoga practice was defined as phases

of consistent practice (at least 45 min, once each week for several months or years) mixed with phases (months or years) of little to no practice. The intermittent yoga group was included in this study because many individuals have *some* yoga experience, but tend to take occasional classes rather than incorporating yoga regularly into their lifestyle. Long-term practice was defined as individuals with a minimum of 3 years or more of regular yoga practice (at least 45 min, once each week).

This study received ethics approval from the Human Research Ethics Board at the University of Manitoba (Fort Garry Campus). All participants provided informed consent prior to participating in this experiment.

2.2. Procedure

After providing informed consent, participants provided demographic information and completed six questionnaires. The questionnaires were presented in random order. These included the Depression, Anxiety, and Stress Scale (DASS-42; Lovibond and Lovibond, 1995), Difficulties in Emotion Regulation Scale (DERS; Gratz and Roemer, 2004), Five-Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006), Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012), Self-Compassion Scale (SCS; Neff, 2003), and The Spiritual Intelligence Self-Report Inventory (SISRI-24; King, 2008). In order to detect the possibility of fatigue, additional statements were added to each questionnaire at random intervals. An example of these statements includes, "Please select 3" or, "Please select 1." No participants responded incorrectly to these statements.

Specific information was also collected from the intermittent and long-term yoga groups on their yoga practice. This information included which limb(s) participants practiced, with the possibility of selecting *asanas*, *pranayama*, meditation, ethical living (toward oneself and others), or any combination of these responses. Participants also indicated which schools of yoga they have practiced, with the opportunity to select any combination of the following: *Ashtanga*, Bikram, *Hatha*, Hot Yoga (non-Bikram style), Integral, Iyengar, *Kripalu*, *Kundalini*, Power, Restorative, *Vinyasa*, Yin, Other, or Unsure. Lastly, information was collected on the format in which participants practiced. Participants were selected if they engaged in formal practices (classes led by a certified Yoga instructor for an individual or a group in-person or live online), informal practices (non-video home practice, YouTube videos, or self-guided through books), or both.

2.3. Questionnaires

2.3.1. Depression, anxiety, and stress scale

The Depression, anxiety, and stress scale (DASS-42) is a 42-item measure of state depression, anxiety, and stress (Lovibond and Lovibond, 1995). Participants indicate on a 4-point Likert scale the degree to which each statement applies over the past week, from 0 (*Did not apply to me at all*) to 3 (*Applied to me very much, or most of the time*). The 42 items consist of 14 statements each corresponding to a measure of depression (MacDonald's $\omega = 0.97$), anxiety ($\omega = 0.95$), or stress ($\omega = 0.96$).

2.3.2. Difficulties in emotional regulation scale

The Difficulties in emotional regulation scale (DERS) is a 36-item self-report measure of emotional regulation (Gratz and Roemer, 2004). Participants indicate on a 5-point Likert scale (*1 = Almost Never (0%–10%); 2 = Sometimes (11%–35%); 3 = About Half the Time (36%–65%); 4 = Most of the Time (66%–90%); 5 = Almost Always (91%–100%)*) the degree to which each of the 36 statements apply to them. Higher scores indicate greater difficulties in emotional regulation. The DERS produces one overall score which encompasses all items as well as scores for six sub-scales. The six constructs of the DERS include, with abbreviations in parentheses, Nonacceptance of Emotional Responses (*Non-Accept*; $\omega = 0.91$), Difficulties Engaging in Goal-Directed Behavior (*Goals*; $\omega = 0.88$), Impulse Control Difficulties (*Impulse*; $\omega = 0.90$), Lack of Emotional Awareness (*Awareness*; $\omega = 0.85$), Limited Access to Emotion Regulation Strategies (*Strategies*; $\omega = 0.92$), and Lack of Emotional Clarity (*Clarity*; $\omega = 0.79$; Gratz and Roemer, 2004). Only the total scores were used in the present investigation.

2.3.3. Five-facet mindfulness questionnaire

The Five facet mindfulness questionnaire (FFMQ) measures the tendency to exhibit mindfulness as a personality trait (also called dispositional or trait mindfulness; Baer et al., 2006). The FFMQ consists of 39 statements; participants rate each statement on a 5-point Likert scale, from *1 = never or very rarely true* to *5 = very often or always true*. The FFMQ produces an overall score of trait mindfulness and scores for each of the five facets; higher scores delineate greater trait mindfulness. The five facets consist of *Observing* (paying attention to both internal and external sensations; $\omega = 0.86$), *Describing* (the ability to describe inner experiences; $\omega = 0.84$), *Acting with Awareness* (mindful engagement in activities; abbreviated as *Acting*; $\omega = 0.90$), *Non-Judgment of Inner Experiences* (treating one's internal experiences with openness and curiosity rather than with negative evaluations; abbreviated as *Non-Judging*; $\omega = 0.91$), and *Non-Reacting to Inner Experience* (the ability to remain objective, separate, and calm while one experiences thoughts and emotions; abbreviated as *Non-Reacting*; $\omega = 0.84$; Baer et al., 2006). For the current study, only the total mindfulness scores were utilized.

2.3.4. Multidimensional assessment of interoceptive awareness

The Multidimensional assessment of interoceptive awareness (MAIA) consists of 32 items in an eight-factor model where individuals rank on a 6-point Likert scale the degree to which each statement applies (*0 = Never; 5 = Always*; Mehling et al., 2012). The MAIA is calculated using a total score, corresponding to greater body awareness, and eight sub-scale scores, corresponding to each construct. The eight-subscales of the MAIA consist of *Noticing* (being aware of one's bodily sensations; $\omega = 0.83$), *Not-Distracting* (not ignoring or avoiding uncomfortable sensations; $\omega = 0.63$), *Not-Worrying* (not experiencing distress during unpleasant or painful sensations; $\omega = 0.64$), *Attention Regulation* (paying attention to and controlling bodily sensations; $\omega = 0.91$), *Emotional Awareness* (connecting bodily sensations with emotions; $\omega = 0.89$), *Self-Regulation* (attending to body sensations in order to regulate distress; $\omega = 0.88$), *Body Listening* (using information from the body to inform decisions; $\omega = 0.88$), and *Trusting* (trusting the validity of one's bodily sensations; $\omega = 0.89$; Mehling et al., 2012). Only the total interoceptive awareness scores were used in the present investigation.

2.3.5. Self-compassion scale

The Self-compassion scale (SCS) is a 26-item self-report measure developed by Neff (2003). Individuals indicate on a five-point Likert scale from *1 (almost never) to 5 (almost always)* the degree to which each statement applies. The SCS is comprised an overall score indicating a general factor of self-compassion as well as six sub-scales.

These subscales include *Self-Kindness* (being understanding and supportive to oneself; ω = 0.87), *Self-Judgment* (a person's tendency to judge themselves for their limitations; ω = 0.89), *Common Humanity* (the ability to recognize that personal difficulties or inadequacies are aspects of life experienced by everyone; ω = 0.82), *Isolation* (the tendency to feel alone or isolated following a mistake or when experiencing difficulties; ω = 0.86), *Mindfulness* (the ability to live in the present moment; ω = 0.84), and *Over-Identification* (the tendency to get "carried away" by negative elements of one's life; ω = 0.85). Self-Judgment, Isolation, and Over-identification are all reversed scores. Greater scores on the SCS indicate greater self-compassion (Neff, 2003). For the current study, only the overall SCS score was used.

2.3.6. Spiritual intelligence self-report inventory

The Spiritual intelligence self-report inventory (SISRI-24) is a 24-item questionnaire that provides a measure of spiritual intelligence (King, 2008). An overall score is calculated by adding all items in the questionnaire, following reverse scoring of one item. A higher score is indicative of greater spiritual intelligence. Four sub-scales (King and DeCicco, 2009) are included in this questionnaire, including *Critical Existential Thinking* (*CET*; the ability to reflect on existential topics such as meaning, purpose, and death; ω = 0.87), *Personal Meaning Production* (*PMP*; the capacity to generate a sense of meaning, control, and mastery of life; ω = 0.88), *Transcendental Awareness* (*TA*; perceiving transcendent aspects of the Self, others, and the world that contribute to a sense of interconnectedness; ω = 0.87), and *Conscious State Expression* (*CSE*; the capacity to freely travel to and from other states of consciousness; ω = 0.93). Higher scores on these sub-scales indicate greater capacity to engage in these aspects that contribute to spiritual intelligence (King, 2008). Only the total scores were used in the present investigation.

2.4. Data analysis

All analyses were performed using IBM SPSS Statistics 28.0 Software. One-way ANOVAs were performed for all analyses. Assumptions were tested for normality (Shapiro–Wilk test, $p > 0.05$), homogeneity of variances (Levene's test, $p > 0.05$), and outliers (inspection of boxplots). Data demonstrating a combination of non-normal distributions and outliers were transformed. If outliers were present, data were left due to the strong likelihood that it represented genuinely unusual values. If variances were heterogeneous, results of a Welch ANOVA were reported instead. The Tukey–Kramer post-hoc test was used for most ANOVAs because it allows for unequal sample sizes. If the assumption of homogeneity of variances was violated (Levene's test, $p < 0.05$), the Games–Howell *post-hoc* test was interpreted instead.

3. Results

3.1. Demographic variables

A total of 38 responses were removed due to incomplete or inaccurate reporting. Therefore, a total of 454 participants remained: ($n_{no\ experience} = 164$; $n_{intermittent} = 161$; $n_{long\text{-}term} = 129$). The demographic characteristics of these participants are included in Tables 1, 2. Information regarding gender was missing for up to 35% of the participants in a given subgroup and was not considered further.

TABLE 1 Participants' yoga, meditation, and praying experience [mean (M) and standard deviation (SD)].

	No experience		Intermittent		Long-term	
	M	SD	M	SD	M	SD
Age	44.5	8.7	46.9	17.4	48.0	16.0
Lifetime yoga experience (years)	N/A	N/A	7.0	8.7	11.9	9.9
Past year yoga experience (hours)	N/A	N/A	49.1	73.1	237.8	397.4
Lifetime meditation experience (years)	3.1	8.2	7.0	9.5	10.8	11.4
Past year meditation experience (hours)	42.9	247.9	57.1	80.2	145.6	285.7
Lifetime experience praying (years)	21.7	19.1	25.0	22.0	23.8	22.6

Information about the participants' yoga experience is summarized in Table 3.

A One-Way ANOVA showed that there was no statistically significant difference among groups with regard to age [$F(2, 451) = 2.43$, $p = 0.09$] or number of years praying [$F(2, 451) = 1.03$; $p = 0.36$]. Meditation experience differed among the groups in terms of hours in the past year [$F(2, 451) = 9.00$; $p < 0.001$] and years in their lifetime [$F(2, 451) = 22.24$; $p < 0.001$]. Post-hoc analysis using the Tukey–Kramer test demonstrated that the long-term group reported more years ($p < 0.001$) and hours in the past year meditating ($p = 0.004$) compared to the no-experience group. Long-term practitioners also reported more years meditating ($p = 0.008$) and hours meditating in the past year ($p = 0.002$) compared to the intermittent group. The intermittent group demonstrated significantly more meditation experience than the no-experience group in years ($p < 0.001$); however, hours meditating in the past year did not differ between the two groups ($p = 0.77$). As expected, using Independent Samples *t*-test, yoga experience differed, with the long-term group reporting more hours in the past year [$t(135) = -5.32$; $p < 0.001$] and years in their lifetime [$t(188) = -4.55$; $p < 0.001$] compared to the intermittent group. Because age and years of prayer were not significantly different among groups, no covariates were used in all subsequent analyses. Meditation history was not used as a covariate due to meditation being a significant part of most yoga practices (Feuerstein, 2003, 2008).

3.2. Total score profiles

A summary of the scores of all scales is included in Table 4 below. One-way ANOVAs were conducted for the total score of each measure

TABLE 2 Participant demographic information (percentage).

		No experience (%)	Intermittent (%)	Long-term (%)
Education	Some high school	7.3	2.5	0.8
	High school diploma	32.9	12.4	7.0
	Some college/ university	24.4	28.6	18.6
	Diploma or degree	29.3	41.6	47.4
	Graduate degree	6.1	13.7	26.4
	Other	0.0	1.2	0.0
Ethnicity	White	82.9	83.2	85.3
	Black	7.3	7.5	7.0
	Latin American	3.0	3.7	2.3
	South Asian	0.0	0.6	2.3
	Filipino	1.2	0.0	0.8
	Indigenous	0.0	0.6	1.6
	Chinese	0.0	0.6	0.8
	Korean	0.6	0.6	0.0
	Japanese	0.6	0.6	0.0
	Arab/West Indian	0.6	0.0	0.0
	Southeast Asian	0.6	0.0	0.0
	Other	3.0	2.5	0.0
Religious/ spiritual affiliation	Agnostic/ atheist/ secular	7.3	11.8	6.2
	Buddhism	0.6	1.2	1.6
	Christian	61.0	60.2	59.7
	Hinduism	0.0	0.6	3.1
	Indigenous	0.0	0.0	0.0
	Judaism	0.6	0.6	3.1
	Muslim	0.6	0.0	3.9
	Other	7.9	7.5	7.0
	None Indicated	22.0	18.0	15.5

to identify differences among the three groups. The Tukey–Kramer test was used to identify differences among groups if the ANOVA was significant. A correction was used to account for multiple comparisons. Because three groups were compared, an adjusted p-value of 0.05/3 was used as the cut-off.

The results for the DASS-42 did not indicate any differences among groups. Depression, Anxiety, and Stress scores from the DASS-42 were not significant (all F-values < 1). We analyzed the proportion of DASS-42 scores that fell in a clinically significant range (moderate, severe, or extremely severe; Table 5). There was a trend for the long-term depression, anxiety, and stress scores to have fewer proportions of clinically significant scores compared to the intermittent and no-experience groups. The intermittent group had a trend for a lower proportion of scores in the clinically significant range for depression. This trend was not seen when comparing the intermittent and no-experience groups for anxiety and stress. These scores were compared using a Chi-squared test. No scores were significant ($\chi^2 < 1.20$; $p < 0.05$), indicating that there were no differences in the proportions of scores in the clinically significant range among the groups.

The one-way ANOVA results were significant for the remaining five questionnaires; however, planned comparisons indicated that not all groups differed from one another. For the DERS, the overall ANOVA was significant: [$F(2,451) = 7.24$, $p < 0.001$, $\eta_p^2 = 0.31$]. As expected, the long-term experience group had lower scores compared to the no-experience group on this measure ($p < 0.001$). However, there were no significant differences on the DERS between the long-term and intermittent groups or between the intermittent and no-experience groups (see Figure 1).

The one-way ANOVAs for the FFMQ [$F(2,451) = 20.88$, $p < 0.001$, $\eta_p^2 = 0.085$] and the SCS [$F(2,451) = 12.95$, $p < 0.001$, $\eta_p^2 = 0.054$] were both significant (see Figure 2). For both of these measures, the long-term group had higher scores than the no experience ($p < 0.001$) and the intermittent experience ($p < 0.006$) groups. However, no significant difference was found between the intermittent and no-experience groups on either the FFMQ or the SCS, although there was a trend for significance for the FFMQ ($p = 0.019$).

In contrast, all groups differed from one another on the MAIA and the SISRI. The one-way ANOVAs for the MAIA [$F(2,451) = 34.09$, $p < 0.001$, $\eta_p^2 = 0.13$] and the SISRI [$F(2,451) = 28.95$, $p < 0.001$, $\eta_p^2 = 0.11$] were significant (see Figure 3). For both of these measures, the long-term group had higher scores than the no-experience group ($p < 0.001$) and the intermittent experience group ($p < 0.006$), and the intermittent group had greater scores compared to the no-experience group ($p < 0.001$).

3.3. Mediation analyses

Mediation analyses were performed using PROCESS v3.5 in SPSS. The long-term and intermittent groups were compared to the no-experience group only. These comparisons were used to determine whether the mechanisms of yoga's benefits are the same for both long-term and intermittent practitioners.

More broadly, mediation was used to investigate which aspects of a yoga practice (trait mindfulness, interoception, and self-compassion) contribute to health benefits (reducing depression, anxiety, stress, and/or emotion dysregulation). Five mediation models were tested, each representing separate hypotheses. Yoga group represented the predictor variable for each model, whereas the mediators and outcomes varied. Yoga group was dummy coded in PROCESS to account for the categorical nature of this variable. Comparisons were between the no-experience group and the intermittent group, and between the no experience and the long-term group. These comparisons are delineated with separate paths and coefficients (IE representing the intermittent experience group and LT representing the long-term practitioner group).

The first model tested our hypothesis that interoceptive awareness (MAIA total score) would mediate the relationship between yoga

TABLE 3 Participant yoga experience (percentage of participants practicing each limb, school, and format).

		Intermittent (%)	Long-term (%)
Limb*	Asanas	47.8	62.8
	Pranayama	55.3	63.6
	Meditation	70.8	71.3
	Ethical living	32.9	39.5
School of yoga*	Ashtanga	5.0	16.3
	Bikram	7.5	16.3
	Hatha	9.3	20.2
	Hot (non-Bikram)	6.8	14.0
	Integral	3.1	14.7
	Iyengar	1.9	11.6
	Kripalu	0.0	7.8
	Kundalini	4.3	14.7
	Power	9.9	26.4
	Restorative	17.4	31.0
	Vinyasa	9.9	33.3
	Yin	4.3	18.6
	Other	5.6	6.2
	Unsure	56.5	14.0
Format of practice	Formal	8.7	8.5
	Informal	63.4	28.7
	Both	28.0	62.8

*Participants were provided the opportunity to select more than one response.

TABLE 4 Summary of scores [mean (M) and median].

	No experience		Intermittent		Long-term	
	M (SE)	Median	M (SE)	Median	M (SE)	Median
Depression (DASS-42)	12.2 (0.9)	9.0	12.0 (1.0)	7.0	10.6 (1.0)	6.0
Anxiety (DASS-42)	9.7 (0.7)	6.0	10.8 (0.8)	8.0	10.3 (0.9)	6.0
Stress (DASS-42)	12.6 (0.8)	10.5	13.9 (0.9)	11.0	12.1 (1.0)	8.0
DERS	91.2 (2.1)	91.0	85.2 (2.2)	82.0	78.8 (2.5)	71.0
FFMQ	121.2 (1.5)	118.0	127.6 (1.7)	125.0	137.3 (2.1)	137.0
SCS	3.0 (0.06)	3.0	3.1 (0.06)	3.1	3.4	3.2
MAIA	2.7 (0.06)	2.8	3.1 (0.7)	3.0	3.4 (0.06)	3.4
SISRI-24	46.6 (1.6)	46.0	55.5 (1.3)	56.0	63.5 (1.7)	65.0

practice (group) and emotion dysregulation (DERS total score). That is, the relationship between yoga practice (intermittent and long-term) and emotion dysregulation would show lesser or no significance when introducing interoceptive awareness as a variable that explains this relationship. Model 4 in PROCESS was used. Models for both the intermittent (Indirect effect = −0.19; SE = 0.047; 95% CI [−0.29, −0.11]) and long-term (Indirect effect = −0.38; SE = 0.064; 95% CI [−0.52, −0.26]) groups were significant (Figure 4).

Our second hypothesis was that self-compassion (SCS total score) and trait mindfulness (FFMQ total score) would *concurrently* mediate the relationship between yoga experience (group) and emotion dysregulation (DERS). Model 4 in PROCESS was used. Comparisons between the no experience and intermittent group (FFMQ Indirect effect = −3.49; SE = 1.28; 95% CI[−6.07, −1.00]; SCS Indirect effect = −0.12; SE = 0.046; 95% CI [−0.36, −0.22]) and the no experience with the long-term group (FFMQ Indirect effect = −8.83; SE = 1.60; 95% CI [−12.09, −5.83]; SCS Indirect effect = −0.31; SE = 0.06; 95% CI [−0.43, −0.21]) were significant (Figure 5).

The remaining three hypotheses were that emotion dysregulation (DERS total score) would mediate the relationship between yoga experience and depression, anxiety, and stress. All models were significant (Figure 4). The model for depression was significant for both the intermittent (Indirect effect = −1.74; SE = 0.87; 95% CI = [−3.41, −0.37]) and long-term (Indirect effect = −3.57; SE = 0.97; 95% CI = [−5.48, −1.64]) groups. The model for anxiety was significant for both the intermittent (Indirect effect = −1.36; SE = 0.68; 95% CI = [−2.68, −0.17]) and long-term (Indirect effect = −2.78; SE = 0.75; 95% CI = [−4.26, −1.30]) groups. The model for stress was significant for the intermittent (Indirect effect = −1.59; SE = 0.79; 95% CI = [−3.14, −0.48]) and long-term (Indirect effect = −3.24; SE = 0.87; 95% CI = [−5.02, −1.59]) groups.

Exploratory mediation analyses were also conducted. The initial analyses used model 4 in PROCESS. First, we tested the hypothesis that interoceptive awareness (MAIA) would mediate the relationship between yoga experience and spiritual intelligence (SISRI). This relationship was significant for both the intermittent (Indirect effect = 0.22; SE = 0.052; 95% CI [0.12, 0.32]) and long-term (Indirect effect = 0.42; SE = 0.065; 95% CI [0.29, 0.55]) groups. This initial analysis was a precursor to the following analyses. Because interoceptive awareness mediated the relationship between yoga experience and both spiritual intelligence and emotion dysregulation, we conducted a second analysis to see if spiritual intelligence would mediate the relationship between yoga experience and emotion dysregulation. This mediation model was also significant for the intermittent (Indirect effect = −1.82; SE = 0.77; 95% CI = [−3.48, −0.45]) and long-term (Indirect effect = −3.43; SE = 1.35; 95% CI [−6.31, −0.93]) groups (Figure 5). These analyses demonstrate that the pathways for yoga-producing benefits are the same for long-term and intermittent practitioners, with interoceptive awareness, mindfulness, self-compassion, and spiritual intelligence being important mediators for emotion dysregulation. A summary of the mediation analyses is provided in Table 6.

4. Discussion

The current study demonstrates that long-term yoga practice is associated with a number of positive outcomes. Relative to non-practitioners and intermittent yoga practitioners, long-term practitioners showed higher levels of self-reported trait mindfulness, interoceptive awareness, self-compassion, emotional regulation abilities, and spiritual intelligence. The diversity of these benefits is noteworthy

TABLE 5 DASS-42 results and clinical interpretation.

	Depression			Anxiety			Stress		
	M	SD	% CS	M	SD	%CS	M	SD	%CS
No experience	12.2	11.8	40.2	9.7	9.3	43.3	12.6	9.9	29.3
Intermittent	12.0	12.4	36.6	10.8	10.1	43.5	13.9	11.0	29.2
Long-term	10.6	11.7	34.1	10.3	10.5	41.9	12.1	11.5	26.4

%CS, percentage of scores in the clinically significant range (moderate, severe, or extremely severe). Depression scores in this range are from 14 to 42. Anxiety scores in this range are 10–42. Stress scores in this range are 19–42.

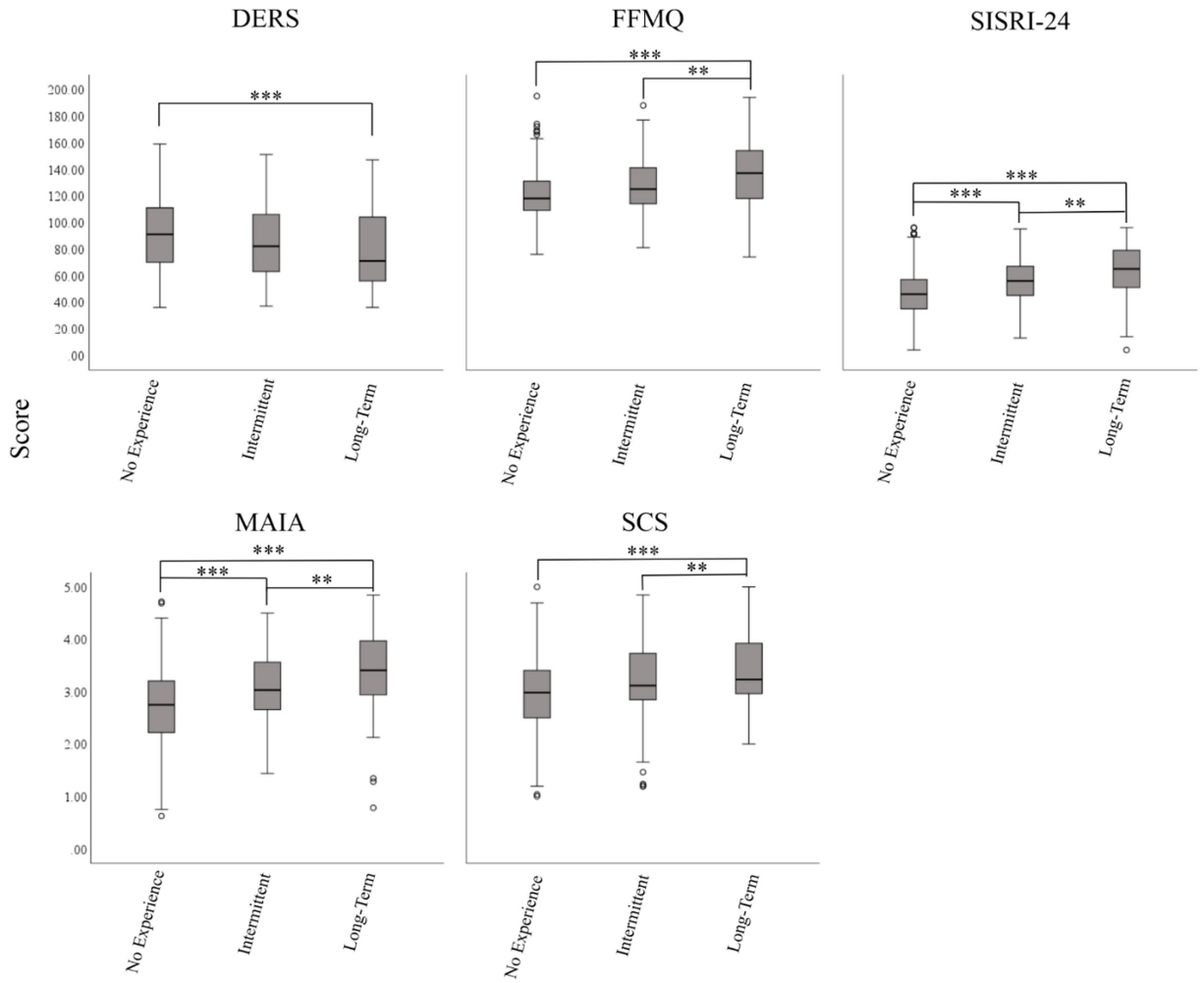

FIGURE 1
ANOVA summary. Margin bars represent ±5% of the mean score. Significance is indicated with **p<0.01 and ***p<0.001.

and suggests that yoga *may* enhance not only body awareness, but also some executive functions (e.g., mindful attention and emotional regulation). Importantly, many of these benefits were not limited to long-term practitioners of yoga—intermittent practitioners also showed higher levels of interoceptive awareness and spiritual intelligence compared to non-practitioners. These results suggest that even inconsistent yoga practice can lead to positive outcomes. It is important to note, however, that the design of the current study does not allow us to make claims about causality; the presence or absence of yoga was not manipulated in an experimental design. It is possible that our results indicate which cluster of personality traits increase the likelihood that someone will consistently practice yoga rather than reflecting the benefits of having practiced yoga. Therefore, for the subsequent discussion of these data, we will focus on traits *associated with* yoga experience. Any discussion of causality will be identified as being speculative.

A key result of the current study related to emotion dysregulation; long-term practitioners had lower scores on the DERS than the intermittent and non-practitioner groups. Our findings are consistent with previous research that reported improvements in emotional regulation following 2 weeks of yoga-based meditation (Patel et al., 2018), short-term yoga interventions for adolescents (Daly et al., 2015; McMahon et al., 2021), 6 weeks of yoga for incarcerated individuals (Willy-Gravley et al., 2021), and a

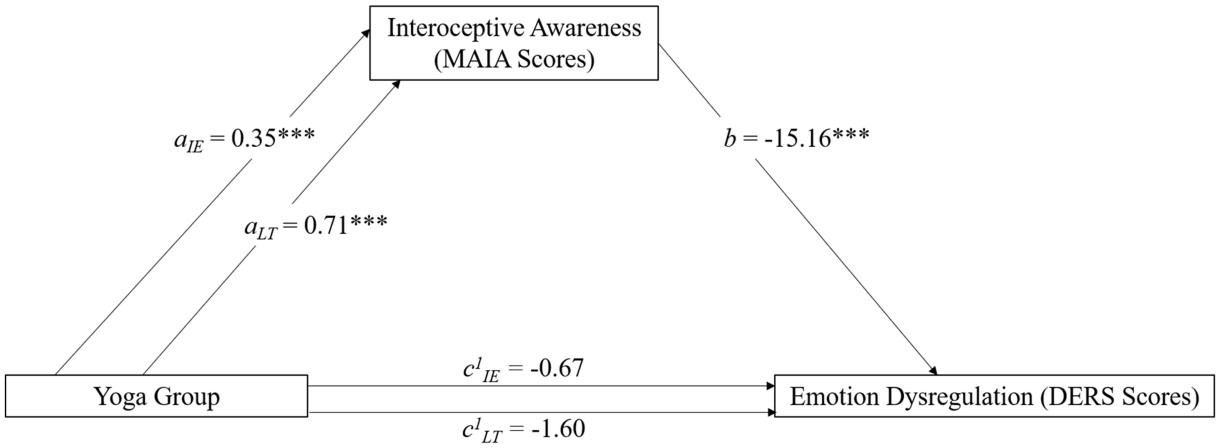

FIGURE 2
Mediation model featuring yoga practice (predictor), emotion dysregulation (outcome), and interoceptive awareness (mediator). Variables with subscript IE represent a comparison between the no experience and intermittent experience (IE) group. Subscript LT represents a comparison between the no experience and the long-term (LT) group. This model demonstrates that the relationship between intermittent and long-term yoga practice and emotion dysregulation is mediated by interoceptive awareness. *** denotes significance with p<0.001. No asterisk represents a non-significant finding.

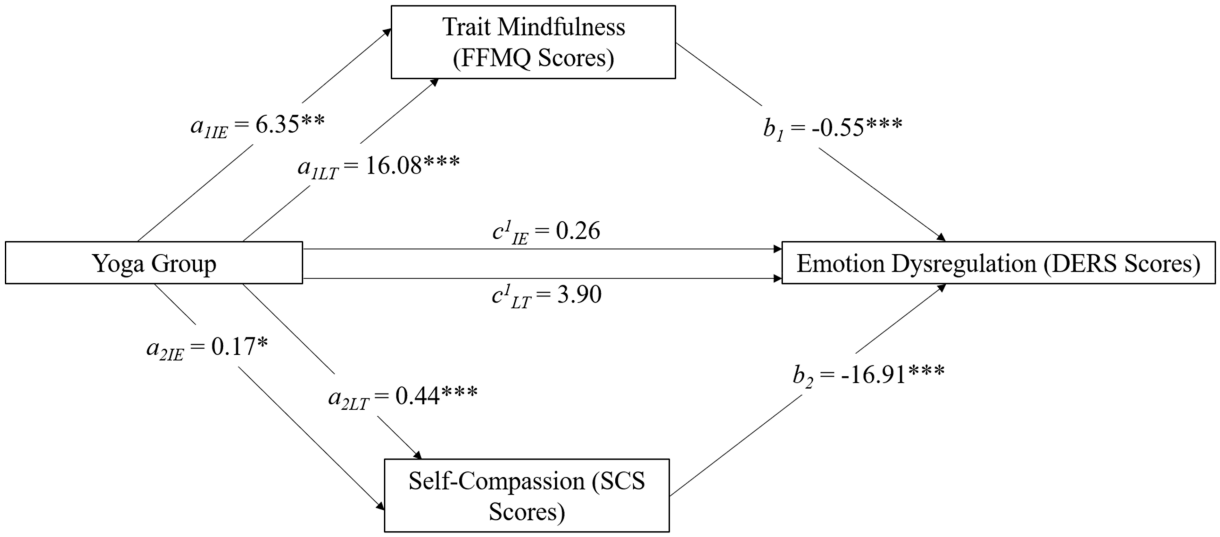

FIGURE 3
Mediation model featuring yoga practice (predictor), emotion dysregulation (outcome), and two mediators (self-compassion and trait mindfulness). Variables with subscript IE represent a comparison between the no experience and intermittent experience (IE) group. Subscript LT represents a comparison between the no experience and the long-term (LT) group. This model demonstrates that the relationship between intermittent and long-term yoga practice and emotion dysregulation is mediated by trait mindfulness and self-compassion. Significance is represented as * (p<0.05), ** (p<0.01), or *** (p<0.001). No asterisk represents a non-significant finding.

minimum of 1 year of yoga practice (Kobylińska et al., 2018). Given that many of these earlier studies involved improvements arising from yoga training, it is likely that the group differences observed in the current research represent a benefit associated with long-term yoga practice. Importantly, the benefits to emotional regulation do not appear to be due to physical activity alone (Daly et al., 2015). One possible mechanism of emotional regulation through yoga practice is cognitive reappraisal (Menezes, 2015; Kobylińska et al., 2018). Menezes (2015) suggested that yoga teaches attention allocation and acceptance, antidotes to rumination, and impulsive reactivity that may contribute to cognitive reappraisal. Future studies could address this possibility by specifically examining cognitive reappraisal—along with other emotional regulation strategies (see McRae and Gross, 2020, for a review)—before and after a yoga training program.

Long-term practitioners also differed from the intermittent and non-practitioner groups on a measure of trait mindfulness. These data are consistent with earlier research showing that the number of months participants practiced yoga positively correlated with FFMQ scores (Snaith et al., 2018). Importantly, our data are also consistent with experimental studies in which participants were measured before and after yoga training. For example, Erkin and Aykar (2021) reported greater scores on the FFMQ in nursing students following 14 weeks of yoga practice. Another study reported improved mindful attention as

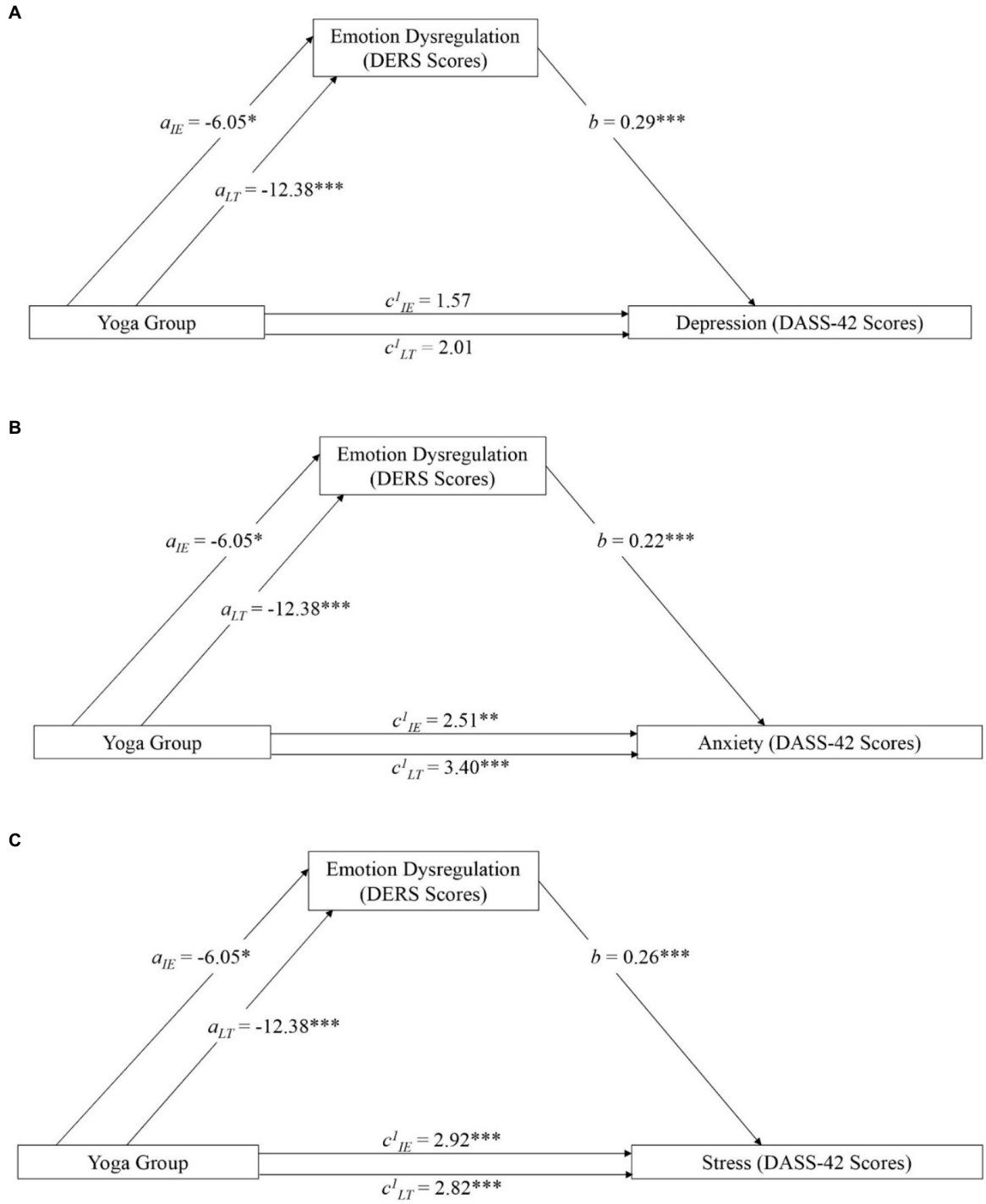

FIGURE 4
Mediation model featuring yoga practice (predictor), emotion dysregulation (mediator), and depression **(A)**, anxiety **(B)**, and stress (**C**; outcomes). Variables with subscript IE represent a comparison between the no experience and intermittent experience (IE) group. Subscript LT represents a comparison between the no experience and the long-term (LT) group. Significance is represented with * (p<0.05), ** (p<0.01), or *** (p<0.001).

measured by the Mindful Attention Awareness Scale (MAAS; Brown and Ryan, 2003) following 2 weeks of daily yoga-based meditation practice (Patel et al., 2018). Taken together, the current study, along with these previous investigations, suggests that yoga practice can enhance trait mindfulness.

The results of our measure of interoceptive awareness were particularly interesting given the key role that bodily awareness plays in most forms of yoga. In our study, long-term practitioners reported higher interoceptive awareness (as shown by scores on the MAIA) than the intermittent and non-practitioner groups. Intermittent practitioners also reported higher interoceptive awareness scores compared to non-practitioners, suggesting that even inconsistent yoga practice may improve awareness of internal bodily sensations. This beneficial effect of yoga is consistent with the results of previous studies using clinical populations. For example, the combination of breath work, mindfulness, and mindful

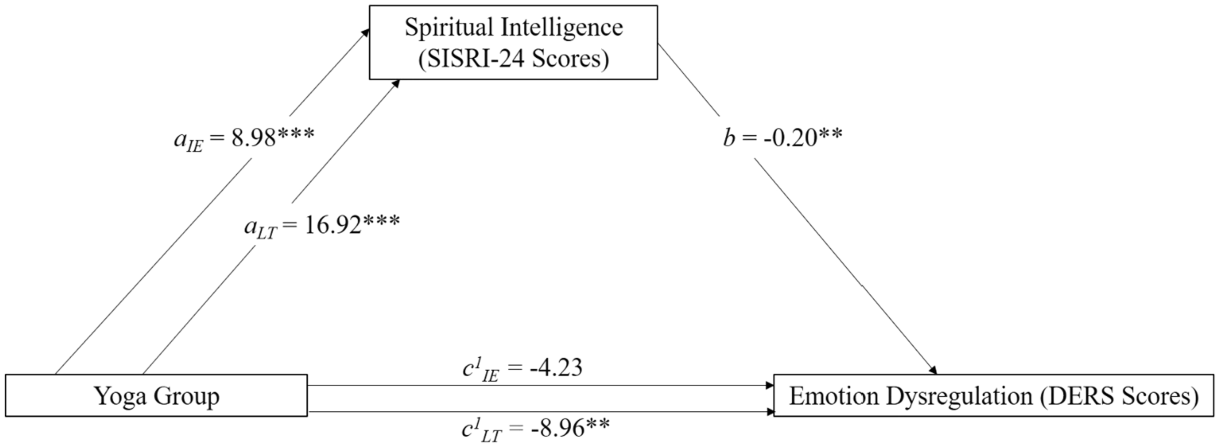

FIGURE 5
Mediation model featuring yoga practice (predictor), emotion dysregulation (outcome), and spiritual intelligence (mediator). Variables with subscript IE represent a comparison between the no experience and intermittent experience (IE) group. Subscript LT represents a comparison between the no experience and the long-term (LT) group. Significance is represented with ** (p<0.01) or *** (p<0.001). No asterisk represents a non-significant finding.

TABLE 6 Mediation analysis summary.

		Total effect	Direct effect	p-value	Indirect effect	95% CI
Analysis 1	Intermittent	−6.1	−0.7	0.05	−0.2	−0.3, −0.1
	Long-term	−12.4	−1.6	0.0002	−0.4	−0.5, −0.3
Analysis 2	Intermittent	−6.1	0.3	0.9	−3.5 (FFMQ) −2.8 (SCS)	−6.1, −1.2 (FFMQ) −12.2, −5.8 (SCS)
	Long-term	−12.4	3.9	0.05	−2.9 (FFMQ) −7.4 (SCS)	−5.7, −0.04 (FFMQ) −10.5, −4.5 (SCS)
Analysis 3	Intermittent	−0.2	1.6	0.1	−1.7	−3.4, −0.4
	Long-term	−1.6	2.0	0.06	−3.6	−5.5, −1.6
Analysis 4	Intermittent	1.2	2.5	0.004	−1.4	−2.7, −0.2
	Long-term	0.6	3.4	0.0003	−2.8	−4.3, −1.3
Analysis 5	Intermittent	1.3	2.9	0.001	−1.6	−3.1, −0.5
	Long-term	−0.4	2.8	0.003	3.2	−5.0, −1.6
Analysis 6	Intermittent	9.0	3.1	0.06	5.9	3.1, 8.7
	Long-term	16.9	5.2	0.005	11.7	8.2, 15.3
Analysis 7	Intermittent	−6.1	−4.2	0.2	−1.8	−3.5, −0.5
	Long-term	−12.4	−9.0	0.009	−3.4	−6.4, −1.0
Analysis 8	Intermittent	−6.1	−1.6	0.6	1.7	0.6, 3.1
	Long-term	−12.4	−3.1	0.3	3.3	1.4, 5.8
Analysis 9	Intermittent	−6.1	−1.6	0.6	−4.4	−6.7, −2.4
	Long-term	−12.4	−3.1	0.3	−8.3	−11.4, −5.6

Analysis 1 consisted of the MAIA (mediator) and DERS (outcome). Analysis 2 consisted of the SCS and FFMQ (concurrent mediators) and DERS (outcome). Analysis 3 consisted of the DERS (mediator) and DASS-42 Depression scale (outcome). Analysis 4 consisted of the DERS (mediator) and DASS-42 Anxiety scale (outcome). Analysis 5 consisted of the DERS (mediator) and DASS-42 Stress scale (outcome). Analysis 6 consisted of the MAIA (mediator) and SISRI-24 (outcome). Analysis 7 consisted of the SISRI-24 (mediator) and DERS (outcome). Analysis 8 consisted of the MAIA and SISRI-24 (sequential mediators) and DERS (outcome). Analysis 9 consisted of the SISRI-24 and MAIA (sequential mediators) and DERS (outcome).

movement contributed to greater MAIA scores in war veterans diagnosed with Post-Traumatic Stress Disorder (PTSD; Mehling et al., 2018). Future research could investigate the relationships between specific elements of yoga (e.g., breathing or postures) on specific subcomponents of interoceptive awareness. These studies could also examine whether yoga practice influences interoception on objective measures such as heartbeat detection rather than self-report measures such as the MAIA.

Similar to interoceptive awareness, self-compassion scores were higher in the long-term practitioner group, but also significantly higher in the intermittent group than in the non-practitioner participants. These results are consistent with other studies incorporating

self-compassion as a construct, including a study of the effects of a 3-day residential yoga program on professional educators (Dyer et al., 2021), an examination of the effects of a 2-week yoga-based meditation program (Patel et al., 2018), a study of nursing students following 14 weeks of yoga practice (Erkin and Aykar, 2021), and an examination of regular yoga practitioners (Snaith et al., 2018). Together, these studies suggest that self-compassion scores may improve with either short-or long-term practicing of yoga. The results of the current study are consistent with this conclusion.

Spiritual intelligence also produced this "graded" pattern of benefits. As with interoceptive awareness and self-compassion, long-term practitioners had greater spiritual intelligence scores on the SISRI-24 compared to intermittent and non-practitioners, and the intermittent practitioners reported greater spiritual intelligence compared to non-practitioners. Few yoga studies have incorporated a quantitative measure of spirituality and compared it to psychological functioning, although there is evidence that spirituality is an important construct for yoga practitioners (Cartwright et al., 2020). The challenge for researchers is to identify the cognitive and emotional components associated with spirituality that may be influenced by yoga practice. Kelly and Moritz (2009) reported that individuals who received lectures and stories on topics of spirituality described feeling a greater sense of connection with themselves, others, and the world while also showing improved self-compassion and mood. Other researchers have suggested an important role for spiritual teachings in emotion reappraisal strategies (Menezes, 2015). It is possible that yogic spirituality helps enhance self-compassion, improve one's mood, and develop emotional regulation strategies that assist with a practitioner's motivation. Additional research is necessary to investigate these possibilities.

A somewhat surprising result from the current study was that the three groups did not differ on measures of depression, anxiety, or stress. This study took place during the COVID-19 pandemic and it is possible that participants exhibited elevated depression, anxiety, and stress levels. However, other studies have reported no significant differences in these, and similar constructs prior to the pandemic (Kiecolt-Glaser et al., 2010; Vollbehr et al., 2018; Papp et al., 2019). These results stand in contrast with those that showed decreased depression and anxiety scores in individuals who practice yoga (e.g., Khalsa et al., 2009; Telles et al., 2015; Snaith et al., 2018). It is unclear what accounts for these differences across studies, although a variety of measures may be factors such as difference in scales, research methodology, or differences in participant demographics. A longitudinal study that includes measures of depression, anxiety, and stress may be useful in delineating the potential protective effects of yoga practice on mental health.

The current study is one of few to investigate a mechanistic model of yoga using mediation analyses (see Boni et al., 2018). These mediation models led to several noteworthy findings. First, they demonstrate that yoga plays a role in reducing emotion dysregulation through two separate paths: a bodily (interoceptive awareness) and spiritual (spiritual intelligence) path. This notion is intriguing, because it suggests an important role for both interoceptive awareness and spiritual intelligence in improving emotional regulation through the practice of yoga for both long-term and intermittent practitioners. This is a unique finding in the literature and warrants further attention from researchers. One possible explanation is that practicing yoga improves interoceptive awareness due to its bodily focus (Emerson, 2015). Practicing yoga may enhance a sense of connection with the Self, others, and the world, contributing to a sense of spirituality (Feuerstein, 2008) and seeing life as more connected and greater than the Self alone (McGonigal, 2019). McGonigal (2019) described the importance of synchronous movement in generating a transcendent state in which people feel connected to others and as part of something greater than themselves. She explained that collective movement helps people combat loneliness, reduce pain, and enhance trust, belonging, and cooperation (McGonigal, 2019). Yoga classes that incorporate collective movement are thus likely to contribute to the aspect of spirituality related to a sense of connection with others and, possibly, the Self.

Traditional yoga philosophy supports these models. In yoga philosophy, one achieves enlightenment through penetration of the *koshas*, five sheaths that surround the Self (Feuerstein, 2008). As an individual penetrates each sheath, from the outermost to the innermost, they may eventually reach the Self and thus achieve a state of enlightenment (Feuerstein, 2008). Thus, our spiritual mediation model may be consistent with this traditional yoga philosophy if we interpret that penetrating the *koshas* enhances spirituality and could lead to improved emotional well-being. We may also interpret this traditional philosophy in another context, where penetrating each sheath is a spiritual practice in and of itself. These mediation models suggest a prominent role for traditional yoga philosophy in the interpretation of spiritual findings.

An additional noteworthy result from our mediation analyses was that yoga may operate through a cognitive path using trait mindfulness and self-compassion for both long-term and intermittent practitioners. This study suggests that trait mindfulness and self-compassion concurrently mediate the relationship between yoga experience and emotion dysregulation. In the absence of these mediators, the relationship between yoga experience and emotion dysregulation was significant, although when these mediators were added to the model, yoga experience became non-significant. This suggests that part of yoga's mechanism for improving emotion dysregulation may be through the incorporation of mindfulness and self-compassion. Consistent with this hypothesis, Wisener and Khoury (2022) reported that trait mindfulness and self-compassion mediated the relationship between emotional regulation and eating as a coping strategy. Additionally, Per et al. (2022) demonstrated that the relationship between emotional regulation and non-suicidal self-injury was mediated by mindfulness and self-coldness (the opposite of self-compassion). When taken together with the first finding, these results highlight the potential importance of physical, mental, and spiritual influences for improving emotional regulation.

An interesting finding from our mediation analyses suggests that emotion dysregulation influenced mood. Emotion dysregulation mediated the relationship between yoga experience and depression, anxiety, or stress for both long-term and intermittent practitioners. This finding is consistent with clinical theoretical orientations that emphasize emotional regulation skills (i.e., Dialectical Behavior Therapy; Linehan, 2014) and emotional processing (i.e., Emotion-Focused Therapy; Greenberg, 2017) for improving mental health. Our finding is also consistent with other studies. Behrouian et al. (2020) found that emotional regulation training in caregivers reduced DASS-21 scores at 1-month follow-up. Patients receiving treatment intervention demonstrated reduced depression and anxiety scores, with emotional regulation as a predicting factor (Khakpoor et al., 2019). Emotional regulation was found to be a mediator between scores on the Adverse Childhood Experiences Scale (ACE) and depression (Cloitre et al., 2019). This finding appears to be robust clinically and in research, suggesting an important role for emotional regulation in influencing mood in a yoga context.

4.1. Limitations

The current study has several limitations that must be addressed in future research. First, the cross-sectional design limits the conclusions that can be made from the findings, specifically with regard to causality. For instance, it is possible that individuals with higher adaptive psychological functioning might be more inclined to engage in a yoga practice. There is also a possibility that certain personality features may predispose an individual to practice yoga, and the findings here are more indicative of personality traits than yoga. The use of a randomized control trial (RCT) experimental design would help address this issue in future research. Second, the solely American sample impedes cross-cultural comparisons; this limitation is important because yoga can serve different functions not only for individuals, but also in different cultures (Feuerstein, 2008). Future research should investigate whether practitioners' intentions and culture of practice influence the magnitude of yoga's benefits. Third, because the data were conducted in an online survey, participants did not undergo clinical screening for mental health or medical conditions. Fourth, our study did not investigate whether individuals experiencing psychological distress (or a diagnosed mental health disorder) would be more or less likely to engage in a yoga practice. This possibility could be addressed in future research by including additional questions about practitioners' motivations for performing yoga. Finally, the division of participants into categories (i.e., non-practitioners, intermittent practitioners, and long-term practitioners) prevented us from using yoga experience as a continuous variable. That said, the use of categories *did* allow us to show the difference between long-term and intermittent practitioners in a simple manner, thus allowing researchers and the general public to easily understand the key findings from this study.

4.2. Conclusion

The results of this study support the continued investigation of how yoga may exert its benefits and, specifically, how the length of yoga practice (i.e., yoga experience) influences these positive effects. The findings suggest that yoga may enhance emotional regulation, trait mindfulness, interoceptive awareness, self-compassion, and spiritual intelligence for long-term practitioners. Intermittent practitioners also see some benefits, although fewer compared to long-term practitioners. Furthermore, two mediation models from this study provide novel evidence that the relationship between yoga experience and emotion dysregulation is mediated by interoceptive awareness, spiritual intelligence, trait mindfulness, and self-compassion. Three mediation models suggest that the relationship between yoga experience and depression, anxiety, and stress are mediated by emotion dysregulation. These models bring an important mechanistic consideration for yoga that may influence future research designs. Studies using pre/post methodology and long-term interventions would be helpful in identifying the specific length and intensity of practice needed to achieve these benefits. Cross-cultural study comparison would also be essential to clarify the generalizability of these models of yoga's potential benefits.

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 University of Manitoba Human Research Ethics Board. The patients/participants provided their written informed consent to participate in this study.

Author contributions

TP and SS designed this study. TP collected the data, performed the data analyses, and wrote the first draft of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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Running to get "lost"? Two types of escapism in recreational running and their relations to exercise dependence and subjective well-being

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Escapism is a fundamental motivation in many forms of activity engagements. At its core, *escapism* is "a habitual diversion of the mind … as an escape from reality or routine". Accordingly, escapism may entail many adaptive and maladaptive psychological antecedents, covariates, and outcomes. However, few studies have been conducted on escapism as a motivational mindset in running. Here, in a sample of recreational runners (N=227), we applied a two-dimensional model of escapism, comprising *self-expansion* (adaptive escapism) and *self-suppression* (maladaptive escapism), and examined how they were related to exercise dependence and subjective well-being. First, confirmatory factor analyses showed that the escapism dimensions were highly diversifiable in the sample. Then, correlational analyses showed that self-expansion was positively correlated to subjective well-being, whereas self-suppression was negatively related to well-being. Self-suppression was more strongly related to exercise dependence compared to self-expansion. Finally, path analyses evidenced an explanatory role of self-expansion and self-suppression in the inverse relationship between exercise dependence and well-being. In conclusion, the present findings support escapism as a relevant framework for understanding the relationship between exercise dependence in running and subjective well-being.

KEYWORDS

addiction, flow, coping, emotion regulation, affect

Introduction

Three decades ago, Baumeister (1991) emphasized the motivational powers of escapism, but the term has mostly been a *rara avis* in the landscape of motivational sciences. In fact, it does not seem to have been empirically explored in relation to exercise or sport engagement at all, only in the consumption of sport as entertainment (Astakhova et al.,

2022). In contrast, the interest in escapism as a distinct form of motivation has escalated in other areas. For instance, escapism has been used as a framework for idiosyncratic experiences in cultural sciences, such as cinematography (Addis and Holbrook, 2010), science of art (Walmsley, 2011), and media science (Wulf et al., 2022). Most importantly, escapism has been incorporated into the clinical assessment of pathological gaming (American Psychiatric Association, 2013; Petry and O'Brien, 2013). One criterion for the assessment of Internet gaming disorder is "use of Internet games to escape or relieve a negative mood (e.g., feelings of helplessness, guilt, and anxiety)" (American Psychiatric Association, 2013, p. 795). The inclusion of this escapism criterion was greatly debated, as escapism does not necessarily coincide with a pathological interest or with detrimental outcomes (Aarseth et al., 2017; Kuss et al., 2017; Hussain et al., 2021).

At its very core, *escapism* is a "habitual diversion of the mind to purely imaginative activity or entertainment as an escape from reality or routine" (Merriam-Webster, n.d.), or "an activity, a form of entertainment, etc. that helps you avoid or forget unpleasant or boring things" (Oxford University Press, 2011). Undoubtedly, these definitions do not infer exclusively maladaptive engagement causing negative consequences, supporting the criticism related to applying escapism as a unidimensional construct (Kardefelt-Winther, 2015).

As in the case of gaming, some people develop a pathological interest in running. About one in four recreational runners (Egorov and Szabo, 2013) and 40% of competitive runners (Juwono et al., 2021) show signs of exercise addiction. What remains unclear, however, is how psychological dependence in running relates to escapism's darker and brighter sides and how these constructs relate to well-being. Thus, in the present study, by applying a two-dimensional operationalization of escapism (Baumeister, 1990, 1991; Stenseng et al., 2012, 2021) in a sample of recreational runners, tapping into both the darker and the brighter sides of escapism, we investigated to which extent the two facets of escapism were differently related to exercise dependence and subjective well-being.

The two-dimensional model of escapism and its relevance for physical exercise

Baumeister (1990, 1991) explored escapism in light of *selfhood*, that is, people's innate ability to monitor, assess, and reflect upon their self-presentations, aims and goals, and their own identity. With this ability for selfhood, it follows that our failures and losses also may be scrutinized in hindsight, which may lead to considerable distress, and when becoming disturbing to an intolerable extent, even lead people into suicidal behavior (Baumeister, 1990; Vohs and Baumeister, 2002). Selfhood may also lead to considerable distress for future occurrences, due to humans' ability to imagine prospective situations and outcomes (Blouin-Hudon and Pychyl, 2015). According to Baumeister (1991), humans seek ways to unwind from this constant self-consciousness through endorsement of activities that pull focus away from their self, if just for their own psychological reward. Moreover, such escapes from self are embedded in our popular culture, such as supporting one's favorite soccer, hockey, or basketball team every Sunday, going to the movies or concerts, or binging Netflix series (Stenseng et al., 2021). However, no efforts to operationalize these forms of everyday escapism were suggested by Baumeister (1991) and his colleagues based on their theoretical work, which stalled empirical investigations of these ideas.

One way of losing oneself is to engage in physical activity, which normally facilitates continuous focus on specific tasks, rules, and actions. The state of flow (Csikszentmihalyi, 1990) has often been used to describe the psychological condition of being cognitively and emotionally absorbed into activities, which has been highlighted as a motivational factor in sport activities. The *flow* state is defined as an engagement in which one's abilities transcend the demands of the activity, which leads to intense cognitive focus, alertness, and a feeling of mastery and joy (Csikszentmihalyi and LeFevre, 1989; Csikszentmihalyi, 1990). A self-report questionnaire was developed to assess nine aspects of flow (see Jackson and Marsh, 1996), which facilitated psychometrical assessments of flow that have spurred a large body of empirical studies (for a review, see Stamatelopoulou et al., 2018). In many respects, flow resembles the state of escape (Stenseng et al., 2012), and correspondingly, it has also been argued that flow has a darker side, instigating an addiction-like interest (Partington et al., 2009). Nevertheless, the concept of flow does not take into account the psychological drive behind the flow-producing activity engagement, and as such, does not fully illuminate the "escape" motives embedded in escapism, a prerequisite clearly stated in the definitions of the term.

Stenseng et al. (2012) presented a two-dimensional model of escapism and developed a corresponding self-report scale (the Escapism scale, see Stenseng et al., 2012, 2021). In their model, the dimensions Self-Suppression and Self-Expansion were identified, stemming from antagonistically different motivational mindsets. Self-Suppression is rooted in *prevention motives* (Higgins, 1998), in the sense that the individual engages in an activity to prevent, or suppress, troublesome thoughts or emotions. With this type of escapism motivation, the main goal of the activity engagement is to distract oneself from uncomfortable mental processes, such as thinking about future challenges and/or rumination about the past ("repetitive, prolonged, and recurrent negative thinking about one's *self*, feelings, personal concerns and upsetting experiences;" Watkins, 2008, p. 164). When these mental processes stir negative emotions, individuals become triggered to suppress and/or alleviate them, and a common response is to dim these troublesome thoughts by pursuing experiences that may outshine them, at least momentarily. A similar motivation is seen in procrastination, simply defined as "putting off for tomorrow what one should have done today" (Milgram et al., 1988, p. 197), where individuals avoid an urgent task due to lack of a proactive mindset; simultaneously, the task becomes more and more pressing, and

the situation more uncomfortable. However, the suppression of negative emotions also dampens positive ones (Gross, 2002), resulting in forms of engagement, independent of type of activity, that are less likely to be accompanied by positive effect. As shown by Stenseng et al. (2012, 2021), self-suppression is related to more trait emotion suppression and lower self-control, as well as fewer positive emotions in activity engagement. Importantly, self-suppression is also negatively related to subjective well-being (Stenseng et al., 2012, Studies 1 and 2; Stenseng et al., 2021).

With the other type of escapism, self-expansion, the motivation is rooted in *promotion motives* (Higgins, 1998). Individuals who engage out of motives to promote positive emotions are likely to gain more positive effect during the activity engagement, but they also experience more long-term benefits from the engagement. This type of motivation is related to more harmonious passion (Stenseng and Phelps, 2016); that is, an interest in an activity that nourishes one's subjective well-being (Vallerand et al., 2003). It has also been shown to be associated with more flow experiences in the activity, compared to self-suppression (Stenseng et al., 2012, Study 3; Stenseng and Phelps, 2016). Moreover, self-expansion has been shown to be related to more basic need satisfaction (e.g., autonomy, relatedness, competence; see Deci and Ryan, 2000) during gaming (Stenseng et al., 2021, Study 1), as well as more positive affect experienced during the activity and higher general subjective well-being (Stenseng et al., 2012, Study 1). Also, when related to online streaming, self-expansion was related to an approach-oriented coping style (Moritz et al., 2016), which normally means acknowledging the challenges and then actively seeking to resolve them, whereas self-suppression was more strongly related to avoidance coping (Stenseng et al., 2021, Study 2), which is characterized by procrastination, suppression, or other measures to temporarily avoid the problem cognitively, in concordance with the *cognitive appraisal hypothesis* of psychological dependence (Szabo, 1995; see also Berczik et al., 2012).

In sum, there is considerable support for a two-dimensional operationalization of escapism, one maladaptive and one adaptive, across several types of activities. The two dimensions, Self-Suppression and Self-Expansion, are differently related to, for example, trait self-regulation, flow and effect in the activity, and subjective well-being. Still, no empirical studies have explored this model in relation to running, which truly is an activity where different psychological mindsets and states are evident (Masters and Lambert, 1989; Siebers et al., 2022), and which also is an activity with enormous popularity (Pereira et al., 2021).

Escapism in relation to exercise dependence and life satisfaction

As argued above, escapism may either be nourishing for one's subjective well-being, or a threat to it, depending on which motivational mindset the escapism behavior reflects. In its maladaptive form, escapism appears to overlap with psychological characteristics of exercise addiction or exercise dependence (for a differentiation of these two, see Szabo et al., 2018).

First, when it comes to personality variables, both self-suppression and exercise dependence are related to lower self-control (Stenseng et al., 2012, Study 1; Zimanyi et al., 2021), but higher trait emotion suppression (Stenseng et al., 2012; Kun et al., 2022, Study 1), and avoidance coping (Egorov and Szabo, 2013; Stenseng et al., 2021, Study 2). Second, both are related to negative effect, or lack of positive effect, during activity engagement as well as after (Hausenblas and Symons Downs, 2002; Stenseng et al., 2012, Study 1; Stenseng et al., 2021, Study 1), as opposed to self-expansion. Third, both self-suppression and exercise dependence are related to intra-and interpersonal conflicts (Stenseng et al., 2012, Study 1; Stenseng et al., 2015). Fourth, both are related to obsessive passion for the activity, whereas self-expansion appears unrelated (Paradis et al., 2013; Stenseng and Phelps, 2016). Finally, both concepts are related to diminished life satisfaction (Hausenblas and Symons Downs, 2002; Stenseng et al., 2012, 2021).

The above-mentioned studies highlight the empirical overlap between self-suppression escapism and exercise dependence. However, these two concepts are anchored in quite different theoretical underpinnings. Most research on exercise dependence is focusing on the phenomenon itself; that is, addiction-like engagement in the activity and its correlational ties to personality characteristics (e.g., self-control, perfectionism, and coping) and as a framework to assess prevalence of this type of addiction across different populations (e.g., Lichtenstein et al., 2014). These empirical investigations have established exercise dependence as a sound, valid phenomenon, with both general and clinical relevance (Hausenblas and Symons Downs, 2002; Terry et al., 2004). However, by predominantly focusing on addiction-like sides of exercise dependence, inspired by other addictions, such as alcoholism (Szabo et al., 2015), this research does not fully illuminate why people maintain their maladaptive activity engagement, although some theoretical alleyways have been suggested (see Berczik et al., 2012; Egorov and Szabo, 2013). This is, after all, the great paradox: why do people keep on engaging in something that is detrimental to their emotional well-being and to their social bonds? What are the psychological nutrients in intense activity engagement that are so rewarding that people keep on doing what is bad for them?

The "state of escape" is arguably one such nutrient in activity engagements (Baumeister, 1991; Stenseng et al., 2012), and it may thus partly explain the paradoxical behavior of exercise dependence. However, in contrast to exercise dependence, the two-dimensional model of escapism targets two separate routes toward the escape experience, and thus suggests that the mere psychological experience in the activity must be seen in light of its motivational mindsets (prevention vs. promotion). To our knowledge, no studies have explicitly studied running from such a dualistic conceptualization of escapism. In fact, very few researchers have explored escapism in running at all. As an exception, Kerrigan et al. (2014) conducted interviews with

runners on how musicalization affected their running experiences. These researchers found several examples on how participants used music to create soundscapes to their running, which promoted their focus during running and thus enhanced their experience of pleasurable escapism in running. Besides this one study, escapism as a motivational factor in running seems to remain unexplored.

The present study

Introductorily, we have described the two-dimensional model of escapism (Baumeister, 1991; Stenseng et al., 2012, 2021) and justified the model's potential relevance for exercise dependence and subjective well-being. Moreover, we pointed at the lack of studies on escapism in running. Accordingly, in this cross-sectional study, in a sample of recreational runners, we first explored the two-dimensional operationalization of escapism as suggested by Stenseng et al. (2012, 2021) using their 14-item Escapism scale. Second, we investigated correlational overlaps between the two escapism dimensions, Self-Suppression and Self-Expansion, to determine their differential relations to exercise addiction and subjective well-being, as well as gender, age, and weekly amount of running. Third, we conducted moderation analyses by means of path modeling to test the additive explanatory effect of the escapism dimensions in explaining the inverse relationship between exercise dependence and well-being, including gender, age, and weekly amount of running as control variables.

Materials and methods

Procedure and participants

Participants were recruited from social media sites for individuals with a particular interest in running (e.g., www.facebook.com/groups/lopeprat). Administrators for these sites were contacted by email to ask for permission to include the link to our online survey questionnaire in their news feed or in their forum. In addition, to recruit additional participants, a sponsored Facebook post was published with the inclusion question: Are you a regular runner? If the response was "yes," they were forwarded to our questionnaire. Ethical concerns were addressed on the first page of the questionnaire, including confirmation of informed consent. On beforehand, the authors aligned the project with the internal policy for research ethics at the respective university. Also, a clinical psychologist was accessible to the participants throughout data collection per e-mail. Only fully answered questionnaires were submittable, ensuring data without missing values. The final sample consisted of 227 regular runners, 115 women and 112 men, with a mean age of 42.7 years ($SD = 11.1$ years). On average, they spent approximately 5 h on running per week ($SD = 2.54$). Nine participants ran more than 10 h per week.

Measures

Dimensions of escapism

The Escapism scale (Stenseng et al., 2012) was used to measure two sets of escapism motives: Self-Suppression and Self-Expansion. The scale has previously been applied to several types of activities, such as sports, gaming, and entertainment (Netflix, HBO, etc.; Stenseng et al., 2015, 2021), and it has demonstrated good factorial validity and internal consistency in all samples. The full scale consists of 14 items, five items to measure Self-Expansion, six items to measure Self-Suppression, and three escapism criterion items. The criterion items tap into the state of escape, which characterizes both dimensions of escapism, as well as time narrowing, cognitive focus, and immersion, and they should thus correlate with both subscales. All items are phrased as an extension of the stem "When I engage in the activity…," which in this case was modified to "When I am running…" to correspond with the activity in focus in the present research. Sample items for Self-Expansion are "I try to learn new things about myself," and "I open up for experiences that enrich my life." Sample items for Self-Suppression are "I try to forget the difficult things in my life," and "I try to suppress my problems." Responses were made on a 5-point Likert scale ranging from *totally disagree* to *totally agree*. Cronbach's alphas were 0.78 for Self-Expansion and 0.86 for Self-Suppression. A composite score of the criterion items correlated 0.54 with Self-Expansion and 0.27 with Self-Suppression, both significant on the 0.01 level.

Exercise dependence

The Exercise Dependence Scale (Hausenblas and Symons Downs, 2002) was used to measure addiction to running. The Exercise Dependence Scale is adapted from the *DSM-IV* (American Psychiatric Association, 1994) assessment for substance dependence, based on seven criteria: (a) tolerance, (b) withdrawal, (c) intention effect, (d) lack of control, (e) time, (f) reduction in other activities, and (g) continuance. Sample items are "I am unable to reduce how long I exercise" and "I would rather exercise than spend time with family/friends." Responses were made on a 6-point Likert scale, ranging from *never* to *always*. Cronbach's alpha was 0.89.

Subjective well-being

The Satisfaction With Life Scale (Diener et al., 1985) was used to measure subjective well-being among participants. This is a five-item scale addressing cognitive evaluations of current life satisfaction, including items such as "In most ways my life is close to my ideal" and "I am satisfied with my life." Responses were made on a 7-point Likert scale, ranging from *totally disagree* to *totally agree*. Cronbach's alpha was 0.9.

Results

The factorial structure of the escapism scale

Although the Escapism scale (Stenseng et al., 2012) has proven relevant across several types of activities, a factorial assessment of the scale was performed in order to examine its performance in relation to running specifically. Thus, a confirmatory factor analysis was performed in Mplus 8.01 (Muthén, 2016). The two-factor solution was examined by means of maximum likelihood estimation, which resulted in good model fits: $\chi^2(43) = 74.78$, $p = 0.002$, RMSEA = 0.057, SRMR = 0.052, CFI = 0.997, TLI = 0.992. Standardized factor loadings for items on the Self-Expansion dimension ranged from 0.84 to 58 and from 0.83 to 0.55 on the Self-Suppression dimension (see Table 1). Results supported the two-dimensional operationalization of escapism embedded in the Escapism scale and that this motivational dualism is found in recreational running.

Bivariate correlations

Bivariate correlation analyses showed, most notably (see Table 2), that Self-Expansion was positively correlated with subjective well-being ($r = 0.17$, $p < 0.05$), whereas Self-Suppression was negatively correlated ($r = -0.38$, $p < 0.01$). Somewhat surprisingly, both Self-Expansion ($r = 0.34$, $p < 0.01$) and Self-Suppression ($r = 0.53$, $p < 0.01$) were positively correlated with exercise dependence, but to substantially different degrees. Self-Expansion and Self-Suppression were only moderately correlated ($r = 0.22$, $p < 0.01$). Of notice, Self-Expansion and Self-Suppression were not differently related to gender ($r \neq p = 0.46$), age ($r \neq p = 0.37$), or amount of running ($r \neq p = 0.08$).

In sum, the correlational analyses supported the two-dimensional conceptualization of escapism, in the sense that Self-Expansion and Self-Suppression were substantially differently correlated to exercise dependence and subjective well-being, but not differently related to age and gender, and they only modestly overlapped each other.

Path analyses

As suggested in the introduction, the two sets of escapism motives could play an explanatory role in how exercise dependence and life satisfaction are empirically entangled. To test this more dynamic approach to the data, which calls for the control of overlapping variance between study variables, we turned to path analyses (Kline, 2015). We are aware of the distinct limitations restricting any causal inferences from path analyses on cross-sectional data (Kline, 2015), and we emphasize that this approach was taken to give a clearer image of the interrelations of the variables, not their true causal structure.

A structural path model was defined in AMOS 28 from the theoretical assumptions outlined in the introduction: Exercise dependence hampers subjective well-being, but the two escapism dimensions add explanatory power to this relationship, controlling for gender, age, and amount of running per week. First, a simple model was tested, containing only exercise dependence as predictor and subjective well-being as outcome, but also including each of the control variables. As expected, a significant relationship was found, also when controlling for these third variables ($\beta = -38.$, $p < 0.001$). Then, when including both Self-Expansion and Self-Suppression as predictors in the model, with additional covariates between all endogenous variables, the relationships between exercise dependence and well-being waned but were still significant ($\beta = -0.28$, $p < 0.001$). However, both Self-Suppression ($\beta = -0.31$, $p < 0.001$) and Self-Expansion ($\beta = 0.32$, $p < 0.001$) had significant predictive value in the model, and in opposite directions (negative vs. positive, respectively), emphasizing their explanatory role in predicting

TABLE 1 Factor loadings for the escapism dimensions, self-expansion and self-suppression, from confirmatory factor analysis performed in Mplus 8.01.

When I run...	Self-expansion	Self-suppression
1. I try to learn new things about myself.	**0.84**	0.07
2. I often surprise myself in a positive way.	**0.64**	0.03
3. I open up for experiences that enrich my life.	**0.60**	0.17
4. I am filled with positive energy that transfers to other parts of my life.	**0.60**	0.08
5. I try to get to know myself better.	**0.58**	0.05
6. I try to forget the difficult things in my life.	0.06	**0.83**
7. I try to suppress my problems.	0.10	**0.79**
8. I want to escape from reality.	0.05	**0.78**
9. I want to escape from myself.	0.01	**0.76**
10. I shut out the difficult things I do not want to think about.	0.15	**0.61**
11. I try to prevent negative thoughts about myself.	0.19	**0.55**

Bold value is standard procedure of only visual character to emphasize the factor structure.

the variance in well-being over and above exercise dependence (see Figure 1).

Discussion

The aims of the present study were threefold:

1. Test a two-dimensional model of escapism in relation to recreational running.
2. Investigate the relations of the two escapism dimensions, Self-Suppression and Self-Expansion, to exercise and subjective well-being and determine their common or differentiated links to gender, age, and amount of running.
3. Test the additive role of the two escapism dimensions in the inverse relationship between exercise dependence and subjective well-being.

First, the factor analyses confirmed a two-dimensional structure of escapism in running. The analyses conveyed an overall structure with good model fits, two distinctive subdimensions, and a substantial proportion of explained variance. Dimensions also correlated similarly with the escapism criterion items and displayed high internal reliability. Results were in accordance with previous findings in other activities, such as leisure activities in general, gaming, swimming, cycling, and streaming (Stenseng et al., 2012, 2021; Stenseng and Phelps, 2016), thus supporting the applicability of the Escapism scale across a variety of activities.

Second, the correlational analyses showed that the two escapism dimensions, Self-Suppression and Self-Expansion, overlapped differently with exercise dependence and life satisfaction. However, these two dimensions were not differently related to age, gender, or amount of time spent running per week. Findings supported the adaptive versus maladaptive dichotomy of Self-Expansion and Self-Suppression, in that Self-Suppression was more strongly related to exercise dependence and lower well-being than Self-Expansion. Importantly, these results show that escapism mindsets are rooted in latent psychological processes more than descriptive characteristics of individuals, such as age, gender, and time spent running.

Third, as tested through path analyses, both Self-Suppression and Self-Expansion moderated the inverse relationship between exercise dependence and subjective well-being, demonstrating their role beyond exercise dependence in explaining individual differences in well-being. As such, these findings support the idea that these escapism mindsets are relevant in explaining both addiction-like engagement in running, as well as levels of general well-being.

TABLE 2 Means, standard deviations, and bivariate correlations from Pearson's *r*-analyses performed in SPSS 25.

	M	*SD*	1	2	3	4	5	6	7
1. Gender	0.51	0.50	-						
2. Age	42.66	11.12	−0.14*	-					
3. Hours spent running	4.84	2.54	−0.14*	−0.09	-				
4. Self-expansion	3.78	0.65	0.11	−0.21**	0.15*	-			
5. Self-suppression	2.23	0.55	0.10	−0.24**	0.02	0.22**	-		
6. Exercise dependence	2.29	0.55	0.05	−0.26**	0.47**	0.34**	0.51**	-	
7. Subjective well-being	5.21	1.24	0.09	0.07	−0.04	0.17*	−0.38**	−0.30**	-

*$p < 0.05$, **$p < 0.01$

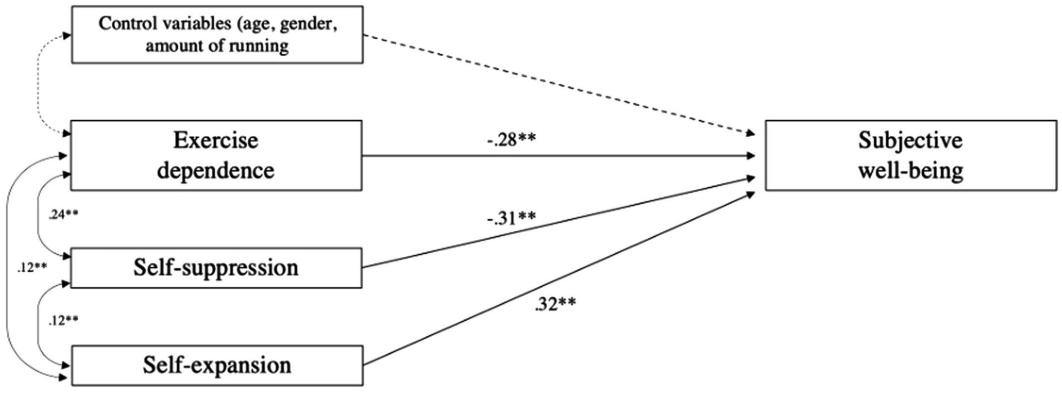

FIGURE 1
Path coefficients (Standardized Betas) and covariates for the full path model tested in AMOS 28. **$p < 0.01$.

As mentioned, escapism as a motivational factor in activity engagements has been highlighted by several authors (Baumeister, 1991; Wulf et al., 2022) and has recently been extensively debated in relation to the inclusion of Internet gaming disorder in *DSM-5* and *ICD-11* (Aarseth et al., 2017). Nevertheless, empirical investigations of this phenomenon in gaming have been rather rare, and somewhat led to ambiguous findings (Hussain et al., 2021). One explanation for this may be that escapism almost exclusively has been operationalized as a unidimensional phenomenon (for an exception, see Hagström and Kaldö, 2014). Although Baumeister (1991) and others (e.g., Hussain et al., 2021) have argued that escapism may have both adaptive and maladaptive underpinnings and outcomes, a two-dimensional operationalization of escapism across activities has been lacking. The present validation of the Escapism scale in a sample of runners, however, adds empirical support to the applicability of a two-dimensional representation of escapism, which to a greater extent seems to capture the totality of escapism as a phenomenon.

The present findings are relatable to exercise dependence in many respects. Exercise dependence, and in this case in relation to running, shares several similarities with other types of addictions. It shares psychological aspects commonly related to non-substance addictions, such as problematic gaming and social media behavior. When intoxication through a substance, such as drugs or alcohol, is taken out of the addiction algorithm, the dependency paradox becomes even more puzzling, but perhaps more interesting psychology-wise. As shown repeatedly in, for example, smoking cessation research (Killen et al., 1992), the psychological dependency is considerably stronger than the physiological one. Thus, the fact that exercise dependence was differently related to the two escapism mindsets in the present study may have relevance to the understanding of the psychological *drive* in other types of addictive behaviors, both substance and non-substance addictions. Somewhat surprising, also Self-expansion was positively correlated to exercise dependence, which shows that addiction-like engagement in running may embed nourishing psychological experiences. This is, at a second glance, perhaps not surprising after all. Even those addicted to an activity find pleasure in the engagement in the activity, to the sense that it becomes impossible to abstain from it, and the positive aspects of escapism may be one such addiction-promoting psychological motive.

The present study supports the notion that activity engagements may be motivated from different motivational mindsets. The two-dimensional mode of escapism applies regulatory focus theory (Higgins, 1998) to illuminate promotion and prevention mindsets in relation to a particular activity, and further how these sets associate with different cognitive and affective experiences, and consequences, in the activity engagement, as well as to general well-being. As such, the escapism model departs from what normally is the primary focus in coping research, which most often assesses coping as a temperamental trait without reference to a particular activity. There are, however, several overlaps between, for example, Roth and Cohens' model of coping (1986), which also is of a dualistic nature, with approach coping and avoidance coping as antagonistic components. Of relevance, Stenseng et al. (2021)study 2 showed that participants' tendencies for avoidance coping were primarily related to Self-Suppression when using streaming services, whereas approach coping was only related to Self-Expansion. Thus, there appears to be an overlap between trait emotion coping and escapism. Future studies should look more closely into how coping mechanisms are related to the escapism mindsets embedded in the two-dimensional model of escapism.

Escapism is, by many authors as well as in bibliographical definitions, described as a shift away from everyday life. Thus, the term does not only entail the state of escape in an activity, such as in the case of flow, but is interpreted as a more holistic perspective of everyday functioning. Escapism (divergence) is seen as a contrast to what is outside (routine); thus, a causal interplay between these two "worlds," so to speak, may emerge. A cascade model may apply, in which lower well-being leads to a stronger self-suppression mindset in the activity, which undermines positive effect and the potentially nourishing experiences in the activity, which then inflicts negatively on life outcomes. This relates to findings in the present study, where Self-Suppression was more strongly related to both exercise dependence and general subjective ill-being, compared to Self-Expansion. Exercise dependence undermines the potential positive psychological consequences from running, but notably, lower general subjective well-being may be seen as both a cause and an outcome of such dependency. One short-term (repeated measures) study found that an increase in general negative effect predicted increase in self-suppression over time (Stenseng et al., 2012, Study 3), but much remains to be investigated regarding how escapism and activity engagements evolve over time in a day-to-day scenario.

Limitations

The present study has several limitations. First, the convenience sample, recruited though several digital channels, may not be representative of recreational runners in general. Nevertheless, derived from the descriptive sample statistics, one may conclude that very few participants were competitive runners, and the gender balance in the sample was rather even. Second, only one measure of escapism was used, and given that escapism in running is a rather uninvestigated theme, a multi-scale approach to the phenomenon would have added more strength to the ecological validity of the findings. Third, subdimensions of exercise dependence were not analyzed in the present study. Although this was beyond the scope of the present study objectives, a deeper look into which subdimensions of exercise dependence overlap most and least

with the escapism dimensions might be fruitful. Fourth, the cross-sectional design of the present study makes it impossible to draw any inferences regarding the causal interplay of escapism, exercise dependence, and well-being. Hopefully, this will be addressed more thoroughly in future studies using longitudinal research designs.

Conclusion

Although prominent researchers such as Baumeister (1991) have highlighted escapism as a fundamental aspect of human motivation and emphasized the dualism to it, a sound operationalization of these stipulations has largely failed to emerge. The two-dimensional model of escapism, with its corresponding scale, may be a pathway toward more empirical scrutiny of this term. In the present study, related to recreational running, the validity of the scale was supported, and its two subdimensions had meaningful correlations to exercise dependence and subjective well-being. In sum, the present findings suggest escapism is a relevant phenomenon in exercise, covering both adaptive and maladaptive aspects of escapism motivation.

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 approval was not provided for this study on human participants because this study contained no personal identifiable information. The patients/participants provided their written informed consent to participate in this study.

Author contributions

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

Conflict of interest

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

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Time-varying associations between loneliness and physical activity: Evidence from repeated daily life assessments in an adult lifespan sample

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Physical activity is a behavior that promotes physical and mental health; yet physical activity has decreased during the COVID-19 pandemic. To promote health during times of challenge, it is important to identify potential barriers to this key health behavior, such as loneliness. This brief report extends previous research on physical activity and loneliness that mainly focused on between-person differences to examine their time-varying associations at the within-person level using repeated daily life assessments. From April 2020 to August 2020, data were collected from a sample of 139 community-dwelling Canadian adults (M_{age}=40.65years, *SD*=18.37; range=18–83years). Each evening for 10 consecutive days, participants reported their loneliness, number of steps, and minutes of moderate-to-vigorous physical activity. Results revealed that, in line with our hypotheses, on days when participants reported more loneliness they also engaged in less moderate-to-vigorous physical activity than on less lonely days (*estimate*=−0.24, *p*=0.007); there was a significant negative association between loneliness and daily number of steps (*estimate*=−18.42, *p*=0.041). In contrast, at the between-person level, overall loneliness was not associated with overall physical activity engagement after accounting for within-person differences and control variables (age, sex, day in study). From an intervention perspective, our findings suggest that it is promising to tackle loneliness on a day-to-day basis to increase physical activity one day at a time. This may be especially relevant during times mandating social-distancing, but also at other times when individuals experience greater feelings of loneliness.

KEYWORDS

physical activity, loneliness, repeated daily assessments, lifespan, moderate-to-vigorous physical activity, number of steps, COVID-19, time sampling

Introduction

Times of challenge that threaten physical and mental well-being, such as the COVID-19 pandemic (Creese et al., 2020; Wettstein et al., 2021; Zheng et al., 2021), highlight the importance of safe everyday behaviors that individuals may engage in to maintain their health (Holmes et al., 2020; Adams et al., 2021). Physical activity is one health-promoting behavior that has been encouraged by health officials during the pandemic as it has the potential to be implemented into daily routines according to social distancing measures (CDC, 2021). Even pre-pandemic, only 20% of adults worldwide engaged in the recommended 150–300 min of moderate or 75–150 min of vigorous physical activity per week (Geneva: World Health Organization, 2020) and emerging research indicates that physical activity behaviors have decreased significantly during the pandemic (Adams et al., 2021; Maltagliati et al., 2021; Shiba et al., 2022). The current brief report aims to better understand salient barriers to physical activity in day-to-day life to support well-being during times when "normal" life is interrupted by extenuating circumstances.

Loneliness is one barrier to physical activity that has become particularly salient during the restrictions of the COVID-19 pandemic (Ernst et al., 2022; Holt-Lunstad and Perissinotto, 2022). Psychological research defines loneliness as the subjective perception of lacking desired social contact and maintains that it is conceptually distinct from feelings of poor social support, perceived stress, depression, or hostility (Cacioppo et al., 2015). Elevated loneliness is associated with negative health outcomes, such as depression and anxiety symptoms (Pels and Kleinert, 2016), and it is as a risk factor for mortality (Holt-Lunstad et al., 2015). Hawkley and Cacioppo (2010) propose a "loneliness loop" model in which social isolation triggers expectations for negative social interactions, which then feed into a self-fulfilling prophecy whereby lonely individuals continue to isolate themselves and exhibit poorer emotional self-regulation, experience fewer positive emotions, and experience lower social control. Together, these consequences of loneliness contribute to a lower motivation for physical activity engagement (Hawkley et al., 2009).

Unsurprisingly, several recent studies have indicated that self-reported loneliness has increased during the COVID-19 pandemic (Elran-Barak and Mozeikov, 2020; Lee et al., 2021; O'Sullivan et al., 2021; Son et al., 2021). In line with Hawkley and Cacioppo's (2010) "loneliness loop" model, recent research found a relationship between home confinement during the pandemic and lower prevalence of physical activity (Shiba et al., 2022). Research also indicates that loneliness has a trait and a state component such that loneliness varies both within-and between-persons (Hawkley et al., 2009; van Roekel et al., 2018). This, with the understanding that physical activity engagement is supported by social engagement and social support (Booth et al., 2000; Leinberger-Jabari et al., 2021), begs the question as to whether there are associations between day-to-day fluctuations in loneliness and daily physical activity behaviors, especially during times of challenge.

Much of the research examining physical activity as a health behavior looks at between-person differences (Creese et al., 2020; Maltagliati et al., 2021); however, repeated daily life assessments from community-dwelling samples also show that there is significant variation in physical activity behaviors at the within-person level (Pauly et al., 2020). Given that we cannot draw within-person conclusions based on between-person differences, analysis of within-person relationships allow us to examine more nuanced and immediate effects of day-to-day barriers to physical activity on physical activity engagement (Kanning et al., 2013). As individuals differ in day-to-day affective states and situational circumstances related to physical activity (Kanning et al., 2013), there is a need to better understand what differentiates a good day from a bad day.

To maximize ecological validity and identify targets for real-world intervention, this brief report uses repeated daily life assessments (Bolger et al., 2003). This measurement-intensive design allows us to capture variation in one's thoughts, feelings, and behaviors across several days. Embracing the meaningful insights gained from getting a snapshot into one's daily life, this method is employed to better understand associations between loneliness and physical activity during times of social distancing.

Embracing that physical activity is shaped by social contexts and that there is significant variation in physical activity on a day-to-day basis (Pauly et al., 2020), this study aimed to extend research on between-person differences in physical activity by examining loneliness on active vs. less active days. This study was launched in April 2020, shortly after the onset of the COVID-19 pandemic, and participants completed daily questionnaires for 10 consecutive days to get a snapshot of their thoughts, feelings, and behaviors during these unique times. We hypothesized that individuals who report more loneliness on a particular day will take fewer steps or engage in less moderate-to-vigorous physical activity that same day as compared to less lonely days. All analyses controlled for variables known to be associated with physical activity, including age, sex, and weekday versus weekend effects (Bellettiere et al., 2015; Burchartz et al., 2022). This project and associated hypotheses were pre-registered on Open Science Framework and can be accessed at the following link: https://osf.io/dvqrt/?view_only=bd39c2a276c84b27aefe77bb7bb64df3I.

Materials and methods

Participants

A total of 139 Canadian residents (M_{age} = 40.65 years, SD = 18.37, range = 18–83) were included in the final analyses of this project (for further details, see Pauly et al., 2021; Choi et al., 2022; Zambrano et al., 2022). The sample self-identified as 80% female, 73% white, 60% having a university degree, and being generally healthy (M_{health} = 3.32, SD = 0.94; on a 1–5 scale). Most participants lived with at least one other person ($M_{household\ size}$ = 2.71, SD = 1.57), 35% reported raising children, 47% self-reported as

not single, and 40% reported being employed at the time of the study. Out of the original 169 participants who completed the daily diary portion of this study, five were removed because they did not provide sex or age data, 24 were removed for completing only one evening questionnaire, and two were removed for never reporting any physical activity data. Participants were recruited through online advertisement, newspaper outlets, and via past participant pools. Participants were eligible for the study if they were 18 years or older, living in Canada, and had access to a computer or mobile device with internet connection to complete the questionnaires. The study was approved by the UBC ethics board [certificate number: H17-01249], and all participants provided informed consent.

Procedure

From April 2020 to August 2020, data were collected online. Eligible participants received a link via email to complete the baseline questionnaire, which involved questions on sociodemographic characteristics, social and personality constructs, physical activity behaviors, and questions specific to the COVID-19 pandemic context. Following the initial questionnaire, participants were invited to complete brief online morning and evening questionnaires for 10 consecutive days, involving questions on affect, context, and activities that day. Participants were asked to self-report their daily number of steps and minutes of moderate-to-vigorous physical activity each evening by either estimating or, if available, using data from their personal fitness watch or smartphone. The average participant completed 6.70 evening questionnaires ($SD = 2.81$), and 73% of participants completed 5 or more evening questionnaires.

All participants were entered to win a $50.00 Amazon gift card for completing the initial questionnaire (1:10 chance of winning), and then entered again for completing 80% of the daily questionnaires (1:5 chance of winning). All procedures were conducted virtually, via email and the Qualtrics survey platform.

Measures

Physical activity

Physical activity was operationalized using number of steps and minutes of moderate-to-vigorous physical activity. During the baseline questionnaire, physical activity was also assessed by self-report at the person-level. Participants were asked to reflect on: "How much time do you typically engage in high to moderate physical activity (the type that makes your heart beat more) on an average day?" ($M_{\text{pre-pandemic}} = 54.76$ min/day, $Median_{\text{pre-pandemic}} = 40.00$, $SD = 52.37$), referring to the amount of activity they engaged in during pre-pandemic times. Also, participants were asked "How much time do you currently spend engaging in high to moderate physical activity on average each day?" ($M_{\text{during-pandemic}} = 38.30$ min/day, $Median_{\text{during-pandemic}} = 30.00$, $SD = 46.71$), referring to their activity engagement at the time of the survey during pandemic restrictions of Spring/Summer 2020. Each evening, participants were asked how many steps they took that day ($M = 5598.00$ steps, $SD = 5524.77$). Participants were prompted to use step data from a personal activity watch or smartphone if they had access to one (a fitness device was used 42% of the time). Participants also reported minutes of moderate-to-vigorous physical activity during each evening questionnaire ($M = 37.61$ min, $SD = 45.32$).

Baseline typical (pre-pandemic times) and current (during pandemic times) moderate-to-vigorous physical activity data were examined and four participants were removed from these analyses as they reported values three standard deviations above the mean. Daily evening physical activity data were examined for outliers, and plots revealed no outliers in addition to the ranges for moderate-to-vigorous physical activity (range: 0–300 min) and number of steps (0–38,693 steps) being within reasonable limits; as such, no data points were removed. Instances where individuals reported 0 daily steps were considered as missing data.

Loneliness

Daily loneliness was assessed during each evening questionnaire for the 10-day study period ($M = 24.72$, $SD = 27.72$). Participants were asked to rate "How lonely did you feel today?." Responses were recorded on a visual analog scale from 0 (Not at all) to 100 (Very Much).

Control variables

Overall self-reported health, weekday, sex, and age were included as control variables in all analyses. Overall self-reported health was measured during the initial baseline questionnaire, where participants were asked to rate their health on a five-point scale (1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good, 5 = Excellent; $M = 3.32$, $SD = 0.94$). Weekday was included as a dummy indexed variable to account for weekday versus weekend behavioral differences in physical activity. Sex was included as a dichotomous female/male variable. Age was included as a control variable and as a moderator variable in exploratory analyses discussed below.

Statistical plan

Given the nested nature of the data underlying this project, a multilevel modelling approach with two levels was used: day level and person level. Moderate-to-vigorous physical activity and number of steps were examined as separate outcome variables, with loneliness as the predictor variable. To account for within-and between-person variation, random intercepts for loneliness and random slopes for daily loneliness were included. Age, overall loneliness, self-reported health, and day in study were grand mean centered, and sex and weekday were included as dichotomous

variables. Please refer to Supplementary material, section 1 for model specifications.

Results

Descriptive statistics and bivariate correlations are presented in Table 1. Bivariate analyses indicated that participants who self-identified as female reported less loneliness ($r = -0.10$, $p < 0.01$) and worse overall health ($r = -0.09$, $p < 0.01$) than those self-identifying as male in this sample. At the bivariate level, loneliness was significantly negatively associated with number of steps ($r = -0.15$, $p < 0.001$); the association between evening moderate-to-vigorous physical activity and loneliness did not reach statistical significance ($r = -0.05$, $p = 0.18$). Age was significantly positively associated with moderate-to-vigorous physical activity at the bivariate level ($r = 0.12$, $p < 0.001$). Using a fitness watch or smartphone to report daily number of steps was associated with reporting more daily steps ($r = 0.29$, $p < 0.001$) and more minutes of moderate-to-vigorous physical activity ($r = 0.13$, $p < 0.001$). Results from the t-test indicate that participants who used a fitness watch reported significantly more steps ($M = 7{,}096$, $SD = 5{,}985$) as compared to participants not using a fitness watch ($M = 3{,}908$, $SD = 4{,}381$), $t(729) = -8.12$, $p < 0.001$.

Intraclass correlation coefficients (ICC's) were calculated for the key study variables. In total, 57% of the variance in number of steps was due to between-person differences (ICC = 0.57) and 43% due to within-person differences. For moderate-to-vigorous physical activity, 38% of variance was due to between-person differences (ICC = 0.38) and 62% due to within-person differences. Between-person differences accounted for 62% of variance in loneliness (ICC = 0.62) and within-person differences accounted for 38% of variance in loneliness.

To better understand our data in the pandemic context, we examined self-reported differences in physical activity pre-pandemic versus during the pandemic at baseline. Consistent with other research emerging during the pandemic, there was a significant difference in moderate-to-vigorous physical activity engagement pre-pandemic ($M = 54.76$ min/day, $SD = 52.37$) and during the pandemic ($M = 38.30$ min/day, $SD = 46.71$); $t(265) = -2.73$, $p = 0.007$. Participants indicated that they engaged in 30% less moderate-to-vigorous physical activity during the pandemic.

Loneliness and physical activity

Results from separate analyses exploring how loneliness was associated with physical activity indices are displayed in Table 2, and results are illustrated in Figure 1. In line with our hypotheses, individuals who reported feeling lonelier on a particular day engaged in significantly less moderate-to-vigorous physical activity ($b = -0.24$, $p = 0.007$). There was a significant negative association between loneliness and daily number of steps ($b = -18.42$, $p = 0.041$). At the between-person level, there was no significant association between overall loneliness on moderate-to-vigorous physical activity engagement or number of steps. These results remained consistent after controlling for the use of a fitness watch or device in models with steps as the outcome variable (Supplementary Table S1).

Additional analyses

To further explore the associations between loneliness and physical activity, additional analyses examined the time-ordering of associations. We first explored morning loneliness as predicting same-evening reported physical activity controlling for between-person differences in age, health, weekday, and sex; however, no significant relationships were found. Time-lagged analyses were also run such that the relationship between previous day loneliness and next-day physical activity was examined with

TABLE 1 Means, standard deviations, and intercorrelations of central study variables (N=139).

Variable	Mean (*SD*)	1	2	3	4	5	6	7
1. Age	40.65 (18.37)							
2. Sex	0.80 (0.40)	−0.07*						
3. Overall health	3.32 (0.94)	0.03	−0.09**					
4. Weekday	–	0.00	0.00	0.05				
5. Evening loneliness	25.10 (27.88)	−0.06	−0.10**	−0.14***	−0.01			
6. Daily MVPA (mins.)	37.61 (45.32)	0.12***	−0.05	0.05	0.02	−0.05		
7. Daily steps	5,598 (5524.77)	0.01	0.03	0.09*	0.03	−0.15***	0.57***	
8. Use of fitness watch or smartphone	Yes: 42% No: 49% missing: 9%	−0.06	0.06	0.11*	−0.02	−0.13***	0.13***	0.29***

SD, standard deviation; MVPA, moderate-to-vigorous physical activity, measured in minutes. Sex was coded as 0 = male, 1 = female; Weekday was coded as 0 = weekday, 1 = weekend. Overall health was measured on a 1–5 scale (1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent). Evening loneliness was measured on a scale from 0 (not at all) – 100 (very much). Participants self-reported whether they used a smartphone or fitness watch to measure their number of steps and use of fitness watch or smartphone was coded as 0 = no fitness watch or smartphone, 1 = used a fitness watch or smartphone. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

TABLE 2 Results from multilevel models examining loneliness and physical activity (N=139).

Predictors	Model 1 (Outcome: Steps)			Model 2 (Outcome: MVPA)		
	B (SE)	*CI*	*p*	*B (SE)*	*CI*	*p*
(Intercept)	5862.03 (1014.47)	3870.33–7853.73	<0.001***	38.14 (6.79)	24.81–51.47	<0.001***
Age	7.09 (21.25)	−34.63 – 48.82	0.739	0.30 (0.14)	0.02–0.57	0.034*
Sex	193.58 (959.79)	−1690.77 – 2077.94	0.840	−4.47 (6.38)	−17.08 – 8.08	0.483
Overall health	435.01 (438.40)	−425.70 – 1295.72	0.321	3.35 (2.81)	−2.16 – 8.87	0.233
Weekday	133.87 (295.73)	−446.73 – 714.48	0.651	1.34 (2.60)	−3.76 – 6.44	0.606
Daily loneliness	−18.42 (8.98)	−36.06 – −0.78	0.041*	−0.24 (0.09)	−0.42 – −0.07	0.007**
Average loneliness	−28.29 (17.27)	−62.19 – 5.61	0.102	0.07 (0.01)	−0.16 – 0.29	0.564
Random effects	***Variance***	***SD***	***Corr***	***Variance***	***SD***	***Corr***
Random intercept	1.69e+07	4109.43	–	747.16	27.33	–
Random slope	1.21e+07	3475.71	–	1217.59	34.89	
Intercept-slope correlation	928.70	30.47	−0.78	0.20	0.44	−0.63

B, unstandardized regression coefficient; CI, confidence interval; SE, standard error; MVPA, moderate-to-vigorous physical activity. Sex was coded as 0 = male, 1 = female. Weekday was coded as 0 = weekday, 1 = weekend. Age and overall health were centered to their means. Unstandardized estimates are reported for intercept and slope variance.

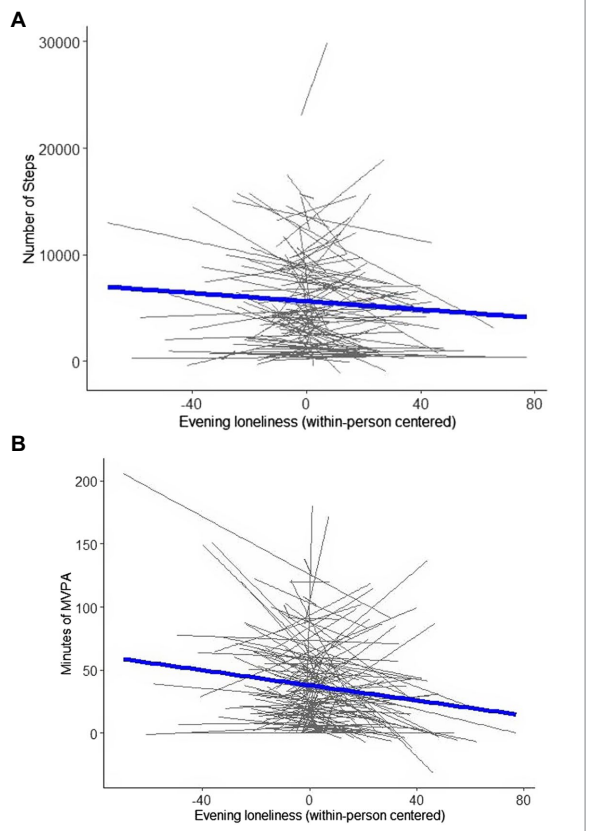

FIGURE 1
Model-implied within-person associations of daily evening loneliness with physical activity indicators (steps and MVPA). MVPA = moderate-to-vigorous physical activity. Number of steps **(A)** and moderate-to-vigorous physical activity **(B)** was higher when individuals felt less lonely than usual.

physical activity indicators as the main outcome variables. There were no significant results from the lagged analyses between loneliness and number of steps or moderate-to-vigorous physical activity at the within-or between-person levels. Age was explored as a moderating variable between loneliness and physical activity, but no significant cross-level interactions were found. In other words, the association between study variables did not significantly differ by age in the present sample. Finally, we conducted analyses controlling for household size to account for social isolation and did not find any significant differences in the reported main results.

All results and model specifications from these additional analyses are reported in Supplementary Tables S2–S6. In sum, this supports the robustness of our results indicating that evening-reported loneliness may be meaningfully associated with same-day physical activity across age groups, over and above social isolation.

Discussion

Physical activity as a health behavior

Despite evidence suggesting that physical activity may be an important coping strategy that mitigates the impact of mandated social distancing on wellbeing (Manuel et al., 2021), research indicates that physical activity engagement has decreased during the pandemic (Adams et al., 2021; Maltagliati et al., 2021). Results from the current study indicating that adults reported a significant decrease in moderate-to-vigorous physical activity compared to pre-pandemic times highlights the importance of supporting physical activity engagement for individuals now, more than ever. Pandemic circumstances may have incurred more loneliness for individuals who do not typically report feeling lonely (O'Sullivan et al., 2021); however, loneliness is an experience that is relevant to almost all individuals at one point or another even during "normal" life (Hawkley and Cacioppo, 2010; Surkalim et al., 2022). The repeated daily life assessment design of the current study allowed us to examine the associations between barriers to physical activity

and physical activity at the within-person level. With significant amounts of day-to-day variation in physical activity behaviors within our sample, we were able to gain a snapshot into our participants daily lives that may be targeted in interventions that are feasible at the day-level.

Contrary to pre-pandemic research, we found that age was significantly positively associated with moderate-to-vigorous physical activity in the present sample at the bivariate level. Although this finding is not consistent with previous work, it does raise an interesting question about how physical activity behaviors may have changed for different age groups during the pandemic. One potential reason for why older adults may have engaged in more physical activity than younger adults may be that their everyday physical activity routines may have been less impacted by social distancing measures than those of younger and middle-aged adults. For example, adults between the ages of 18 and 54 years old make up 60.60% of gym members around the world (The Global Health and Fitness Association, 2022) and older adults report walking, gardening, and home exercise as the top physical activities they engage in (The Canadian Fitness and Lifestyle Research Institute, 1996). As a result, older adults may have been less impacted by the closing of fitness facilities and found their routines less disrupted. Also, older adults are often retired and may not have experienced a large increase in sedentary behavior due to classes being moved to a virtual environment and middle-aged adults with children found themselves balancing work, homeschooling and child care, which may have left little room to carve out intentional physical activity in their day-to-day lives.

Loneliness and physical activity

Our results indicated a significant negative within-person relationship between evening-reported loneliness and concurrent evening-reported physical activity behaviors from that same day; no significant between-person relationships between these main study variables were found. One possible explanation for not finding significant between-person results may be the similar restrictions Canadians experienced during the pandemic. As the pandemic unfolded, fitness facilities and in-person exercise opportunities slowed, and sometimes, entirely stopped. Because of this, individuals may have found themselves in a similar situation to their peers, which may have restricted between-person variance in physical activity behaviors. Interestingly, our results indicate that, even in these unique circumstances, the time-varying relationship between loneliness and physical activity still matters. From an intervention perspective, this may support targeting loneliness on a day-to-day basis since intensive loneliness interventions are often time and resource intensive (Osborn et al., 2021). For example, it may be more feasible to target loneliness on a day-to-day basis by encouraging individuals to engage in activities that make them feel less lonely, such as a phone call with a friend, rather than providing broad statements on how to reduce loneliness such as establishing new close friend connections (Osborn et al., 2021). Experimental research has also found that interventions were most successful when they involved a cognitive behavioral therapy or psychological reframing component (Masi et al., 2011) and recent research has found merit in internet use to support communication with friends and reduce loneliness (Sharabi and Margalit, 2011). These interventions may be explored as ways to target daily loneliness and the subsequent health behaviors that are associated with loneliness. This may be especially relevant during times of mandated social-distancing, but also at other times when individuals experience greater feelings of loneliness throughout their life such as during a health crisis or during turbulent life or world events.

Alternative explanations

In our additional analyses exploring the time-ordering of our results, we found that after accounting for between-person differences in age, health, weekday and sex, daily reported morning loneliness did not predict daily physical activity, despite significant effects between evening reported loneliness and physical activity behaviors. This may suggest that momentary appraisals of loneliness are not sufficient for predicting physical activity outcomes, and that reflective self-reported assessment of how lonely one felt on a particular day may be more powerful in predicting physical activity behaviors.

We explored the robustness of our results by examining time-lagged associations between loneliness and physical activity indices. There were no significant within-person results from these lagged analyses, suggesting that loneliness from the previous day does not significantly predict next-day physical activity behaviors. This may be explained with the understanding that affective states, such as loneliness, have a state component which may fluctuate by day (Hawkley et al., 2009; van Roekel et al., 2018) such that each day's loneliness appraisals serve as a better predictor of same-day physical activities. This may suggest that loneliness be targeted on a finer time scale, such that interventions target daily loneliness as opposed to overall loneliness, which is the focus of most current interventions (Osborn et al., 2021). In the larger loneliness literature, interventions that address negative cognitions around loneliness by promoting activities like personal contact, counselling and community engagement show the strongest evidence for effective intervention (Osborn et al., 2021). Given the risk of social isolation creating a "loneliness loop" whereby individuals continue to distance themselves from others and feed their negative cognitions around loneliness (Hawkley and Cacioppo, 2010), momentary intervention that interrupts this loop may be an alternative approach to explore. As discussed above, small-scale daily behaviors to interrupt loneliness (such as calling a friend) may have the potential to serve as feasible interventions to address the significant time-varying associations between loneliness and physical activity.

Further, age was explored as a moderating variable between loneliness and physical activity. We did not find any significant cross-level interactions between age and our main predictor variables. In other words, the association between study variables did not significantly differ by age. It is important to keep in mind that our sample was relatively homogeneous, and only included 29 participants aged 60 years or older and 10 participants under the age of 20.

Limitations and future directions

It is important to note that the current study was conducted entirely online given the COVID-19 restrictions. Because of these circumstances, participants who expressed interest in the study may be considered a convenience sample, and our sample was relatively homogeneous, with the majority of respondents self-identifying as female, white, highly educated, and relatively healthy. The current study uses a correlational design and cannot address the direction of the relationship between physical activity and loneliness or the underlying mechanism of this relationship. For example, the loneliness-physical activity association may be bi-directional such that physical activity promotes social engagement and thus decreases same-day feelings of loneliness.

Physical activity was assessed via self-report, without the use of "objective" measurement instruments such as accelerometers, which provide data that can later be examined in-lab. As discussed above, there was a positive relationship between the use of a fitness watch or device in reporting number of steps and physical activity reported in the evening. This may be indicative of individuals who use these devices having elevated health conscientiousness and thus engaging in more physical activity. Alternatively, it may point to the fact that individuals may not be accurate in reporting their physical activity engagement. Literature suggests that individuals often under-report daily activities such as gardening or running errands as physical activity, but may also significantly over-report moderate and vigorous physical activity (Prince et al., 2008).

In future research, we would ideally include the use of an activity tracker to gain better insight into differences in daily "objective" vs. "subjective" number of steps and moderate-to-vigorous physical activity measures. In addition, we recognize the importance of understanding how key demographic characteristics, such as parenting, employment, or relationship status may influence physical activity behaviors. For example, parents balancing childcare, working from home, and home-schooling during the pandemic would have faced unique barriers to engaging in regular physical activity. We aim to incorporate a more comprehensive understanding of these sample characteristics in future study designs.

Conclusion

The present study provides evidence of loneliness as a meaningful barrier to physical activity for adults during the COVID-19 pandemic. This main finding builds on past literature indicating that loneliness and physical activity have a negative association at the between-person level; and it extends these results to a community sample using repeated daily life assessments. By exploring potential barriers to physical activity in the daily lives of adults, we aimed to shed light on potential targets of intervention that may be particularly useful during times of challenge. Findings from this research may extend to other particularly challenging times, where "normal" social contact is not possible. This builds on literature highlighting the importance of social connectedness and social interaction for health and wellbeing across the lifespan.

Data availability statement

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

Ethics statement

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

Author contributions

CH designed and directed the project and supervised the work. DG and TP helped design the project and provided feedback. TB created a theoretical framework, preregistered hypotheses, performed data analysis, and wrote the manuscript. YC contributed to the data analysis and together with EZ provided feedback. All authors commented on the manuscript and contributed to the final version of the manuscript.

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Conflict of interest

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

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.1021863/full#supplementary-material

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Assessing basic and higher-level psychological needs satisfied through physical activity

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Background: There has been increasing interest in the extent to which the fulfillment of psychological needs is associated with physical activity engagement. However, a vast majority of studies consider only *basic* psychological needs such as relatedness, competence, and autonomy—with *higher-level* psychological needs such as challenge, creativity, and spirituality rarely being addressed. The aim of this study was to examine the preliminary reliability (i.e., internal consistency) and validity (i.e., discriminant, construct, and predictive) of a multi-dimensional scale to assess a range of basic and higher-level psychological needs satisfied through physical activity.

Methods: A sample of 75 adults (ages 19–65years, 59% female, 46% White) completed a baseline questionnaire measuring 13 psychological needs subscales (i.e., physical comfort, safety, social connection, esteem from others, individual esteem, learning, challenge, entertainment, novelty, creativity, mindfulness, aesthetic appreciation, and morality), exercise enjoyment, and exercise vitality. Participants then completed 14 days of accelerometer monitoring of physical activity and ecological momentary assessment of affective responses during physical activity sessions in daily life.

Results: Internal consistency reliability was acceptable (>0.70) for all subscales except for mindfulness, aesthetic appreciation, and morality. Ten of the 13 subscales exhibited discriminant validity by differentiating between engagement (vs. no engagement) in at least one physical activity type (e.g., brisk walking and yoga/Pilates). All the subscales, except physical comfort and esteem from others, were associated with at least one of the construct validation criteria (e.g., exercise enjoyment, affective response during exercise). Five of the subscales were associated with at least one of the predictive validation criteria (i.e., light, moderate, vigorous intensity activity measured by accelerometer).

Conclusion: Having the capacity to assess whether one's current physical activity is failing to fulfill various psychological needs—combined with recommendations about which types of activities may satisfy those needs—may address an important gap in physical activity promotion.

KEYWORDS

psychological needs, physical activity, ecological momentary assessment, accelerometry, reliability, validity, scale development

1. Introduction

Although regular participation in physical activity leads to many health benefits (Hamasaki, 2016; Wahid et al., 2016; McTiernan et al., 2019), as little as 10% of U.S. adults engaged in recommended levels of ≥150 min/week of moderate-to-vigorous physical activity (Troiano et al., 2008). Progress in physical activity intervention research has stalled in recent years partially due to its focus on social and cognitive determinants of behavior—resulting in interventions that have modest effects on long-term physical activity change (Hartmann-Boyce et al., 2014; Gourlan et al., 2016). An area that has received increased attention in terms of potential influence on physical activity engagement is the extent to which behaviors are perceived as pleasurable (Rhodes and Kates, 2015). When individuals experience a pleasurable behavior, it is rewarding, and they are drawn to it in the future. However, an unpleasant experience can lead to future avoidance of that behavior (Dunton et al., 2020). Whether physical activity is perceived as pleasurable and rewarding may depend on the extent to which it fulfills the individual's psychological needs (Teixeira et al., 2018). Indeed, the satisfaction of psychological needs is thought to lead to optimal well-being and positive emotional states (Deci and Ryan, 2002). Thus, satisfaction of psychological needs during physical activity offers a promising direction for physical activity intervention.

A variety of psychological needs have been studied in motivational psychology. Self-Determination Theory (SDT) suggests that intrinsic motivation for a behavior comes from satisfying basic psychological needs for relatedness, competence, and autonomy (Ryan and La Guardia, 2000). These needs from SDT fall in the middle of Maslow's Hierarchy of Human Needs (Maslow, 1943). Maslow's Hierarchy proposes a wider range of psychological needs, suggesting that humans behave to satisfy biological and safety needs at the lowest level, which are followed by needs for belongingness and esteem (similar to relatedness, competence, and autonomy from SDT), and then at the top of the hierarchy are higher-level needs for self-actualization (Deci and Ryan, 1985, 2000, 2008; Deci et al., 1991; Ryan and Deci, 2018). Although true self-actualization remains a somewhat elusive concept, it is thought to consist of "growth needs" that allow individuals to use and capitalize upon their unique preferences and abilities to reach their full potential (Goldstein, 1939; Whitehead, 2017). Higher-level psychological needs that have been proposed and studied in the self-actualization domain include creativity, challenge, learning, novelty, variety, entertainment and escapism, beauty and aesthetics, mindfulness and spirituality, and morality and altruism (Brock and Livingston, 2004; Gao et al., 2017; Sylvester et al., 2018; González-Cutre et al., 2020). Although lower-level and basic needs (e.g., biological, safety, belonging/relatedness, esteem/competence, and autonomy) are thought to be universally important for most people, the importance of these *higher-level* needs may vary depending on individual values and skills (Goldstein, 1939; Whitehead, 2017). Likewise, behaviors and experiences may differ in the extent to which they are able to satisfy higher-level psychological needs based on their purpose or context (Verstuyf et al., 2013; González-Cutre et al., 2020). Thus, providing tailored physical activity recommendations to fulfill higher-level psychological needs offers a critical missing link to understanding how to promote pleasurable experiences and sustained behavior engagement.

Although interest is growing in understanding how physical activity can fulfill psychological needs, a vast majority of studies consider only *basic* psychological needs derived from SDT (i.e., relatedness, competence, and autonomy; Wilson et al., 2003; Kirkland et al., 2011; Brunet et al., 2016; Kanning and Hansen, 2017; Teixeira et al., 2018; Antunes et al., 2020). This literature generally shows that satisfying needs for autonomy and competence through physical activity is associated with greater concurrent and prospective engagement (actual and self-reported) in physical activity behavior (Teixeira et al., 2012). Receiving much less attention, previous work has shown that physical activity can fulfill *higher-level* psychological needs for novelty (Fernández-Espínola et al., 2020; Engels et al., 2022), entertainment (Laor, 2020), creativity (Richard et al., 2018), and learning (Holt and Neely, 2011). Unlike basic psychological needs from SDT, the importance of these higher-level psychological needs may vary across people, and the extent to which these needs are satisfied may differ across types of physical activity (e.g., running, team sports, and hiking). However, to date, there are no existing validated measures that capture a full range of basic and higher-level psychological needs satisfied through physical activity. Having an instrument to capture which psychological needs are satisfied by what types of physical activity and for whom this occurs is an important step toward developing interventions in this area.

Thus, the overall objective of this study was to examine the preliminary reliability and validity of a multi-dimensional scale to assess a range of psychological needs satisfied during physical activity. The first aim was to identify a parsimonious set of internally-consistent of items to assess each of the proposed physical activity-related psychological need satisfaction dimensions. The outcome of this step was to narrow down the length of the target instrument (so that it could be reasonably administered without undue participant burden). The second aim was to evaluate discriminant validity by examining whether dimension-specific physical activity-related psychological need satisfaction differed across different types of physical activities. According to the conceptualization of self-actualization, higher-level psychological needs allow individuals to make the most of their unique preferences and abilities (Goldstein, 1939; Whitehead, 2017). Furthermore, activities may differ in the extent to which they are able to satisfy higher-level psychological needs depending on their purpose or context (Verstuyf et al., 2013; González-Cutre et al., 2020). Therefore, higher-level psychological needs (e.g., creativity, aesthetic appreciation, and morality), in particular, should differ in the extent to which they are satisfied across different types of activities. The third aim was to evaluate construct validity by examining whether dimensions of physical activity-related psychological need satisfaction were associated with exercise enjoyment, exercise vitality, and affective response during physical activity. The fourth aim was to assess predictive validity by examining whether dimensions of physical activity-related psychological need satisfaction were associated with device-based physical activity levels.

2. Materials and methods

2.1. Overview and design

This study used an observational design with a baseline questionnaire followed by 14 days of real-time monitoring and experience sampling during individuals' daily lives using accelerometers and personal smartphones. No intervention was involved, and participants were asked to engage in their usual levels of physical activity. A 14-day protocol was used to capture a sufficient

number of physical activity sessions during which affective responses could be measured while minimizing overall participant burden. Data were collected between August 2020 and 2021. Due to the federal, state, local, and university restrictions resulting from the COVID-19 pandemic, all study procedures were conducted in a fully remote manner.

2.2. Participants and recruitment

Potential participants were contacted through postings to social media and ResearchMatch (a national health volunteer registry that was created by several academic institutions and supported by the U.S. National Institutes of Health as part of the Clinical Translational Science Award program). Individuals previously participating in University of Southern California research studies were also contacted if they had indicated that they were interested in hearing about future research opportunities. Potential participants were asked eligibility screening questions online. Inclusion criteria were as follows: (1) 18–65 years old; (2) currently engage in ≥60 min of structured physical activity per week; (3) able to speak and read English; and (4) use an Android smartphone as the primary personal phone. Exclusion criteria were: (1) cardiovascular, respiratory, muscular, or bone/joint problems that preclude physical activity; (2) inability to answer smartphone-based surveys for extended periods of time due to work, caregiving, or driving requirements; (3) a body mass index <18 or > 37.5 kg/m^2 (categorized as underweight or morbidly obese); (4) been treated for cancer within the past 6 months; (5) current cigarette smoker; (6) diabetic; (7) unable or unwilling to answer smartphone-based surveys while exercising; (8) take psychotropic medications; or (9) receive treatment for any psychiatric disorder. Additionally, participants who swam for physical activity more than once a week were excluded because the accelerometer device could not be worn in the water. If participants were eligible, a videoconference appointment was made to obtain informed consent.

2.3. Procedures

All procedures were conducted in accordance with the Declaration of Helsinki and approved by the University of Southern California institutional review board for the study of human subjects. During the initial videoconference session, participants were consented for the study and provided their mailing address. Following this session, participants received an electronic link to complete the online baseline questionnaire (on their own time) assessing satisfaction of psychological needs through physical activity, types of physical activity, physical activity level, exercise enjoyment and vitality, demographics, and other psychological factors. After successful completion of the baseline questionnaire, a waist-worn accelerometer was mailed to the participant and a videoconference orientation session was scheduled. During the orientation session, study staff provided instructions on how to download the study smartphone application and complete the study's real-time monitoring procedures of responding to smartphone-based Ecological Momentary Assessment (EMA) surveys (Shiffman et al., 2008) and wearing an accelerometer over the next 14 days. Individuals were compensated up to $150 for participating in the study with incentives based upon compliance to study procedures.

2.4. Measures

2.4.1. Satisfaction of psychological needs through physical activity

The investigators developed an original instrument to assess the satisfaction of basic and higher-level psychological needs. A top-down approach was taken in which 13 different psychological need dimensions were identified *a priori*, which mapped onto Maslow's Hierarchy of Human Needs and SDT (i.e., physical comfort, safety, social connection, esteem from others, individual esteem, learning, challenge, entertainment, novelty, creativity, mindfulness, aesthetic appreciation, and morality). For each dimension, the investigators then generated a range of potential items. The item generation process was intended to be creative and avoid redundancy by developing items that conveyed unique concepts. This step was intended to be as open-ended and unconstrained as possible to foster the creative process. No limits were imposed on the maximum number of items to be generated. The larger list of items was then narrowed down based on face validity (i.e., most closely represented the intended psychological need dimension). Face validity is a relatively quick and straightforward way of determining whether items seem to be useful when first looking at them. This step involved removing items that did not appear to be relevant or appropriate on the surface (e.g., incorrect use of synonyms or poor fitting examples) for measuring the intended construct. In addition, redundant items were further excluded, and grammatical corrections were made. Lastly, items that referred to specific types and amounts of physical activity were removed to make the instrument applicable to a wide range of populations. After these steps, a total of 65 face-valid items remained with each psychological need dimension being assessed by 2–13 items (e.g., feeling discomfort, doing something dangerous, cooperating with others, showing off skills, mastering tasks, doing things I have not done before, using my imagination, focusing on the present moment, learning something new, being challenged, being entertained, being in nature, and helping people; see Supplementary material).

Participants in the current study completed this 65-item instrument to measure satisfaction of psychological needs during physical activity. They were asked to "Think about any moderate or vigorous physical activity or exercise (including brisk/fast walking, classes, and sports) that you have done over the past 4 weeks." Using a nine-point response scale ranging from 1 = not at all to 9 = a lot, participants evaluated the extent to which their recent physical activity involved the satisfaction of basic and higher-level psychological needs in the 13 dimensions.

2.4.2. Types of physical activity

Participants reported usual types of physical activity performed. Survey instructions asked, "For the physical activity that you just described (in the last 7 days), please indicate what type of exercises you did/typically do (select all)." Response options included: brisk/fast walking, jogging or running, yoga or Pilates, hiking, and team sports (e.g., soccer, basketball, and football). Other types of physical activity (including dance, elliptical machine, swimming, bicycling or cycling, weight-lifting or strength training, and other) were also assessed but not used in the current analyses due to low frequency of reporting.

2.4.3. Exercise enjoyment

Enjoyment was assessed with the Physical Activity Enjoyment Scale (PACES; Kendzierski and DeCarlo, 1991). The questionnaire provided the instructions, "Please rate how you feel about the moderate or vigorous physical activity or exercise (including brisk/fast walking,

classes, and sports) you have been doing in the past 4 weeks." This statement is followed by 18 items that are answered on a seven-point bipolar response scale (e.g., 1 = I enjoy it to 7 = I hate it, 1 = I feel bored to 7 = I feel interested, and 1 = I dislike it to 7 = I like it). Eleven items are reverse-scored. Higher scores indicate greater enjoyment. In the present study, PACES had high internal consistency (Cronbach's $\alpha = 0.81$).

2.4.4. Exercise vitality

Vitality describes a state of feeling alive, energized and alert that is thought to be a component of eudaimonic well-being (Ryan and Deci, 2001). As such, vitality contributes to psychological well-being. Vitality through exercise was assessed using a four-item version of the Subjective Vitality Scale (Ryan and Frederick, 1997). Participants were given the statement, "When I engaged in physical activity or exercise (including brisk/fast walking, classes, and sports) in the past 4 weeks…," which was followed by the responses: I felt alive and vital; I felt so alive I just wanted to burst; I had energy and spirit; and I felt energized. Each response was scored on a seven-point Likert scale ranging from 1 = not at all to 7 = very true. In the present study, this scale had high internal consistency (Cronbach's $\alpha = 0.85$).

2.4.5. Affective response during physical activity *via* EMA

Participants completed EMA surveys through a commercial smartphone application that had been downloaded to their personal smartphone at the beginning of the study (movisensXS by movisens GmbH; Karlsruhe, Germany). Participants were asked to engage in their usual levels of physical activity during the 14-day study. Immediately before each naturally-occurring physical activity bout, participants were instructed to manually press a button in the EMA app to indicate the start of a physical activity session. The EMA app then automatically prompted a *during-physical activity* survey 15 min later. The first item asked, "Are you finished exercising?" If the response was "no," items assessing momentary affect were triggered and the app automatically promoted another during-physical activity survey 15 min later (30 min after the start of the physical activity session). If the participant indicated that they were still not finished exercising at that point, another during-physical activity survey was prompted after 45 min (75 min after the start of the physical activity session). Answering "yes" to having finished physical activity led to a separate post-physical activity EMA survey not included in the present analyses. Each *during-physical activity* survey assessed affective response by asking, "How are you feeling right now?" with items measured through a digital visual analog semantic differential sliding scale, which were converted to scores from 0 to 100 based on distance between the anchor points. Four affective response items were used, which mapped onto core affective valence (Bad-Good), energetic arousal (Exhausted-Energized), activated negative and positive affect (Miserable-Thrilled), and interest (Bored-Interested; Russell, 1980; Thayer, 1990; Wilhelm and Schoebi, 2007; Wolff et al., 2021). An item measuring tense arousal (Relaxed-Nervous) was also assessed but not included in the current analyses given the lack of hypothesized relation with psychological needs satisfaction through physical activity. Each EMA survey required about 30 s to complete.

2.4.6. Device-based physical activity level

Physical activity level was also measured using a waist-worn Actigraph, Inc., GT3X model accelerometer at a frequency of 30 Hz with a 30-s epoch. The device was worn on the right hip, attached to an adjustable belt, at all times except while sleeping, bathing, or swimming. Periods of non-wear (>60 continuous minutes of zero activity counts) and non-valid days (<10 h of wear) were not included in the analyses. A custom-built R program applied cut points for time spent in light, moderate, and vigorous intensity physical activity based on national data (Troiano et al., 2008; Belcher et al., 2010) and were generated from the Freedson prediction equation (Freedson et al., 1998, 2005; Roemmich et al., 2000; Harrell et al., 2005; Belcher et al., 2010; Laska et al., 2012). Time spent in light, moderate, and vigorous physical activity was summed for total physical activity and divided by the number of minutes of valid device wear time to calculate the percent if valid wear time spent engaging in physical activity.

2.4.7. Participant characteristics

Participants self-reported the following characteristics: age, gender identity, race, ethnicity, total family income for the past 12 months, marital status, educational attainment, number of children, and employment status. Participants were not required to answer these questions if they preferred not to.

2.5. Statistical analyses

Prior to analyses, all inversely worded items were reverse-coded. Variables were screened for normality. As a result, vigorous intensity physical activity measured by accelerometer was log transformed to address positive skew. Light and moderate intensity physical activity met normality assumptions and were not transformed.

The first aim was to identify a parsimonious set of items to assess each of the *a priori* identified 13 psychological needs dimensions. To do so, we eliminated items from each subscale that did not favorably contribute to scale reliability measured by internal consistency (i.e., how closely related a set of items are as a group). Using SPSS (Version 28.0.0.0), internal consistency reliability was generated by entering all items (ranging from 2 to 13 items per subscale) hypothesized to assess a needs satisfaction dimension. Cronbach's alpha coefficients, which are a function of the number of items and the average inter-correlations among items, were calculated for each subscale. Cronbach's alpha "if item deleted" values were used to monitor improvements in internal consistency reliability associated with one-at-a-time stepwise removal of each item from the subscale. The item whose removal contributed to the greatest improvement in Cronbach's alpha was eliminated at each step. When stepwise removal no longer improved the Cronbach's alpha, the procedure was halted. Means were calculated for the remaining set of items representing each subscale, which were used in further analyses. Additional descriptive statistics, including standard deviations, were generated for the final set of items included in each subscale. Bivariate intercorrelations among the subscales were also estimated.

The second aim was to evaluate discriminant validity by examining whether subscales of psychological needs satisfied through physical activity differed across types of physical activities that individuals perform. Independent samples *t*-tests compared the means of each needs satisfaction subscale between individuals who did versus did not report engaging in various types of physical activity (i.e., brisk/fast walking, jogging or running, yoga or Pilates, hiking, and team sports) over the past 7 days. Separate *t*-tests were run for each activity type. As an additional conservative measure, Bonferroni corrections for family-wise error rates were applied (13 tests per activity type, $\alpha = 0.05/13 = 0.004$).

The third aim was to evaluate construct validity by examining whether psychological needs satisfied through physical activity were associated

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with exercise enjoyment, exercise vitality, and affective response during physical activity. Bivariate correlations tested the extent to which each psychological needs subscale was associated with exercise enjoyment and vitality. The associations between each psychological needs subscale and affective responses during exercise (good-bad, energized-exhausted, thrilled-miserable, and interested-bored) were also examined.

The fourth aim was to assess predictive validity by examining whether psychological needs satisfied through physical activity are associated with device-based physical activity levels. Bivariate correlations tested whether each psychological needs subscale was related to levels of physical activity over the next 14 days.

3. Results

3.1. Data availability

A total of 75 participants were enrolled in the study. Participants were missing data on the psychological needs dimensions as follows: mindfulness ($n = 1$), individual esteem ($n = 2$), and physical comfort ($n = 2$). Furthermore, two participants were missing data on the exercise enjoyment scale, and one participant was missing data on the exercise vitality scale. A total of 66 individuals responded to EMA prompts, of which 59 individuals provided data for at least one EMA prompt during physical activity ($n = 584$ prompts total across all participants; $M = 9.92$, SD = 8.0, range = 1–40 prompts per participant). There were 47 participants who responded to at least one EMA prompt +30 min into the physical activity bout ($n = 214$ prompts total across participants; $M = 4.55$, SD = 3.18, range = 1–14 prompts per person). All 75 participants had complete data on the types of physical activity performed in the past 7 days. A total of 64 participants had at least one valid day (≥10 h) of accelerometer data ($M = 11.47$, range = 1–14 days per person). With casewise deletion of missing data, the sample sizes ranged from 45 to 75 across the analyses.

3.2. Demographics

Of the total sample ($N = 75$), 8% were Hispanic White, 18% African-American, 21% Asian, 46% were Non-Hispanic White, and 7% more than one race. Ages ranged from 19 to 65 years ($M = 39.8$, SD = 13.0 years). Participants identified as 58.7% female, 38.7% male, and 2.6% trans/non-binary. In terms of their marital status, 34% were married, 11% were divorced or separated, 15% were members of an unmarried couple, 39% were never married, and 1% widowed. The highest level of educational attainment was as follows: 4% high school, 13% some college, 83% college degree or higher. Among the total sample, 68% were employed for wages or self-employed, 8% were unemployed, 16% were students, 4% were homemakers, and 4% retired. Sixty-five percent of participants had one or more children. The annual household income breakdown was as follows: 25% < $35,000, 31% ≥ $35,000 and < $65,000, 21% ≥ $65,000 and < $105,000, and 23% ≥ $105,000.

3.3. Descriptive statistics for validation criteria

Of the total sample ($N = 75$), 67% reported engaging in brisk walking for physical activity in the past 7 days, 39% engaged in jogging or running, 28% did yoga or Pilates, 23% went hiking, and 7% performed team sports. The average scores for exercise enjoyment and exercise vitality were 5.09 (SD = 0.76) and 5.61 (SD = 0.91), respectively, on a seven-point scale. The average scores for the affective response during exercise scales from EMA were as follows ($n = 47$): Good-Bad ($M = 78.68$, SD = 13.34), Energized-Exhausted ($M = 71.18$, SD = 16.50), Thrilled-Miserable ($M = 73.55$, SD = 13.08), and Interested-Bored (73.83, SD = 16.24) on a 0–100 scale. Of the 64 participants for whom accelerometer data were available, engagement in physical activity was as follows: light ($M = 179.0$ min/day, SD = 46.14), moderate ($M = 33.66$ min/day, SD = 22.67), and vigorous (median = 1.33 min/day, SD = 8.89).

3.4. Descriptive statistics and internal consistency of the psychological needs satisfaction subscales

Table 1 shows descriptive statistics for the psychological needs satisfied through physical activity subscales after removal of items not contributing favorably to internal consistency. Means, standard deviations, and Cronbach's alphas for the remaining items in each subscale are shown. The stepwise item removal process left each subscale with 2–3 items (33 items total; see Table 2). A reliability coefficient of 0.70 or higher is considered "acceptable" in most social science research (Taber, 2018). Cronbach's alphas were greater than 0.70 for all subscales except mindfulness, aesthetic appreciation, and morality. Subscales that were most highly endorsed (i.e., highest mean values) were physical comfort and safety needs satisfied through physical activity, and the least highly endorsed were receiving esteem from others and social connection through physical activity.

TABLE 1 Descriptive statistics for psychological needs satisfied through physical activity.

Sub-scale	Num. items	*M* (SD)	Cronbach's alpha	*N*
Physical comfort	2	6.76 (1.84)	0.825	73
Safety	2	8.65 (0.79)	0.850	75
Social connection	3	3.67 (2.38)	0.876	75
Esteem from others	3	3.28 (2.03)	0.797	75
Individual esteem	3	5.42 (2.08)	0.813	73
Learning	2	5.23 (2.23)	0.773	75
Challenge	3	4.76 (2.02)	0.769	75
Entertainment	2	5.33 (2.07)	0.742	75
Novelty	3	4.57 (1.99)	0.818	75
Creativity	3	4.96 (2.35)	0.863	75
Mindfulness	3	5.09 (2.00)	0.673	74
Aesthetic appreciation	2	5.07 (2.02)	0.516	75
Morality	2	4.71 (2.52)	0.696	75

Results generated after stepwise deletion of items not contributing to increasing Cronbach's alphas. Response scales ranges from 1 = not at all to 9 = a lot.

TABLE 2 Satisfaction of psychological needs through physical activity instrument (33 items).

Sub-scale	Items
Physical comfort	Feeling physical discomfort (R)
	Feeling exhaustion (R)
Safety	Feeling unsafe (R)
	Feeling threatened (R)
Social connection	Being a part of a team
	Cooperating with others
	Being with other people
Esteem from others	Receiving praise from others
	Being recognized for what I've done
	Showing off my skills
Individual esteem	Being competent at something
	Mastering challenging tasks
	Accomplishing difficult things
Learning	Building my skills
	Learning something new
Challenge	Being challenged
	Taking risks
	Solving problems
Entertainment	Being interested
	Being entertained
Novelty	Doing things I have not done before
	Being curious about things
	Exploring things
Creativity	Using my imagination
	Being playful
	Expressing my emotions
Mindfulness	Connecting to my spirituality
	Relaxing
	Focusing on the present moment
Aesthetic Appreciation	Being in nature
	Going places that I have not gone before
Morality	Helping other people
	Doing the right thing

Instructions: "Think about any moderate or vigorous physical activity or exercise (including brisk/fast walking, classes, sports) that you have done over the past 4 weeks. Please rate the extent to which those physical activities involved the following things. 1 = Not at all….0.9 = A lot." Results generated after stepwise deletion of items not contributing to increasing Cronbach's alphas. R= reverse coded.

3.5. Intercorrelations among psychological needs satisfied through physical activity

Table 3 shows intercorrelations among the psychological needs satisfied through physical activity subscales. The satisfaction of psychological needs for physical comfort and safety through physical activity subscales only had small correlations with the other subscales. Satisfying needs for social connection and esteem from others through physical activity were moderately positively associated with the other subscales except mindfulness and aesthetic appreciation. Satisfying needs for individual esteem, learning, challenge, novelty, creativity, and entertainment were either higher or moderately positively correlated each other. Satisfying psychological needs for mindfulness, aesthetic appreciation, and mindfulness were moderately positively correlated with each other and most other subscales.

3.6. Discriminant validity

To test discriminant validity, we examined whether satisfaction of different psychological needs varied across types of physical activity. Figure 1 shows differences in the scores for the satisfaction of psychological needs subscales by participation (yes vs. no) in a range of physical activity types. Individuals who engaged in brisk walking reported greater satisfaction of needs for entertainment, novelty, creativity, mindfulness, and aesthetic appreciation than individuals who did not engage in brisk walking. Participation in jogging or running was associated with less satisfaction of physical comfort needs. Furthermore, individuals who participated in yoga or Pilates had greater satisfaction of needs for individual esteem and entertainment than those who did not participate in yoga or Pilates. Hiking was associated with greater satisfaction of needs for aesthetic appreciation. Lastly, participants who engaged in team sports reported lower satisfaction of physical comfort needs, and higher needs satisfaction for social connection, individual esteem, esteem from others, and morality through physical activity. After Bonferroni corrections were applied, differences in novelty, mindfulness, and aesthetic appreciation for brisk walking and differences in social connection and morality for team sports remained significant.

3.7. Construct validity

To test construct validity, we examined associations of psychological needs satisfaction through physical activity with questionnaire-reported exercise enjoyment and vitality, and various affective responses measured through EMA during physical activity. Table 4 shows that satisfying psychological needs for safety, individual esteem, entertainment, and mindfulness through physical activity were positively associated with exercise enjoyment. Satisfying psychological needs for social connection, individual esteem, learning, challenge, entertainment, novelty, creativity, mindfulness, aesthetic appreciation, and morality through physical activity were positively related to exercise vitality. Table 5 shows that satisfying psychological needs for entertainment and mindfulness were positively associated with feeling good during physical activity. Furthermore, satisfying psychological needs for social connection, learning, entertainment, novelty, and creativity were associated with feeling more energized (than fatigued), thrilled (than miserable), and interested (than bored) during physical activity. Additionally, satisfying psychological needs for individual esteem was associated with feeling more energized (than fatigued) and interested (than bored) during physical activity. Also, satisfying psychological needs for challenge was associated with feeling more energized (than fatigued) and thrilled (than miserable) during physical activity. Lastly, mindfulness was associated with feeling more interested (than bored) during physical activity.

TABLE 3 Intercorrelations among psychological needs satisfied through physical activity.

Sub-scale	Physical comfort	Safety	Social connection	Esteem from Others	Individual esteem	Learning	Challenge	Entertainment	Novelty	Creativity	Mindfulness	Aesthetic appreciation	Morality
Physical Comfort	--												
Safety	0.228	--											
Social Connection	−0.168	−0.284	---										
Esteem from Others	−0.163	−0.290	0.653	---									
Individual Esteem	−0.214	−0.062	0.446	0.505	---								
Learning	−0.085	−0.087	0.562	0.601	**0.787**	---							
Challenge	−0.201	−0.160	0.676	0.660	**0.801**	**0.779**	---						
Entertainment	−0.078	−0.073	0.591	0.559	**0.706**	0.656	**0.745**	---					
Novelty	−0.007	−0.065	0.577	0.446	0.542	0.612	**0.718**	**0.719**	---				
Creativity	−0.023	−0.133	0.670	0.638	0.666	**0.717**	**0.813**	**0.752**	**0.771**	---			
Mindfulness	0.020	0.089	0.350	0.316	0.571	0.545	0.529	0.666	0.516	0.664	---		
Aesthetic appreciation	−0.027	−0.113	0.331	0.442	0.270	0.337	0.460	0.515	0.551	0.484	0.464	---	
Morality	−0.103	−0.202	0.627	0.639	0.514	0.487	0.611	0.573	0.457	0.636	0.511	0.414	---

Light gray = small correlation (r's = 0.01–0.39), gray = moderate correlation (r's = 0.40–0.69), and **bolded** = large correlation (r's = 0.70–0.99). ns = 71–75.

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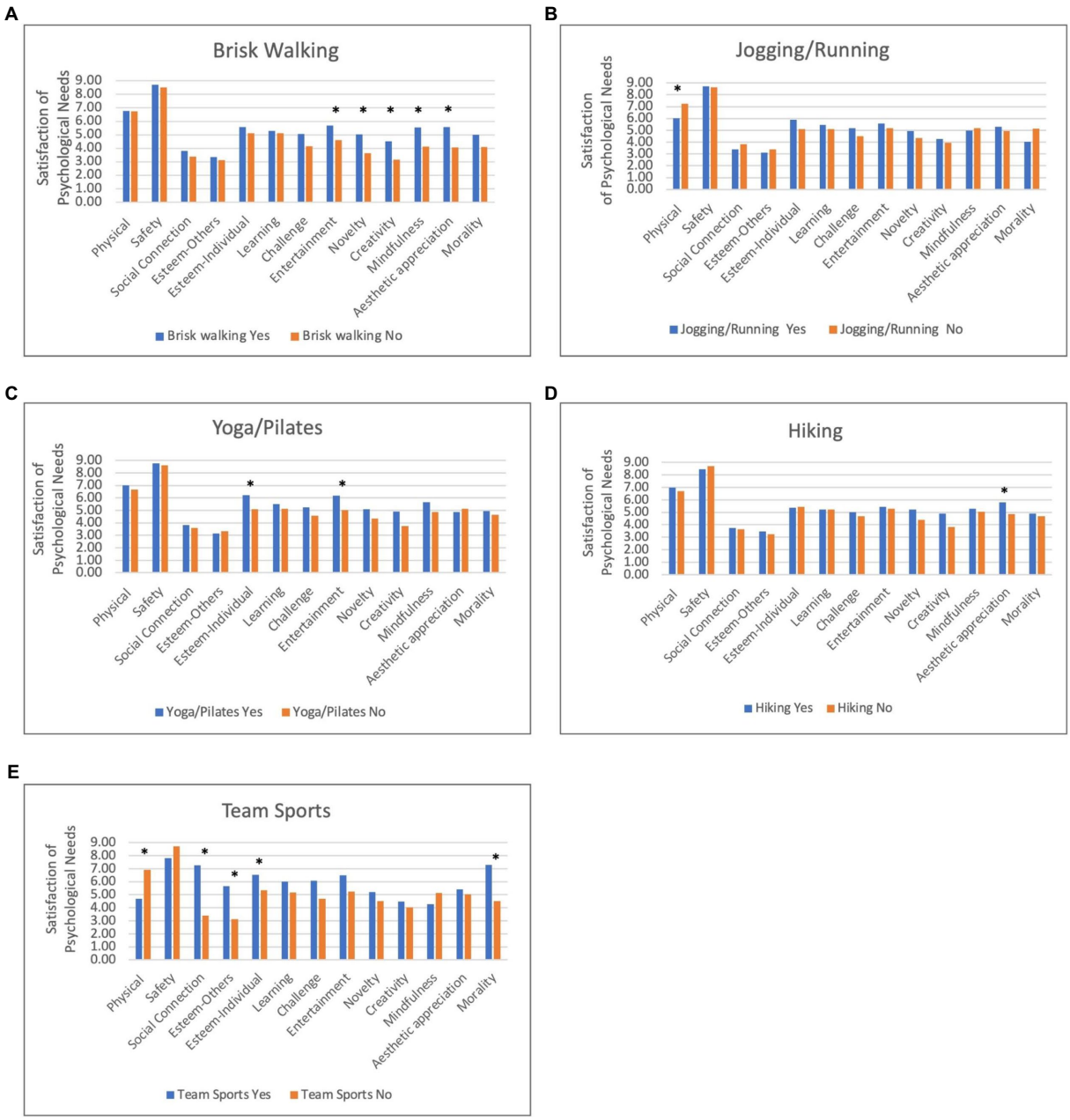

FIGURE 1
Differences in related psychological need satisfaction by past 7-day engagement (yes vs. no) in different types of physical activity: **(A)** Brisk Walking; **(B)** Jogging/Running; **(C)** Yoga/Pilates; **(D)** Hiking; and **(E)** Team Sports. *p<0.05.

3.8. Predictive validity

Predictive validity was assessed by examining whether psychological needs satisfied through physical activity were associated with reported and monitor-based physical activity levels. Table 6 shows that satisfying psychological needs for entertainment, novelty, and mindfulness were positively associated with light intensity physical activity. Satisfying psychological needs for aesthetic appreciation through physical activity were positively associated with moderate intensity physical activity. Lastly, satisfying psychological needs for physical comfort through physical activity was negatively associated with vigorous intensity physical activity. Satisfying psychological needs for safety, social connection, esteem from others, individual esteem, learning, entertainment, creativity, and morality were not significantly associated with any of the physical activity outcome measures.

4. Discussion

The aim of this study was to examine the preliminary reliability and validity of a multi-dimensional scale to assess a range of psychological needs satisfied through physical activity. This instrument improves upon existing measures of psychological needs satisfaction through physical activity by assessing a combination of both basic (e.g., physical comfort, safety, social connection, esteem from others, and individual esteem) and higher-level (e.g., learning, challenge, entertainment, novelty, creativity,

TABLE 4 Bivariate correlations of psychological needs satisfied through physical activity with exercise enjoyment and exercise vitality.

Sub-scale	Exercise enjoyment		Exercise vitality	
	r	*p*	*r*	*p*
Physical comfort	0.205	0.087	0.010	0.932
Safety	0.263	**0.025**	0.085	0.470
Social connection	0.084	0.479	0.254	**0.029**
Esteem from others	0.016	0.890	0.193	0.100
Individual esteem	0.239	**0.045**	0.296	**0.001**
Learning	0.207	0.079	0.335	**0.004**
Challenge	0.116	0.330	0.316	**0.006**
Entertainment	0.295	**0.011**	0.352	**0.002**
Novelty	0.138	0.243	0.325	**0.005**
Creativity	0.196	0.097	0.377	**0.001**
Mindfulness	0.334	**0.004**	0.462	**<0.001**
Aesthetic appreciation	0.117	0.325	0.231	**0.048**
Morality	0.129	0.278	0.246	**0.035**

Values of $p < 0.05$ are bolded. ns = 72–74.

TABLE 5 Bivariate correlations of psychological needs satisfied through physical activity with affective responses during physical activity measured through ecological momentary assessment.

Sub-scale	Good-Bad		Energized-Exhausted		Thrilled-Miserable		Interested-Bored	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Physical comfort	0.127	0.074	0.119	0.431	0.181	0.228	0.111	0.464
Safety	0.120	0.423	0.155	0.297	0.118	0.430	0.142	0.342
Social connection	0.263	0.074	0.300	**0.041**	0.367	**0.011**	0.308	**0.035**
Esteem from others	0.002	0.991	0.086	0.567	0.056	0.056	0.072	0.630
Individual esteem	0.235	0.121	0.378	**0.009**	0.217	0.153	0.294	**0.050**
Learning	0.273	0.063	0.363	**0.012**	0.335	**0.021**	0.408	**0.004**
Challenge	0.186	0.211	0.333	**0.022**	0.293	**0.046**	0.270	0.067
Entertainment	0.385	**0.008**	0.434	**0.002**	0.390	**0.007**	0.398	**0.006**
Novelty	0.187	0.208	0.373	**0.010**	0.354	**0.015**	0.328	**0.025**
Creativity	0.257	0.082	0.350	**0.016**	0.373	**0.010**	0.355	**0.014**
Mindfulness	0.402	**0.006**	0.274	0.065	0.276	0.063	0.323	**0.028**
Aesthetic appreciation	−0.127	0.395	−0.062	0.681	−0.124	0.408	−0.142	0.339
Morality	0.085	0.568	0.107	0.475	0.100	0.503	0.087	0.559

Values of $p < 0.05$ are bolded. ns = 45–47.

mindfulness, aesthetic appreciation, and morality) needs. Understanding how physical activity may fulfill a range of different psychological needs could facilitate greater understanding of how to promote rewarding experiences and sustained physical activity behavior engagement.

Overall, analyses yielded a parsimonious set of reliable items for each of the 13 subscales measuring the satisfaction of psychological needs through physical activity. After stepwise removal of items not favorably contributing to internal consistency, most psychological needs subscales were comprised of 2–3 items with acceptable reliability (Cronbach's alpha >0.70; Taber, 2018). The exceptions were the mindfulness, aesthetic appreciation, and morality subscales, whose reliabilities were moderate (range 0.516–0.696). Some caution may need to be exerted when interpreting findings from these three subscales—especially the aesthetic appreciation scale, which had the lowest reliability—or authors may otherwise choose not to use them. Following what would be expected from Maslow's Hierarchy of Human Needs, participants in this sample rated that physical activity most highly satisfied their needs for physical comfort and safety. Maslow's Hierarchy suggests that these two basic needs must be satisfied before other higher-level needs can be pursued (Deci and Ryan, 1985, 2000, 2008; Deci et al., 1991; Ryan and Deci, 2018). Surprisingly, the least satisfied psychological needs subscales in the current sample were receiving esteem from others and social connection through physical activity. Both Maslow's Hierarchy and SDT would suggest that these types of social needs, similar to belongingness and relatedness, are quite important to achieving well-being and successful behavioral engagement (Deci and Ryan, 1985, 2000, 2008; Deci et al., 1991; Ryan and La Guardia, 2000; Ryan and Deci, 2018). However, the current study occurred during the year and a half of the COVID-19 pandemic (Aug 2020–2021). Therefore, COVID

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TABLE 6 Bivariate correlations of psychological needs satisfied through physical activity with device-based physical activity behavior.

Sub-scale	Light intensity/valid minute		Moderate intensity/valid minute		Vigorous intensity/valid minute	
	r	*p*	*r*	*p*	*r*	*p*
Physical comfort	0.046	0.723	0.021	0.869	−0.300	**0.018**
Safety	0.024	0.851	0.033	**0.**798	0.107	0.401
Social connection	0.130	0.305	0.032	0.802	0.008	0.952
Esteem from others	0.075	0.555	0.103	0.419	0.135	0.288
Individual esteem	0.169	0.184	−0.073	0.572	0.069	0.590
Learning	0.225	0.074	−0.044	0.731	0.104	0.414
Challenge	0.188	0.137	0.060	0.637	0.102	0.424
Entertainment	0.330	**0.008**	−0.100	0.994	0.120	0.347
Novelty	0.247	**0.049**	0.135	0.287	0.160	0.205
Creativity	0.168	0.184	0.029	0.822	0.014	0.913
Mindfulness	0.285	**0.024**	0.022	0.800	0.073	0.571
Aesthetic appreciation	0.186	0.141	0.249	**0.047**	0.189	0.135
Morality	0.105	0.407	−0.011	0.933	−0.067	0.597

Physical activity was assessed over 7 days. Valid minute indicates the time that the accelerometer device was worn. Vigorous intensity has been log transformed to adjust for non-normality. *p* values < 0.05 are bolded. ns = 63–64.

recommendations for social-distancing were in effect during much of the study, which may have limited social interactions during physical activity. Also, outside of COVID, individuals may generally find it difficult to find or arrange for others (including friends and family members) to accompany them during physical activity sessions due to conflicting interests, varying abilities, or scheduling problems (Kerr and Hertel, 2011). The lower levels of satisfaction of social needs through physical activity may be indicative of a problem that should be addressed on a population level to promote healthy levels of physical activity engagement. Physical activity interventions and programs may benefit from specifically seeking out ways for participants to satisfy needs for social interactions and connection to others.

Findings supported the discriminant validity of the subscales by showing that psychological needs satisfied through physical activity vary across different types of physical activities. For example, the fact that brisk walking satisfied needs for entertainment, novelty, creativity, mindfulness, and aesthetic appreciation whereas jogging and running failed to satisfy any psychological needs suggests that unique aspects of these forms of physical activity (such as intensity, muscle groups involved, and context) may fulfill different psychological wants and desires. Lower intensity activities such as brisk walking may provide opportunities for mindfulness and creativity because they require less physical exertion and attention (Yogev et al., 2008). Further evidence for discriminant validity of the subscales was shown by the association of yoga and Pilates with the fulfillment of individual esteem and entertainment needs. The strengthening, flexibility, and balance skills utilized by the types of body movements in yoga and Pilates may satisfy individual esteem needs because they allow opportunities to feel competent and master tasks (Lopes et al., 2019). Given that hiking is a type of activity that necessitates being outdoors, the satisfaction of psychological needs for appreciation through it was consistent with expectations. Discriminant validity of the subscales was particularly salient with regard to participation in team sports, as it was the only type of activity that satisfied needs for social connection, esteem from others, and morality. Interestingly, participating in running and jogging, and team sports was associated with lower satisfaction of physical comfort needs, suggesting that those types of activities may be riskier or more physically demanding. Overall, the pattern of discriminant associations indicates not all psychological needs are equally satisfied across types of activities.

To examine the construct validity, we examined whether psychological needs satisfied through physical activity were associated with exercise enjoyment, exercise vitality, and affective response during physical activity. The extent to which satisfaction of psychological needs through physical activity leads to more pleasant experiences while exercising supports the overarching theoretical framework driving this research question (Ryan and Deci, 2001; Deci and Ryan, 2002). Almost all the subscales were positively associated with exercise vitality whereas a smaller subset (i.e., safety, individual esteem, entertainment, and mindfulness) were associated with exercise enjoyment. This pattern of findings suggests that the satisfaction of psychological needs through physical activity may be more closely linked to pleasant physical experiences such as feeling alive, energized, and alert, as measured by the exercise vitality scale. In contrast, more cognitive- and attention-focused psychological needs subscales (e.g., entertainment and mindfulness) were associated with aspects of the physical activity experience that involved evaluations and judgments (e.g., like it, feel interested) measured by the exercise enjoyment scale. Interestingly, entertainment and mindfulness were the only psychological needs subscales that were associated with the affective response during physical activity item measuring core affective valence (i.e., Good-Bad). However, most of the satisfaction of psychological needs subscales were positively associated with the affective response during physical activity items that reflected affective arousal (i.e., Energized-Exhausted), activated positive and negative affect (i.e., Thrilled-Miserable), and interest (i.e., Interested-Bored). The overall pattern of these findings suggests that the fulfillment of psychological needs does contribute to pleasant experiences during physical activity, especially when those experiences are assessed in real-time during real-world physical activity situations as opposed to retrospective evaluative judgments of past physical activity.

The final goal of this paper was to evaluate predictive validity by examining whether psychological needs satisfied through physical activity were associated with device-based physical activity levels. The

purpose of this analysis was to examine whether the fulfillment of psychological needs leads to greater engagement in the target behavior, as theory and prior evidence would suggest (Wilson et al., 2003; Gholidahaneh et al., 2020). Satisfying needs for physical comfort was negatively associated with levels vigorous intensity physical activity. These findings suggest that exercising in a way that meets needs for physical comfort (e.g., avoiding pain and exhaustion) most likely involves shorter and lower intensity physical activity sessions. Furthermore, satisfying needs for entertainment, novelty, and mindfulness may be positively associated with light intensity physical activities because they allow for greater attention to the present surroundings (Yogev et al., 2008) and opportunities to explore new environments and types of movement (Hull and Stewart, 1995; Lakicevic et al., 2020). Similar to the discriminant validity results described above, aesthetic appreciation was associated with higher self-reported levels of moderate intensity activity, most likely because walking can more easily increase from light to moderate intensity while outdoors. Overall, linkages between the various psychological needs subscales (i.e., novelty, mindfulness, and aesthetic appreciation) and device-measured physical activity further support their validity in predicting the target behavior.

4.1. Strengths and limitations

Strengths of this study included the use of real-time and device-based measures of validation criteria, as well as a relatively diverse study sample in terms of age, race, and income levels. In contrast, limitations included missing data and a relatively modest sample size, which did not permit confirmatory factor analyses and could primarily detect moderate to large effect sizes. However, the goal of this study was to shorten the length of the target instrument (so that it could be reasonably administered without undue participant burden) and provide preliminary evidence of its reliability and validity—both of which can be accomplished with relatively modest sample sizes. Another potential limitation is the lower reliability of the mindfulness, aesthetic appreciation, and morality subscales, which may influence the statistical conclusion validity of the later analyses using those subscales. In the current paper, lower reliability of those subscales may bias later correlation coefficients toward the null hypothesis. Further work using larger and more heterogeneous samples is needed to test its factor structure and test–retest reliability, and to provide more evidence of validation using additional measures of physical activity experiences and behavior. In particular, whether the instrument is reliable and valid in child and adolescent populations needs to be studied.

5. Conclusion

This study provided preliminary evidence of the reliability and validity of a multi-dimensional scale to assess a range of basic and higher-level psychological needs satisfied through physical activity. This instrument addresses a critical gap in the research literature that is a lack of available measures of higher-level psychological needs. Having the capacity to assess whether one's current physical activity is failing to fulfill basic and higher-level psychological needs may have important applications in clinical and intervention settings. For example, the tool can be used by therapists or fitness professionals to determine whether one's current physical activities are satisfying their psychological needs. If not, it may explain why an individual is having difficulty achieving physical activity goals or why various intervention strategies are not working. A novel adaptive physical activity promotion strategy would be to recommend alternative types of activities to better satisfy those needs and test again at a later time. This type of information can serve as the basis for intervention programs and physical activity prescriptions that are individually-tailored to meet psychological needs with the goal of promoting more pleasant experiences and sustainable behavior.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by University of Southern California Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

Author contributions

GD wrote the first draft of the manuscript and performed the statistical analysis. GD, BD, and MK contributed to the conception and design of the study. BD, RC-L, CN, MH, and MK contributed to manuscript editing and revision, and GD incorporated final edits. All authors contributed to the article and approved the submitted version.

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

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Supplementary material

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Mental and physical conditions associated with physical inactivity among Farhangian University students during virtual classes: A cross-sectional study

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Background: The level of mobility and general health has decreased among students in virtual classes during COVID-19 pandemic. The present cross-sectional study aims to investigate the mental and physical conditions related to inactivity among the students of Farhangian University during the virtual classes.

Methods: This is a cross-sectional study. 475 students (214 females and 261 males) were selected as the statistical sample of the study based on Morgan's Table from Farhangian University, Iran. The statistical population includes students studying at Farhangian University of Mazandaran province that using Convenience Sampling the sample size based on Morgan's Table, 475 students consisting of 214 females and 261 males were randomly selected as the statistical sample of the study. The research instruments of this study include International Physical Activity Questionnaire, Saehan Caliper (SH5020), Coopersmith Self-Esteem Scale, Beck Depression Questionnaire, and Nordic Skeletal and Muscular Disorders Questionnaire. For data analysis, independent sample *t*-test was employed to compare two groups. All analyses were conducted using spss24 software.

Results: With respect to students' skeletal-muscular disorders, findings proved that both genders suffered physical conditions during virtual classes. The research findings showed that the average weekly activity level among women is 634 Met/min with a standard deviation of ±281, and the average weekly activity level among men is 472 Met/min with a standard deviation of ±231. Fat percentage by gender, men's average fat percentage is 47.21% (S. D±4.74) and women's average fat percentage is 31.55% (S. D±4.37). Also, the self-esteem scores of male and female students were obtained 29.72 and 29.43, respectively, and the difference between the two was considered significant ($p < 0.05$). On the other hand, 67% (No. 25) of female students and 32% (No. 12) of male students suffered from high depression. Also, based on students' skeletal-muscular disorders, findings of our study showed that both genders suffered physical conditions during virtual classes.

Conclusion: This study suggests increasing the level of physical activity to reduce body fat mass, increase mental health and reduce skeletal disorders, which can be properly accomplished through university planning and prioritizing the health of male and female students.

KEYWORDS

activity, Farhangian University, virtual classes, mental complications, student

Introduction

Industrial development, upsetting situation of COVID-19, holding of virtual classes, and life mechanization have created major effects on individuals' lifestyles and have brought sedentary lifestyles to societies (Nayak et al., 2022). This inactivity in students, as the active class of future society, can cause structural and strategic problems for any country (Yang et al., 2022). Therefore, inactivity should be considered as a serious major problem for the future of the country (Montero-Simó et al., 2022). The role of comprehensive education is in providing education for all humanistic dimensions, which includes not only the intellectual aspect of the individual, but also all psychological and physical aspects (Yuan et al., 2022). This type of comprehensive and inclusive education is beneficial for educational environments such as universities and colleges (Demchenko et al., 2021). Today, in order to better adapt to the surrounding environment, individuals in society need a balance of physical readiness and body composition (Mazza et al., 2020), and if they do not have favorable conditions in terms of physical condition and body composition, they usually become aloof, pessimistic and isolated; in other words, they will not have proper mental balance (Izquierdo, 2005).

Although the measures taken to combat the epidemic have contributed to many people staying at home around the world, this has led people to a sedentary life at home (Chen et al., 2020; Demirci, 2020).

The measures taken to combat the corona disease forced many people around the world to stay at home which led to a sedentary life and weighted gain (obesity; Chen et al., 2020). Obesity is a chronic condition that occurs as a result of intervention in individuals' genetics or their environment, which is definitely affected by society, culture, psychological, metabolic, biochemical and genetic conditions (Kim et al., 2021). Research findings showed that male students who were living in the city were more likely to be obese (39.4%) than male students in the suburbs (35.5%). Likewise, female students in the city were more exposed to obesity (20.6%) compared to females in the suburbs (19.1%). Findings have shown that male students living in the city are more likely to be obese (39.4%) than male students who live in the suburbs (35.5%). Likewise, 20.6% of female students living in the city were exposed to obesity compared to those female ones (19.1%) living in the suburbs. The increasing prevalence of obesity and overweight among children and adults in the United States of America is a warning for doctors and public health officials (Halpern et al., 2021). In different countries, obesity is probably caused by a decrease in physical activity and an inappropriate way of lifestyle. High levels of health and hygienic indices and physical capabilities reflect the health and potentialities of a society (Wang et al., 2021). It has been well proven that the level of physical activity begins to decrease during adulthood and with age resulting to weight gain, which is associated with weight gain. The evidence that proves the relationship between physical activity in childhood and adolescence and inactivity in individuals in the form of longitudinal studies is rare or does not exist at all. A longitudinal study of 5,700 men and women found a link between childhood activity and obesity in adulthood. It is possible that those who do not engage in sports activities and then become overweight are genetically predisposed to this factor because both physical activity and body size are affected by genetic factors (Chaput et al., 2020). In the last few years, inactivity has become widespread in such a way that since the 1990s, it has been proposed as one of the main factors of death due to cardiovascular diseases (Ralapanawa and Sivakanesan, 2021). Those individuals who have done intense physical activity enjoy better health conditions than those with moderate and light activities (Rosenberger et al., 2019). Studies on the level of inactivity and public health showed that the increase in inactivity is associated with the increase in obesity, as well as decrease in physical activity with a decrease in general health (McCoy and Morgan, 2020). Research related to the level of mobility in different stratum of society has progressed such that it has been shown that the effect of the education level on food intake, obesity and other health risk factors (mobility level) has changed over time (Su et al., 2022). In addition to the fact that regular physical activity leads to an increase in physical readiness, it has been shown that there is a significant relationship between high physical readiness and high self-esteem (Reddy et al., 2021). Some researchers showed that yoga practice and physical exercises strongly influence individuals' personality, their coping skills and cognitive performance (Pascoe et al., 2021; Farhang et al., 2022; Sinha and Kumari, 2022). Compared to the other groups, Yoga practitioners had higher sattva Guna (balance feature) and preferentially, employed brain regions associated with self-regulation and inhibitory control. Also, other researchers stated that physical activity is essential for children' current and future health, though most of them do not do 60 min of moderate to intense physical activity daily (Ito et al., 2021; Tandon et al., 2021).

As mentioned, the sedentary life caused by the Corona period leads to obesity, but in addition to the physical effects, it may also affect some psychological factors such as self-esteem (Wang et al., 2020). Studies have indicated that exercising affects self-esteem, and a sense of competence and control. Programs related to physical activity are among the most common ways to increase self-esteem (Mazereel et al., 2021). In addition, compared to complex and heavy activities, simple activities such as aerobic sports have the greatest effect on self-esteem (Ryan, 2008). It has been proved that low self-esteem is related to depression, low mental health and less progress in education (Sánchez-SanSegundo et al., 2022). The impact of physical activity (PA) in reducing the symptoms of depression in children and adolescents has been reported by Dale et al. (2019) through the analysis of 26 articles (Dale et al., 2019). Also, positive effects of PA on the prevention of depression has been reported in older adults (Smaradottir et al., 2020). Despite this, students are prone to depression and examining the role of physical activity on their level of depression is of great importance. a growing body of evidence to suggest that, regular exercise can significantly reduce the risk of depression, anxiety and is considered useful in the prevention of about 25 diseases (Wu et al., 2020). In this regard, evidence from adult studies shows that physical activity is inversely related to depressive symptoms (Kandola et al., 2019). These findings showed Exercise as an intervention for anxiety and depression has been demonstrated in both of the animal studies and human clinical trials.

Beyond the physical conditions of people, COVID-19 is associated with significant mental pressure, which strongly affects mental health (Brooks et al., 2020; Torales et al., 2020). One of the psychological factors that can be related to Corona is self-esteem. Self-esteem is related to dissatisfaction with body image in obese ones who follow weight loss diets (Chang and Kim, 2022). In general, it has been well proven that a decrease in individuals' self-esteem is related to a decrease in their general health level (Hajek and König, 2019). The

relationship between self-esteem and obesity has not been well proven yet (Fields et al., 2021). Although challenges related to self-esteem have significant results on one's health, due to incomplete results, it is difficult to argue that low self-esteem is a consequence rather than a cause (Bleidorn and Schwaba, 2018). The decrease in muscle volume and general excessive thinness caused by lack of movement endangers health of the body's skeleton (Jestratijevic et al., 2022). As a result of excessive muscle wasting, the trunk will not be able to perform its functions in maintaining the body and preserving its natural alignment, hence, resulting in bad standing, bad sitting situations, and overall wrong movement habits (Wijngaarde et al., 2020). This makes the spine and chest unable to grow normally and remain in a normal state. In addition to the ugliness and deformity of the body, the unnatural curvature of these organs, causes the blood flow and breathing to not be performed properly and naturally (Hast and Garrison, 2000).

The most important consequences of lack of movement are illness and reduction of muscle volume and strength (Bonnet et al., 2019). The above items are related to each other and there is a direct relationship between the two factors of muscle cross section and the amount of power that a muscle is able to generate. On the other hand, maintaining the skeletal balance of the body is the responsibility of the muscles, especially the amount of strength and power of each muscle. Those individuals who do not have enough physical preparation (readiness), get tired sooner during performance of physical activities. Muscle fatigue in the body will naturally reduce physical ability and reduce the power level that the muscle can represent during working situations (Blocquiaux et al., 2020). In other words, working with tired muscles is the same as working with weak muscles, and the adverse effects that occur as a result of muscle weakness in a person are also like those of working in extreme fatigue conditions. Fatigue and posture may be the cause and effect of each other. In this way, the presence of fatigue caused by other factors such as physical activities in the body can be influential in disrupting the balance of an appropriate posture. On the other hand, lack of having a proper body posture is a reason for causing more fatigue; the more the body size is out of proportion and balance, the more energy is required to keep it straight, because the muscles related to the way the body is positioned to maintain balance have less mechanical merit. On the other hand, they should be involved in activities, which, in turn, will cause body fatigue (Gaudiino and Di Stefano, 2021). If the child's daily activity is less than normal, the weight of other parts of his/her body will gradually decrease and the weight and volume of the subcutaneous fat tissue will increase, which eventually leads to the child's obesity. Due to the fact that subcutaneous fat does not accumulate in all parts equally, and in some parts such as around the abdomen, hips, and in general, the middle part of the body is more than the organs (arms and legs), the child's body position becomes abnormal (Lemaitre et al., 2021).

According to the reports of Center for Disease Control and Prevention in 2018, 29% of school students did not pay attention to physical education classes (Brustio et al., 2018). Meanwhile, another study report stated that students with daily physical activity demonstrate higher academic performance (Páez-Maldonado et al., 2020). Physical activity is a behavior that has many proven health benefits, and it is noteworthy that it is one of the most effective ways to prevent chronic diseases such as coronary heart disease and diabetes (Speelman et al., 2011).

This study aims to determine the frequency and conditions (mental and physical) associated with inactivity in students of Farhangian University during the virtual classes. The main objective will be to measure the level of physical activity and effects of inactivity on mental and physical factors among students studying at Farhangian University of Mazandaran province.

Research methodology

The method applied in this study is survey type and cross-sectional research design. The statistical population includes all male and female students studying at Farhangian University of Mazandaran province. Students were selected randomly and clustered in such a way that initially the campuses of Mazandaran province were divided based on the city and their population, and students of the cities were randomly selected. The number of samples were selected based on the population; hence, more samples would be allocated to campuses with larger populations; In the following, based on the statistics received from Farhangian University of Mazandaran province, according to the sample size based on Morgan's Table, 475 students consisting of 214 females and 261 males were randomly selected as the statistical sample of the research. Students with intellectual disabilities, epilepsy, vestibular problem, and hearing or visual impairment were excluded from the study. Ethics approval was obtained from the appropriate institutional ethics review board in Farhangian University. The ethnicity of students was controlled; they were all Iranian. Participants were not told about the purpose of the study. They signed informed consent form and authorized their participation in the study. They were also informed that the data gathered in this study would be kept completely private.

Research instruments

The amount of physical activity

After obtaining informed consent, the amount of physical activity was calculated using International Physical Activity Questionnaire (Craig et al., 2003). In this questionnaire, the physical activities performed by the individuals during the last week were asked, and activities performed for more than 10 min were recorded, which included job activities, moving manner, doing household chores, and leisure activities. This questionnaire inquires the amount of intense and moderate physical activity and walking during the last week. According to the scoring protocol of IPAQ questionnaire, the amount of physical activity of a person can be extracted and reported in two ways:

The total amount of physical activity of the individual during the last week in terms of MET-minutes/week

MET (Tan et al., 2021) is a unit used to estimate the energy consumption due to physical activity. The value of one MET is approximately equal to the amount of energy consumption of a person at rest. All physical activities can be classified as multiples of the amount of energy consumption in a resting state. In this questionnaire, 3.3 METs for walking, 4 METs are considered for moderate physical

activity, and 8 METs for intense physical activity. To calculate the total amount of physical activity in a week, the amount of walking (MET × minutes × day) should be added together with the amount of moderate physical activity (MET × minutes × day) and the amount of intense physical activity (MET × minutes × day) in last week.

Classification of individuals' physical activity in three levels: Low, medium and high

High physical activity means that an individual has intense physical activity at least 3 days a week and a total of at least 1,500 MET-minutes, or that s/he does any combination of intense, moderate, walking activities for seven or more days, with a total of at least 3,000 MET—minutes per week. Moderate physical activity means that an individual has at least 20 min of intense physical activity 3 days a week or more, or that 5 days or more a week has at least 30 min of intense, moderate activity or walking. Low physical activity means that an individual does not report any activity or the reported physical activities do not meet the criteria of high or moderate physical activity (Fogelholm et al., 2006). In the present study, after conducting preliminary studies on the necessity of conducting research on two categories of low and moderate activity intensity, the high physical activity category of the intended samples were disregarded; therefore, the category of high activity level will be excluded from the study, and the current study will be based on the level of activity and percentage of body fat, as well as the level of self-esteem of two classes with a low and moderate level of physical activity.

To determine the validity of the questionnaire, the content validity method was used. Its reliability was measured by the test–retest method, and the correlation coefficient was obtained 0.62 for the awareness and attitude section and 0.74 for the performance section (Moghaddam et al., 2012).

Fat percentage

Also, the participants' fat percentage was measured with a Saehan (SH5020) fat meter (caliper) made in England in three points of the body (men: chest, thigh, abdomen) and (women: triceps, upper arm, thigh; Onsori and Galedari, 2015). In order to increase the reliability of the subcutaneous fat measurement process, each part of the body was measured three times with a specific time interval, and all measurements were performed on the right side of the body (Soltani et al., 2018). To determine the fat percentage of the individuals, the measured values were put into Jackson Pollock's fat measurement formula and the fat percentage was calculated. The standing height of the participants was measured using Height meter model 216 (Seca). For this purpose, the subjects stood such that the rear part of their shoulders touched the height measuring device; They kept their hands next to their body and close to their feet. The weight of each person was measured using a (Seca) model scale.

Coopersmith self-esteem questionnaire—short form

Ryden (1978; Morrison et al., 1973) is a 58-item self-report, pencil-paper questionnaire, 8 of which are lie-detectors, and the other 50 items are divided into four subscales of general self-esteem, social self-esteem, family self-esteem, and educational self-esteem. The purpose of this questionnaire is to evaluate students' self-esteem. This test has different forms. The original test was primarily designed for 8–15-year-old (form A, or school form), but a later revision was designed for subjects over 16 (form C, or adult form). Some items were rewritten to adapt the original form for adults' use (form C; for instance, children were replaced with individuals, and school with work). There is also a short form of the test (form B, Coopersmith and Brout, 1961) which consists of 25 items and is extracted from the 50-item scale. Coopersmith designed this form as an alternative form for when time is limited. The reliability coefficient of this test is also reported as 0.77. Coopersmith's self-esteem scale was also standardized in Iran (Narimani and Mousazadeh, 2010).

Depression scale

Beck depression questionnaire was first developed by Beck et al. (1961) and Jackson-Koku (2016). Beck (1979) made a major revision to cover a wider range of symptoms and provide more consistency with the diagnostic criteria for depressive disorders in Diagnostic and Statistical Manual of Mental Disorders (DSM-IV). Beck's depression questionnaire is a type of self-assessment test and can be completed in 5 to 10 min. The test consists of a total of 21 items related to different symptoms, in which the participants must answer on a four-point scale from zero to three. These articles cover areas such as sadness, pessimism, feelings of incapability and failure, guilt, sleep disturbances, loss of appetite, self-loathing, etc. Accordingly, 2 items are devoted to emotion, 11 items to cognition, 2 items to overt behaviors, 5 items to physical signs and 1 item to interpersonal semiotics. Thus, this scale determines different degrees of depression from mild to very severe, and its scores range from a minimum of 0 to a maximum of 63. Cronbach's alpha coefficient of this questionnaire was reported as 0.84 (Farshchi et al., 2018).

Musculoskeletal disorders

In order to examine skeletal-muscular ailments by the doctor, Nordic questionnaire was employed, which is a standardized questionnaire for examining disorders and disease associated with working and daily affairs (López-Aragón et al., 2017). The reliability of this scale has been reported as 0.73 using Cronbach's alpha (Namnik et al., 2016).

For data analysis, multivariate analysis of variance (MANCOVA) were conducted on dependent variables with activity group as an independent variable and gender as a covariate. Independent pair sample t-test statistical method was applied to compare two groups. Statistical level of significance for all analyses was set at $p < 0.05$, and effect sizes were calculated as partial η2 (η2p). All analyses were carried out using spss24 software.

Results

According to the research findings (Demographic characteristics of participants) and the ratio of male and female students in Farhangian University of Mazandaran province, 59% of the participants of this study were male and 41% were female students. The findings of this study showed that 73% of the (No. 348) students

had low physical activity and 27% (No. 127) had sufficient physical activity.

Also, among 73% of (No. 348) sedentary students, 40% were women (No. 138) and 60% were men (No. 210). On the other hand, among 27% of students (No. 127) with sufficient mobility, 85% were men (No. 109) and 15% were women (No. 18). Table 1 shows the mean and standard deviation of depression, self-esteem and fat percentage based on gender and activity level.

Also, the research findings from examination of pervasiveness of obesity of the students showed that the average fat percentage of the subjects was 25.19 (S. D ± 7.44), which according to gender, the average fat percentage of men was obtained 47.21% (S. D ± 4.74) and the average fat percentage of women was reported 31.55% (S.D. ± 4.37). This difference between men and women is considered significant with $p < 0.05$. Also, the average level of physical activity of all students is 578 Met/min (S.D. ± 284), and the present study showed that the average weekly activity level among women is 634 Met/min with a standard deviation of ±281 and the average weekly activity level among men is 472 Met/min with a standard deviation of ±231 (Table 1; Figure 1).

Also, regarding students' level of self-esteem, findings proved that 74% of all male and female students (No. 356) had high self-esteem and 26% of them (No. 119) had low self-esteem. Among these 74%, the share of female students is 46% (No. 164) and share of male ones is 54% (No. 192). On the other hand, among those who had low self-esteem, female students accounted for 42% (No. 50) and male ones accounted for 58% (No. 69). However, no significant difference was found between the level of activity and self-esteem.

Based on this, the total self-esteem of the participants was 28.6 (SD ± 5.7). The average score of the students with high self-esteem is 30 and the average score of the students with low self-esteem is 21. Also, the self-esteem scores of male and female students were obtained 29.72 and 29.43, respectively. The difference between the two was considered significant ($p < 0.05$; Figure 2).

Also, regarding the level of depression among students, the findings presented that 82% of all male and female students (No. 438) had low depression and 18% of them (No. 37) had high depression. Among these 82%, share of the female students is 45% (No. 203) and share of male ones is 55% (No. 236). On the other hand, female students accounted for 67% (No. 25) and male ones accounted for 32% (No. 12) of high depression. However, no significant difference was found between the level of activity and depression (Figure 3; Table 2).

As illustrated in Table 3, the analysis of MANCOVA with gender as covariate showed that, a significant difference between individuals in two levels of activity (active, inactive) in the variables of self-esteem [$F(1, 472) = 17.14$, $p = 0.001$, $\eta p2 = 0.035$], body fat percentage [$F(1, 472) = 37.107$, $p = 0.001$, $\eta p2 = 0.073$] and depression [$F(1, 472) = 316.43$, $p = 0.001$, $\eta p2 = 0.401$], respectively. The results of independent pair samples *t*-test showed that the active group of active people had better average scores in all three variables of self-esteem, fat percentage and depression, respectively, compared to inactive people, all ($Ps < 0.05$).

Discussion

The present study aimed to investigate the mental and physical conditions related to inactivity among the students of Farhangian University during the virtual classes due to COVID-19 pandemic. Determining the prevalence and pattern of mental disorders and musculoskeletal pain is the first step in the prevention, diagnosis and treatment of such disorders. This is despite the fact that a targeted and

TABLE 1 Comparison of body fat percentage, self-esteem, and depression of male and female students based on their activity level.

	Sex	Activity	Mean	Number	Standard deviation (SD)	T	sig
Fat percentage	Male students	Active	20.19	71	4.62		
		Inactive	21.54	190	4.43	1.22	0.004
		Total	21.47	261	4.74		
	Female students	Active	30.15	52	4.43	1.45	0.002
		Inactive	31.64	162	4.18		
		Total	31.55	214	4.37		
Self-esteem	Male students	Active	30.82	192	5.47	2.37	0.001
		Inactive	29.45	69	5.16		
		Total	29.72	261	4.37		
	Female students	Active	29.46	164	6.46	2.97	0.004
		Inactive	28.48	50	6.37		
		Total	29.43	214	6.52		
Depression	Male students	Active	20.64	192	6.31	1.86	0.004
		Inactive	27.39	69	6.29		
		Total	25.71	261	6.43		
	Female students	Active	20.52	164	5.67	2.17	0.003
		Inactive	29.61	50	6.44		
		Total	25.65	214	6.30		

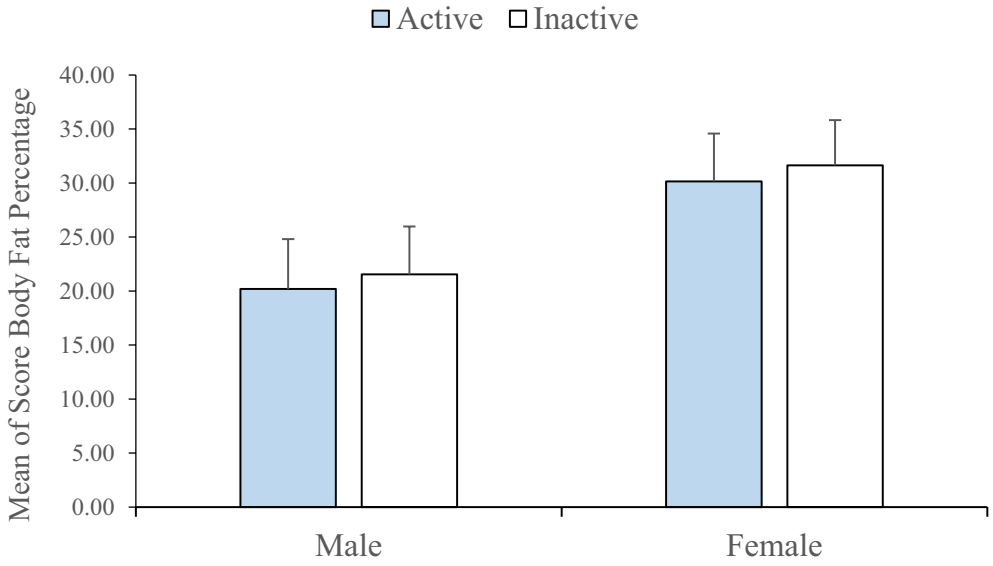

FIGURE 1
Mean body fat percentage in two active and inactive groups based on gender.

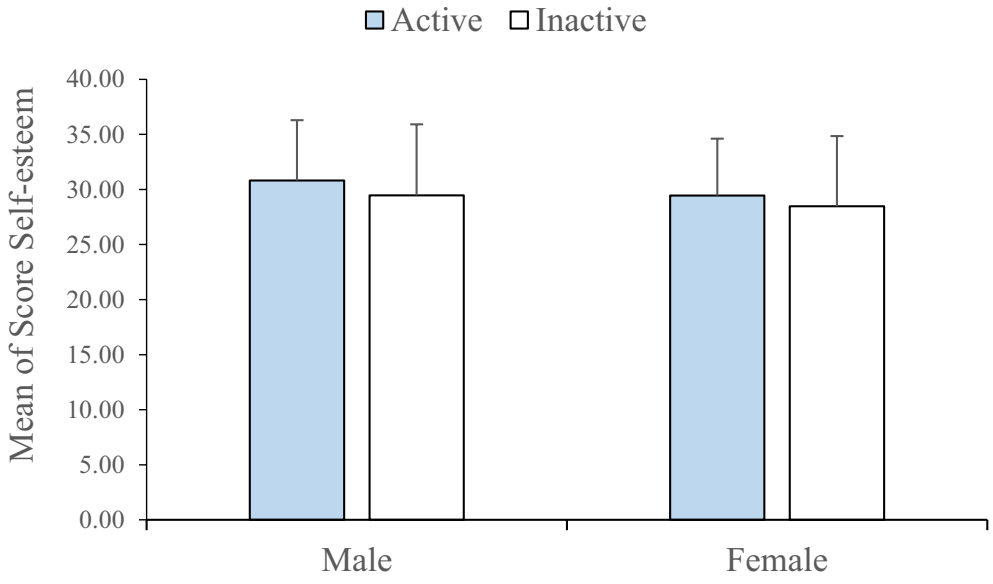

FIGURE 2
Mean self-esteem scores in two active and inactive groups based on gender.

acceptable documented study in this field has not been conducted during COVID-19 era, when students had to use virtual space for classrooms instead of physically attending the class. Therefore, through this research results, appropriate solutions and detailed plans can be taken to alleviate the mental and physical conditions of students.

Results of this study suggests that the prevalence of inactivity among students is high, and about 73% of all individuals did not participate in any of the intense and moderate activities, while in other countries such as Saudi Arabia, the prevalence of physical inactivity includes more than 43% of society (Al-Hazzaa, 2007). In United States, the prevalence of overweight is 36% and obesity is 21% (Davis and Gergen, 1994; Gordon-Larsen, 2001). This amount is reported as 18% (Ramos de Marins, 2001) in Ireland and 33% (McCarthy et al., 2002) in Brazil. Also, the present research results showed that female students had less physical activity (73%) than male ones (51%). Male students demonstrated more physical activity at all levels than female ones. In relation to the number of female students to male ones, the current research results indicated that the activity level of female students was much lower than that of male students, which could be due to the fact that during the Corona period, social restrictions and the closure of sports halls were more for girls. On the other hand,

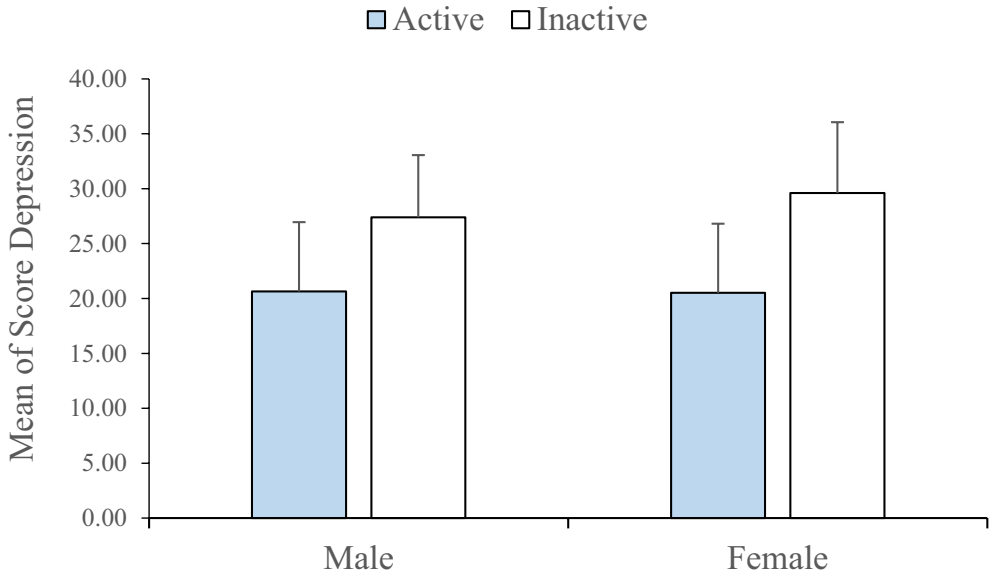

FIGURE 3
Mean depression scores in two active and inactive groups based on gender.

TABLE 2 Results of MANCOVA in activity and inactivity groups in three variables of self-esteem, fat percentage and depression.

Sources		Sum of squares	Df	Mean squares	F	*P* Value	Eta squares η2
Intercept	Self esteem	332.83	2	166.616	20.763	0.001	0.081
	Body fat	11822.3	2	5911.16	1246.5	0.001	0.842
	Depression	5364.7	2	2682.36	158.38	0.001	0.402
Gender	Self esteem	206.8	1	206.8	25.813	0.001	0.052
	Body fat	11733.03	1	11733.03	2474.31	0.001	0.840
	Depression	98.712	1	98.712	6.04	0.004	0.121
Activity	Self esteem	137.42	1	137.42	17.14	0.001	0.035
	Body fat	175.96	1	175.96	37.107	0.001	0.073
	Depression	5359.02	1	5359.02	316.43	0.001	0.401
	Self esteem	3783.01	472	8.015			
Error	Body fat	2238.19	472	4.742			
	Depression	7993.63	472	16.93			

lack of physical activity facilities for both male and female students had a significant impact on their lack of exercise.

Furthermore, researchers have stated that highly-educated individuals have a low level of activity, while other researchers (Lewis, 2005) showed that the amount of physical activity decreases in those with low education. Moreover, based on a study (Hajian-Tilaki and Heidari, 2007), no significant relationship was found between physical activities and education levels, which is consistent with the study of other researchers (Trockel et al., 2000; Wilsgaard et al., 2005). Meanwhile, the average level of physical activity in this study showed that there is a significant difference between the level of physical activity of men and women, i.e., men, participated in this study, have a higher level of physical activity than women. Meanwhile, the average level of physical activity in this study showed that there is a significant difference between the level of physical activity of men and women, i.e., men, participated in this study, have a higher level of physical activity than women. Moreover, during the last three decades, a significant increase in obesity among children and adults has been observed (Carter et al., 2011). This issue has spread to the point that by the increase in individuals' education level, their body fat percentage increases, too (Marmot, 2003). At the same time, other researchers have reported results contrary to this finding (Morrill et al., 1991) that of the present study, educated ones had a not very high amount of fat mass. The prevalence of obesity in Venezuela is 74% for men and 56% for women (Campos et al., 2003), which is consistent with results of this study regarding the difference between women and men' level of physical activities. However, this rate in Palestine is 48% for men and 65% for women (Campos et al., 2003), which proves contradictory results with our findings. According to all the findings, the present study showed that the difference in fat mass

TABLE 3 Description and comparison of skeletal and muscular disorders.

Musculoskeletal disorder	Disorder score of active male students	Disorder score of inactive male students	T	Sig	Disorder score of active female students	Disorder score of inactive female students	T	Sig
	Mean±SD	Mean±SD			Mean±SD	Mean±SD		
All disorders	1.92 ± 2.35	3.92 ± 6.35	2.24	0.003	1.62 ± 3.35	4.92 ± 6.35	3.24	0.043
Total disorders in the last 12 months	1.35 ± 2.48	4.74 ± 5.19	1.98	0.034	1.28 ± 2.97	6.41 ± 3.93	2.62	0.036
Total disorders in the last 7 months	1.56 ± 2.82	5.42 ± 2.32	2.63	0.042	1.67 ± 2.28	7.46 ± 3.14	3.57	0.049
Total disorders leading to prevention of physical activity	2.12 ± 1.47	5.15 ± 2.27	2.86	0.038	1.37 ± 3.83	7.37 ± 2.46	2.64	0.027

between sedentary and sufficiently active participants was significant. This means that sedentary ones had a higher fat mass. Another research has shown that the low participation of individuals in educational programs is related to the decrease of their self-esteem, which have a positive correlation (Suss et al., 1996).

This means that by reducing study hours, students' self-esteem decreases, too; this is in line with results of the present study because the students of Farhangian University had high self-esteem. So, it can be concluded that individuals' level of self-esteem probably increases by the increase in their education level. Moreover, no significant relationship was observed between the level of activity and high/low self-esteem, which means that both low-activity and sufficient activity groups showed high self-esteem scores; In this regard, other research findings found a significant relationship between self-esteem and obesity (French et al., 1995), which is consistent with the findings of our study; in contrast to these results, another study proved that obese women had lower self-esteem (Pesa et al., 2000). This could be due to the fact that with by the weight increase, the amount of mobility would reduce, and the individual will have fewer social connections and less participation in daily activities, which can possibly reduce his/her self-esteem. In the case of the present study, it can be said that due to the high educational level among the participants and their status in high social and cultural levels, low mobility could not impact their self-esteem. According to the research results (Scherrer and Preckel, 2019), it is stated that self-esteem does not change significantly with changes in the amount of fat mass, in line with the findings of the present study, because there was no statistically significant difference between sedentary and physically active students in their body fat mass. While in an opposite claim (Davis and Gergen, 1994; Guinn et al., 1997; Anderson et al., 2006; Wang et al., 2009), they showed that there is an inverse relationship between individuals' body weight and self-esteem, i.e., with a decrease in body weight, the amount of self-esteem increases, and with an increase in body weight, self-esteem decreases. On the other hand, other scientists (Childress et al., 1993) claimed that the level of self-esteem among overweight children was significantly lower than their normal counterparts, which is not consistent with the findings of this study, because a significant difference was not observed between the amount of fat mass as well as the activity level with the level of self-esteem, perhaps the reason for this difference can be attributed to the age differences between children and adults.

With respect to the level of depression of Farhangian University students, the findings showed that the level of depression of female students during the COVID-19 pandemic and virtual classes was higher than that of male ones, but this was relatively small, and it can be expected with the increase of psychological and counseling interventions, the case would be reduced. On the other hand, no significant difference was found between the level of activity and depression.

Also, in relation to the degree of the musculoskeletal disorders of the students, findings suggested that among active male students, the highest frequency of pain, discomfort and numbness in last 12 months were related to the wrists and hands (No.17), and in the last 7 days related to back (No. 16), and the most skeletal pain that caused them to stop physical activity in the last 12 months was pain in the knees (No. 21). Also, in sedentary male students, the highest prevalence of pain, discomfort and numbness in the last 12 months was related to the back (No. 42) and in the last 7 days, it was related to the thigh (No. 64), and the most skeletal pain in the last 12 months which made them quit physical activity was related to back pain (No. 74). On the other hand, in female students, the highest prevalence of pain, discomfort and numbness in the past 12 months was related to neck (No. 15) and during the last 7 days, it was related to wrists and hands (No. 22), and the most skeletal pain that caused them to leave physical activity in the last 12 months was related to shoulder pain (No. 31). Also, in sedentary female students, the highest frequency of pain, discomfort and numbness in the last 12 months was related to the back (No. 72), and in the last 7 days, it was related to the shoulders (No. 103), and the most skeletal pain in the last 12 months, which made them quit physical activity was related to back pain (No. 108).

In general, findings of this study are similar to the global statistics of the COVID-19 pandemic and its impact on individuals' physical and mental factors. It seems that the conditions related to the corona epidemic, as a result, presence of the students in-person, can have negative effects on students. Therefore, it can be concluded that even students and their level of understanding of benefits of physical activity cannot prevent mental and physical problems for them. It is expected that students who use modern scientific resources and are relatively aware of the dangers of obesity and inactivity are not exposed to such injuries, however, in practice, during virtual classes, students of Farhangian University were not sufficiently active; as a

result of which physical and mental conditions are observed among them. Also, results related to the degree of psychological factors (self-esteem and depression) showed that in terms of mental health, both female and male students were not in a satisfactory condition due to lack of training and other related factors. It can be concluded that during COVID-19 era, due to health restrictions and government policies regarding quarantine and pandemic, and on the other hand, holding virtual classes and sitting next to communication devices for class, students did not have enough time for exercise. Actually, they did not enjoy physical activity because physical activity was not a priority for students of Farhangian University during the COVID-19.

Therefore, this study suggests increasing the level of physical activity to reduce body fat mass, enhance mental health, and reduce skeletal disorders, which can be properly accomplished through organized university planning and prioritizing health of the male and female students. However, findings of the present study were only limited to the students of Farhangian University in Iran. It is suggested to investigate the effects of inactivity associated with Corona on the physical and mental factors in a wider student's community of and even students from different nations in future studies.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by Farhangian University. The patients/participants provided their written informed consent to participate in this study.

Author contributions

MH contributed to the conceptualization, data curation, investigation, methodology, project administration, resources, supervision, validation, visualization, and writing (reviewing and editing) of the study. MP and SNK contributed to the conceptualization, data curation, investigation, methodology, and writing (reviewing and editing) of the study. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

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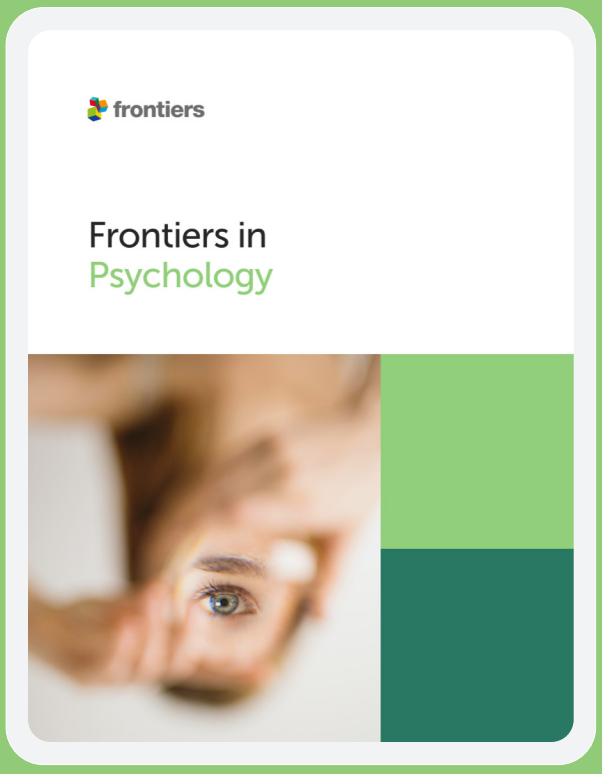

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