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Motivation for physical activity, volume II

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Motivation for physical activity, volume II

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Editorial: Motivation for physical activity, volume II

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Editorial on the Research Topic
Motivation for physical activity, volume II

Introduction

Motivation is a cornerstone of human behavior, directing the choices and actions shaping physical and mental wellbeing. Within the realm of physical activity, understanding the factors that drive participation, and adherence holds profound implications for public health, education, and clinical interventions. Building on the success of the first volume (Rogowska and Morouço, 2024), this Research Topic presents a diverse collection of 10 articles that delve into the psychological, social, and behavioral determinants of physical activity across various populations and contexts. Guided by contemporary theories (e.g., self-determination theory), these studies illuminate the intricate interplay between motivation and physical activity, offering valuable insights for researchers, practitioners, and policymakers.

The contributions in this Research Topic span a broad spectrum of research areas, from theoretical explorations of motivational constructs to practical interventions aimed at fostering physical activity. Collectively, they enrich our understanding of how motivational processes operate in diverse settings and populations.

Motivation and self-efficacy across life stages

The relationship between self-efficacy and motivation is foundational in understanding physical activity behaviors across different stages of life. Tao et al. investigate the links between self-efficacy and motivation levels among emerging adults through the lens of self-determination theory. Their findings underscore the importance of fostering intrinsic motivation to enhance physical activity levels in this critical developmental stage. Similarly, Grasaas and Sandbakk analyze trends among Norwegian adolescents, revealing positive associations between self-efficacy and adherence to physical activity recommendations.

Personality and psychological factors

Individual differences in personality and psychological characteristics shape how people engage with physical activity. Zhang W. et al. delve into the dualistic model of passion to examine how self-oriented perfectionism influences exercise participation. This study highlights the nuanced role of personality traits in shaping physical activity behaviors. Complementing this, Zhang Y. et al. explore procrastination's impact on physical activity among university students, identifying the chain-mediated roles of time management and exercise motivation.

Family and environmental influences

The role of the social and physical environment is crucial in shaping early and sustained engagement in physical activity. The family environment emerges as a critical determinant in Huang et al.'s study, which explores associations between family factors and physical activity clustering in preschool children. This emphasis on early life determinants aligns with the national-level analysis by Guo et al., who examine recreational screen time and its impact on Chinese children and adolescents' activity levels.

Interventions to enhance physical activity

Intervention strategies remain central to efforts to promote physical activity and improve health outcomes. Innovative interventions are also represented. Gómez-Cuesta et al. evaluate the efficacy of a mobile app-based program in improving fitness and body composition, highlighting its adaptability across varying activity levels. Martinez Kercher et al. investigate the psychological and motivational underpinnings of resistance training outcomes in adults, demonstrating the pivotal role of psychological needs and self-efficacy.

Educational and clinical contexts

Physical education and mental health contexts offer unique opportunities to study motivation's role in promoting physical activity. The mediating role of motivation is explored in Miao et al.'s study, which highlights how perceived variety-support in physical education enhances learning engagement among middle school students. Meanwhile, Chen et al. provide evidence of the protective effects of physical activity against depression in adolescents, offering critical insights into mental health interventions.

Broader context and future directions

The insights offered by this Research Topic place the study of physical activity motivation within a broader context of contemporary behavioral science. They reflect the multidimensionality of motivation, emphasizing that sustaining engagement in physical activity demands an integrative approach—one that accounts for individual, social, and environmental factors.

Looking ahead, the field stands poised for significant developments. Emerging technologies, such as AI-driven or web-based personalized interventions, and the growing recognition of cultural and contextual factors, offer promising avenues for further exploration. Additionally, experimental and longitudinal research are crucial to explore the long-term effects of motivational strategies for physical activity adherence. The studies featured in this Research Topic collectively advance our understanding of the complex dynamics that motivate individuals to engage in physical activity. By addressing diverse populations and using various theoretical frameworks, they provide a robust foundation for future research and practice. It is our hope that these contributions will encourage further innovation and collaboration toward healthier, more active societies.

Author contributions

PM: Writing – original draft, Writing – review & editing. AR: Writing – review & editing. BB: Writing – review & editing.

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Adherence to physical activity recommendations and associations with self-efficacy among Norwegian adolescents: trends from 2017 to 2021

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Background: The crucial role of physical activity (PA) in promoting well-being and overall health of adolescents is widely acknowledged. Previous global studies have consistently revealed low adherence to PA recommendations among adolescents, emphasizing potential links between PA engagement and self-efficacy in school-based populations. However, there is a need for further exploration of this relationship, in particularly gender differences and taking into account the potential influences of the COVID-19 pandemic. The objective of this study is to provide a comprehensive description of adherence to PA recommendations and its associations with self-efficacy in Norwegian school-based adolescents over the period from 2017 to 2021.

Methods: Cross-sectional data on physical activity (PA) levels and self-efficacy among 13–19-year-old Norwegian adolescents were collected from the Norwegian Ungdata Survey during the period 2017 to 2021. The survey, conducted in Norwegian lower- and upper-secondary schools, was administered electronically during school hours. All data collected is anonymous and has received approval from the Norwegian Agency for Shared Services in Education and Research (SIKT). Statistical analyses were performed using SPSS software.

Results: Girls consistently exhibited lower adherence to PA recommendations (17.6–19.8%) compared to boys (27.7–31.1%) each year from 2017 to 2021 (all $p < 0.01$). Similarly, girls reported lower self-efficacy (14.1 to 14.8 out of 20) than boys (15.5 to 15.9) during the same period (all $p < 0.01$). Regression analyses highlighted robust positive associations between PA and self-efficacy in those adhering to PA recommendations (i.e., physically active at least 5 times a week) and strong inverse associations for those reporting inactivity (never active) in both girls and boys from 2017 to 2021.

Conclusion: Adolescents in Norway report PA adherence ranging from 15 to 30%, with girls consistently exhibiting lower adherence to PA recommendations and reporting lower self-efficacy than boys. Notably, there are substantial associations between self-efficacy and both adherence to PA recommendations and inactivity over time. These findings underscore the significance of promoting adherence to PA recommendations during adolescence, especially among girls. Policymakers in Norway should focus on initiatives to increase PA levels among adolescents in both lower and upper secondary schools.

KEYWORDS

exercise habits, health behavior, mental health, PA recommendations, adolescents

1 Background

Physical activity (PA) is crucial for the well-being and overall health of adolescents (1). Adolescence represents a critical period encompassing physical, psychological, and social development, with a pronounced emphasis on the pursuit of independence (1–3). During this phase, behavioral habits are often formed, and the decision to engage in physical activity emerges as a significant determinant of future health (1, 4).

Extensive evidence underscores physical inactivity in adolescence as a predictor of increased risks for developing non-communicable chronic diseases, elevated morbidity and mortality rates, as well as heightened susceptibility to economic burdens on society due to social support requirements and diminished work capacity (5–7). Consequently, there is a growing global concern about inactivity, and international data reveals that 81% of adolescents fail to meet PA guidelines, with substantial variations observed across countries, regions, genders, and religions (8). A comprehensive study involving 146 countries disclosed that 84.7% of girls and 77.6% of boys did not achieve sufficient physical activity levels (8). Harmonizing accelerometer measures of PA across Europe, Steen-Johannsen and colleagues demonstrated that two-thirds of European children and adolescents are inadequately physically active (9). Furthermore, the findings suggested that boys exhibited higher activity levels and lower sedentary behavior across all age categories compared to girls. Both girls and boys demonstrated a yearly reduction in PA levels from 13 to 17 years of age (9).

For children and adolescents aged 5 to 17 years, the World Health Organization (WHO) recommends "*at least an average of 60 min per day of moderate-to-vigorous intensity, mostly aerobic, physical activity, across the week and should incorporate vigorous-intensity aerobic activities, as well as those that strengthen muscle and bone, at least 3 days a week*." According to the Norwegian public health report from 2018 (Folkehelserapporten), half of the boys and 40% of girls aged 15 adhered to the PA guidelines in Norway (10, 11). Given the emergence of Covid-19, which has significantly impacted the daily lives of school-based adolescents, there is a clear need for updated research on adherence to PA recommendations over time, both before and after the pandemic, in Norwegian girls and boys.

According to the systematic review and meta-analysis by Rodriguez-Ayllon and colleagues, investigating the role of PA and sedentary behavior on the mental health of preschoolers, children, and adolescents (12), revealed that PA, especially among adolescents, can improve their self-efficacy. The theory of self-efficacy focuses on how performance or behavior influences one's beliefs (13) and according to Albert Bandura, self-efficacy is defined as "*how well one can execute courses of action required to deal with prospective situations*" (14). Self-efficacy has also been shown to be a predictor for PA, presumably as a motivator and self-regulating mechanism (15, 16). However, the relationship is complex because self-efficacy is argued to influence PA engagement and be influenced by PA engagement (17).

Self-efficacy has been identified as an important determinant of both present and future health behavior (18–21). Bandura argues that self-efficacy impacts activity choices, persistence when facing challenges or barriers, and the effort or intensity in tasks (22). A higher belief in one's own capacity impacts activity choices and activity level. As a result of a higher PA level, there is even higher self-efficacy, thereby creating a positive feedback loop. Thus, engagement in PA seems to be a preferred method for increasing self-efficacy, as engaging in PA boosts the feeling of success and self-belief (23, 24).

According to Spence and colleagues, self-efficacy also contributes to explain gender differences in PA levels among adolescents, in which boys are shown to have higher self-efficacy compared with girls (25). Norwegian studies have also reported that girls tend to report lower self-efficacy than boys in both younger and older adolescents (26–28). Previous findings have revealed a significant differences in self-efficacy of young people doing exercise regularly compared to sedentary ones (23). Further, research evidence indicates that promoting different types of physical activities provide an increase in self-efficacy in school-based adolescents, such as yoga interventions and resistance training (29, 30). Hence, PA engagement might be a relevant indicator for the degree of self-efficacy in Norwegian school-based adolescents regardless of activity type, yet this remains unknown.

There is a clear need to investigate PA levels and self-efficacy in a school-based sample of Norwegian adolescents before and after the pandemic using nationwide data. As the concept of self-efficacy is interwoven with PA and is reported to be a self-regulatory mechanism by which change is possible (31, 32), it is particularly interesting to address these relationships over time. By using nationwide data over time to explore how different levels of PA impact self-efficacy in Norwegian girls and boys, a clearer link between PA levels and mental health benefits can be established. Moreover, such insights may enhance our understanding of how much PA is required to impact the directional nature of self-efficacy. Therefore, the objective of this study is to provide a comprehensive description of adherence to PA recommendations and its associations with self-efficacy in Norwegian school-based adolescents over the period from 2017 to 2021.

We hypothesize that: (i) PA levels and self-efficacy are lower in girls than boys. (ii) Adherence to PA recommendations (highest level of PA) is strongly associated with self-efficacy in girls and boys every year from 2017–2021. (iii) Inactivity (lowest level of PA) is inversely associated with self-efficacy in both girls and boys.

2 Methods

2.1 Study design and participants

This study utilized cross-sectional data from the Norwegian Ungdata Survey, conducted annually from 2017 to 2021. Ungdata is a

Abbreviations: PA, Physical Activity; SES, Socioeconomic Status; CI, Confidence Interval; SD, Standard Deviation; NOVA, Norwegian Social Research; Korus, Regional Center for Drug Rehabilitation; KS, The Municipal Sector's Organization; SIKT, Norwegian Agency for Shared Services in Education and Research; WHO, World Health Organization; GSE, General Self-Efficacy; OTCA, Over the Counter Analgesics; STROBE, Strengthening The Reporting Of Observational Studies.

nationwide survey recognized as the most comprehensive source of information on Norwegian adolescents' health and lifestyle (33).

The study includes Norwegian adolescents from lower (aged 13 to 16 years of age) and upper secondary school (aged 16 to 19 years of age). The national reports from Ungdata encompass data from the last three recent years. Between 2017 and 2019, a total of 259,700 adolescents participated, with 146,400 responders from lower secondary school (grades 8th, 9th, and 10th) and 113,300 responders from upper secondary school (grades 1st, 2nd, and 3rd). During this period, 80% of all lower secondary school pupils and 60% of all upper secondary school pupils in Norway took part. From 2018 to 2020, the participation rates were 79% in lower secondary school and 65% in upper secondary school. Notably, due to the pandemic, findings from 2021 are reported separately. In 2021, a total of 140,000 pupils from 8th grade to 3rd grade participated, reflecting an 83% response rate from lower secondary schools and a 67% response rate from upper secondary school (34).

2.2 Outcomes

The Ungdata study encompasses demographic measures, including gender, grade level, respective municipalities, and various health-related questions. Due to the survey's anonymity, age data is not available.

Physical activity (PA) levels were assessed using the question, "*How often are you so physically active that you become short of breath or sweaty?*" Respondents could choose from six response alternatives ranging from "never active" to different times a week, up to "at least 5 times a week." In this study, the response "at least 5 times a week" was used as a proxy for compliance with World Health Organization (WHO) recommendations for PA. Single-item measures of PA have demonstrated strong reliability and concurrent validity (35). The single-item measure of PA is considered a potentially useful assessment tool for evaluating changes in moderate-vigorous PA levels, especially when device-based measures or longer questionnaires are impractical (36). Given the study period spanning from 2017 to 2021, the applied physical activity (PA) questions were considered most appropriate for addressing the current paper's aim. However, enhancing the single-item measure, such as incorporating more comprehensive or objective measures, would have improved the sensitivity to PA levels in subjects. This PA question was part of the mandatory module of the Ungdata survey, included in all participating municipalities.

Self-efficacy was measured using the Norwegian 5-item version of the General Perceived Self-Efficacy Scale (GSE) (37). GSE is developed for assessing the global confidence in one's abilities to cope with the tasks, demands, and challenges of life in general and reported as a valid and reliable psychometric scale (38–40). GSE encompass five statements, rated on a scale from 1 (completely wrong) to 4 (completely right). Scores of the GSE items are summed into a total score ranging from 5 to 20, wherein higher scores indicate higher GSE levels. Questions related to self-efficacy were part of the optional module, and thus, the inclusion of these questions varied across municipalities from 2017 to 2021 (Supplementary File S1).

Covariates considered in the adjusted analysis for each year (2017–2021) included the following factors: socioeconomic status (SES), perceived school stress as an indicator of psychological well-being (41), and over-the-counter analgesics (OTCA) use as an indicator of health status. SES was assessed using several questions related to parental educational level, the presence of books in the home, and the level of prosperity. The total sum of these three categories was calculated and recoded into values ranging from 0 to 3, with 0 representing the lowest SES and 3 the highest SES (42). This measure is reported as a validated construct of SES (42). Perceived school stress was measured by the statement "*I get stressed by the schoolwork?*" with five response alternatives: "never," "seldom," "sometimes," "often" and "very often." OTCA use was assessed with the question "*How often have you used non-prescription drugs (Paracet, Ibux and similar) during the last month?*" Participants could choose from five response alternatives: "never," "less than once a week," "at least weekly," "several times a week," and "daily."

2.3 Data collection

Ungdata is conducted by Norwegian Social Research (NOVA) at Oslo Metropolitan University in collaboration with the regional center for drug rehabilitation (KoRus) and the municipal sector's organization (KS). Surveys are administered electronically during one school hour with a teacher present. Pupils who choose not to participate are provided with alternative schoolwork assignments. The survey comprises a mandatory basic module for all municipalities and some optional questions that municipalities can select from. Adolescents from nearly all municipalities in Norway are represented, with different municipalities participating each year. According to Ungdata, the research evidence derived from these surveys is well-suited for planning and initiating interventions related to adolescents and public health (33). The Ungdata project is financed from the national budget through grants from the Norwegian Directorate of Health (33).

2.4 Ethical consideration

Participation in the Ungdata survey is voluntary, and informed written consent was obtained from the adolescents. All questions from Ungdata included in this current study have been approved by the Norwegian Agency for Shared Services in Education and Research (ref. 821,474), known as SIKT (43). As the survey is conducted during the spring, adolescents in upper secondary school were 16 years or older and thus did not need parental consent. Participants in lower secondary school required additional parental approval to participate. Due to the anonymity of the data, age was not included. The study is conducted in accordance with the Helsinki Declaration and is reported according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (44).

2.5 Statistical analyses

All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive measures for continuous variables are presented as means and standard deviations (SDs), while categorical variables are reported as counts and percentages. Adherence to PA levels was categorized into those likely complying with WHO guidelines for PA recommendation (reporting PA at least 5 times a week) and those not complying (all other categories). Descriptive measures were stratified by grade levels (8th to 3rd grade) and by gender. Chi-square tests and

TABLE 1 Overview of adherence to physical activity recommendations (expressed as a percentage) in Norwegian girls and boys by grade level from 2017 to 2021.

	Grade Level						
	8th grade	9th grade	10th grade	1st year	2nd year	3rd year	Total score
Year: 2017							
Girls	23.3%	22.5%	20.8%	17.7%	16.7%	13.5%	19.8% *
	$n = 9,443$	$n = 8,963$	$n = 8,988$	$n = 8,579$	$n = 6,053$	$n = 4,385$	$n = 47,552$
Boys	32.4%	33.7%	32.2%	29.5%	28.4%	27.9%	31.1%
	$n = 9,570$	$n = 9,072$	$n = 9,010$	$n = 8,604$	$n = 5,806$	$n = 3,376$	$n = 46,691$
Year: 2018							
Girls	20.2%	20.8%	18.9%	15.6%	14.7%	13.0%	17.6% *
	$n = 6,349$	$n = 6,278$	$n = 5,909$	$n = 5,710$	$n = 4,712$	$n = 4,034$	$n = 33,668$
Boys	29.2%	28.8%	30.1%	26.4%	23.5%	26.9%	27.7%
	$n = 6,154$	$n = 6,083$	$n = 5,627$	$n = 5,461$	$n = 4,622$	$n = 3,032$	$n = 31,668$
Year: 2019							
Girls	21.8%	21.4%	20.4%	17.7%	16.5%	13.5%	18.8% *
	$n = 10,112$	$n = 9,826$	$n = 9,821$	$n = 10,595$	$n = 9,105$	$n = 5,918$	$n = 56,337$
Boys	29.1%	30.4%	31.9%	27.4%	26.7%	28.3%	28.9%
	$n = 9,898$	$n = 9,606$	$n = 9,502$	$n = 10,474$	$n = 9,183$	$n = 4,698$	$n = 54,704$
Year: 2020							
Girls	20.2%	20.8%	19.9%	19.3%	16.7%	16.9%	19.0% *
	$n = 2,114$	$n = 1966$	$n = 2079$	$n = 2,302$	$n = 1806$	$n = 1771$	$n = 12,403$
Boys	29.9%	32.9%	34.0%	29.7%	29.3%	32.5%	31.1%
	$n = 2,116$	$n = 1850$	$n = 2,127$	$n = 2,264$	$n = 2,528$	$n = 1,097$	$n = 11,731$
Year: 2021							
Girls	19.3%	19.9%	20.5%	17.7%	17.1%	16.7%	18.7% *
	$n = 12,455$	$n = 12,401$	$n = 12,341$	$n = 10,597$	$n = 9,067$	$n = 7,146$	$n = 65,495$
Boys	29.7%	32.6%	34.2%	29.4%	28.3%	31.9%	31.0%
	$n = 12,459$	$n = 12,425$	$n = 12,021$	$n = 10,594$	$n = 8,635$	$n = 4,743$	$n = 62,423$

n, the number of total responders, %, the percentage of the total responders adhering to the recommendation of physical activity (reported at least 5 times).
* = $p < 0.01$.

t-tests were employed to assess yearly differences between boys and girls for PA levels and self-efficacy, respectively.

Linear regression analyses were conducted to explore the association between PA levels and self-efficacy. The predicting independent categories of PA were recoded into dummy variables. Both crude and adjusted multiple regression analyses were presented, with regressions displaying beta coefficients along with 95% confidence intervals. The adjusted regression analysis included covariates such as SES, perceived school stress, and OTCA use. p-values <0.05 were considered statistically significant, and all tests were two-sided. Given the large sample size and low missing, bootstrapping nor imputation was not considered necessary.

3 Results

3.1 Participants

A total of 433,046 Norwegian school-based adolescents reported their PA levels, and 196,786 reported their self-efficacy between 2017 and 2021. Among them, 195,557 adolescents provided responses for both measures. The response rate for PA levels remained consistently high, ranging from 91.9 to 93.8% each year, while the response rate for self-efficacy varied more (from 51.8 to 77.4%) and was not consistently reported across all municipalities (refer to Supplementary File S1 for details). An equal gender distribution was observed throughout the period, ranging from 49.6 to 50.4%.

3.2 Descriptive statistics

The total scores revealed lower adherence to PA recommendations in girls compared to boys every year from 2017 to 2021 ($p < 0.01$). Adherence to PA recommendations for girls ranged from 17.6 to 19.8% during the same period (Table 1). Girls reported lower adherence to PA recommendations in upper secondary school (1st – 3rd grade) compared to lower secondary school (8th to 10th grade) every year. There was a tendency of decreasing adherence to PA levels over time as the girls' cohorts progressed through yearly grading levels, with the lowest adherence typically found in the 3rd year, except for 2020.

TABLE 2 Overview of self-efficacy (mean/SD) in Norwegian girls and boys by grade level from 2017 to 2021.

	Grade level						
	8th grade	9th grade	10th grade	1st year	2nd year	3rd year	Total score
Year: 2017							
Girls	15.0 (2.7)	14.6 (2.7)	14.6 (2.7)	14.7 (2.7)	14.8 (2.7)	14.9 (2.5)	14.8 (2.7) *
	$n = 2,872$	$n = 2,867$	$n = 2,909$	$n = 3,693$	$n = 3,171$	$n = 2,543$	$n = 18,222$
Boys	15.9 (2.8)	15.7 (2.8)	15.8 (2.9)	16.0 (2.8)	16.0 (2.8)	16.2 (2.8)	15.9 (2.8)
	$n = 2,950$	$n = 2,869$	$n = 2,793$	$n = 3,569$	$n = 3,085$	$n = 1967$	$n = 17,416$
Year: 2018							
Girls	14.6 (3.1)	14.3 (2.9)	14.5 (2.9)	14.5 (2.8)	14.6 (2.9)	14.5 (2.5)	14.5 (2.8) *
	$n = 319$	$n = 376$	$n = 323$	$n = 849$	$n = 673$	$n = 611$	$n = 3,201$
Boys	15.2 (3.3)	15.3 (3.3)	15.7 (3.2)	15.5 (3.3)	15.5 (3.1)	16.0 (2.7)	15.5 (3.2)
	$n = 304$	$n = 370$	$n = 328$	$n = 796$	$n = 727$	$n = 429$	$n = 3,017$
Year: 2019							
Girls	14.6 (3.1)	14.4 (3.0)	14.5 (2.9)	14.6 (2.9)	14.7 (2.8)	14.8 (2.6)	14.6 (2.9) *
	$n = 7,520$	$n = 7,696$	$n = 7,851$	$n = 8,041$	$n = 7,157$	$n = 4,557$	$n = 43,290$
Boys	15.5 (3.1)	15.5 (3.2)	15.6 (3.1)	15.8 (3.2)	15.9 (3.0)	16.1 (2.9)	15.7 (3.1)
	$n = 7,388$	$n = 7,399$	$n = 7,506$	$n = 8,114$	$n = 7,186$	$n = 3,715$	$n = 41,799$
Year: 2020							
Girls	14.5 (2.8)	14.2 (3.0)	14.4 (2.8)	14.4 (2.7)	14.5 (2.5)	14.9 (2.7)	14.5 (2.8) *
	$n = 999$	$n = 922$	$n = 1,084$	$n = 1,249$	$n = 1,025$	$n = 1,101$	$n = 6,572$
Boys	15.6 (3.0)	15.5 (3.0)	15.7 (2.9)	15.5 (3.0)	15.7 (3.0)	16.0 (2.8)	15.7 (3.0)
	$n = 972$	$n = 901$	$n = 1,064$	$n = 1,188$	$n = 1,005$	$n = 664$	$n = 5,971$
Year: 2021							
Girls	13.9 (3.1)	13.9 (3.0)	14.1 (2.9)	14.2 (2.9)	14.3 (2.8)	14.5 (2.7)	14.1 (2.9) *
	$n = 4,313$	$n = 4,628$	$n = 4,701$	$n = 5,146$	$n = 4,392$	$n = 3,584$	$n = 27,465$
Boys	15.2 (3.1)	15.2 (3.1)	15.4 (3.1)	15.6 (3.0)	15.8 (3.0)	15.9 (2.9)	15.5 (3.0)
	$n = 4,297$	$n = 4,709$	$n = 4,623$	$n = 4,986$	$n = 4,232$	$n = 2,349$	$n = 25,941$

$* = p < 0.01$.

For boys, adherence to PA recommendations ranged from 27.7 to 31.1% from 2017 to 2021. Boys reported relatively consistent adherence to PA recommendations from 8th grade to 3rd year during the same period. The highest yearly adherence was found in either 9th or 10th grade (33.7% or 34.2%, respectively). The lowest levels of adherence were found in the 2nd year for boys in most years, except for 2017.

The total score indicates that girls consistently reported lower self-efficacy (ranging from 14.1 to 14.8 out of 20) than boys (15.5 to 15.9) each year from 2017 to 2021 (all years $p < 0.01$). The findings revealed minimal to negligible fluctuations in reported self-efficacy from 8th grade to 3rd year annually (Table 2). Girls demonstrated a gradual decrease in the total score of self-efficacy each year, declining from a mean (SD) of 14.8 (2.7) in 2017 to 14.1 (2.9) in 2021. Additionally, the results unveiled slight variations in reported self-efficacy among boys from 8th grade to 3rd year, with the highest self-efficacy score consistently observed in the 3rd year for boys each year in the period. The mean total score for boys was marginally higher in 2017 (mean (SD): 15.9 (2.8)) compared to 2021 (mean (SD): 15.5 (3.0)), yet no clear trend was identified.

3.3 Regressions analyses

For both girls and boys, including crude and adjusted regressions, the findings consistently revealed the strongest positive associations among those adhering to PA recommendations (at least 5 times a week) and the strongest inverse (negative) associations for those reporting inactivity (never active) concerning self-efficacy (Table 3). This examination was conducted every year from 2017 to 2021. In the case of girls, those who did not meet PA recommendations exhibited a significantly inverse association ($p < 0.01$) with self-efficacy from 2017 to 2020. The association in 2021 was borderline significant ($B = -0.81$, 95% CI; [−1.66 to 0.04]) after adjusting for SES, perceived stress, and OTCA use (Table 3). After adjusting for selected covariates, girls reporting adherence to PA levels (at least 5 times a week) revealed a positive significant association ($p < 0.05$) with self-efficacy in 2018, 2020, and 2021. For boys, associations between adhering to PA recommendations (at least 5 times a week) and self-efficacy remained significant ($p < 0.05$) every year after adjusting for covariates from 2017 to 2021. Boys reporting inactivity showed an inversely significant association ($p < 0.01$) with self-efficacy every year, except in 2020.

TABLE 3 Association between physical activity levels and self-efficacy in Norwegian adolescents (2017–2021): gender and grade-level stratification in crude and adjusted analyses.

	Girls						Boys					
	Unadjusted			Adjusted			Unadjusted			Adjusted		
	B	95% CI	p-value	B	95% CI	p-value	B	95% CI	p-value	B	95% CI	p-value
2017												
Never	-1.59	-2.06: -1.13	<0.01	-1.41	-1.87: -0.95	<0.01	-1.67	-2.12: -1.22	<0.01	-1.56	-2.01: -1.11	<0.01
Seldom	-1.24	-1.57: -0.92	<0.01	-1.14	-1.46: -0.83	<0.01	-1.02	-1.34: -0.70	<0.01	-0.98	-1.31: -0.66	<0.01
1-2 times a month	-0.87	-1.19: -0.55	<0.01	-0.79	-1.10: -0.47	<0.01	-0.71	-1.03: -0.39	<0.01	-0.68	-1.00: -0.35	<0.01
1-2 times a week	-0.56	-0.86: -0.26	<0.01	-0.54	-0.83: -0.24	<0.01	-0.36	-0.63: -0.08	0.01	-0.42	-0.70: -0.14	<0.01
3-4 times a week	-0.24	-0.54: 0.05	0.11	-0.30	-0.60: -0.01	0.04	0.08	-0.19: 0.36	0.54	-0.00	-0.28: 0.27	0.99
At least 5 times	0.19	-0.11: 0.50	0.21	0.11	-0.19: 0.41	0.47	0.58	0.30: 0.85	<0.01	0.48	0.20: 0.75	<0.01
2018												
Never	-2.27	-3.38: -0.96	<0.01	-3.38: -0.96	-3.13: -0.72	<0.01	-1.88	-3.02: -0.74	<0.01	-1.74	-2.89: -0.58	<0.01
Seldom	-0.77	-1.58: 0.03	0.06	-1.58: 0.03	-1.41: 0.21	0.15	0.61	-0.23: 1.46	0.16	0.52	-0.34: 1.38	0.24
1-2 times a month	-0.25	-1.07: 0.57	0.55	-1.07: 0.57	-0.91: 0.74	0.84	0.69	-0.17: 1.54	0.11	0.66	-0.20: 1.53	0.13
1-2 times a week	-0.06	-0.82: 0.70	0.88	-0.82: 0.70	-0.73: 0.79	0.94	1.08	0.33: 1.82	<0.01	0.98	0.22: 1.75	0.01
3-4 times a week	0.37	-0.39: 1.13	0.34	-0.39: 1.13	-0.36: 1.17	0.30	1.41	0.66: 2.26	<0.01	1.31	0.55: 2.08	<0.01
At least 5 times	0.81	0.03:1.59	0.04	0.03:1.59	-0.00: 1.55	0.05	1.99	1.24: 2.74	<0.01	1.89	1.12: 2.67	<0.01
2019												
Never	-1.54	-1.97: -1.12	<0.01	-1.30	-1.73: -0.87	<0.01	0.98	-1.38: -0.58	<0.01	-1.12	-1.55: -0.68	<0.01
Seldom	-0.90	-1.28: -0.53	<0.01	-0.69	-1.08: -0.31	<0.01	-0.22	-0.57: 0.14	0.23	-0.35	-0.74: 0.04	0.08
1-2 times a month	-0.55	-0.93: -0.17	<0.01	-0.33	-0.72: 0.06	0.10	-0.06	-0.42: 0.29	0.74	-0.21	-0.60: 0.18	0.30
1-2 times a week	-0.18	-0.55: 0.19	0.34	-0.04	-0.41: 0.34	0.85	0.47	0.13: 0.80	<0.01	0.30	-0.08: 0.68	0.12
3-4 times a week	0.19	-0.18: 0.56	0.30	0.27	-0.11: 0.65	0.16	0.92	0.59: 1.26	<0.01	0.71	0.33: 1.08	<0.01
At least 5 time	0.62	0.25: 0.99	<0.01	0.67	0.29: 1.05	<0.01	1.49	1.15: 1.83	<0.01	1.26	0.89: 1.64	<0.01
2020												
Never	-0.98	2.12: 0.16	0.09	-1.68	-2.89: -0.48	<0.01	-0.51	-1.94: 0.93	0.49	-0.98	-2.57: 0.62	0.23
Seldom	-0.66	-1.69: 0.38	0.21	-1.14	-2.25: -0.03	0.04	0.78	-0.56: 2.12	0.26	0.10	-1.42: 1.62	0.90
1-2 times a month	-0.03	-1.06: 1.01	0.96	-0.57	-1.68: 0.53	0.31	0.84	-0.52: 2.19	0.23	0.27	-1.25: 1.80	0.73
1-2 times a week	0.11	-0.90: 1.12	0.83	-0.48	-1.57: 0.60	0.38	1.18	-0.14: 2.50	0.08	0.55	-0.95: 2.05	0.47
3-4 times a week	0.59	-0.42: 1.60	0.25	-0.09	-1.18: 0.99	0.87	1.63	0.32: 2.95	0.02	0.97	-0.53: 2.47	0.20
At least 5 times	1.18	0.16: 2.19	0.02	0.42	-0.67: 1.51	0.45	2.20	0.88: 3.52	<0.01	1.51	0.01: 3.01	0.05

(Continued)

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TABLE 3 (Continued)

	Girls						Boys					
	Unadjusted			Adjusted			Unadjusted			Adjusted		
	B	95% CI	*p*-value	*B*	95% CI	*p*-value	*B*	95% CI	*p*-value	*B*	95% CI	*p*-value
2021												
Never	-0.64	-1.42: 0.13	0.10	-0.81	-1.66: 0.04	0.06	-1.66	-2.46: -0.86	<0.01	-1.40	-2.34: -0.46	<0.01
Seldom	-0.22	-0.96: 0.52	0.56	-0.37	-1.19: 0.45	0.37	-0.42	-1.19: 0.35	0.28	-0.22	-1.13: 0.69	0.64
1-2 times a month	0.46	-0.28: 1.20	0.22	0.26	-0.56: 1.08	0.53	-0.22	-0.99: 0.55	0.58	0.09	-0.83: 1.00	0.85
1-2 times a week	0.76	0.03: 1.49	0.04	0.50	-0.32: 1.30	0.23	0.34	-0.42: 1.10	0.38	0.50	-0.40: 1.40	0.28
3-4 times a week	1.12	0.39: 1.85	<0.01	0.80	-0.01: 1.61	0.05	0.78	0.03: 1.54	0.04	0.92	0.02: 1.82	0.05
At least 5 times	1.67	0.94: 2.40	<0.01	1.27	0.46: 2.08	<0.01	1.38	0.63: 2.14	<0.01	1.50	0.60: 2.40	<0.01

^Adjusted for: SES, perceived stress from school and over the counter analgesics use.

4 Discussion

This study aimed to investigate adherence to physical activity (PA) recommendations and its association with self-efficacy among Norwegian school-based adolescents from 2017 to 2021. Results consistently indicated lower adherence to PA recommendations and lower self-efficacy in girls compared to boys each year during the study period. Regression analyses highlighted robust positive associations between PA adherence (engaging in physical activity at least 5 times a week) and self-efficacy, while the strongest inverse associations were observed in those reporting inactivity (never active). These patterns held true for both girls and boys across all years from 2017 to 2021.

As hypothesized, our study consistently found lower adherence to PA recommendations in girls compared to boys each year, aligning with a global trend widely reported in the literature (8, 45–47). Our results closely parallel the international data presented by Guthold et al., who conducted a comprehensive analysis of 298 population-based surveys involving 1.6 million participants to assess global trends in insufficient PA among adolescents aged 11 to 17 years (8). Their findings indicated approximately 15% adherence in girls and around 22.5% in boys to PA recommendations worldwide, with noticeable variations across countries. In our study, we observed a slightly higher adherence to PA levels, ranging from 17.6 to 19.8% in girls and 27.7 to 31.1% in boys over the study period. However, our adherence rates appear somewhat lower than those reported by Steen-Johannsen et al. in their study on European children and adolescents, where two-thirds were identified as insufficiently physically active (9). It is essential to note that adherence to PA recommendations may decline from early to late adolescence, as evident in both our data and international findings (8). Therefore, caution should be exercised when comparing total average PA scores based on the average age across different populations and studies.

When comparing our findings of adherence to physical activity (PA) recommendations with earlier data from the UngKan3 study on 15-year-old Norwegian adolescents, we observed lower adherence rates than those reported by Steene-Johannessen and colleagues in 2018 (11). In their study, adherence rates of 40 to 50% were reported for Norwegian girls and boys, respectively. Despite the smaller sample size in the UngKan3 study, which included 1,325 participants from the 10th grade, it featured a comprehensive set of PA measures, including accelerometers, enhancing the validity of their findings. However, the response rate among 10th graders was 57.3%, introducing some uncertainty due to non-responders. In contrast, the larger nationwide sample in the Ungdata study provides valuable supplementary research evidence for mapping PA levels in Norwegian school-based adolescents, particularly over time. Surprisingly, our data showed no clear impact of the pandemic on PA engagement. This could be attributed to adolescents finding alternative ways to remain physically active or the rapid changes in restrictions during the pandemic, entailed respondents to complete the Ungdata survey while schools were open, and thus in a period of reduced restrictions.

Interestingly, our findings revealed a more pronounced decrease in adherence to PA recommendations among girls compared to boys from 8th to 3rd grade each year. The potential barriers explaining these gender differences are likely multifaceted, involving various factors. A recent systematic review by Martins and colleagues, examining adolescents' perspectives on the barriers and facilitators of

PA, identified five overarching themes: individual factors (e.g., self-efficacy), social and relational factors (e.g., friends and family), PA nature factors (e.g., school-based PA), life factors (e.g., time), and sociocultural and environmental factors (e.g., availability of PA facilities) (48). It is noteworthy that most studies included in this systematic review primarily recruited girls, particularly for the first two identified factors (individual and social/relational factors), which may play a more significant role in explaining gender differences compared to the other factors (PA nature, life factors) that are more structurally based. Additionally, findings among preadolescents highlighted that self-efficacy, rather than peer or parent support, was associated with higher PA and less sedentary time (49), emphasizing the importance of individual factors.

Self-efficacy emerges as one of the pivotal individual factors influencing physical activity (PA) engagement. The concept of self-efficacy is considered a self-regulatory mechanism capable of inducing change (31, 32). Promoting PA engagement to enhance self-efficacy appears to be a logical approach. According to Bandura, self-efficacy comprises several components (13): (i) Performance accomplishments (personal experience), (ii) Vicarious experiences (observations of others), (iii) Verbal persuasion (encouragement), and (iv) A person's physiological state (physiological reactions). Intriguingly, engagement in PA naturally addresses all these components. Through PA involvement, adolescents not only augment their personal experience but also identify role models (observations of others), potentially increasing their belief in their own capacity. A meta-analysis by Ashford et al. explored the most effective strategies to change self-efficacy for promoting lifestyle and recreational physical activity in adults. Twenty-seven interventions were identified, demonstrating a significant relation to self-efficacy. Importantly, interventions reporting the most effective ways to promote self-efficacy included feedback on participants' past performances (i), vicarious experiences (ii), and feedback by comparing performance (21). Thus, PA engagement appears crucial for promoting self-efficacy, providing feedback that adolescents can reflect upon. Additionally, coaches and schoolteachers, through facilitation and feedback, play an essential role in enhancing performance accomplishments and PA experiences in adolescents.

As hypothesized, adherence to PA recommendations (highest and lowest levels of PA) demonstrated a strong/inverse association with self-efficacy in girls and boys nearly every year from 2017 to 2021. The accumulated findings over the period provide solid evidence of the link between PA levels and self-efficacy among Norwegian adolescents. A positive feedback loop of PA engagement yields higher self-efficacy, further promoting and facilitating PA engagement. However, the bidirectional nature should be discussed, as correlates between PA levels and self-efficacy are well-known (50). In the study "Explaining adolescent exercise behavior change: a longitudinal application of the transtheoretical model" (51), a cross-lag panel design was employed to investigate the direction of the association between PA and self-efficacy. PA and self-efficacy were evaluated at baseline and after 3 years. Findings revealed that PA levels at baseline determined self-efficacy levels 3 years later, whereas self-efficacy did not predict PA levels 3 years later (51). However, other studies examining self-efficacy and PA using a cross-lag panel in other populations have reported self-efficacy as the determinant of the association (52, 53). Regardless of the directionality of the associations, PA levels and self-efficacy are interwoven phenomena that should be addressed in future observational and longitudinal research. Moreover, findings of low adherence to PA recommendations among Norwegian adolescents over time indicate the need for promoting PA on a structural level, such as implementing more mandatory PA in both lower and upper secondary school.

4.1 Strengths and limitations

This study boasts several strengths that contribute to its robustness. The utilization of nationwide data from all regions of Norway ensures a high level of representativity. The large number of participants and the consistently high response rate (ranging from 91.9 to 93.8%) regarding PA levels enhance the study's validity. The incorporation of data from the Ungdata survey, acknowledged as the most comprehensive source of information on Norwegian adolescents' health, further bolsters the study's credibility. The dataset is meticulously cleaned, featuring stringent procedures for identifying unserious responses and a standardized, validated variable for socioeconomic status (SES) (33). Additionally, adherence to the STROBE guidelines (44) in reporting strengthens the study by ensuring accurate and consistent reporting practices. Finally, the accumulated consistency of the findings combined with the statistical strength throughout the study period using nationwide data, led to extensive evidence with clear differences over time, which enables a robust conclusion of findings.

While the annual data collection offers the advantage of assessing trends over time, it is crucial to recognize several inherent limitations. The anonymity of the data, without provided IDs for responders, prevents the implementation of repetitive statistical measures. Consequently, specific trends within the exact same study sample cannot be tracked. Municipalities have the flexibility to enter or exit the study, but a considerable portion tends to remain within the same study population each year, with 3rd graders discontinuing and new 8th graders entering. Descriptive stratification by grades and year proves useful in examining changes in specific cohorts over time.

A notable limitation stems from the lower sample size in the self-efficacy measure, attributed to a lower response rate and fewer municipalities including these questions. This reduction in sample size introduces risks of bias and diminishes the overall validity of the data. Furthermore, due to the comprehensive nature of health aspects covered in the Ungdata survey, questions often lack a clear origin (34). Therefore, a significant limitation lies in the use of a one-item non-validated instrument regarding PA level as a proxy for PA recommendations. The question exclusively gages the frequency of PA, neglecting other crucial aspects encompassed in PA recommendations, such as duration and intensity. Furthermore, bias related to gender differences in self-reporting of PA and self-efficacy might have influenced the validity of findings, as it is suggested that women tends to underestimate PA engagement and own performances compared to men (54, 55).

5 Conclusion

Our study, conducted among Norwegian adolescents from 2017 to 2021, uncovered significant gender disparities in adherence to physical activity (PA) recommendations and self-efficacy. Girls consistently reported lower adherence to PA recommendations and lower self-efficacy compared to boys during this period. Additionally, our data underscored robust associations between adherence to PA recommendations, levels of physical activity, and self-efficacy over time. These findings emphasize the crucial need for promoting adherence to PA recommendations in adolescence, with a specific focus on addressing the observed gender differences. The implications extend to policymakers and the Norwegian government, urging concerted efforts to create an environment conducive to increased physical activity among adolescents. By enhancing adherence to PA recommendations, policymakers can contribute not only to physical well-being but also to mental health, as reflected in improved self-efficacy. This, in turn, may empower adolescents to face and overcome challenges with a heightened belief in their own capabilities. The study advocates for targeted interventions and policies aimed at fostering a more active and resilient adolescent population in Norway.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: Data supporting the results of this study is available upon request from the Norwegian Agency for Shared Services in Education and Research (SIKT). Reference to dataset from SIKT: https://doi.org/10.18712/NSD-NSD3007-V3. Requests to access these datasets should be directed to https://sikt.no/.

Ethics statement

The studies involving human participants were reviewed and approved by Norwegian Agency for Shared Sevices in Education and Research (SIKT). The patients/participants provided their written informed consent to participate in this study.

Author contributions

EG: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. ØS: Conceptualization, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing.

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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/fpubh.2024.1382028/full#supplementary-material

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The relationships between emerging adults self-efficacy and motivation levels and physical activity: a cross-sectional study based on the self-determination theory

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Objectives: The study aims to examine the associations between exercise self-efficacy, motivation, physical activity, and body composition among emerging adults.

Design: Cross-sectional.

Methods: A convenience sample of 147 emerging adults participated in the Releasing Weight (RELEW) project. The InBody720 analyzer was used to measure body composition, and the International Physical Activity Questionnaire-Short, the Shortened Physical Activity Self-Efficacy Scale, and the Treatment Self-Regulation Questionnaire were used to measure self-reported physical activity, self-efficacy, and motivation. Structural Equation Modeling was used to exam the complex relationships among multiple variables. in this study. The Partial least squares structural equation modeling analysis with bootstrapping in Smart PLS 3 was employed to explore the path coefficients and t-values for the relationships that were thought to exist. Significance was determined using a threshold of $p < 0.05$.

Results: The mean age of 147 participants was 18.5 ± 1.87, of whom 51.7% were female, recruited for this study. Exercise self-efficacy has a significant positive correlation with exercise motivation ($r = 0.220$, $p = 0.008$) and physical activity ($r = 0.279$, $p < 0.001$). Exercise motivation does not demonstrate significant associations with physical activity ($r = 0.094$, $p = 0.298$). Utilizing SEM, the model explained 9.2% of exercise self-efficacy, 11.8% of physical activity, and 68.3% of body composition variance. Mediation analysis revealed that exercise self-efficacy partially mediated the relationship between exercise motivation and physical activity ($\beta = 0.106$, $t = 2.538$, $p < 0.05$), and physical activity partially mediated the relationship between exercise self-efficacy and body composition ($\beta = -0.296$, $t = 4.280$, $p < 0.001$).

Conclusion: This study sheds light on the complex relationships among motivation, self-efficacy, physical activity and body composition during emerging adulthood. Our results highlight the mediating role of self-efficacy and its impact on physical activity behaviors, offering valuable insights for targeted interventions and policy development to improve health outcomes in this demographic.

KEYWORDS

emerging adulthood, physical activity, structural equation modeling, self-efficacy, motivation levels, self-determination theory

1 Introduction

Emerging adulthood, occurring between adolescence and full adulthood, is a critical transitional phase for health behavior development, significantly impacting long-term wellbeing (Arnett, 2000). Engaging in physical activity during this period greatly affects long-term health outcomes and overall wellbeing. Research consistently shows that physical activity behaviors during emerging adulthood play a crucial role in shaping future health outcomes (van Sluijs et al., 2021). Studies demonstrate that individuals maintaining higher physical activity levels during this phase exhibit reduced risks of chronic diseases later in life (Posadzki et al., 2020; Hale et al., 2021). Moreover, physical activity during emerging adulthood correlates with improved mental health outcomes and enhanced cognitive abilities (Chekroud et al., 2018; Heissel et al., 2023). Despite these benefits, there's a concerning trend of declining physical activity levels during the transition from adolescence to emerging adulthood (Corder et al., 2019). This decline is influenced by academic pressures, increased work commitments, changes in social environments, and shifts in priorities (Lee et al., 2012; Farooq et al., 2020). Personality traits and societal roles also contribute to increased sedentary behaviors during this period (Champion et al., 2023). Understanding and addressing this decline is crucial to mitigating immediate health risks and preventing long-term consequences.

Numerous studies emphasize the significant role of physical activity in influencing body composition during emerging adulthood (Barbour-Tuck et al., 2018; Collins et al., 2023). Higher physical activity levels are associated with more favorable body composition profiles, including lower adiposity and higher lean muscle mass, reducing the risks of chronic diseases later in life. The interplay between psychological factors like self-efficacy and motivation also influences physical activity behaviors (Cao et al., 2023; Medeiros et al., 2023). Even though these factors have been looked at separately in studies, there hasn't been a full look at how they all affect physical activity behaviors, especially in young adults just starting to become adults. This makes it harder to get a full picture of how exercise engagement works during this changing time.

Structural equation modeling (SEM) and mediation analysis constitute the core methodologies utilized to investigate the relationships among variables in this study. SEM allows for the simultaneous examination of complex relationships between observed and latent variables, offering a robust analytical framework for testing theoretical models (Stein et al., 2017). This study utilizes latent variable modeling to represent unobservable constructs using multiple observed indicators. Specifically, self-efficacy, motivation, physical activity, and body composition are conceptualized as latent variables composed of various observed indicators. Therefore, by integrating SEM and mediation analysis into the study design, a comprehensive understanding of the mechanisms underlying the relationship between exercise motivation, exercise self-efficacy, physical activity, and body composition can be obtained within the specific demographic of emerging adults.

1.1 Theoretical framework

Self-determination theory (SDT), introduced by Deci and Ryan (1985), focuses on human motivation and personality development, highlighting intrinsic psychological needs like autonomy, competence, and relatedness. SDT categorizes motivation into intrinsic and extrinsic forms (Tóth-Király et al., 2022), with intrinsic motivation driven by internal factors like enjoyment, while extrinsic motivation involves external rewards or pressures. Individuals closely link intrinsic motivation to the need for competence, seeking effectiveness and mastery in their interactions (Ryan and Deci, 2020).

Self-efficacy, rooted in social cognitive theory (SCT), proposed by Bandura (1978), revolves around an individual's belief in their capacity to effectively perform specific tasks or manage challenging situations. This belief in personal abilities and competencies directly correlates with the need for competence in SDT. An individual's confidence and perceived capabilities strongly influence their sense of mastery and effectiveness in various activities, contributing to the fulfillment of the competence need as outlined by SDT (Bandura, 2012). Therefore, while self-efficacy may not fully encapsulate the entirety of competence needs, it is undeniably interconnected with and contributes significantly to fulfilling competence needs within the SDT framework.

The relationships between self-efficacy, intrinsic motivation, and the fulfillment of psychological needs, as elucidated by SDT and SCT, provide a comprehensive lens to explore the dynamics of physical activity engagement among emerging adults in our study. Therefore, the purpose of the original initial study was to aim to explore and elucidate the relationships between self-efficacy and motivation on physical activity behaviors among emerging adults, specifically whether exercise motivation mediates the link between exercise self-efficacy and physical activity. However, during the analysis process, this study initially tested the model with motivation as a mediator and found it was a poor fit to the data. The absence of a good fit under the traditional formwork of SDT highlights the nuanced pathways through which motivational factors impact actual behavioral outcomes.

While SDT has conventionally proposed a hierarchical model where the satisfaction of psychological needs drives motivation, contemporary empirical findings indicate a more intricate and reciprocal relationship between self-efficacy and motivation. Recent empirical research has provided further support for the notion of a reciprocal relationship between self-efficacy and motivation within the framework of SDT. For instance, studies by Zhang et al. (2022) and Ma et al. (2023) have demonstrated that individuals with higher levels of self-efficacy exhibit greater motivation to engage in physical activity. Conversely, Trautner and Schwinger (2020) found that heightened motivation can positively influence self-efficacy beliefs, reinforcing the bidirectional nature of this relationship. This evolving understanding challenges the traditional hierarchical view within SDT, highlighting the dynamic interplay between self-efficacy and motivation in shaping behavior. Further research by Gryte et al. (2024) and Lev-Arey et al. (2024) underscores the importance of considering both self-efficacy and motivation as integral components in interventions aimed at promoting sustained physical activity participation among various populations. As a result, we redefined self-efficacy as the mediator.

Therefore, this study aims to examine the interrelationship between self-efficacy and motivation and their collective influence on physical activity behaviors among emerging adults, with a particular focus on exploring how exercise self-efficacy mediates the link between exercise motivation and physical activity. This study's hypotheses are as follows (see **Figure 1**):

- Exercise motivation is positively associated with exercise self-efficacy.
- Exercise motivation is positively associated with physical activity.
- Exercise self-efficacy is positively associated with physical activity.
- Exercise self-efficacy is positively associated with body composition.
- Exercise self-efficacy mediates the relationship between exercise motivation and physical activity.

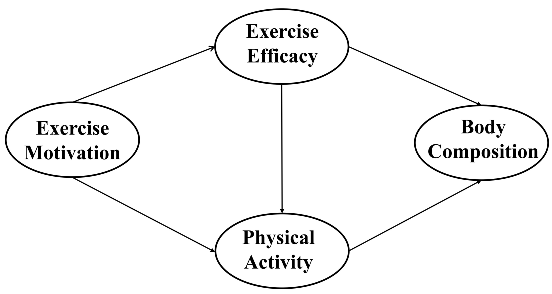

FIGURE 1
Motivation, self-efficacy and behavior-based self-determination theory model.

2 Materials and methods

2.1 Study design

This study initially investigated the mediate of exercise motivation between exercise self-efficacy and physical activity in the framework of SDT and SCT. However, the SEM results indicated suboptimal fit indices for the proposed model, which explored the mediating role of motivation in the efficacy-physical activity relationship (the dataset is available in **Supplementary File 1**). Considering the intertwined relationship between motivation and efficacy, the positions of motivation and exercise efficacy were switched. The investigation was conducted at a university located in Hangzhou, China. This report follows the guidelines of Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) (Ghaferi et al., 2021). The STROBE checklist can be found in **Supplementary File 2**.

2.2 Participants

2.2.1 Sources of participant

The recruitment of participants was based on convenience sampling and was drawn from previous studies (Xu et al., 2023). The researchers distributed the research information sheet to students in common areas such as libraries, cafeterias, and student lounges in various departments and academic programs, ensuring representation from diverse backgrounds. Collaboration with faculty members and student organizations was also used to reach a wider pool of participants. The selection of participants was carried out by providing information about the study and its objectives to potential participants. Those who expressed interest and met the eligibility criteria were invited to participate in the study. The eligibility criteria for participants in this study included being (1) aged 18 to 25 years; (2) absence of any disease affecting participation in physical activity; and (3) willing to voluntarily participate in the study.

2.2.2 Sample size

The sample size was determined based on the recommended guidelines for SEM (Wolf et al., 2013), which emphasize the need for an adequate sample size to ensure statistical power and reliable estimation of model parameters. The complexity of the SEM model, including the number of latent variables, observed variables, and paths to be estimated, was considered (Raykov and Marcoulides, 2012). The model is expected to have 14 estimated parameters. A general rule of thumb suggests that a minimum of 10–20 observations per estimated parameter is desirable to achieve stable and reliable estimates, resulting in a sample size of 140 (Bentler and Chou, 1987). Considering a possible 10% non-response rate and a potential invalid questionnaire, we used a convenience sampling method to recruit a total of 155 college students.

2.3 Data collection

The data collection phase took place concurrently with the recruitment phase, spanning from July 2023 to October

TABLE 1 Sociodemographic characteristics of the whole sample.

Variables	Frequency (%)/mean (standard deviation)/ (median [IQR])
Age (mean ± SD)	19.5 (1.87)
Sex (%)	
Male	71 (48.3)
Female	76 (51.7)
School year (%)	
Freshman	87 (59.2)
Sophomore	19 (12.9)
Junior	17 (11.6)
Senior	24 (16.3)
Location (%)	
Urban	97 (66.0)
Rural	50 (34.0)
Weight categories (%)	
Underweight	8 (5.4)
Healthy weight	23 (15.7)
Overweight/obesity	116 (78.9)
Physical activity rating (%)	
Inactive	51 (34.7)
Minimally active	66 (44.9)
HEPA active	30 (20.4)
Physical activity levels (median [IQR])	
Walking	247.5 [99, 594]
Moderate-intensity activity	160 [0, 360]
Vigorous-intensity activity	240 [0, 720]
Total (walking + moderate + vigorous)	1,010 [499, 1,657.5]
Exercise self-efficacy (mean ± SD)	23.48 (7.08)
Exercise motivation (mean ± SD)	67.82 (11.38)
Body composition (mean ± SD)]	
Height	164.88 (7.19)
Weight	58.19 (13.21)
Body mass index	21.27 (3.73)
Body fat	15.3 (7.29)
Body fat percentage	25.67 (8.05)
Waist-hip ratio	0.83 (0.07)
Visceral fat area	63.47 (36.48)
Metabolic equivalent	1,138.93 (801.99)

HEPA, health-enhancing physical activity; SD, standard deviation; IQR, interquartile range; physical activity level in MET-min/week, MET, metabolic equivalent; height in centimeters (cm); weight in kilograms (kg).

2023. During this period, a convenience sampling technique was employed to distribute 155 questionnaires among college students. Participants were provided with the questionnaires. The researchers ensured that the data collection process adhered to ethical guidelines and maintained participants' confidentiality. The researchers emphasized the voluntary nature of participation and assured the confidentiality and anonymity of responses. The questionnaires were administered in a controlled environment (classrooms and designated research spaces) to minimize distractions and ensure accurate responses. Participants were given sufficient time to complete the questionnaires, and any queries or concerns were addressed promptly.

2.4 Measurement

The study collected data on various aspects, encompassing demographic characteristics, body composition, physical activity levels, self-efficacy, and motivation levels. To enhance the transparency of our methodology, the questionnaire utilized in this study has been made available as **Supplementary File 3** or at the following link: https://osf.io/pbd53/.

2.4.1 Demographic characteristics

Self-reported data was collected on demographic information: age, sex, school year (freshman, sophomore, junior, senior, etc.), location (urban vs. rural).

2.4.2 Body composition

A height meter, securely fixed to a vertical surface, was used to measure the height. To ensure accuracy, the assistant repeated the height measurement twice. The average of the repeated measurements was used to minimize potential measurement errors. Body composition, which included body weight, body mass index (BMI), body fat (BF), percentage of body fat (BF%), waist-hip ratio (WHR), and visceral fat area (VFA), was collected using the analyzer InBody720 (Biospace, USA), which applies bioelectrical impedance analysis (BIA). The InBody720 offers a variety of advantages and accuracy in body composition testing (Park et al., 2016).

2.4.3 Physical activity levels

Physical activity levels were obtained through self-reported measures provided by the participants. The self-reported data were collected using the International Physical Activity Questionnaire-Short (IPAQ-S) with 7 items, which had been translated into Chinese by Macfarlane et al. (2007). Participants were asked to report their frequency, duration, and intensity of exercise over the past week. The questionnaire collects information on the frequency, duration, and intensity of physical activity across various domains. The IPAQ-S provides a formula to calculate the total physical activity level. It involves multiplying the number of days per week by the total time spent per day for each activity category. The results are then summed to obtain the total time spent in physical activity per week. A sample item was "During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling?" The scale demonstrates a retest reliability ranging from 0.66 to 0.88 (Macfarlane et al., 2007).

2.4.4 Self-efficacy

The self-efficacy was obtained using the shortened physical activity self-efficacy scale (PASEESC) in simplified Chinese

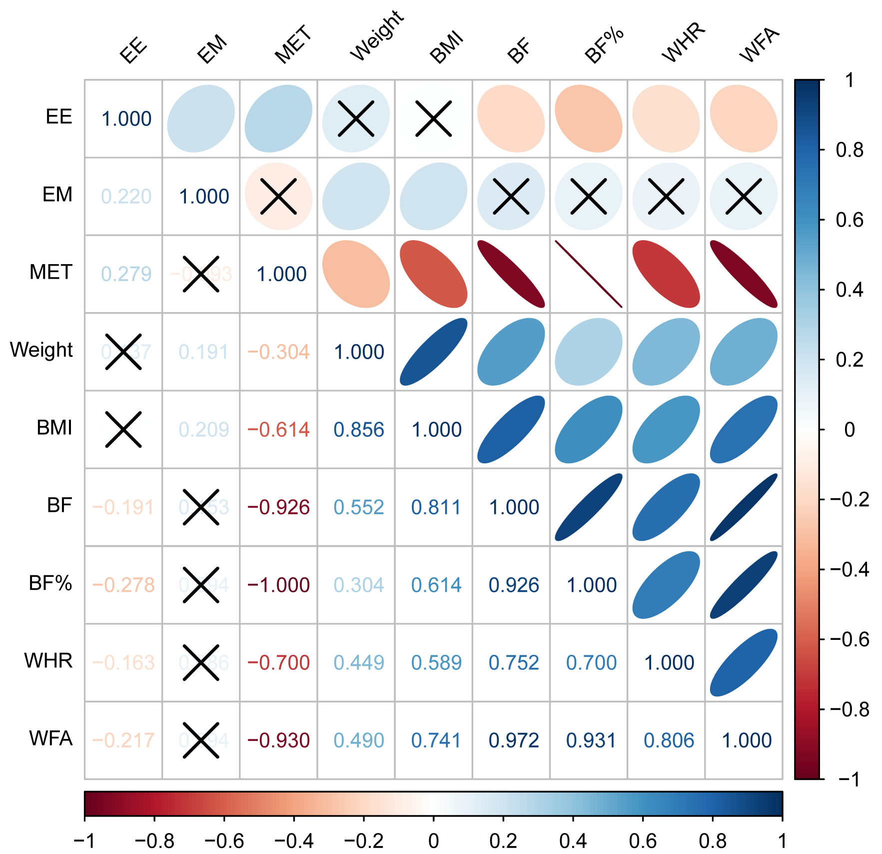

FIGURE 2
Correlations between exercise self-efficacy, exercise motivation, physical activity and body composition. Blue, positive correlation; red, negative correlation; dark color, high correlation; upper half, color plots; lower half, numerical plots; ×, $p > 0.05$; EE, exercise self-efficacy; EM, exercise motivation; MET, metabolic equivalent; BMI, body mass index; BF, body fat; BF%, body fat percentage; WHR, waist-hip ratio; VFA, visceral fat area.

(Chen et al., 2019). The 8-item scale was assessed using a Likert scale ranging from 1 to 5, where 1 represents "disagree a lot" and 5 represents "agree a lot." Participants with higher scores demonstrated a greater perception of self-efficacy. Furthermore, the effectiveness and consistency of the scale in evaluating psychological issues in Chinese teenagers have been proven, as indicated by a Cronbach's alpha value of 0.87 (Zhou and Huo, 2022). The head of the scale reads, "Please evaluate to what extent you feel the following description fits you when participating in physical activity." A sample item was "I can be physically active on most days of the week." The reliability of the scales in this study was assessed using Cronbach's α coefficient, which yielded a value of 0.92 (Chen et al., 2019).

2.4.5 Motivation levels

The Treatment Self-Regulation Questionnaire (TSRQ) was used to determine participants' motivation levels (Ryan and Connell, 1989). The TSRQ scale is a widely used tool to measure motivation for healthy behaviors (Teixeira et al., 2012). It includes a total of 15 items combined to form four component scores (i.e., individual autonomous motivation, internal regulation, external regulation, and no motivation), each of which has a range of (not at all true) 1 to 7 (very true) points. The sum of these four TSRQ component scores is the total TSRQ score, with higher scores indicating higher motivation levels. The head of the scale reads, "Regarding the extent to which you feel the following descriptions match you, please evaluate and judge the following 15 descriptions based on your actual feelings and experiences." A sample item was "Because physical activity is very important for being as healthy as possible." In this study, the Cronbach's α of the four dimensions was 0.936, 0.827, 0.869, and 0.894, and the total reliability test of the scale is Cronbach's α = 0.826 (Teixeira et al., 2012).

2.5 Ethical approval

The study has been approved by the ethical committee of Hangzhou Normal University (202259); all methods were performed in accordance with Helsinki guidelines. The voluntary nature of participation was emphasized throughout the entire process. The data collection process adhered to ethical guidelines. The confidentiality was assured by the anonymity of responses and the use of a case number.

2.6 Statistical analysis

Structural equation modeling served as the primary analytical technique to explore complex relationships among

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TABLE 2 Correlation coefficients of variables.

Variables	Exercise motivation	Exercise self-efficacy	Physical activity
Exercise motivation	1	–	–
Exercise self-efficacy	0.220**	1	–
Physical activity	0.279**	−0.093	1

**$p < 0.01$.

TABLE 3 Factor loadings and convergent validity results.

Variables	Factor loadings	α	CR	AVE
Exercise self-efficacy		0.925	0.940	0.726
EE1	0.890			
EE3	0.916			
EE4	0.879			
EE6	0.708			
EE7	0.784			
EE8	0.914			
Body composition		0.935	0.947	0.750
BF%	0.861			
BF	0.985			
Weight	0.708			
VFA	0.986			
WHR	0.766			
BMI	0.854			

α, Cronbach's alpha; CR, composite reliability; AVE, average variance extracted.

observed and latent variables. Latent variable modeling, a key aspect of SEM, allowed for the representation of unobservable constructs using multiple observed indicators, thereby capturing underlying dimensions inferred from observed variables. Self-efficacy, motivation, and physical activity were conceptualized as latent variables comprised of multiple observed indicators.

A mediation analysis was conducted to explore the indirect effects of motivation on physical activity through self-efficacy. An indirect effect refers to the influence that a predictor variable has on an outcome variable through an intervening variable. A direct effect, on the other hand, represents the influence of a predictor variable on an outcome variable without any intervening variables. The total effect encompasses both the direct and indirect effects, providing a comprehensive understanding of the overall impact of the predictor variable on the outcome variable (Baron and Kenny, 1986). The bootstrap method within the product of coefficients approach was employed to model the indirect effect, involving the multiplication of path coefficients representing relationships between the independent variable (motivation) and the mediator (self-efficacy) and between the mediator and the dependent variable (physical activity).

The partial least squares (PLS) method was chosen to construct the model due to its suitability for our sample size and skewed distribution, emphasizing predictive relevance over strict model fit to covariance structures (Cramer, 1993). Smart PLS (version 3) software facilitated the analysis of the structural equation model and the testing of theoretical hypotheses. Bootstrapping techniques, employing 5,000 resamples, were utilized within the product of coefficients approach to model the indirect effect. This involved multiplying path coefficients representing the relationships between the independent variable (motivation) and the mediator (self-efficacy), and between the mediator and the dependent variable (physical activity). Significance was determined using t-values exceeding 1.96 for a two-tailed test (Mackinnon et al., 2004).

Criteria for convergent validity included factor loading (> 0.708), Cronbach's α (> 0.9), and composite reliability (CR, > 0.9) (Diamantopoulos et al., 2012; Hair et al., 2019). Convergent validity was evaluated by calculating the average variance extracted (AVE), which should exceed 0.5. Discriminant validity was assessed using the heterotrait-monotrait (HTMT) ratio of correlations, with thresholds below 0.85 indicating distinct constructs (Henseler et al., 2015). Structural models were evaluated based on the coefficient of determination (R^2). R^2 ranges from 0 to 1, with higher values indicating greater explanatory power to explain the data (Henseler et al., 2009) stated that R^2 values of 0.75, 0.50, and 0.25 might be deemed significant, moderate, and weak.

It is important to note that the model should not have collinearity difficulties, as indicated by a variance inflation factor (VIF) of less than 5 (Becker et al., 2015). The predictive accuracy of the model was explained using the blindfolding-based cross-validated redundancy measure (Q^2), which should have a value greater than 0 to indicate the predictive accuracy of this structural equation model. As a rule of thumb, Q^2 values above 0, 0.25, and 0.50 indicate small, medium, and large predictive accuracies for PLS pathway models (Hair et al., 2019). The global fit of the PLS modeling was explained using the goodness-of-fit (GoF), with 0.1, 0.25, and 0.36 being the small, medium, and large values of the global fit of the model, respectively (Wetzels et al., 2009).

Additionally, several metrics associated with covariance-based SEM (CB-SEM) were computed to evaluate model fit to further enhance the evaluation of structural equation models, including the chi-square test statistic, Goodness of Fit Index (GFI), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Incremental Fit Index (IFI), and Root Mean Square Error of Approximation (RMSEA), with established thresholds applied for assessment (Shi et al., 2019). Acceptable thresholds for these indices were as follows: GFI, CFI, TLI, and IFI values above 0.90 indicate good model fit (Bentler, 1990). RMSEA values below 0.08 indicate acceptable fit, with values below 0.05 indicating close fit (Browne and Cudeck, 1992).

The statistical analysis utilized SPSS (Statistical Product and Service Solutions, version 26). To describe the data, descriptive statistics were used. Either mean and standard deviation (mean ± SD) or median and interquartile range (IQR) were used, depending on how the Shapiro–Wilk test showed the data was distributed. Due to the skewed distributions of our variables, correlations were examined using the Spearman correlation coefficient (r). R (version 4.2.3) was utilized to visually represent correlations between variable dimensions, with syntax examples provided in **Supplementary File 4**.

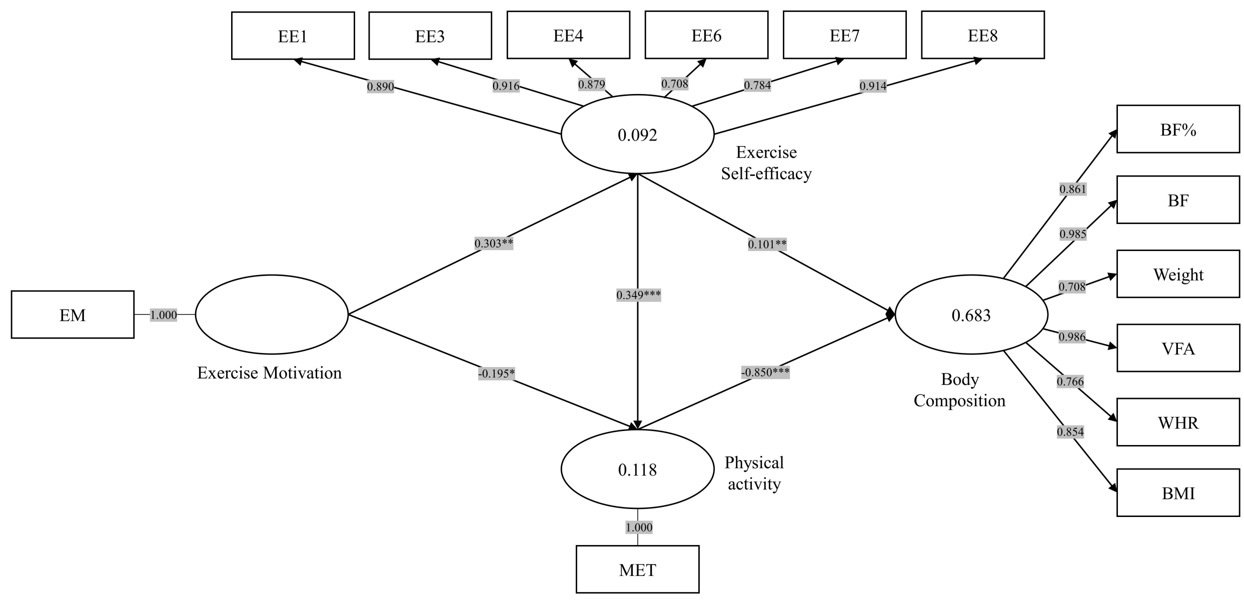

FIGURE 3
Structural equation modeling of exercise self-efficacy, exercise motivation, physical activity and body composition.

TABLE 4 Discriminant validity of the model.

Variables	1	2	3	4
1. Exercise motivation	–	–	–	–
2. Exercise self-efficacy	0.312	–	–	–
3. Physical activity	0.089	0.277	–	–
4. Body composition	0.164	0.177	0.765	–

3 Results

3.1 Demographics of the study population

The demographic characteristics of all participants are listed in **Table 1**. A total of 147 people were investigated, including 71 men and 76 women. Regarding the school year, the largest proportion of students were freshmen, making up 59.2% of the sample. In terms of home location, the majority of students (66%) reside in urban areas, while 34% are from rural areas. The weight categories of the participants revealed that 5.4% of students were classified as underweight, 15.7% fell within the healthy weight range, and a significant proportion of 78.9% were categorized as overweight or obese. 44.9% of students reported engaging in moderate-intensity activity, while 20.4% reported engaging in vigorous-intensity activity.

3.2 Bivariate correlations between all study variables

The Spearman correlation coefficient was utilized to assess the strength and direction of these relationships (**Figure 2**; Crawford, 2006) stated that r values of 0–0.19, 0.2–0.39, 0.40–0.59, 0.6–0.79, and 0.8–1 can be considered very weak, weak, moderate, strong, or very strong correlations. The statistical analysis revealed correlations among the variables under study. Exercise motivation has a positive correlation with exercise self-efficacy (r = 0.220, $p < 0.05$), indicating a relationship categorized as "weak." However, no statistically significant relationships were observed between exercise motivation and physical activity (r = 0.094, $p > 0.05$),

TABLE 5 Goodness of fit of the structural model.

Variables	SSO	SSE (overlapping)	SSE (communality)	Q^2 (redundancy)	Q^2 (communality)	R^2
Exercise motivation	147	147				
Exercise self-efficacy	882	827.720	407.552	0.062	0.538	0.092
Physical activity	147	131.714		0.104		0.118
Body composition	882	488.637	383.171	0.446	0.566	0.683

SSO, standardized solution output; SSE, standardized structural equation residuals; Q^2 = 1-SSE/SSO; Q^2(Redundancy) = 1-SSE(Overlapping)/SSO; Q^2 = (Communality) = 1-SSE(Communality)/SSO.

nor with various indicators of body composition such as weight, BMI, BF, BF%, WHR, and VFA. In contrast, exercise self-efficacy exhibited a positive correlation with physical activity ($r = 0.279$, $p < 0.001$), indicating a weakly strong relationship. Further examination focusing on physical activity uncovered a negative correlation with weight ($r = -0.304$, $p < 0.001$), body fat ($r = -0.926$, $p < 0.001$), and WHR ($r = -0.700$, $p < 0.001$), highlighting weak to very strong associations. Exercise self-efficacy displayed a negative correlation with several body composition indicators, including BF ($r = -0.191$, $p < 0.05$), BF% ($r = -0.278$, $p < 0.05$), WHR ($r = -0.163$, $p < 0.05$), and VFA ($r = -0.217$, $p < 0.05$). Table 2 shows the results of the Spearman correlation analysis between the main variables.

3.3 Testing the fit of the model

The reflective measurement model used factor loading, Cronbach's, and CR coefficients to assess item reliability and internal consistency reliability. All factor loadings were greater than 0.708, as shown in Table 3, indicating that the model had acceptable item reliability. All Cronbach's α and CR coefficients were above 0.90, indicating acceptable consistency and reliability (Diamantopoulos et al., 2012). All AVEs were greater than 0.5, and the results indicated that the model had acceptable convergent validity. The model depicted in Figure 3 was formulated using the PLS method implemented in Smart PLS 3.

To further enhance the evaluation of our structural equation model, we computed several metrics associated with the CB-SEM. The chi-square (χ^2) statistic was found to be 417.498 with 197 degrees of freedom, resulting in a ratio of χ^2/df = 2.119. While the χ^2/df ratio slightly exceeded the recommended threshold of 2, other fit indices showed acceptable values, such as the GFI at 0.797, the CFI at 0.909, the TLI at 0.894, and the IFI at 0.91. However, the RMSEA was found to be 0.088, slightly above the desirable cutoff of 0.08. Although the RMSEA 90% confidence interval ranged from 0.079 to 0.099, indicating some uncertainty around this estimate, the overall model fit was reasonable, with several indices indicating good fit, while the RMSEA slightly deviated from the ideal range.

The discriminant validity of the model was assessed using the HTMT ratios of the correlations, as shown in Table 4. The variables fall under different conceptual constructs. When the HTMT was < 0.85, it indicated that the discriminant validity of the model was acceptable (Henseler et al., 2015). Therefore, the measurement model used in this study demonstrated acceptable reliability and validity.

Table 5 demonstrates the goodness of fit for the SEM. The coefficient of determination (R^2) is a measure of the explanatory power within the model. The model's independent variables explain a proportion of the dependent variable's variance. The values indicated that the model was able to explain 9.2% of exercise self-efficacy, 11.8% of physical activity, and 68.3% of body composition, measured as weak and moderate levels of explanatory power (Henseler et al., 2009), respectively.

Additionally, the blindfold-based cross-validation redundancy measure (Q^2) provides an assessment of the precision of the structural model forecasts, indicating the extent to which the model can accurately predict the observed data. The analysis yielded Q^2 values of 0.062 for exercise self-efficacy, 0.104 for physical activity, and 0.446 for body composition. These values suggest that exercise self-efficacy and physical activity have a weak impact on the structural model, while composition plays a significant role. The goodness-of-fit (GoF) assesses the quality of both structural and measurement models simultaneously. The estimated GoF value of 0.346 indicates a moderate fit of the model (Wetzels et al., 2009).

TABLE 6 Analysis of regression relationship among variables.

Hypothesized paths	Standard path coefficients	*t*-value	95% CI
Exercise motivation → Exercise self-efficacy	0.303**	3.243	(0.105, 0.472)
Exercise motivation → Physical activity	−0.195*	2.463	(−0.343, −0.038)
Exercise self-efficacy → Physical activity	0.349***	4.467	(0.192, 0.498)
Physical activity → Body composition	−0.850***	38.163	(−0.902. −0.815)
Exercise self-efficacy → Body composition	0.101**	2.645	(0.031, 0.176)

Levels of statistical significance (***$p < 0.001$, **$p < 0.01$, *$p < 0.05$). The regression coefficients are the equivalent of direct effects (path coefficients adjusted for the presence of the mediators).

In Smart PLS 3, the conceptual model was analyzed using PLS-SEM with the bootstrapping approach. The results, as depicted in Table 6, reveal significant path coefficients and *t*-values for several paths. The regression coefficients are equivalent to direct effects (path coefficients adjusted for the presence of mediators). The pathways of exercise motivation–exercise self-efficacy and exercise motivation–exercise physical activity were statistically significant ($\beta = 0.303$, $t = 3.243$, $p < 0.01$; $\beta = -0.195$, $t = 2.463$, $p < 0.05$). The results showed that the pathways from exercise self-efficacy to physical activity were statistically significant ($\beta = 0.349$, $t = 4.467$, $p < 0.001$). Moreover, the pathways from physical activity ($\beta = -0.850$, $t = 38.163$, $p < 0.001$) and exercise self-efficacy ($\beta = 0.101$, $t = 2.645$, $p < 0.01$) to body composition were also significant.

The results of the mediation effect test are displayed in Table 7. The direct effect of exercise motivation on physical activity is negative and statistically significant ($\beta = -0.195$, $t = 2.463$, $p < 0.05$). However, when considering the indirect effect ($\beta = 0.106$, $t = 2.538$, $p < 0.05$), the total effect (the sum of the direct and indirect effects) of exercise motivation on physical activity is negative but not significant ($\beta = -0.089$, $t = 1.137$, $p > 0.05$), suggesting that the presence of unmeasured mediators acting in the opposite direction to self-efficacy may reduce the overall beneficial effects of increased exercise motivation for increasing physical activity.

TABLE 7 Summary of mediation effect test results.

Effect	Path	Path coefficients	t-value	95% CI
Direct effect	Exercise motivation → Physical activity	−0.195*	2.463	(−0.343, −0.038)
Indirect effect	Exercise motivation → Self-efficacy → Physical activity	0.106*	2.538	(0.033, 0.200)
Total effect	Exercise motivation → Physical activity	−0.089	1.137	(−0.239, 0.065)
Direct effect	Self-efficacy → Body composition	0.101*	2.645	(0.031, 0.176)
Indirect effect	Self-efficacy → Physical Activity → Body composition	−0.296***	4.280	(−0.438, −0.162)
Total effect	Self-efficacy → Body composition	−0.196***	2.782	(−0.338, −0.055)

Levels of statistical significance (***$p < 0.001$, *$p < 0.05$).

Regarding the relationship between exercise self-efficacy and body composition, the total effect of exercise self-efficacy on body composition remains negative and significant (β = −0.196, $t = 2.782$, $p < 0.01$). Besides, the indirect effect through physical activity is negative and significant (β = −0.296, $t = 4.280$, $p < 0.001$), indicating that higher exercise self-efficacy is associated with better body composition. However, the direct effect is positive and statistically significant (β = 0.101, $t = 2.645$, $p < 0.01$), indicating that unmeasured mediators acting in the opposite direction to physical activity to reduce the overall beneficial effects of increased exercise self-efficacy for improving body composition.

4 Discussion

This study emphasized exercise self-efficacy as a significant factor influencing physical activity, particularly among young adults. Our findings extend this understanding by revealing negative correlations between exercise self-efficacy and various body composition measures, highlighting its potential impact on overall health outcomes. The observed positive relationship underscores the role of self-efficacy beliefs in influencing individuals' decisions to initiate and sustain physical activity (Pan et al., 2022). Individuals with high self-efficacy levels, confident in their ability to perform physical tasks, are more likely to adopt and adhere to exercise routines, reflecting a proactive approach to maintaining an active lifestyle (Di Maio et al., 2021), which aligns with Bandura's social cognitive theory and emphasizes the influential role of self-perceived capabilities in shaping behavioral outcomes. Moreover, the implications suggest that interventions targeting self-efficacy enhancement could effectively promote physical activity at both individual and community levels (Alshagrawi and Abidi, 2023). These findings contribute to the growing literature on the interplay between psychological factors and health behaviors, offering practical implications for interventions promoting sustained physical activity engagement. Additionally, our research has illuminated a noteworthy correlation between individuals' motivation for engaging in physical activity and their self-efficacy beliefs. The observed correlation suggests that individuals with higher levels of motivation may concurrently exhibit enhanced self-efficacy, thereby fostering a positive feedback loop that potentially contributes to sustained engagement in physical exercise. Our results align with existing literature that posits a relationship between motivation and self-efficacy, emphasizing the dynamic nature of these constructs within the context of physical activity. Research has shown that exercise motivation not only positively predicts exercise climate and exercise self-efficacy but also plays an important role in predicting exercise behavior among college students (Zhao et al., 2023).

The absence of a direct correlation between motivation and physical activity was observed, with self-efficacy potentially mediating this association, which highlights the nuanced pathways through which motivational factors impact actual behavioral outcomes. Individuals with higher motivation levels demonstrate an increased likelihood of engaging in physical activity when coupled with elevated self-efficacy beliefs. Firstly, according to SDT, individuals are motivated to engage in behaviors that fulfill their basic psychological needs for autonomy, competence, and relatedness. In the context of exercise, individuals may possess high levels of intrinsic motivation, which arises from a genuine interest in and enjoyment of physical activity. However, their intrinsic motivation may not necessarily translate into actual exercise behavior if they lack confidence in their ability to perform the activities required (i.e., low exercise efficacy) (Rhodes et al., 2022). Thus, exercise efficacy acts as a mediator between intrinsic motivation and exercise behavior. Research supporting this notion has shown that individuals with higher levels of self-efficacy are more likely to autonomously engage in physical activity, as they feel competent in their ability to successfully complete exercise tasks (Teixeira et al., 2012; Brand and Cheval, 2019; Zhao et al., 2023). Besides, a study exploring the relationship between self-efficacy-mediated motivation and physical activity in patients with heart failure noted that after controlling for self-efficacy, the relationship between motivation and physical activity was no longer significant, suggesting full mediation (Klompstra et al., 2018). Secondly, socio-cultural factors such as societal norms and environmental constraints may impact individuals' perceived self-efficacy in initiating and maintaining physical activity routines (Zhang et al., 2022). Moreover, individual differences in personality traits, such as trait self-esteem and neuroticism, may also moderate the relationship between motivation, self-efficacy, and physical activity behaviors (Kekalainen et al., 2020; Rhodes and Courneya, 2003). Finally, the temporal dynamics of motivation and self-efficacy, as well as the cyclical nature of physical activity engagement, may further complicate the direct association between these constructs (Rhodes and Dickau, 2012).

The finding of a positive and statistically significant path coefficient between exercise self-efficacy and body composition in the mediated effects analysis demands nuanced interpretation. It is essential to recognize the intricate interplay of factors underlying this relationship. Previous research has extensively documented the positive association between exercise self-efficacy and engagement in physical activity behaviors (Li et al., 2018; Zhang et al., 2024). Higher levels of self-efficacy are often linked to greater motivation and confidence in one's ability to overcome barriers to exercise and adhere to exercise regimens (Schunk and DiBenedetto, 2021; Kekalainen et al., 2024). Consequently, individuals with elevated exercise self-efficacy may be more inclined to engage in physical activity, thereby potentially mitigating the adverse effects of poor body composition. However, the observed positive path coefficient between exercise self-efficacy and body composition's direct effect may be confounded by the mediating role of physical activity. Physical activity serves as a crucial intermediary in the relationship between exercise self-efficacy and body composition. As individuals with higher exercise self-efficacy are more likely to engage in regular physical activity, the beneficial effects of exercise self-efficacy on body composition may be fully mediated through increased physical activity levels (Kim et al., 2017; Dishman et al., 2021).

While motivational factors are acknowledged as key contributors to health-related behaviors, the observed divergence invites further exploration into the interplay of psychological, social, and environmental influences that may modulate the impact of motivation on actual physical activity levels (Herrera et al., 2016). Thus, it is essential to consider the possibility of indirect pathways and moderating variables that shape the complex dynamics between motivation and behavioral outcomes. In addition, the interplay between motivation, self-efficacy, and subsequent physical activity levels underscores the importance of considering these intricate relationships in the design of interventions aimed at promoting and sustaining healthy behaviors. Recognizing self-efficacy as a mediator adds depth to our understanding of the motivational processes influencing physical activity, emphasizing the need for tailored strategies that enhance both motivation and self-efficacy to foster effective behavior change.

In summary, while this revised model may not entirely align with the traditional SDT framework, it represents an empirical understanding of the dynamics at play in our specific context of emerging adults' physical activity behavior. Through this adaptation, we aimed to ensure that our model accurately reflected the observed relationships, thus contributing to a deeper comprehension of the factors influencing physical activity engagement among emerging adults.

5 Study limitations

Despite the study's contributions, limitations exist that warrant consideration. Primarily, the cross-sectional nature of our research design poses constraints on inferring causality or establishing predictive relationships among the variables examined. While our study highlights associations between these constructs, caution must be exercised when assuming causal relationships. Additionally, the sample size and demographics might limit the generalizability of our findings. Considering the limitations posed by our sample size and demographics, we therefore applied PLS, which served as a valuable analytical approach for mitigating limitations associated with smaller sample sizes, non-normal distributions, or exploratory analyses. However, the constraints related to sample size and demographics, albeit mitigated to an extent by the chosen analytical method, still warrant careful consideration when interpreting and applying our results beyond the studied context. Moreover, the study acknowledges potential confounding biases that could impact the results. Sensitivity analyses were not conducted to investigate the potential effects of confounding biases, whether measured or unmeasured, on the results. Future research could consider employing sensitivity analyses to further explore these potential biases and their impact on the findings. Besides, the study recognizes the presence of social desirability biases and recall biases associated with self-report measures of physical activity. In our study, we attempted to mitigate these biases by employing validated self-reported measures and emphasizing the importance of providing honest and accurate responses. However, participants may have provided responses that they deemed socially desirable or may have inaccurately recalled their physical activity levels. The data collected at a single time point may not fully capture the dynamic and evolving nature of these factors over time. Future research could explore strategies to minimize social desirability and recall biases, such as employing ecological momentary assessment techniques or combining self-report measures with objective assessments. And longitudinal or experimental studies are warranted to have a better understanding of the temporal dynamics of self-efficacy, motivation, and physical activity among emerging adults.

Taken together, addressing the identified limitations could guide future research endeavors. Longitudinal studies are needed to examine the developmental trajectories of self-efficacy and motivation over time and their impact on sustained exercise engagement. Additionally, investigating potential moderating variables, such as social support or environmental factors, may provide further insights into the complex dynamics underlying motivational processes. Furthermore, applying advanced statistical techniques, such as longitudinal cross-lagged mediation modeling, can elucidate specific developmental and causal relationships among these constructs. By addressing these research gaps, future studies can advance our understanding of the motivational determinants driving physical activity behaviors and inform the development of more effective interventions targeting exercise promotion among emerging adults.

6 Conclusion

In conclusion, our study illuminates the dynamics between motivation, self-efficacy, and physical activity in emerging adulthood. These findings underscore the significance of self-efficacy as a mediator and exercise self-efficacy in influencing physical activity behaviors, providing a nuanced perspective for developing targeted interventions and policies to enhance health outcomes in this demographic.

Data availability statement

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

Ethics statement

Approval for this study was obtained from the Ethics Committee of Hangzhou Normal University (ratification date: November 14, 2022, 2022059). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

YT: Conceptualization, Methodology, Project administration, Writing – original draft, Writing – review & editing. TaX: Conceptualization, Project administration, Visualization, Writing – original draft, Writing – review & editing. XW: Formal analysis, Methodology, Software, Writing – review & editing. CL: Writing – review & editing. YW: Formal analysis, Methodology, Writing – review & editing. ML: Investigation, Writing – review & editing. TiX: Investigation, Writing – review & editing. XQ: Investigation, Methodology, Writing – review & editing.

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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.2024.1342611/full#supplementary-material

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The relationship between self-oriented perfectionism and exercise participation: based on the dualistic model of passion

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Background: During the critical formative years of college, active participation in sports not only helps to alleviate stress, but also promotes the development of healthy habits. Although the multifaceted benefits of exercise have been widely recognized, there is a relative dearth of research on the relationship between personality traits, particularly college students' self-oriented perfectionism (SOP), and exercise participation.

Methods: A questionnaire survey of 374 college students was conducted using the snowball sampling method. SPSS 26.0 and Mplus 8.3 were employed in this study to analyze the correlations between the variables, and on this basis, the effect of SOP on exercise participation was examined. The study also used 5,000 bootstrap samples and a 95% bias-corrected confidence interval to test the significance of the mediating effects.

Results: Correlation analysis showed that SOP was positively correlated with exercise participation. Harmonious passion and obsessive passion were positively correlated with SOP, and exercise participation. Further, the results of structural equation analysis revealed that SOP increased exercise participation. Harmonious passion and obsessive passion positively mediated the effect between SOP and exercise participation, respectively.

Conclusion: This study provides new perspectives to better understand college students' exercise participation, emphasizing the importance of SOP and its influence on exercise participation through harmonious and obsessive passions. These findings have important implications for the development of effective exercise promotion strategies.

KEYWORDS

self-oriented perfectionism, passion, harmonious passion, obsessive passion, exercise participation

1 Introduction

The university stage is a critical period in personal development (San Román-Mata et al., 2020), when academic pressures, career planning challenges, and relationship changes combine to affect the physical and mental health of college students (Iqbal et al., 2023). In this context, exercise participation is particularly important. Research has shown that regular exercise participation not only helps individuals regulate their body weight and body fat percentage and prevent obesity (Brzuszkiewicz et al., 2022; Gomes et al., 2023), but also has a positive impact on college students' resilience (Zach et al., 2021), emotional intelligence (San Román-Mata et al., 2020) and mental health (Ma et al., 2021). Despite the benefits of exercise participation to an individual's physical and mental health, college students still face a number of challenges in adhering to exercise participation, including academic pressures, time constraints, and fewer available fitness classes (Pellerine et al., 2022). Therefore, it is critical to explore the motivations for promoting exercise participation among college students and to integrate physical activity into their daily lives to promote their physical and mental health.

Prior research has shown that exercise participation is mainly influenced by a variety of factors such as individual characteristics, environmental characteristics, and exercise traits (Teunissen et al., 2023). For example, goal setting can increase an individual's exercise participation (Swann et al., 2021). A safe and well-resourced community environment provides residents with more opportunities to exercise and stimulates their interest in participating in physical activity (Zhang et al., 2022). Although previous scholars have explored the antecedents that promote exercise participation from different perspectives, few scholars have examined the relationship between college students' tendency toward SOP and exercise participation behaviors.

SOP represents a self-demanding tendency to evaluate and define oneself by establishing high standards and striving for perfection (Verner-Filion and Vallerand, 2016). This pursuit of perfection is not only reflected in a number of domains, such as academic and social activities (Bong et al., 2014; Nepon et al., 2016), but is even more pronounced in physical activity, where it can greatly influence an individual's exercise behavior and performance. Many sports psychologists have been keenly interested in how athletes' perfectionism affects exercise performance (Ahmed et al., 2021). Prior research has shown that college students with SOP tendencies seek perfection and have higher persistence and achievement motivation (Vink and Raudsepp, 2018). We believe that this characteristic of SOP will be a driving force for university students to motivate them to set and pursue perfection in their sport and to participate more actively in sports.

To better understand the relationship between SOP and exercise participation, this study also considered the role of passion in their relationship. Passion is a strong inclination toward activities that people enjoy, that they consider important, and that they invest time and energy in, and is a central part of one's identity (Yukhymenko-Lescroart, 2022). According to the dualistic model of passion, there are two types of passion, harmonious and obsessive passion, which stem from intrinsically true desires and are aligned with an individual's values and goals, whereas obsessive passion manifests itself as uncontrollable impulses to exercise (Lee et al., 2024). Prior research has shown that passion is the ability to drive individuals to sustain their engagement in sports activities, whether out of a love of the sport itself or the need to pursue personal fulfillment, and that this strong inclination not only promotes sustained participation in exercise, but also increases athletic performance and psychological well-being (Li, 2010; Schellenberg et al., 2021). However, existing research has failed to explicitly explore how dualistic passions play a potential mediating mechanism in the relationship between SOP and exercise participation among college students. This study is based on the Theory of Planned Behavior, which suggests that personality traits influence attitudes and behavioral intentions, which ultimately shape behavior (Potwarka, 2015). In this framework, college students who exhibit SOP may set high exercise goals and strive for perfection in their pursuit of personal performance and achievement. This may lead to the development of both harmonious and obsessive passions for exercise, ultimately promoting their exercise participation.

This study presents a new perspective to understand college students' exercise participation. First, this study investigates the relationship between SOP and exercise participation based on the theory of planned behavior. This not only enriches the application of the theory of planned behavior in different domains, but also provides a new perspective to understand the relationship between personality traits and motor behavior. Second, by examining the role of harmonious and obsessive passions in the relationship between SOP and exercise participation, this study provides a deeper understanding and a new theoretical framework for examining how personality traits influence exercise participation.

2 Theoretical framework and hypotheses

2.1 Self-oriented perfectionism and exercise participation

Perfectionism is a personal character trait in which individuals set high standards and rigorously evaluate behaviors in the pursuit of perfection (Flett and Hewitt, 2020). Perfectionism is a multifaceted concept that includes SOP. SOP is a personality trait characterized by setting high goals for oneself, being strict with oneself, and criticizing one's own behavior if one fails to achieve them (Hewitt et al., 2020). This trait of perfectionism encourages individuals to set higher personal goals and increases their motivation and self-discipline to achieve them (Oh, 2019). Goal-setting theory (GST) suggests that specific and challenging goals can significantly increase an individual's motivation and performance (Locke and Latham, 2002). According to goal-setting theory, college students with SOP tend to set high standards and strive for perfection in exercise participation, and such specific and challenging goals may promote their efforts and improve their exercise participation to reach goals. Prior research has shown that athletes with SOP strive for perfection in sports, and have improved athletic performance (Nordin-Bates et al., 2024). Based on goal-setting theory and prior research, we believe that college students who strive for self-perfection in sports will invest a great deal of time and effort in improving their exercise participation to achieve the high standards and goals they set for themselves. Therefore, we hypothesize the following:

> *Hypothesis 1*: SOP is positively related to exercise participation.

2.2 Mediating effects of harmonious and obsessive passion

Passion is an individual's intense fondness and affinity for activities (e.g., sports) that they believe define their self-identity (Vallerand et al., 2003). In other words, when people feel passionate about an activity, it means that they enjoy it immensely and see it as somehow an important part of their identity and self-concept.

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Vallerand (2020) propose that developing enthusiasm for an activity involves two processes: firstly, assessing the activity, including personal interest, its value, and the emotional experience it brings, and secondly, incorporating the activity into one's personal identity. Passion is presented as either harmonious passion or obsessive passion through the dualistic development of the internalization process (the extent to which the activity becomes part of the individual's self-identity) (Vallerand, 2010). Specifically, harmonious passion is an individual's strong desire and positive emotional engagement to perform a specific activity (Jang et al., 2023). When college students have a harmonious passion for a sport, they are pleased and satisfied by the sport itself, and this pleasure and identification makes them more willing and happy to participate in the exercise participation (Vallerand and Verner-Filion, 2020). Previous research has shown that when individuals participate in exercise out of personal interest, they experience more positive emotions and a sense of achievement (Annenkova et al., 2021), and this positive emotional state not only makes the exercise experience more enjoyable, but also motivates individuals to continue their exercise participation (Vallerand et al., 2003). Pérez García and Guzmán Luján (2019) found that harmonious passion promotes an individual's intention to exercise.

In contrast, obsessive passion is a process in which an individual internalizes an activity into their self-identity due to internal or external pressures (Vallerand et al., 2023). This internalization may stem from a reliance on a sense of self-worth or social acceptance, or because the excitement from the activity itself is too strong (Vallerand, 2008). In this scenario, college students with an obsessive passion for exercise will prioritize exercise, devote more time to it, and even set aside or neglect other important activities (Bureau et al., 2019). Bonneville-Roussy et al. (2011) argued that individuals with obsessive passions who engage in such activities that are desirable (e.g., health behaviors) motivate individuals to actively participate. Based on the theory of planned behavior, individuals tend to engage in behaviors that they perceive to be generally beneficial (Ajzen, 1991; Ajzen and Albarracín, 2007). In the context of exercise, obsessive passion can serve as a key intrinsic motivator for individuals to engage in exercise when their exercise goals align with their long-term health interests or personal achievement goals, thereby promoting exercise participation.

According to theory of planned behavior, individual personality traits can affect behavioral intentions and behaviors through attitudes and beliefs that influence behavior (Potwarka, 2015). College students with SOP traits have a strong drive to achieve high personal standards and assert their self-worth (Hill et al., 2018), and in athletic situations, this personality trait can facilitate exercise participation through exercise-influenced attitudes (harmonious passion and obsessive passion). Specifically, individuals with SOP traits have extremely high standards for the self, and when they strive to meet these standards, the positive emotions that come with exercise motivate them to be more focused and committed to these activities, promoting a harmonious passion in the individual, which leads to higher levels of exercise participation. On the other hand, when college students with SOP traits closely associate their personal identity, accomplishments, and exercise, this association may lead to college students' reliance on the success and recognition that comes with exercise participation, which can promote the obsessive passion for exercise, demonstrate high levels of motivation and perseverance (Barr et al., 2015), and promote exercise participation. Based on this, this study proposes the hypothesis:

> *Hypothesis 2*: Harmonious passion mediates the relationship between SOP and exercise participation.
>
> *Hypothesis 3*: Obsessive passion mediates the relationship between SOP and exercise participation.

2.3 Participants and procedures

This study utilized the professional data collection platform "Credamo" to conduct a questionnaire survey targeting college students, employing a "snowball" sampling method. First, the researchers invited 50 college students around them to participate in the survey and asked these participants to forward the link to the questionnaire to their college friends. This process was continued until data saturation. The questionnaire was distributed via WeChat, China's main social media platform. The questionnaire was designed to include basic information on SOP, Harmonious passion, Obsessive Passion, exercise participation, and demographics. To preclude data duplication, the system was configured to permit each IP address to access the survey link only once. Furthermore, a 7-point Likert scale attention check question (instructing respondents to select 'Strongly Agree') was incorporated into the questionnaire to safeguard data quality.

Drawing on previous studies (Ahmed et al., 2021; Pellerine et al., 2022), the inclusion criteria for this study were as follows: (1) Current enrollment in an undergraduate institution. (2) Ages between 18 and 22 years, aligning with the typical age range of Chinese college students (Naseer and Rafique, 2021).(3) Voluntary consent for participation. (4) Regular exercise participation for a minimum of 2 months (Yuan et al., 2022).(5) Absence of diseases preventing physical activity (Pan et al., 2022). The exclusion criteria were as follows: (1) Exceeding the specified age range. (2) Incomplete or improperly filled questionnaires. (3) Failure to pass the attention check (Shamon and Berning, 2019). (4) Survey completion time less than 2 min. (5) Answers are illogical or patterned(Meterko et al., 2015). (6) Presence of missing data. Through these rigorous screening criteria, 23 questionnaires failing the attention check and 15 questionnaires not meeting the inclusion criteria were excluded. The final valid sample comprised 374 students from 15 provinces, including Beijing, Tianjin, Hebei, and Jiangsu, with 198 females (52.9%) and 176 males (47.1%), and a mean age of 20.39 years ($SD = 1.7$). The survey included 96 college students (25.7%) in the first year, 97 students (25.9%) in the second year, 110 students (29.4%) in the third year, and 71 students (19%) in the fourth year.

This study implemented pilot testing, data cleaning, and reliability and validity tests to ensure data completeness and reliability. Specifically, two rounds of pilot tests were conducted, and based on the feedback received, the questionnaire was subsequently adjusted and refined (Aftab et al., 2023). Secondly, strict data cleaning was conducted according to the inclusion and exclusion criteria to ensure the quality of the analyzed data. Finally, the scales employed in the study were tested for reliability (Cronbach's alpha) and validity (confirmatory factor analysis: CFA) to ascertain robustness.

All participants voluntarily took part in the survey and were informed that it was anonymous and confidential. Electronic consent was obtained from all participants for the study. The study procedures were conducted in accordance with the ethical standards of the Chinese Psychological Association and the 1964 Declaration of Helsinki, as well as its subsequent amendments or similar ethical standards. This study (2024011204) was approved by the Ethics Committee of Tianjin Normal University.

2.4 Measures

The scale used in this study was originally in English, and based on Brislin (1986) suggestion, a translation and back-translation method was used to convert it into Mandarin and then translate it back into English to ensure clarity of the measurement tool. The questionnaire was improved in the first and second rounds of pilot testing with 20 and 25 participants, respectively. The main purpose of the test is to identify items that are not clearly expressed in Mandarin. Comments from participants in the first round indicated that some items were ambiguous, and we amended these items to improve their accuracy. A second round of testing confirmed the complete clarity of the questionnaire.

2.4.1 Self-oriented perfectionism

The SOP scale of the Multidimensional Perfectionism Scale (MPS) developed by Hewitt and Flett (1991) was used in this study. The scale is a one-dimensional structure with 15 items (e.g., "My goal is to be perfect in everything"), each of which has a 7-point scale ranging from 1 (not at all) to 7 (perfectly), with the higher the total score, the higher the individual's degree of SOP (Cronbach's $\alpha = 0.91$).

2.4.2 Passion

The present study used the Passion Scale developed by Vallerand et al. (2003) to measure the level of sports passion among college students. The scale consists of 2 subscales, Harmonious Passion and Compulsive Passion, with a total of 14 items (e.g., "The new things I get from sport give me more value"), and the questionnaire is scored on a 7-point Likert scale. In the reliability test, the Cronbach's α coefficient was 0.93 for the total scale and 0.96 and 0.91 for the subscales.

2.4.3 Exercise participation

The exercise participation scale used by Ahn et al. (2016) was adopted for this study. The scale consists of three questions. Specific entries included the question, "How much time do you spend on physical activity each day, other than school physical education classes?" with response scales of 1 (no participation or less than 30 min), 2 (30 min - 1 h), 3 (1 h - 2 h), and 4 (more than 2 h). "How often do you participate in physical activity in a week?" with a response scales of 1 (no participation or 1 time), 2 (2–3 times a week), 3 (4–5 times a week), and 4 (6–7 times a week). "If you have participated in physical activity, for how long?" with response scales of 1 (no participation or less than 3 months), 2 (3 months - 6 months), 3 (6 months - 1 year), and 4 (more than 1 year). Each item was rated on a 4-point Likert scale, with higher scores indicating greater levels of exercise participation (Cronbach's $\alpha = 0.75$).

2.4.4 Data analysis strategy

After collecting the questionnaire data, the study was processed using the following methods: Firstly, CFA was executed using Mplus 8.3 software. Secondly, the reliability of the scale was assessed by Cronbach's α coefficient and tested for discriminant validity using Fornell and Larcker (1981) criteria. In addition, a Harman's one-factor test was conducted to detect common method bias (Podsakoff et al., 2012). Finally, the significance of the indirect effect of harmonious passion versus obsessive passion was tested using a bootstrap sample of 5,000 and 95% bias-corrected confidence intervals to ensure that the interval of significant indirect effects did not contain a zero (Preacher and Hayes, 2008).

3 Results

3.1 Reliability and validity

Prior to formulating the hypotheses, this study conducted a CFA on the following variables: SOP, harmonious passion, obsessive passion, and exercise participation as a means of assessing the fit of the measurement model. The results of the analyses showed a good fit for the four factors as follows: $\chi^2/df = 2.37$, CFI = 0.93, TLI = 0.92, RMSEA = 0.06, and SRMR = 0.04.

The lowest value of Cronbach's alpha coefficient in the study was 0.75, indicating good reliability of the scale. In addition, convergent validity was satisfactory, with the combined reliability (CR) of each construct ranging from 0.75 to 0.96 (CR > 0.70). The mean variance extracted for each construct ranged from 0.51 to 0.76 (AVE > 0.50), which all exceeded the suggested threshold, showing good discriminant validity as the square root of the AVE was greater than the correlation of all factors. In addition, this study used Harman's one-factor test to test the presence of common method bias in the collected data (Podsakoff et al., 2012), which showed that the variance explained by the rotated first factor was 41.22%, which is less than 50% indicating that the data in this study did not have a significant common method bias.

3.2 Descriptive statistics and correlation analysis

Descriptive statistical analysis of demographic information and research variables were conducted in this study to capture the basic characteristics of the data. In addition, correlation analysis was conducted to gain a deeper understanding of the potential links between the variables. The results of the analysis are shown in Table 1. The results showed significant positive correlations between SOP and harmony passion ($r = 0.45$, $p < 0.01$), obsessive passion ($r = 0.46$, $p < 0.01$), and exercise participation ($r = 0.47$, $p < 0.01$). Furthermore, there was a significant positive correlation between passion for harmony and exercise participation ($r = 0.48$, $p < 0.01$). Similarly, there was a significant positive correlation between obsessive passion and exercise participation ($r = 0.53$, $p < 0.01$).

TABLE 1 Descriptive statistics, correlations, and reliabilities.

Variables	*M*	*SD*	1	2	3	4	5	6	7
1. Gender	1.53	0.50	1						
2. Age	20.39	1.17	−0.01	1					
3. Class	2.42	1.07	−0.03	0.49**	1				
4. Self-oriented perfectionism	4.69	0.98	0.04	0.02	0.04	1			
5. Harmonious passion	3.80	1.37	0.06	0.05	−0.05	0.45*	1		
6. Obsessive passion	3.68	1.18	−0.01	0.10	0.02	0.46**	0.44**	1	
7. Exercise participation	2.29	0.74	−0.07	0.03	0.03	0.47**	0.48**	0.53**	1

$N = 374$. Gender = "male" (1), "Female" (2); Class = "first year" (1), "second year" (2), "third year" (3), "fourth year" (4).
*indicates statistical significance at the $p < 0.05$ level. **indicates statistical significance at the $p < 0.01$ level.

3.3 Structural equation modeling test

After confirming the existence of correlation between all the main variables, this study used Mplus 8.3 to build structural equation modeling to further analyze the relationship between the variables, and the results are shown in Table 2 and Figure 1. To test Hypothesis 1, the analyses revealed a significant positive effect of SOP on exercise participation ($\beta = 0.55$, $p < 0.001$; see Model 3). The results support hypothesis 1. Model 1 and model 4 results showed a significant positive effect of SOP on exercise participation through harmonious passion ($\beta = 0.16$, $p < 0.001$, 95% C.I = [0.90, 0.25]), suggesting a complementary mediating effect (Zhao et al., 2010). The results support hypothesis 2. The results of Model 2 and Model 5 showed that SOP had a significant positive effect on exercise participation through obsessive passion ($\beta = 0.20$, $p < 0.001$, 95% C.I = [0.14, 0.29]), suggesting a complementary mediating effect (Zhao et al., 2010). The findings support Hypothesis 3. In addition, this study employed the Sobel test to assess the mediating effect's significance. The results of the analysis showed a significant mediation effect of harmonious passion between SOP and exercise participation ($z = 4.68$, $p < 0.001$). The mediation effect of obsessive passion between recognition of SOP and exercise participation was significant ($z = 6.90$, $p < 0.001$).

4 Discussion

Based on the theory of planned behavior, we conducted hypothesis testing and found supportive evidence that college students' SOP directly influences exercise participation. It also indirectly increases levels of exercise participation through harmonious passion or obsessive passion. Below, we discuss the theoretical and practical implications of these results, the limitations of the study, and directions for future research.

4.1 Theoretical implications

This study provides a theoretical contribution to understanding college students' exercise participation behaviors. Firstly, this study extends existing research on factors influencing exercise participation. Existing research has focused on the effects of an individual's gender, education, social and psychological factors on sport participation (Li et al., 2023), while less research has been conducted on the role of individual personality traits, particularly SOP, in exercise participation. The results of the present study demonstrated that SOP tendency is one of the important predictors of college students' sports participation, filling the gap of the effect of SOP tendency on sports participation that has not been investigated in the prior studies.

Second, the results of this study suggest that harmonious passion and obsessive passion mediate the relationship between SOP and exercise participation. This finding provides empirical support for the dichotomous model of passion in sport psychology, revealing a complex mechanism for the role of passion in the relationship between SOP and exercise participation. Consistent with the theory of planned behavior (Ajzen, 1991), the results of this study suggest that both harmonious passion and obsessive passion can be used as attitudes to elucidate the link between SOP and participation in exercise. Harmonious Passion provides value to participation in the activity itself and allows college students to participate more autonomously (Yukhymenko-Lescroart, 2021). The results of this study support previous findings. Consistent with Lee et al. (2023), harmonious passion plays a significant mediating role between self-determined motivation and athletes' commitment to exercise, and athletes' self-determined motivation is enhanced by harmonious passion, which influences their continued exercise participation and commitment to the sport and improves performance and satisfaction (Gu et al., 2022). In addition, Yukhymenko-Lescroart (2021) showed that harmonic passion acts as a mediator to enhance individual athletic performance and psychological well-being, positively regulating athletes' psychological state and behavioral performance. Therefore, college students with SOP can also enjoy exercise by developing an intrinsic interest in it and positive emotions, which can increase their exercise participation.

Unlike harmonious passion, obsessive passion stems from internal and external pressures and even insecurity about self-worth (Vallerand, 2008). Most prior research has focused on the possibility that obsessive passion may cause negative outcomes for individuals such as negative emotions or fatigue (Curran et al., 2011). For example, Lopes and Vallerand (2020) found that the higher an athlete's obsessive passion, the higher the burnout. However, our findings suggest that obsessive passion plays a motivational role in exercise, increases college students' exercise participation, and positively mediates the relationship between SOP and exercise participation. This result suggests that that college students with SOP trait may be compelled to internalize exercise participation due to the pressure to be perfect, increasing the individual's obsessive passion for exercise and increasing the level of exercise participation. The results of this study are consistent with the study by Dalla Rosa and Vianello (2020), demonstrating the positive mediating effect of obsessive passion. By revealing this complex mechanism, this study enriches the study of obsessive passion and contributes to a comprehensive understanding of obsessive passion.

4.2 Practical implications

Our study provides some implications for physical educators to promote exercise participation among college students. Firstly, we found that college students with a higher SOP have higher levels of exercise participation due to their pursuit of high standards and perfection. This suggests that not only athletes (Waleriańczyk and Stolarski, 2021), but also college students can benefit from higher levels of SOP in terms of sports participation. Based on this finding, physical educators should encourage and guide college students with high SOP tendencies to exercise their pursuit of high standards and excellence and transform this drive into positive motivation to participate in the exercise. For example, physical educators can incorporate interactive goal-setting sessions into their physical education programs to encourage students to set achievable goals for themselves in physical activity.

Second, our study identified a critical positive mediating effect of harmonious and obsessive-compulsive passions between SOP and exercise participation. This suggests that by fostering a harmonious passion, physical educators can help students transform their intrinsic drive for perfection into a driving force for active participation in physical activity, facilitating participation in exercise in a healthier, more balanced way. Specifically, we recommend designing interventions in universities that encourage students to develop a passion for harmony and apply it to physical activity. For example, physical education programs and activities could be designed to be more flexible and varied, giving students the opportunity to explore different types of sports and to find activities that they truly enjoy. University students could also be encouraged to play sports in a group setting to enhance harmonious passion through social interaction and group identity.

Finally, for current college students, SOP has a facilitating effect on exercise participation through obsessive passion. This implies that perfection-seeking students may participate in exercise more frequently due to obsessive passion, and that they see exercise as a means of realizing their personal values, and so show greater commitment and persistence in exercise participation. Therefore, it is crucial for university students to have a deep understanding of their behavioral motivations and emotional states. Teachers need to set more realistic and balanced goals for their college students, with athletic goals that are challenging but achievable, and to teach college students effective time management skills to ensure that they have enough time for study, leisure, socializing and rest.

4.3 Limitations and future recommendations

This study has several limitations. First, this study was only a cross-sectional study of Chinese college students, which has some limitations in terms of the generalizability of the study and the causality of the variables. Therefore, future studies should adopt a longitudinal design, experimental intervention, or control group approach to more accurately and effectively explore the causal relationship between SOP and exercise participation.

Second, considering that this study was limited to a specific population of Chinese university students, the generalizability of the findings may be limited. Future studies should also expand the scope of sample selection to include college students of different cultural backgrounds or other groups to enhance the generalizability and representativeness of the findings.

TABLE 2 Mediating role of harmonious and obsessive passions.

Dependent variables	Harmonious passion		Obsessive passion		Exercise participation					
	Model 1		Model 2		Model 3		Model 4		Model 5	
Measure	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*	β (*SE*)	*p*
1.Gender	0.03 (0.05)	0.570	−0.05 (05)	0.374	−0.10 (0.05)	0.054	−0.11 (05)	0.022	−0.08 (05)	0.105
2. Age	0.12 (0.05)	0.032	0.16 (06)	0.006	0.09 (0.06)	0.162	0.04 (0.06)	536	0.01 (0.06)	0.890
3. Class	−0.13 (0.05)	0.015	−0.08 (0.06)	0.177	−0.04 (0.06)	0.546	0.02 (0.06)	0.763	0.00 (0.06)	0.968
4. Self-oriented perfectionism	0.48 (0.05)	0.000	0.52 (0.06)	0.000	0.55 (0.05)	0.000	0.35 (0.08)	0.000	0.29 (05)	0.000
5. Harmonious passion							0.43 (0.08)	0.000		
6. Obsessive passion									0.51 (0.05)	0.000
R^2	0.24		0.29		0.32		0.46		0.50	
ΔR^2	0.23		0.28		0.31		0.45		0.49	
F	16.51***		21.36***		58.04***		105.06***		123.33*	

$N = 374$. β is standardized regression coefficients, SE is the standard error. Bootstrap sample size = 5,000. gender = "male" (1), "female" (2).
*indicates statistical significance at the $p < 0.05$ level. ***indicates statistical significance at the $p < 0.001$ level.

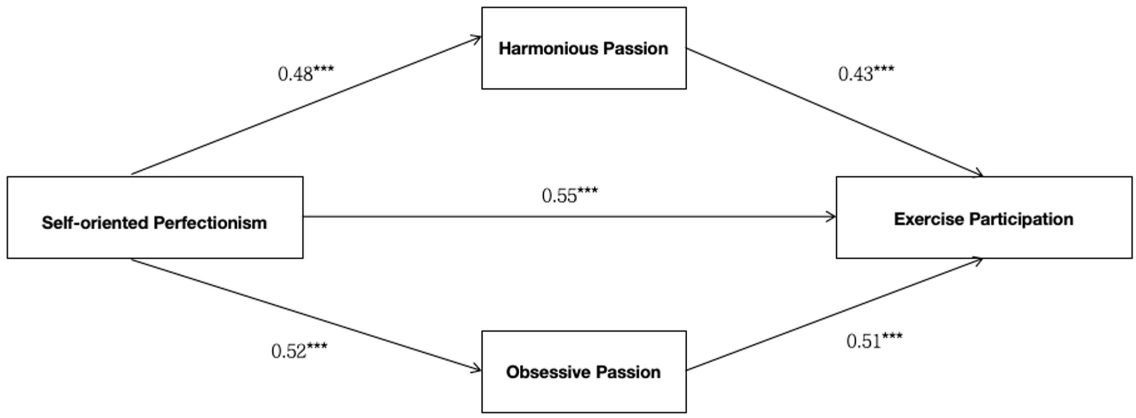

FIGURE 1
Parallel intermediation model.

Third, this study only examined Chinese college students' SOP and failed to examine whether the perfectionist tendencies of other-oriented perfectionism and socially prescribed perfectionism had an impact on college students' exercise participation. Individuals may react differently to actions due to different perfectionist tendencies. For example, socially prescribed perfectionism assumes that significant others hold high expectations of themselves and that others pressure themselves for perfection (Verner-Filion and Vallerand, 2016). This socially prescribed perfectionism may be a pressure or a motivator for college students' exercise participation, and future research could explore how this external motivation may affect exercise participation.

Fourth, Although the results of Harman's one-factor test showed that CMB was not a serious problem in this study, this value (41.22%) was relatively high. This suggests that common method bias may still be a potential problem. Future research should consider employing multiple data collection methods, such as cross-validating findings through longitudinal designs or utilizing diverse data sources, to further mitigate the risk of common method biases and to more robustly substantiate findings.

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 humans were approved by Ethics Committee of Tianjin Normal University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants in accordance with the national legislation and the institutional requirements.

Author contributions

WZ: Data curation, Software, Writing – original draft, Writing – review & editing. YZ: Conceptualization, Data curation, Methodology, Writing – review & editing. FJ: Data curation, Methodology, Writing – review & editing. HS: Investigation, Software, Writing – review & editing.

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The authors declare that the research was conducted without commercial or financial relationships that could be construed as potential conflicts of interest.

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Physical activity and recreational screen time among Chinese children and adolescents: a national cross-sectional study

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Background: The increasing prevalence of physical inactivity and prolonged Recreational Screen Time (RST) among children and adolescents is emerging as a significant public health concern. This study investigates the current status of Physical Activity (PA) and RST among Chinese children and adolescents from 2017 to 2019. It also examines variations in PA and RST across different school levels, genders, urban–rural areas, regions, and seasons.

Methods: A national cross-sectional survey, conducted in China from 2017 to 2019, included 53,101 children and adolescents from grades 4 to 12 (aged 10 to 18 years old). Data on PA and RST were collected via self-administered questionnaires. The study employed descriptive statistics, calculated weighted prevalence rates, and conducted differential analysis across diverse demographic groups.

Results: Between 2017 and 2019 in China, merely 28.73% of children and adolescents adhered to World Health Organization's PA guidelines, while 76.09% met China's RST guidelines. Notably, females, higher-grade students, rural residents, and children and adolescents from southern regions exhibited significantly lower levels of PA compared to their male, lower-grade, urban, and northern counterparts. Concurrently, RST was significantly higher among males, lower-grade students, rural residents, and those from northern regions. Seasonal variations were also observed, with lower PA and higher RST in autumn and winter as compared to spring.

Conclusion: The study reveals a concerning low level of PA among Chinese children and adolescents, with marked disparities in PA and RST across different groups. This underscores the need for targeted health promotion strategies to enhance PA and mitigate RST among various child and adolescent populations.

KEYWORDS

children and adolescents, physical activity, recreational screen time, Chinese, cross-sectional study

1 Introduction

Physical activity (PA), defined as any bodily movement that results in energy expenditure in skeletal muscles, such as walking, cycling, exercising, or doing household chores (1). Recreational Screen Time (RST), on the other hand, encompasses discretionary screen activities conducted while sedentary, such as watching television, playing video games, and using computers (2). Both PA and RST significantly influence the health and well-being of children and adolescents. Extensive research indicates that higher levels of PA, coupled with reduced RST, are effective in preventing and managing various health issues, including obesity and type 2 diabetes (3). Additionally, adequate PA and less RST enhances physical health, boosts cognitive abilities, improves academic performance, and reduces mental stress (3).

The World Health Organization (WHO) recommends that children and adolescents should engage in at least 60 min of Moderate-to-Vigorous Physical Activity (MVPA) daily to be considered active (3). Similarly, health guidelines from countries like Canada and China advocate for limiting RST to under 2 h per day for this demographic (2, 4). Despite these recommendations, adherence rates among children and adolescents are alarmingly low globally – only about 27 to 33% meet the WHO's PA guidelines, and a mere 34 to 39% adhere to the RST guidelines of Canada and China (5, 6).

The same concerning phenomenon of low levels of PA and increased RST is also observed amongst Chinese children and adolescents, particularly in the context of rapid social transformation, economic growth, and widespread adoption of personal electronic devices in China (7, 8). Notably, in the Global Report Card on Physical Activity for Children and Youth, China ranks among the lowest in terms of PA and RST indicators (9). To support the Chinese government and organizations in formulating policies and initiatives to promote PA and reduce RST in children and adolescents, several nationally representative studies have examined the prevalence and current state of PA and RST among this demographic. For instance, Fan et al.'s (10) survey revealed that approximately 30% of Chinese children and adolescents met the WHO's PA guidelines. Similarly, Zhu et al.'s (11) study found that 34.1% of Chinese children and adolescents adhered to the WHO's PA guidelines, and 65.4% adhered to China's RST guidelines, respectively. However, Liu et al.'s (12) survey indicated a significant decline, with only 14% of participants meeting the WHO's PA guidelines and just 51% adhering to China's RST guidelines. These studies also indicated variations in PA and RST based on sociodemographic factors such as gender and age. The sharp decrease in adherence between 2017 and 2020 might be partly attributed to the pandemic, but the lack of comprehensive data from 2017 to 2020 hinders a thorough understanding of the current state and hampers the development of effective policies.

To bridge this gap, our study, under the auspices of the Construction of a Big Data Platform for Children and Adolescents' Sports and Fitness in China (CBDPCASF) project, assessed the current status of PA and RST among Chinese children and adolescents during 2017–2019. The objectives were twofold: (1) to augment existing data regarding PA and RST among this population during the specified period, and (2) to elucidate the distribution of PA and RST across various demographics, including gender, school levels, urban–rural areas, regions, and seasonal variations.

2 Materials and methods

2.1 Study design and participants

This study was a component of the CBDPCASF project. Funded by the National Social Science Foundation of China, the CBDPCASF is a major national initiative aimed at gathering data on the sports participation and health of Chinese children and adolescents. Between 2017 and 2019, the project conducted three cross-sectional surveys. Each annual survey utilized stratified sampling methods, reflecting the distribution of student populations across various school levels in China. Schools participating in the CBDPCASF project, encompassing primary, middle, and high schools, were selected for the study. Subsequently, children and adolescents in grades 4 to 12 (aged 10 to 18 years old) from these schools were invited to participate. The study received approval from the Human Experimentation Ethics Committee at East China Normal University (Registration Code: HR 222–2019) and was conducted in strict accordance with the principles outlined in the Declaration of Helsinki. Furthermore, the research adhered to the STROBE guidelines for cross-sectional studies.

Over these 3 years, a total of 53,101 students from 150 schools in 18 provinces participated. This included 27,555 students from 120 primary schools, 18,115 students from 63 middle schools, and 7,431 students from 28 high schools.

2.2 Procedures

In September of each year from 2017 to 2019, the CBDPCASF project team randomly selects a variety of primary, middle, and high schools from those participating in the CBDPCASF project, according to the proportion of students at different school levels in China. These schools are invited to participate in this study, and are free to choose when to conduct the survey anytime from September of the current year to June of the following year. During the selected time periods, invitations for the survey are extended to students in grades 4 to 12 through their schools. Teachers inform the students about the purpose of the study as well as its potential risks and benefits, and informed consent is also obtained from willing students and their guardians.

After consent was secured, trained research assistants distributed online questionnaires to the students using the Questionnaire Star platform (13). The questionnaires were completed by the students via smartphones or computers. Post data collection, the research assistants classified the area status (urban or rural) and regional location (north or south) of each student's school using Baidu Maps and the Qinling-Huaihe Line. Baidu Maps, the largest map service provider in China, can determine whether a location is urban or rural based on the name of the place entered (14). The Qinling-Huaihe Line is a geographical divide in China, with regions north of this line typically having drier, colder climates, poorer air quality, and lower levels of economic development compared to regions south of the line (15). The season of each student's survey participation was determined based on the completion date of the questionnaire, with March–May classified as spring, June–August as summer, September–November as autumn, and December–February as winter. After collecting data over 3 years, data from annual surveys conducted between 2017 and 2019 were consolidated to form the dataset for this study.

2.3 Instruments

To assess participants' PA, the study employed the Chinese adaptation of the Physical Activity Questionnaire for Older Children (PAQ-C) (16). The PAQ-C, a self-report instrument, evaluates PA over a 7-day recall period. Its reliability and validity in assessing PA among Chinese children and adolescents are well-established (17, 18). The questionnaire comprises 10 items, beginning with questions about the frequency of engagement in various PA such as swimming, martial arts, and basketball. Items 2 to 8 inquire about PA during specific periods, including physical education classes, recess, after-school hours, evenings, and weekends. The ninth question probes the frequency of engaging in more than 30 min of PA daily over the past week, while the final item addresses any special circumstances that may have limited PA in the preceding week. The first 9 items utilize a five-point Likert scale, ranging from 1 (lowest level or frequency of PA) to 5 (highest level or frequency of PA). The last question presents a binary choice, "Yes" or "No," to indicate whether any special circumstances last week restricted the participants' engagement in PA. The final PA score was s calculated as the average of scores from questions 1 to 9, reflecting the participants' level of PA over the past 7 days (16). Furthermore, according to a comparative study of PAQ-C and accelerometer data by Voss et al. (17), a PAQ-C score exceeding 2.87 corresponds to a daily MVPA duration of over 60 min. Consequently, this study classified a PAQ-C score above 2.87 as compliant with the WHO's PA guidelines.

Participants' RST was evaluated using the Chinese adaptation of the Adolescent Sedentary Activity Questionnaire (ASAQ) (19). The ASAQ, a 7-day recall tool, has proven reliable and valid for studying sedentary time among Chinese children and adolescents (19, 20). It consists of 6 items that assess RST on weekdays and weekends, focusing on time spent watching TV, movies, and using smartphones, computers, or tablets (excluding educational or work purposes). The calculation of participants' weekly RST is achieved by summing the total of the 6 items, and the average daily RST is obtained by dividing the weekly RST by 7 (19). According to the RST guidelines of Canada and China (2, 4), participants with less than 2 h of daily RST are considered to have met the RST guidelines.

Demographic information, including school, gender, and school level, was also collected during the survey.

2.4 Statistical analyses

Participants with incorrect (3,809), outlier (608, based on Tukey's method) (21), or irrelevant responses (those unable to engage in PA due to special circumstances or pre-existing medical conditions, totaling 3,151) were excluded from the analysis.

The representation factor for each student was determined using the 2019 data on total students across different school levels, as provided by the Ministry of Education of China (22). This factor was then applied as a weighting variable in subsequent analyses. Weighted percentages for the overall sample were calculated based on gender, area, region, and season. Unweighted percentages for different school level samples were also calculated based on gender, area, region, and season. Both unweighted and weighted prevalence rates for adherence to PA and RST guidelines, along with their 95% confidence intervals (CIs), were calculated across gender, area, region, and season. A Generalized Linear Model, both weighted and unweighted and adjusted for demographic covariates (gender, area, region, season, and school level), was employed to analyze the difference in adherence to PA and RST guidelines.

All analyses were conducted using Python (Python 3.10, Python Software Foundation, Wilmington, DE, United States) with the statsmodels, pandas, and scipy libraries (23). A two-sided significance level was set at 0.05.

3 Results

3.1 Sample characteristics

Following the data cleaning process, the final analysis included a total of 45,533 participants, consisting of 24,040 primary school students, 15,081 middle school students, and 6,412 high school students. Of these, the weighted proportion of female participants was 48.66%, rural participants accounted for 18.93%, and participants from the southern region comprised 39.48%. The proportions of participants surveyed in spring, autumn, and winter were 46.43, 24.96, and 28.61%, respectively. The unweighted sample sizes divided by gender, area, region, season, and school level, along with their corresponding weighted or unweighted percentages, are detailed in Table 1.

3.2 Prevalence and differences in meeting PA guidelines

Between 2017 and 2019, only 28.57% of children and adolescents met the PA guidelines. A trend of decreasing adherence was observed with increasing school levels: 32.85% in primary school, 23.65% in middle school, and only 19.67% in high school. The detailed weighted and unweighted prevalence rates for different genders, areas, regions, and seasons are presented in Table 2.

In terms of associations as measured by odds ratios (ORs), female children and adolescents were significantly less likely to meet PA guidelines compared to males, with an OR of 0.570 (95% Confidence Interval [CI]: 0.569–0.571). Similarly, rural children and adolescents were less likely to adhere to PA guidelines than their urban counterparts, evidenced by an OR of 0.782 (95% CI: 0.780–0.783). Additionally, children and adolescents from southern regions demonstrated lower adherence compared to those from northern regions, with an OR of 0.986 (95% CI: 0.985–0.987). Seasonal variations were also evident; children and adolescents surveyed in winter and autumn were less likely to meet PA guidelines compared to those surveyed in spring, with ORs of 0.916 for winter (95% CI: 0.914–0.917) and 0.745 for autumn (95% CI: 0.744–0.746). Detailed associations between meeting PA guidelines and factors such as gender, area, region, and season, as measured by ORs, are presented in Table 3.

3.3 Prevalence and differences in meeting RST guidelines

The results from 2017 to 2019 indicate that 81.61% of children and adolescents adhered to the RST guidelines. Notably, adherence to the guidelines increased with ascending school levels: 80.58% in primary school, 81.33% in middle school, and 86.67% in high

TABLE 1 Unweighted sample size, with corresponding weighted and unweighted percentages of school level participation.

	No. of participants by school level (Weight %)[a]			
	All school level	Primary school	Middle school	High school
Overall	45,533	24,040 (100%)	15,081 (100%)	6,412 (100%)
Gender				
Male	23,321(51.34%)	12,631 (52.54%)	2,993 (46.68%)	7,697 (51.04%)
Female	22,212(48.66%)	11,409 (47.46%)	3,419 (53.32%)	7,384 (48.96%)
Area[b]				
Urban	36,831 (81.07%)	19,705 (81.97%)	5,219 (81.39%)	11,907 (78.95%)
Rural	8,702 (18.93%)	4,335 (18.03%)	1,193 (18.61%)	3,174 (21.05%)
Region[c]				
North	17,042 (60.52%)	12,353 (51.39%)	3,232 (50.41%)	12,906 (85.58%)
South	28,491 (39.48%)	11,687 (48.61%)	3,180 (49.59%)	2,175 (14.42%)
Season[d]				
Spring	13,032 (46.43%)	10,742 (44.68%)	3,570 (55.68%)	6,882 (45.63%)
Autumn	21,194 (24.96%)	6,689 (27.82%)	478 (7.45%)	4,140 (27.45%)
Winter	11,307 (28.61%)	6,609 (27.49%)	2,364 (36.87%)	4,059 (26.91%)

[a]The all school level percentages were calculated based on the proportion of students in different school levels in 2019, with the percentages for different school levels not being weighted.
[b]Area classifications are based on the urban or rural status of each school, as designated by the Baidu Maps Open Platform.
[c]Regions were delineated by the natural geographic boundaries of China, specifically the Qinling-Huaihe Line.
[d]The season was determined based on different months: March–May for spring, June–August for summer, September–November for autumn, and December–February for winter. Since summer is the school holiday period for students, no survey was conducted during this season.

school. Detailed weighted and unweighted prevalence rates for different genders, areas, regions, and seasons are available in Table 2.

In terms of associations as measured by ORs, the study found that female children and adolescents were more likely to meet the RST guidelines compared to males, with an OR of 1.361 (95% CI: 1.360–1.363). Rural children and adolescents were less likely to adhere to RST guidelines than their urban counterparts, as evidenced by an OR of 0.897 (95% CI: 0.895–0.898). Additionally, children and adolescents from southern regions showed higher adherence compared to those from northern regions, with an OR of 1.096 (95% CI: 1.094–1.097). Seasonally, adherence rates were lower in winter and autumn than in spring, with ORs of 0.824 for winter (95% CI: 0.822–0.825) and 0.979 for autumn (95% CI: 0.977–0.981). The associations between meeting RST guidelines and factors such as gender, area, region, and season, as measured by ORs, are detailed in Table 3.

4 Discussion

This study examined the PA and RST among Chinese children and adolescents, revealing that only 28.73% met the WHO's PA guidelines, while 76.09% adhered to the RST guidelines of China and Canada. Notably, differences in PA and RST were observed across various demographics, including gender, area, region, and season, with these variances being more pronounced across some school levels.

Globally, previous research indicates that 27 to 33% of children and adolescents meet PA guidelines, but only 34 to 39% adhere to RST guidelines (6). The PA levels among Chinese children and adolescents align with the global average, however, their RST is significantly lower. In fact, the RST of Chinese children and adolescents appears to be indeed less than that of other countries. For instance, a 2017 national survey also reported that 65.4% of Chinese children and adolescents had less than 2 h of daily RST (11). This could be attributed to China's status as a developing country with generally lower household incomes, leading to fewer children owning personal electronic devices. Additionally, the rigorous Chinese education system, particularly the emphasis on entrance exams for high schools and colleges, may compel students to dedicate more time to studies than screen-based recreation. Therefore, in China, greater efforts should be directed towards enhancing PA among children and adolescents.

Consistent with global trends, our study found that in China, males and younger children are more likely to meet PA guidelines, whereas females and older children are more likely to meet RST guidelines (5, 11, 24). The underlying reasons, explored in prior research, include physiological differences, interest disparities, varying levels of social support, shifts in academic pressure, environmental factors, and perceptions of PA (25–27). Despite these gender and age disparities, the harms of insufficient PA and excessive RST do not differ by gender or age, underscoring the need for targeted interventions focusing on the PA of females and older children, and the RST of males and younger students.

Studies by Cai et al. (28) and Song et al. (29) as well as Wagner et al. (30) demonstrate that urban children and adolescents have higher levels of PA and more RST compared to their rural counterparts, attributed to better access to PA facilities and electronic devices. Conversely, research by Euler et al. (31) and Sandercock et al. (32) shows that rural children and adolescents engage in higher levels of PA but less RST than those in urban areas. This difference is primarily due to rural children and adolescents having more space for PA, frequently needing to assist with family labor tasks, and having fewer electronic devices (31, 32). Distinct from both scenarios, our study indicates that compared to urban children and adolescents, those in rural areas exhibit both lower levels of PA and more RST. We believe that the

TABLE 2 Weighted and unweighted prevalence of meeting PA and RST guidelines among chinese children and adolescents by gender, area, region, season, and school level.[a]

	All school level	Primary school	Middle school	High school
Meeting PA guidelines (95% CI)[b]				
Overall	28.57 (28.15–28.98)	32.85 (32.26–33.44)	23.65 (22.97–24.32)	19.67 (18.69–20.64)
Gender				
Male	33.90 (33.29–34.52)	37.34 (36.50–38.19)	28.89 (27.88–29.91)	28.87 (27.24–30.49)
Female	23.04 (22.48–23.60)	27.87 (27.05–28.70)	18.17 (17.29–19.05)	11.61 (10.54–12.69)
Area				
Urban	29.39 (28.93–29.86)	34.03 (33.37–34.69)	23.88 (23.11–24.64)	20.16 (19.07–21.25)
Rural	24.86 (23.94–25.79)	27.50 (26.17–28.83)	22.78 (21.32–24.24)	17.52 (15.36–19.68)
Region				
North	28.47 (27.91–29.03)	32.50 (31.68–33.33)	23.57 (22.84–24.30)	20.61 (19.21–22.00)
South	28.78 (28.05–29.50)	33.22 (32.36–34.07)	24.09 (22.29–25.89)	18.71 (17.36–20.07)
Season				
Spring	29.21 (28.41–30.00)	34.76 (33.61–35.90)	22.76 (21.47–24.05)	17.81 (16.27–19.35)
Autumn	25.11 (24.25–25.97)	28.94 (27.86–30.03)	20.48 (19.25–21.71)	17.57 (14.16–20.99)
Winter	30.17 (29.55–30.80)	34.11 (33.21–35.01)	26.07 (25.03–27.11)	21.18 (19.84–22.52)
Meeting RST guidelines (95% CI)[b]				
Overall	81.61 (81.25–81.97)	80.58 (80.08–81.08)	81.33 (80.71–81.96)	86.67 (85.83–87.50)
Gender				
Male	79.46 (78.94–79.99)	78.63 (77.92–79.35)	78.67 (77.75–79.58)	84.70 (83.41–85.99)
Female	83.88 (83.39–84.37)	82.74 (82.05–83.44)	84.11 (83.28–84.95)	88.39 (87.31–89.46)
Area				
Urban	81.81 (81.41–82.21)	80.71 (80.16–81.26)	81.99 (81.30–82.68)	86.24 (85.31–87.18)
Rural	80.85 (80.00–81.69)	80.00 (78.81–81.19)	78.86 (77.44–80.28)	88.52 (86.71–90.33)
Region				
North	80.93 (80.44–81.42)	79.51 (78.80–80.22)	81.59 (80.92–82.26)	85.83 (84.63–87.03)
South	81.99 (81.35–82.62)	81.71 (81.01–82.42)	79.82 (78.13–81.50)	87.52 (86.37–88.66)
Season				
Spring	79.43 (78.73–80.14)	78.47 (77.48–79.46)	78.94 (77.68–80.19)	84.64 (83.19–86.10)
Autumn	82.56 (81.80–83.32)	82.75 (81.84–83.65)	80.56 (79.35–81.76)	85.77 (82.64–88.91)
Winter	82.29 (81.77–82.82)	80.53 (79.79–81.28)	83.22 (82.33–84.10)	88.12 (87.06–89.18)

[a]The all school level prevalence is weighed based on the proportion of students in different school levels in 2019, with the prevalence for different school levels not being weighted.
[b]CI, confidence interval.

higher levels of PA observed among urban children and adolescents in China, compared to their rural counterparts, corroborate the assumptions posited by Cai et al. (28) and Song et al. (29) Specifically, urban youths benefit from greater accessibility to PA facilities and have more opportunities for organized PA. However, the notably higher amounts of RST among rural children and adolescents compared to their urban counterparts may primarily be attributable to the phenomenon of parents from rural China working away from their hometowns (33), resulting in less supervision and potentially more time spent on electronic devices by these children. Therefore, prioritizing the enhancement of PA for rural children and adolescents through increased opportunities for PA, and managing their RST through heightened supervision, should be emphasized in China.

In China, the Qinling-Huaihe Line serves as a crucial geographical and economic boundary. Regions north of this line typically experience more arid and colder climates, poorer air quality, and lower levels of economic development compared to the south (15, 34). This study found that children and adolescents in the southern regions are less likely to meet PA guidelines but more likely to adhere to RST guidelines than those in the north. Guthold et al.'s (5) research indicates that children in economically affluent regions engage in more PA due to greater opportunities for such activities. Contrary to these findings, our study reveals that children in the economically advanced south demonstrate lower levels of PA. We hypothesize that this discrepancy may be attributable to the higher precipitation in southern China (15), which indirectly reduces the PA of children and adolescents (35). The relationship between RST, economic status, and regional disparities is more complex. Studies have produced varied findings, for instance, research by Demetriou et al. (36) suggests that in regions with higher levels of economic development, children and

TABLE 3 Odds ratios for meeting PA and RST guidelines by gender, area, region, season, and school level.

	All school level	Primary school	Middle school	High school
Meeting PA guidelines (95% CI)				
Gender				
Male	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Female	0.570 (0.569–0.571)	0.646 (0.612–0.683)	0.548 (0.507–0.592)	0.324 (0.284–0.369)
Area				
Urban	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Rural	0.782 (0.780–0.783)	0.719 (0.666–0.775)	0.892 (0.809–0.983)	0.910 (0.761–1.089)
Region				
North	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
South	0.986 (0.985–0.987)	0.960 (0.906–1.017)	1.041 (0.935–1.160)	0.565 (0.467–0.683)
Season				
Spring	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Autumn	0.745 (0.744–0.746)	0.748 (0.699–0.801)	0.748 (0.681–0.821)	0.434 (0.322–0.584)
Winter	0.916 (0.914–0.917)	1.012 (0.944–1.084)	0.816 (0.742–0.898)	0.472 (0.387–0.577)
Meeting RST guidelines (95% CI)				
Gender				
Male	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Female	1.361 (1.360–1.363)	1.312 (1.230–1.400)	1.449 (1.333–1.574)	1.383 (1.197–1.599)
Area				
Urban	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Rural	0.897 (0.895–0.898)	0.978 (0.898–1.066)	0.738 (0.666–0.818)	1.217 (0.985–1.503)
Region				
North	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
South	1.096 (1.094–1.097)	1.143 (1.068–1.224)	0.906 (0.808–1.017)	0.786 (0.617–1.000)
Season				
Spring	1 [Reference]	1 [Reference]	1 [Reference]	1 [Reference]
Autumn	0.979 (0.977–0.981)	1.136 (1.048–1.232)	0.811 (0.733–0.896)	0.668 (0.471–0.948)
Winter	0.824 (0.822–0.825)	0.900 (0.830–0.975)	0.689 (0.621–0.764)	0.606 (0.471–0.779)

adolescents tend to have increased screen time (9). Conversely, Brodersen et al. (37) present findings that indicate more screen time among children and adolescents in regions with lower economic development. These differences could be related to the country where the study was conducted. In China, due to the pressures of entrance exams for high schools and colleges, affluent families typically enroll their children in various after-school tutoring classes (38). This leads to a reduction in their children's RST, which may explain why the duration of RST among children and adolescents in southern China is less than in the northern regions. Therefore, in assessing the status of PA and RST among children and adolescents in different regions and formulating intervention measures, it is crucial to take into account the local economic, environmental, and social conditions.

Global studies indicate seasonal variations in PA and RST, with lower PA and higher RST observed in winter and autumn compared to spring, primarily due to more favorable springtime weather for PA (39–41). This study's results confirm this, with children and adolescents surveyed in spring being more likely to meet both PA and RST guidelines compared to those surveyed in winter and autumn. This suggests that when weather conditions are less favorable, children's and adolescents' PA and RST should receive more attention, and conditions should be created to minimize the impact of climate on these behaviors, such as building more indoor activity spaces.

To our knowledge, this is the first study reporting on PA and RST among Chinese children and adolescents for the period 2017–2019, right before the pandemic. The study's strengths include its nationally representative sample and consistent survey tools across different years. Most importantly, it provides an essential update on the status of PA and RST among Chinese children and adolescents during 2017–2019.

Despite these contributions, this study has several limitations. First, the self-reported nature of the survey tools might not accurately capture the actual PA and RST of children and adolescents, potentially leading to deviations in the calculation of prevalence rates. Although these inaccuracies do not significantly alter our understanding of the distribution of PA and RST, future studies could employ more objective measures, such as triaxial accelerometers, to enhance accuracy. Second, the PA questionnaire used in our study lacks detailed information regarding the duration and frequency of activities. As a result, our calculations of PA prevalence were based on criteria from Voss's research, which limits their comparability with other studies. Future research should incorporate measures of intensity, frequency, and duration into PA assessment tools to improve reliability and comparability. Third, there were significant differences in the sample sizes across different seasons, although we used statistical methods such as adding weight variables to minimize the impact of these differences on the study results, caution is still needed when interpreting the season-related outcomes. Finally, as this study employs a cross-sectional design, it is unable to determine causality between school levels, urban–rural settings, regions, seasons, and PA or RST. Readers should bear this in mind when interpreting the results of this study.

5 Conclusion

From 2017 to 2019 in China, only 28.57% of children and adolescents adhered to the WHO's PA guidelines, whereas 81.61% met the RST guidelines of China and Canada. Notably, females, older students, rural residents, and those in southern regions exhibited lower levels of PA compared to their male, younger, urban, and northern counterparts. Simultaneously, males, younger students, rural residents, and those in northern regions had longer periods of RST compared to females, older students, urban dwellers, and children and adolescents from southern regions. Furthermore, it was observed that, compared to the spring, children and adolescents engage in less PA and more RST during the autumn and winter. Consequently, targeted efforts are essential to enhance PA among females, older students, rural residents, and southerners, while simultaneously reducing RST among males, younger students, rural residents, and northerners. Additionally, it is crucial to develop PA facilities that are not affected by climatic conditions to increase PA and reduce RST among this demographic group.

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 humans were approved by Human Experimentation Ethics Committee of East China Normal University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

MG: Data curation, Formal analysis, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing. YZ: Data curation, Writing – review & editing. XW: Conceptualization, Writing – review & editing.

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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 effects of physical activity on adolescents' depression: evidence from China

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Background: Depression is becoming a common threat to the mental health of Chinese adolescents. As an intermediate stage between being healthy and having depression, identifying factors influencing depressive may contribute to providing more options for the prevention and treatment of depression.

Objective: The study aims to explore the effects of physical activity on adolescent depression, focusing on the times and hours of activity per week.

Methods: The study used a cross-sectional dataset collected in Ruyang County, Henan Province in September 2022, including a sample of 5,629 adolescents in 31 compulsory public schools in the county. We utilized Ordinary Least Squares (OLS) to analyze the impact of physical activity on adolescents' depression scores, and probit model to analyze the influence of physical activity on adolescents' depression. To examine whether there is a U-shaped relationship between physical activity and depression, we included the squared terms of times and hours of activity in models.

Results: The results showed that: (1) The times of physical activity significantly reduces Chinese adolescent depression. An increase in physical activity by one time per week is associated with a mean decrease of 0.354 points in depression scores ($p < 0.01$). However, an increase of one time of physical activity per week is associated with an average 1% increase in the likelihood of experiencing depression($p < 0.05$), while the hours of physical activity was statistically insignificant. (2) Physical activity has a U-shaped (not linear) relationship with adolescent depression, with 7–8 times per week or 7–9 h of physical activity per week being the optimal range.

Conclusion: The study found that increasing the frequency of physical activity positively impacts adolescent depression, while increasing the hours does not show a significant association. Furthermore, a U-shaped relationship exists between times of activity, hours of activity, and adolescent depression, suggesting that moderate activity is optimal.

KEYWORDS

physical activity, depression, adolescents, China, CES-D scale

1 Introduction

Depression is becoming a common threat to the mental health of Chinese children and adolescents (Tepper et al., 2008). This concern stems from reports indicating that depression is increasingly becoming the predominant challenge among Chinese youth (Tepper et al., 2008). A comprehensive meta-analysis, encompassing over 230,000 Chinese children and adolescents, uncovered that a range of 10.3 to 54.5% of screened adolescents exhibited positive indications of depression, signaling a rising prevalence of depressive symptoms among this demographic (Li et al., 2019). As a transitional phase between being healthy and having depression, students with subthreshold depression may either progress to more severe depression or improve with preventive intervention (Jiang et al., 2019). Therefore, identifying more influences on depression may help provide more options for the prevention and treatment of depression.

There are many factors influencing adolescent depression, including academic stress (Zhu et al., 2021), physical activity (Stanton and Reaburn, 2014), sleep (Zou et al., 2023), and obesity (Wang et al., 2022), and adolescents' risk of depression varies by gender (Salk et al., 2017), grade, and region (rural or urban) differences exist (Li et al., 2019). A systematic evaluation study found that sleep deprivation increases the risk of depressive mood, while exercise decreases this risk (Pemberton and Fuller Tyszkiewicz, 2016).In a meta-analysis, it was found that females, higher grades, and rural adolescents exhibited a higher risk of developing depression (Li et al., 2019).

In recent years, research on the impact of physical activity on depression has gained increasing popularity (Pascoe and Parker, 2019; Laird et al., 2023). Several cross-sectional studies have demonstrated a correlation between poor physical activity and depression prevalence, particularly in low- and middle-income nations (Stubbs et al., 2016; Mc Dowell et al., 2018). Multiple prospective observational and cohort studies suggest that activity of any intensity can prevent depression, with greater physical activity associated with a lower likelihood of depression (Mammen and Faulkner, 2013; Schuch et al., 2018; Guo et al., 2022). Moderate to strenuous physical activity reduces the risk of psychological problems and suicidal ideation by reducing academic stress and increasing life satisfaction (Liu et al., 2020).

Current research consistently indicates that physical activity can complement standard treatments for individual depression, often improving depressive symptoms similarly to antidepressant medications and psychotherapy (Josefsson et al., 2014; Rebar et al., 2015). Adolescents who participate in aerobic exercise can significantly reduce their levels of stress, tension, or anxiety, thereby helping to alleviate negative emotions and prevent mental health issues (Hilyer et al., 1982; Khalsa et al., 2012; Edwards et al., 2017). Moderate to vigorous physical activity is closely associated with a reduced risk of depression, contributing to its prevention (McDowell et al., 2018). In treating and preventing adolescent depression, physical activity emerges as a more practical and acceptable option compared to psychotherapy and medication (Rohden et al., 2017; Hetrick et al., 2021).

The effect of physical activity or exercise on depression varies with different frequencies and durations (Wang et al., 2022). Most studies have found that there is a positive dose–response relationships between exercise duration/frequency and depressive symptoms improvement (Roeh et al., 2019). Adhering to current WHO guidelines for physical activity, which recommend 150–300 min per week (or a minimum of 30 min per day for 5 days per week) of moderate-intensity aerobic activity, was associated with a 28% lower risk of major depression (McDowell et al., 2018). In studies of adults, exercise frequency was also found to be negatively associated with depressive symptoms and overall well-being (Hassmén et al., 2000). Another study showed that there is an U-shaped relationship between the physical activity levels and mental health symptom relief in adolescents (Shimura et al., 2023).

It is important to emphasize that, although exercise is often used synonymously with physical activity in reports, their definitions should not be conflated (Budde et al., 2016). Physical activity is defined as any body movement generated by skeletal muscles, characterized by its modality, frequency, intensity, duration, and context of practice, with exercise being a subset of it (Budde et al., 2016). In this study, we focus on physical activity, providing evidence from Chinese adolescents[1] on the impact of times and hours of activity on depression. Additionally, by incorporating quadratic terms in our regression model, we further explore the nonlinear effects of physical activity on depression.

2 Materials and methods

2.1 Data collection

This study uses a cross-sectional dataset collected in September 2022 from Ruyang County, Henan Province. All participating students, their parents, and school teachers and principals were fully informed about the survey's purpose and agreed to participate.

The sample was collected using a multi-stage, stratified, random sampling procedure. It covers 31 primary and secondary schools across 11 towns in Ruyang County. The specific steps are as follows: first, one middle school and one primary school were randomly selected from each town, resulting in 11 primary schools and 10 middle schools (there is no public middle school in Sanlitun Town). Second, to ensure a high follow-up rate, fourth and fifth graders were selected from primary schools, and seventh and eighth graders were selected from middle schools. Finally, two fourth-grade and two fifth-grade classes were randomly selected from each primary school, and two seventh-grade and two eighth-grade classes were randomly selected from each middle school. All students in the selected classes were included in the sample.

The survey included student questionnaires, parent questionnaires, and school questionnaires. Students completed the questionnaires within a limited time on-site, with instructions from the surveyors. Parent questionnaires were conducted using Wenjuanxing (Wenjuanxing is an app designed as an online survey platform to assist users in creating, sharing, and analyzing survey questionnaires). School questionnaires were completed through interviews between surveyors and school principals. After ensuring the completeness and

1 The World Health Organization defines adolescence as the period between the ages of 10 and 19years, and this paper follows this definition, with the age of the sample falling within that age range and therefore defined as adolescents. For more details, see: https://www.who.int/topics/adolescent_health/en/.

TABLE 1 CES-D scale items and factors.

	Scale items	Factors
1	I was bothered by things usually do not bother me	Depressed mood
2	My appetite was poor	Somatic complaints
3	I felt that I could not shake off the blues even with help from my family or friends	Depressed mood
4	I felt I was just as good as others	Positive mood
5	I had trouble keeping my mind on what I was doing	Somatic complaints
6	I felt depressed	Depressed mood
7	I felt that everything I did was an effort	Somatic complaints
8	I felt hopeful about the future	Positive mood
9	I thought my life had been a failure	Depressed mood
10	I was fearful	Depressed mood
11	My sleep was restless	Somatic complaints
12	I was happy	Positive mood
13	I talked less than usual	Somatic complaints
14	I felt lonely	Depressed mood
15	People were unfriendly	Interpersonal
16	I enjoyed life	Positive mood
17	I had crying spells	Depressed mood
18	I felt sad	Depressed mood
19	I felt that people disliked me	Interpersonal
20	I could not get "going"	Somatic complaints

CES-D scale can only be used for screening depressive and cannot be used for diagnosis (Perreira et al., 2005).

validity of the questionnaires and excluding missing data and outliers, 5,629 observations were retained.

2.2 Variable selection

2.2.1 Dependent variables

The dependent variable in this study is calculated based on the Center for Epidemiologic Studies Depression Scale (CES-D). The depression measurement properties of the CES-D have been empirically tested and can assess samples of children and adolescents (The BELLA Study Group et al., 2008). The scale demonstrates adequate internal consistency, good content validity, and appropriate convergent and discriminant validity, making it a reliable self-report tool for detecting depression in Chinese children and adolescents (William Li et al., 2010; Dou et al., 2021; Zhu et al., 2021).

The CES-D is currently the only internationally disseminated test that uses a multidimensional approach to measure depressiveness in children and adolescents (The BELLA Study Group et al., 2008). The CES-D includes 20 standardized items for assessing depressive symptoms (see Table 1). These items encompass four factors: depressive affect, positive affect, somatic symptoms, and interpersonal relations. Respondents are asked to report the frequency of specific emotions they experienced over the past week, with scores ranging from 0 to 3. A score of "0" represents "rarely or less than 1 day," "1" represents "some of the time or 1–2 days," "2" indicates "a moderate amount of the time or 3–4 days," and "3" indicates "most or all of the time or 5–7 days." The total score for all items provides a measure of depressive tendency, ranging from 0 to 60, with higher scores indicating more severe depression (Zhu et al., 2021). Therefore, we selected the depression score as the primary measure of adolescent depression, calculated by summing the items on the CES-D scale, as shown in Table 1.

Based on relevant international and Chinese studies, this paper adopts the commonly used cutoff score of 16 to determine the presence of depressive tendencies (McKhann et al., 1997; Blumenthal et al., 2003; Jiang et al., 2019; Dou et al., 2021). In this study, depression is used as another dependent variable, when the score of depression≤15 indicates no depression, while the score of depression ≥16 indicates the presence of depression (Blumenthal et al., 2003). It is important to emphasize that the CES-D scale's classification of depression serves as a screening result and should not be used as a clinical diagnosis (Perreira et al., 2005).

2.2.2 Independent variables

Physical activity is our key independent variable.[2] We measured physical activity in terms of times of activity variables and hours of activity variables. The times of activity is measured by "How many times per week do you participate in physical activities (including badminton, soccer, long-distance running, etc.)?." The hours of activity is obtained by multiplying "On average, how long (in hours) do you participate in physical activity each time?" multiplied by times of activity, which represents the total amount of time a youth spends in physical activity during the week.

2.2.3 Control variables

Previous empirical studies have shown that many demographic variables are related to adolescent depression (Zhu et al., 2021; Zou et al., 2023), so we selected some demographic variables to control the variables. Individual characteristics control variables are as follows: gender, grade, household registration, the level of education of the father and mother. In addition, several studies have found that sleep deprivation increases the risk of depressive (Ojio et al., 2016; Li et al., 2020). Thus, we included the hours of sleep as a control variable to more objectively reflect the effect of physical activity on depression levels in adolescents. Table 2 shows all the variables and definitions of variables selected.

2.2.4 Descriptive statistical analysis of variables

The depression level, physical activity and demographic characteristics of the sample of 5,629 Chinese adolescents are shown in Table 2. Table 2 shows: the average depression score of adolescents was 14.608 (SD = 8.785); about 34.5% of adolescents exhibit varying degrees of depressive tendencies; adolescents engaged in about 2.208 times physical activities per week (SD = 1.596), and the hours of physical activity per week was 2.710 h (SD = 2.974), which is much lower than the number of hours recommended by the World Health Organization; and the average hours of sleep was more than 9 h

2 The WHO definition of physical activity is used in this paper. WHO defines physical activity as any bodily movement produced by skeletal muscles that requires energy expenditure. See: https://www.who.int/news-room/fact-sheets/detail/physical-activity.

TABLE 2 Definition of variables and descriptive results ($n = 5{,}629$).

Variable	Definition	Mean ± SD	min	max
Dependent variables				
Depression score	Denotes the total depression score calculated from the CES_D scale.	14.608 ± 8.785	0	56
Depression	When score of the CES_D scale less than 16 is no depression, depression =0, 1 otherwise.	0.345	0	1
Independent variables				
Times of activity	The times of activity times per week	2.208 ± 1.596	0	10
Hours of activity	The hours of activity per week	2.710 ± 2.974	0	20
Control Variables				
Hours of sleep	The hours of sleep per day	9.739 ± 1.572	6	15
Boy	boy = 1, girl = 0	0.514	0	1
Grade	grade(four, five, seven, eight)	5.799 ± 1.571	4	8
Rural	Whether household registration is in a rural area, 1 for yes, 0 otherwise	0.834	0	1
Edufather	Father's years of education	9.970 ± 2.584	0	16
Edumother	Mother's years of education	9.834 ± 2.951	0	16

Mean indicates the mean value. SD denotes standard deviation.

(Mean = 9.739, SD = 1.572), which is within the range recommended by the National Sleep Foundation and the Canadian recommendations of the 24-h physical activity guidelines for children and adolescents (Tremblay et al., 2016; Mireku and Rodriguez, 2021); there was little gender difference, with 83.4% of the sample coming from rural areas and parents with almost 9 years of education.

2.3 Methods

We used ordinary least squares (OLS) to analyze the effect of physical activity on adolescent depression score (Equation 1) and probit modeling to analyze the effect of physical activity on adolescent depression (Equation 2). In order to verify whether there is an U-shaped relationship between physical activity and depression, we used a quantile regression model for the analysis.

In addition, we incorporated school fixed effects into the model, aiding in controlling for unobserved school-related confounders such as school culture, instructional quality, and geographical location. In summary, the introduction of school fixed effects allows for a more precise reflection of the impact of physical activity on depression across various school environments.

The regression model established is as follows:

$$\text{depression score}_i = \alpha_0 + \alpha_1 X_i + \lambda Z + \text{Scool}_\text{j} + \varepsilon_i \quad (1)$$

$$\text{depression}_i = \beta_0 + \beta_1 X_i + \sigma Z + \text{Scool}_\text{j} + \mu_i \quad (2)$$

Where X_i is the independent variable, including times of activity and hours of activity; Z is the group of control variable (see Table 2); School_j is the school fixed effects.

To examine whether there is a U-shaped relationship between physical activity and depression, we included the squared terms of times of activity and hours of activity in models (1, 2). By analyzing the coefficients of both the linear and squared terms, we can determine the optimal weekly times and hours of physical activity. Specifically, we calculate the optimal values by dividing the coefficient of the linear term by twice the negative coefficient of the squared term (Shimura et al., 2023).

3 Results

3.1 Regression results

Regression results for the effect of physical activity on adolescent depression scores are given in Table 3. The results in Table 3 show that using the OLS method, times of activity was significantly negatively correlated with adolescent depression score, whether or not hours of sleep were controlled for ($p < 0.01$). However, when controlling for hours of sleep, hours of activity was negatively correlated with adolescent depression score, but this was not statistically significant ($\beta = -0.053$, $p = 0.172$). The results in column 1 of Table 3 indicate that after controlling for hours of sleep and other demographic characteristics, an increase in physical activity by one time per week was associated with a mean decrease of 0.354 points in depression scores ($\beta = -0.354$, $p < 0.01$).

The marginal effect of physical activity on the depression in adolescents using a probit regression model (see Table 4). The depression of adolescents decreased by an average of 1% when the times of activity increased by once a week, as shown in column 1 of Table 4. Our results indicate that times of activity significantly alleviated adolescent depression, whereas the relationship between the hours of activity and adolescent depression was not significant in either Table 3 or Table 4 without accounting for hours of sleep.

The regression results after adding the square term are shown in Table 5. The results in Table 5 indicate that there is a U-shaped relationship between physical activity and adolescent depression, suggesting that physical activity is not as good as more. Based on the formula for calculating the optimal weekly times and hours of physical activity (Shimura et al., 2023), we determined that the optimal times is 7.300–7.452 times per week ($-0.775/(2 \times 0.052) = 7.452$, $-0.073/$

TABLE 3 The effect of physical activity on depression score.

Variable	Depression score			
Times of activity	−0.354***	−0.391***		
	(0.075)	(0.068)		
Hours of activity			−0.041	−0.055
			(0.044)	(0.044)
Hours of sleep	−1.081***		−1.093***	
	(0.092)		(0.092)	
Boy	−0.414	−0.309	−0.455	−0.349
	(0.305)	(0.319)	(0.309)	(0.325)
Grade	−0.533	−0.473	−0.601*	−0.547
	(0.338)	(0.374)	(0.344)	(0.382)
Rural	−0.711*	−0.802*	−0.691*	−0.784*
	(0.356)	(0.432)	(0.348)	(0.424)
Edufather	−0.135**	−0.148**	−0.144**	−0.157***
	(0.056)	(0.056)	(0.056)	(0.056)
Edumother	−0.079*	−0.091*	−0.082*	−0.094**
	(0.044)	(0.045)	(0.043)	(0.044)
School fixed effects	Yes	Yes	Yes	Yes
Constant	31.396***	20.454***	31.287***	20.217***
	(1.949)	(1.802)	(1.981)	(1.828)
Observations	5,629	5,629	5,629	5,629
R-squared	0.067	0.035	0.063	0.031

Numbers in parentheses are robust standard errors clustered to the school level. "Yes" indicates that this factor was controlled for. ***$p < 0.01$. **$p < 0.05$. *$p < 0.1$.

TABLE 4 The marginal effects of physical activity on depression.

Variable	Depression			
Times of activity	−0.011**	−0.012***		
	(0.004)	(0.004)		
Hours of activity			−0.001	−0.001
			(0.002)	(0.002)
Hours of sleep	−0.047***		−0.047***	
	(0.004)		(0.004)	
Boy	−0.022	−0.017	−0.023*	−0.019
	(0.016)	(0.017)	(0.016)	(0.017)
Grade	−0.023	−0.020	−0.025	−0.023
	(0.017)	(0.018)	(0.017)	(0.019)
Rural	−0.027	−0.003	−0.025	−0.029
	(0.017)	(0.020)	(0.016)	(0.019)
Edufather	−0.005*	−0.006**	−0.006**	−0.006**
	(0.003)	(0.003)	(0.003)	(0.003)
Edumother	−0.003	−0.003	−0.003	−0.004
	(0.003)	(0.003)	(0.003)	0.003
School fixed effects	Yes	Yes	Yes	Yes
Observations	5,629	5,629	5,629	5,629

Numbers in parentheses are robust standard errors clustered to the school level. "Yes" indicates that this factor was controlled for. ***$p < 0.01$. **$p < 0.05$. *$p < 0.1$.

TABLE 5 Regression results of non-linear effects of physical activity on depression.

Variable	Depression score	Depression	Depression score	Depression
Times of activity	−0.775***	−0.073**		
	(0.216)	(0.035)		
Times of activity2	0.052**	0.005		
	(0.024)	(0.004)		
Hours of activity			−0.396***	−0.047***
			(0.120)	(0.017)
Hours of activity2			0.024***	0.003***
			(0.006)	(0.001)
Control variables	Yes	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes	Yes
Constant	31.768***	1.672***	31.740***	1.679***
	(1.957)	(0.306)	(1.950)	(0.304)
Observations	5,629	5,629	5,629	5,629

Numbers in parentheses are robust standard errors clustered to the school level. Times of activity2 and hours of activity2 are squared terms of times of activity and hours of activity, respectively. "Yes" indicates that this factor was controlled for. $*p<0.1$.$***p<0.01$. $**p<0.05$.

(2 × 0.005) = 7.300, Table 5, Columns 1 and 3, Figure 1). The optimal hours is 7.833–8.250 h per week (−0.396/(2 × 0.024) = 8.250, −0.047/(2 × 0.003) = 7.833, Table 5, Columns 2 and 4). Thus, our results suggest that the 7–8 times per week and 7–9 h of activity per week were found to be associated with optimal improvement in depression.

3.2 Heterogeneity analysis

Some studies have shown that there are significant differences in depressive symptoms among adolescents by gender, grade, and region (Lee et al., 2013; Wesselhoeft et al., 2013; Salk et al., 2017; Li et al., 2019). Therefore, we analyzed the effect of times of activity on depression score and depression across gender, grade, and region (see Tables 6, 7 for results). The regression coefficients in Table 6 show that there is a significant mitigating effect of times of activity on adolescent depression across gender, grade level, and region, and that times of activity has a greater mitigating effect on adolescent depression in boys, upper grades (junior high school students), and urban areas. The results in Table 7 show that times of activity has a significant effect on whether or not adolescents are depressed in boys and upper grades (junior high school students), with a greater mitigating effect on whether or not adolescents are depressed in urban areas.

4 Discussion

We found that the times of physical activity improved adolescent depression, while the relationship between the hours of physical activity and depression was not significant. This is similar to the results of Roeh et al. (2019) and Mead et al. (2009). It probably due to the fact that for adolescents, the shorter the effective duration of physical activity, the more likely to increase adolescents' motivation to participate in physical activity (Downs et al., 2013). Decreased energy levels are a characteristic symptom of depressed individuals for whom long-term sustained exercise may be too demanding. Although this study has similar results to the aforementioned studies, there are two key differences. First, our focus is on physical activity rather than exercise, and the two have different meanings (Budde et al., 2016). Second, our study differs from Roeh et al. (2019) in the definition and measurement of variables. In Roeh et al. (2019), the duration of exercise refers to the length of each exercise session, whereas we measure the total hours of activity over a week for adolescents (Roeh et al., 2019). Our results suggest that increasing the frequency of physical activity, rather than the total number of hours, is more effective in improving adolescent depression, which is consistent with the special emphasis in the "Healthy China 2030 Action Plan," which emphasizes that school-age children and adolescents should participate in no less than 60 min of in-school physical activity per day (as opposed to the total number of hours per week), and recommends that they should engage in moderate-intensity activity at least three times per week.[3] Approximately 170 million children and adolescents in China have inadequate levels of physical activity (Chen et al., 2020). This study therefore adds to the consensus that physical activity may have benefits for adolescent depression, and that increased physical activity has a very important role to play in the healthy growth and lifelong well-being of adolescents.

In addition, we found an U-shaped relationship between physical activity and depression in adolescents, suggesting that higher physical activity frequency is not better. This is similar to the findings of Chen et al. (2020) and Shimura et al. (2023), indicating that physical activity is not linearly associated with depression improvement (Chen et al., 2020; Shimura et al., 2023). In addition, several studies have confirmed that more activity is not always better, and that too much or too long and out of the optimal range of physical activity is detrimental to depression, i.e., optimal frequency of physical activity or duration of activity

3 Available: http://www.gov.cn/zhengce/2016-10/25/content_5124174.htm

TABLE 6 Results of the heterogeneity analysis of times of activity on depression score.

Variable	Depression score					
	Boy	Girl	Elementary	Junior	Rural	Urban
Times of activity	−0.399***	−0.262**	−0.348***	−0.376**	−0.351***	−0.401***
	(0.099)	(0.124)	(0.088)	(0.132)	(0.091)	(0.119)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	29.270***	33.025***	26.558***	30.180***	31.704***	32.201***
	(2.210)	(2.969)	(1.470)	(2.193)	(2.127)	(3.730)
Observations	2,893	2,736	3,219	2,410	4,697	932

Numbers in parentheses are robust standard errors clustered to the school level. Elementary denotes lower elementary students; junior denotes upper junior high school students. “Yes” indicates that this factor was controlled for. *$p<0.1$. ***$p<0.01$. **$p<0.05$.

TABLE 7 Results of the heterogeneity analysis of times of activity on depression.

Variable	Depression					
	Boy	Girl	Elementary	Junior	Rural	Urban
Times of activity	−0.046**	−0.009	−0.020	−0.047**	−0.031**	−0.033*
	(0.019)	(0.017)	(0.013)	(0.024)	(0.015)	(0.018)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
School fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.710***	1.475***	1.070***	1.305***	1.626***	2.277***
	(0.392)	(0.361)	(0.182)	(0.331)	(0.320)	(0.682)
Observations	2,893	2,736	3,219	2,410	4,697	932

Numbers in parentheses are robust standard errors clustered to the school level. Elementary denotes lower elementary students; junior denotes upper junior high school students. “Yes” indicates that this factor was controlled for. ***$p<0.01$. **$p<0.05$. *$p<0.1$.

should be maintained to improve neuroticism and enhance resilience thereby alleviating or protecting against depressive symptoms (Kuwahara et al., 2015; Chekroud et al., 2018; Kim et al., 2018; Shimura et al., 2023). We have found that while increased frequency of physical activity is associated with improved depression in adolescents, it may be counter-productive when exceeding the optimal range of physical activity of approximately seven to eight times per week and 7 to 9 h of activity per week, i.e., too frequent or too prolonged physical activity. To date, no guidelines or optimal goals have been developed for levels of physical activity that are effective in preventing depression. We must emphasize that we can only offer possible interpretations of these results. The findings of this study may help set the standard for further research.

The analysis of heterogeneity in Tables 6, 7 shows that increasing the times of physical activity has a significant ameliorating effect on the level of depression among adolescents of different genders, grades, and regions, and that there is some variability in the effect on whether adolescents are depressed or not. The differences between Tables 6, 7 may stem from differences in sample characteristics, and variable selection. It may be due to the fact that boys, upper grades and urban adolescents engage in more strenuous physical activity and therefore increase endorphin secretion, better adjusting the psyche thus reducing the level of depression (Bender et al., 2007; Goldfield et al., 2011). Therefore, we are going to need to take these factors into account to interpret these differences with caution.

Our study still has some limitations. First, the measurement of the dependent variable in this paper may be affected by individual subjective factors and have response bias, and cannot be used for accurate individual depression diagnosis, which can be combined with other clinical assessment tools and doctors' diagnosis to make a comprehensive judgment in the future study, so as to improve the accuracy of the measurement of depression in adolescents. Diagnosis to synthesize the judgment, thus improving the precision of measuring depression in adolescents. Second, due to the limited nature of the data, there were no data on activity intensity. Therefore, we only included times and hours of activity as a key influencing factor in this study, and future research could include more other influencing factors. Finally, cross-sectional data only allowed us to make possible interpretations of the causal relationship between physical activity and depression. Therefore, it is suggested that it could be supplemented as panel data in further future studies to assess the causal effect of physical activity on depression in adolescents.

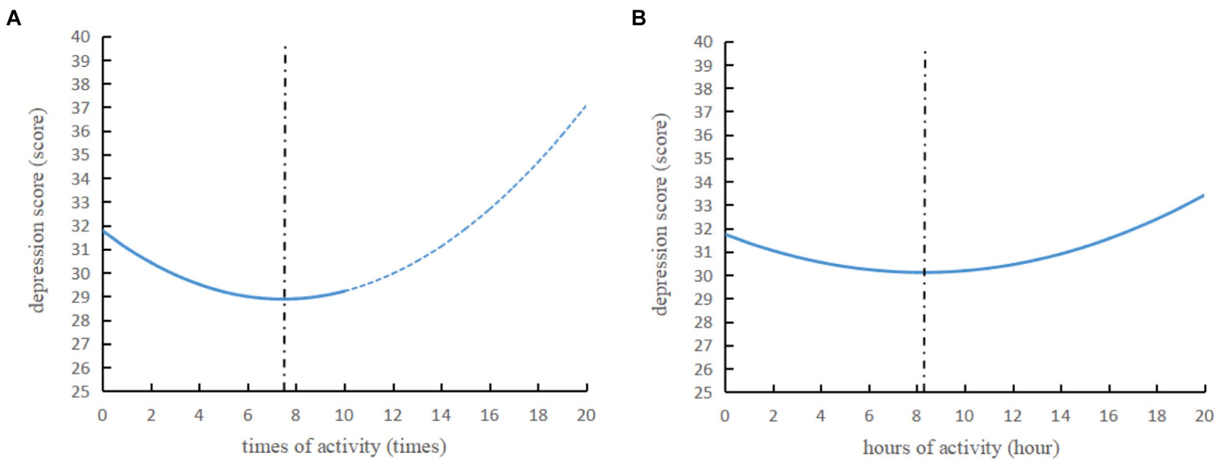

FIGURE 1
The optimal level of physical activity calculated from the results of the quadratic equation The curve formula in panel **(A)** is depression score = −0.775 × (times of activity) + 0.052 × (times of activity2) + 31.768, and the curve formula in panel **(B)** is depression score = −0.396 × (hours of activity) + 0.024 × (hours of activity2) + 31.740. The values of x range from 0 to 10 times. To better illustrate the U-shaped curve, values greater than 10 are shown with a blue dashed line. According to the quadratic function formula, the optimal activity times in panel **(A)** are calculated to be 7.452 times, and the optimal activity duration in panel **(B)** is calculated to be 8.250 h, indicated by a black vertical dashed line. Times of activity2 and hours of activity2 are squared terms of times of activity and hours of activity, respectively.

5 Conclusion

We explored the effects of physical activity on depression in a group of Chinese adolescents, using data from 5,629 cross-sectional studies. The results of the study reflect that increasing the times of activity is a positive factor in improving adolescent depression, but increasing the hours of physical activity was not significantly associated with adolescent depression. Therefore, we believe that adolescents should be encouraged to encourage the formation of a regular physical activity habit and increase the frequency of activity, which should preferably be spread out over several days per week rather than concentrated in 1 or 2 days.

Our results also illustrated that there is a U-shaped relationship between times of activity, hours of activity and depression. Therefore, we recommend that adolescents engage in physical activity 7 to 8 times and 7 to 9 h per week. Activity frequency and hours in this range are associated with improved depression, so moderate activity is key.

We found differences in the effects of physical activity on depression among adolescents of different genders, grades, and regions. Therefore, it is advisable to pay attention to the feedback and experiences of individuals and different groups and adjust the frequency and hours of activities to accommodate different needs and preferences. In addition, we can find that sleep has a significant mitigating effect on adolescent depression in all regression results. Therefore, it is important to recognize the influence of other factors (e.g., sleep duration) on depression in addition to physical activity. Incorporating these factors into intervention strategies can contribute to an integrated approach to improving adolescents' depression. Our findings and recommendations provide valuable guidance for parents, educators, and community organizations on effectively using physical activity to reduce the probability of depression in adolescents.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: the data is considered proprietary or under intellectual property rights, which restrict its distribution without permission. Requests to access these datasets should be directed to zhangyingcau@126.com.

Ethics statement

The studies involving humans were approved by China Agricultural University Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

HC: Data curation, Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing. ML: Data curation, Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing. WZ: Data curation, Formal analysis, Investigation, Writing – original draft. HW: Writing – original draft, Data curation, Formal analysis. YZ: Conceptualization, Data curation, Formal analysis, Methodology, Resources, Writing – review & editing. SL: Data curation, Formal analysis, Writing – review & editing, Conceptualization, Methodology, Resources.

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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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A mobile app-based intervention improves anthropometry, body composition and fitness, regardless of previous active-inactive status: a randomized controlled trial

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Introduction: The use of mobile apps to promote physical activity in adolescents can improve health-related parameters. However, previous studies have not evaluated whether the benefits depend on the users' prior active or inactive status. Therefore, the main objective was to analyze differences in physical activity levels, adherence to the Mediterranean diet (AMD), anthropometry, body composition, and physical fitness between active and inactive adolescents.

Methods: The study was conducted through a randomized controlled trial (RCT) with 462 adolescents, divided into experimental (EG) and control groups (CG), further categorized as active and inactive. Variables of physical activity, kinanthropometry, body composition, and physical fitness were measured before (pre-test) and after (post-test) a 10-week intervention using step-tracking apps (Strava, Pacer, MapMyWalk, and PokémonGo) at least three times per week.

Results: The results showed that inactive EG adolescents significantly increased their physical activity levels, body mass, and muscle mass, and improved in all fitness variables except the countermovement jump (CMJ). The sum of three skinfolds also significantly decreased. Active EG adolescents increased body and muscle mass and improved in all fitness variables. Additionally, they significantly reduced fat mass and the sum of three skinfolds. All covariates, mainly gender and maturity, had significant effects on the study variables. Comparing changes between the active EG and CG groups, significant differences were found in body mass index (BMI) and CMJ in favor of the EG. However, while significant differences were observed in the study variables when analyzing each app individually, there were no differences between the changes produced by each app in these variables.

Conclusion: After a 10-week program of physical activity promoted through step-tracking apps, improvements were observed in fat variables, cardiorespiratory fitness, and curl-up performance. Furthermore, only inactive adolescents perceived an increase in their level of physical activity. The measurement protocol was registered prior to the start of the intervention at ClinicalTrials.gov (code: NCT04860128).

KEYWORDS

adolescents, anthropometry, body composition, gender, healthy lifestyle, mobile phone, mobile application, physical activity

1 Introduction

Physical inactivity, is a concept that tends to be confused with sedentary lifestyle (1). This term is defined as the failure to meet the minimum guidelines on physical activity practice established by organizations such as the World Health Organization (WHO) or the American College of Sports Medicine (ACSM) (2). Although the scientific literature on the health benefits of physical activity is numerous, physical inactivity has grown exponentially in recent decades in the world population (3, 4). Thus, a high percentage of the world's population is currently considered inactive, with women accounting for a large part of this percentage (5, 6). As a consequence of the above, physical inactivity is currently the fourth leading cause of death in the world (2). In addition, is also one of the most determining factors in the prevalence of chronic diseases such as obesity, hypertension, diabetes, or metabolic syndrome, becoming one of the major public health problems (5, 7–9). Not surprisingly, it is estimated that given the consequences of physical inactivity on health, this factor generates a health expenditure of around 53.8 million euros/dollars worldwide (10).

This situation is especially relevant during adolescence, as it is a crucial stage for the establishment of physical activity, along with other healthy behaviors, preventing the onset of chronic diseases (7–9, 11). The adolescent population has been greatly affected by physical inactivity in recent years (12). In addition, puberty has become one of the critical stages in which a higher percentage of adolescents drop out of physical activity (13). The COVID-19 pandemic greatly contributed to this, as it drastically affected the period of movement of this population (14). The main consequences of the pandemic were the decrease in physical activity and the increase of screen time, resulting in an increase in physical inactivity and sedentary behaviors in adolescents (13, 15, 16). Although the confinement eventually ended, some of the unhealthy habits acquired by adolescents during the pandemic seem to persist (17). Thus, the pre-pandemic levels of physical activity have not been recovered in this population (18).

As a consequence of the above, 80% of adolescents currently do not meet the minimum physical activity recommendations established by the WHO (6). These recommendations include 60 min of moderate to vigorous intensity physical activity per day to promote physical fitness, a healthy anthropometry and body composition, and a greater adherence to the Mediterranean diet (AMD) (6, 19, 20). For children and adolescents, these recommendations can be undertaken as part of leisure and recreational activities, physical education, transport (cycling, walking and hiking) or household chores (21). Regarding transport, previous research has shown that walking between 11,500 and 14,000 steps per day is the optimal measure that corresponds to the recommendations for moderate to vigorous intensity physical activity (22). In addition, walking becomes relevant in this population because has shown that programs of 8 weeks or more can improve cardiorespiratory fitness, adherence to diet pattern and body mass index (BMI) in adolescents (21, 23, 24). This is because walking has been shown to increase physiological activity and the process of energy expenditure, with potential long-term weight control (25, 26).

Even with the wide variety of possibilities, the minimum levels of physical activity are not reached in the adolescent population, which is even more worrying for females and older adolescents, as this inactivity could affect their health status (27, 28). In this context, the subject of physical education during the compulsory education stage can contribute toward the acquisition of healthy lifestyle habits and the promotion of physical activity in the adolescent population (29–31). However, in Spain the educational curriculum only considers 2 h of physical education per week, which is insufficient to increase the time of motor engagement and comply with WHO recommendations (32, 33). For this reason, previous research has promoted the practice of school and out-of-school physical activity outside physical education hours. In this regard, active recess, physical activity programs in out-of-school leisure time, and active travel to school programs stand out (34–36). All of them have been shown to be effective strategies to increase the daily time dedicated to moderate to vigorous intensity physical activities in the adolescent population, allowing for a reduction in the rate of obesity (37, 38).

In recent years, the inclusion of mobile step-tracking apps has become a new trend in the interventions used to promote the practice of physical activity among adolescents (39, 40). These studies are characterized by two aspects: (a) the use of step tracker app through mobile phones in the classroom (41, 42); and (b) the use of these step tracker apps outside school hours (43). Regarding the former, the results have not been very encouraging, as they have shown the disadvantage that the step tracker mobile apps used are not designed for use in an educational center, limiting the possible benefits (44). Regarding the second aspect, it has shown significant benefits on the level of physical activity, physical fitness, kinanthropometry and body composition of adolescents, mainly when its use is promoted by the physical education subject (45, 46).

The usefulness of mobile apps for the promotion of physical activity in the adolescent population lies in the following reasons: (a) mobile phones are fully integrated in the lives of adolescents (47) and apps have proven to be useful for the generation of a healthy habit in which the mobile phone is a fundamental part (46); (b) one of the main reasons for the abandonment of physical activity programs is the lack of motivation of the participants (48), as many of them do not perceive themselves as sufficiently competent or autonomous during sport activities (49), so apps can solve this situation by enabling adolescents to practice autonomously and in activities of their own choice (50); (c) the possibility of interacting with other users through the app is another reason for using it (50), as the relationship with others is one of the main reasons for this population to practice physical activity (51); and (d) the use of the app promoted by the physical education subject in schools allows adolescents who take the intervention to obtain an academic reward, which provides greater motivation to continue using it due to the increase in external regulation (52), avoiding the initial abandonment of the intervention. In this way, mobile apps for the promotion of physical activity in adolescents could fulfill the key aspects of the theory of self-determination (53) by developing in adolescents a feeling of competent, autonomous and social relations, which could encourage adolescents to make more consistent use of these apps than other types of interventions that do not promote these three issues.

Despite the benefits found with the use of mobile applications promoted from the subject of physical education, this area of research has been under explored, and there are still many unknowns to be resolved (40, 45). Little is known about whether the previous level of physical activity of adolescents could be a determining factor in the use of step tracker mobile apps. This is because previous studies have shown differences in the effectiveness of physical activity intervention depending on the previous physical activity level of the adolescents (54). In this respect, a lower level of physical activity at the beginning of the intervention program, commonly measured by questionnaires recording physical activity in the last week, is related to higher effectiveness of intervention in adolescents (54–56). Only one previous study used step tracker mobile apps with inactive adolescents between 12 and 15 years of age, obtaining improvements in their cardiorespiratory fitness and decreasing their BMI (57). However, this research did not include a group of initially active adolescents to compare whether the benefits were truly superior in the initially inactive group.

Furthermore, although it has been found that the benefit of using this type of mobile application in physical education may be higher among females, and that it may depend on the number of steps taken, no studies have analyzed whether these factors may also differentiate between active and inactive students (58). In addition, one aspect that has not been considered in research conducted with mobile applications in adolescents is the effect that the maturational process may have on the changes observed. Thus, the duration of the interventions with mobile apps is not excessively long, varying between eight and 12 weeks, which leads to consider that the maturational process plays a fundamental role in the changes found in the adolescents, but there is no scientific evidence to contrast this (59, 60). On the other hand, it has been observed that the use of different mobile applications can lead to small changes in the different study variables. However, it is not known whether this could be affected by the level of physical activity of the adolescents who use them (61). Therefore, the objectives of the present research were: (a) to analyze the differences in the level of physical activity, AMD, anthropometry, body composition, and physical fitness of active and inactive adolescents achieved by a 10-week program of after-school use of step tracker mobile apps promoted from the physical education subject; and (b) to determine the influence of gender, maturity, the app used and the number of steps taken with the mobile apps on the study variables.

According to the aims of the present research, it is expected that the use of mobile step-tracking apps will be more effective on the study variables in inactive adolescents, since their starting level of physical activity is lower than that of active ones (H1); and that gender, maturity, app used and the number of steps taken with the mobile apps will influence the changes produced in the study variables after the use of the mobile apps (H2).

2 Materials and methods

2.1 Design

A randomized controlled trial (RCT) was conducted, consisting of a 10-week intervention in which step tracker mobile apps were used to promote physical activity in the adolescent population. An experimental group (EG) and a control group (CG) were used in the research. With the pre-test measurement of physical activity level, the EG and CG adolescents were divided into active and inactive according to the cut-off values of the "Physical Activity Questionnaire for Adolescents" (PAQ-A) (55). Participants were measured before starting the intervention (pre-test) and after finishing the intervention (post-test). In each measurement, the level of physical activity, kinanthropometric and body composition variables, AMD, and physical fitness were assessed. EG active and inactive participants used one of the step tracker mobile apps selected for the research (Strava, Pacer, MapMyWalk, and PokémonGo). The adolescents used the apps for 10 weeks, a minimum of three times per week, covering the proposed target distance for each week, which was incremental as the intervention progressed. The CG active and inactive adolescents did not use any step tracker mobile apps and continued to attend physical education classes as usual.

The study design followed the principles of the Declaration of Helsinki and was previously approved by the institutional committee of the Catholic University of Murcia (code: CE022102). In addition, the measurement protocol was registered prior to the start of the intervention at ClinicalTrials.gov (code: NCT04860128), and complied with the Consolidated Standards of Reporting Trials (CONSORT) guidelines (62).

The sampling was non-probabilistic by convenience. The intervention took place in two public centers of compulsory secondary education in the Region of Murcia. These centers had a high number of students enrolled in compulsory secondary education (more than 200 students per center). For their selection, the compulsory secondary school in the Region of Murcia with the largest sample of adolescents was contacted and, if the selected school did not wish to participate, the next public school with the largest number of students in compulsory secondary education would be chosen. However, the two centers initially contacted agreed to participate in the research. Once both centers were selected, a meeting was held with each management team to inform them of the research objectives and procedures. Once approval was received, a meeting was held with the teachers in charge of physical education and, subsequently, with the students and their parents. Participation was completely voluntary and the adolescents who were interested provided informed consent signed by themselves and their parents authorizing data collection and subsequent publication of the anonymous data.

2.2 Participants

To calculate the sample size, we used the methodology from previous studies based on the standard deviation (SD) (63). Thus, the SD of previous studies in which physical activity practice was promoted by means of step tracker mobile apps (SD = 0.66) was used (64). For an estimated error (d) of 0.06 and a confidence interval of 95% (95% CI), the minimum sample needed for conducting the study was 380 adolescents.

A total of 925 adolescents were potentially eligible between the two schools. The initial participation was 462 adolescents, with 430 adolescents participating in the research at the end (270 EG; 160 CG). The number of adolescents who were active and inactive at the beginning of the study was similar (209 active and 221 inactive). The participation of males and females was homogeneous (225 males and 205 females). The age of the adolescents was between 12 and 16 years (mean age: 13.76 ± 1.41 years). The sample selection flow diagram is shown in Figure 1.

The inclusion criteria were (a) age between 12 and 16 years old; (b) not presenting any disease or pathology that would hinder participation; and (c) attending compulsory secondary education. The exclusion criteria were (a) not regularly attending physical education classes during the school year (compulsory for more than 80% of the sessions); (b) not having a cell phone, among the adolescents in the EG; (c) changing educational center; (d) starting some type of systematic physical activity, understood as an activity performed more than three times a week for a duration of more than 60 min a day (such as a specific sport or going to the gym), but without considering the fact of starting to walk, since this was one of the objectives of the research; (e) abandoning the physical activities that were performed regularly before the beginning of the research; and (f) using one of the step tracker mobile apps designated for the research prior to the start of the research. Starting or abadoning any type of systematic physical activity was asked to adolescents in the post-test, together with the PAQ-A questionnaire. A specific question was included after the PAQ-A specifying what was meant by systematic physical activity, which adolescents were asked to answer dichotomously (yes or no).

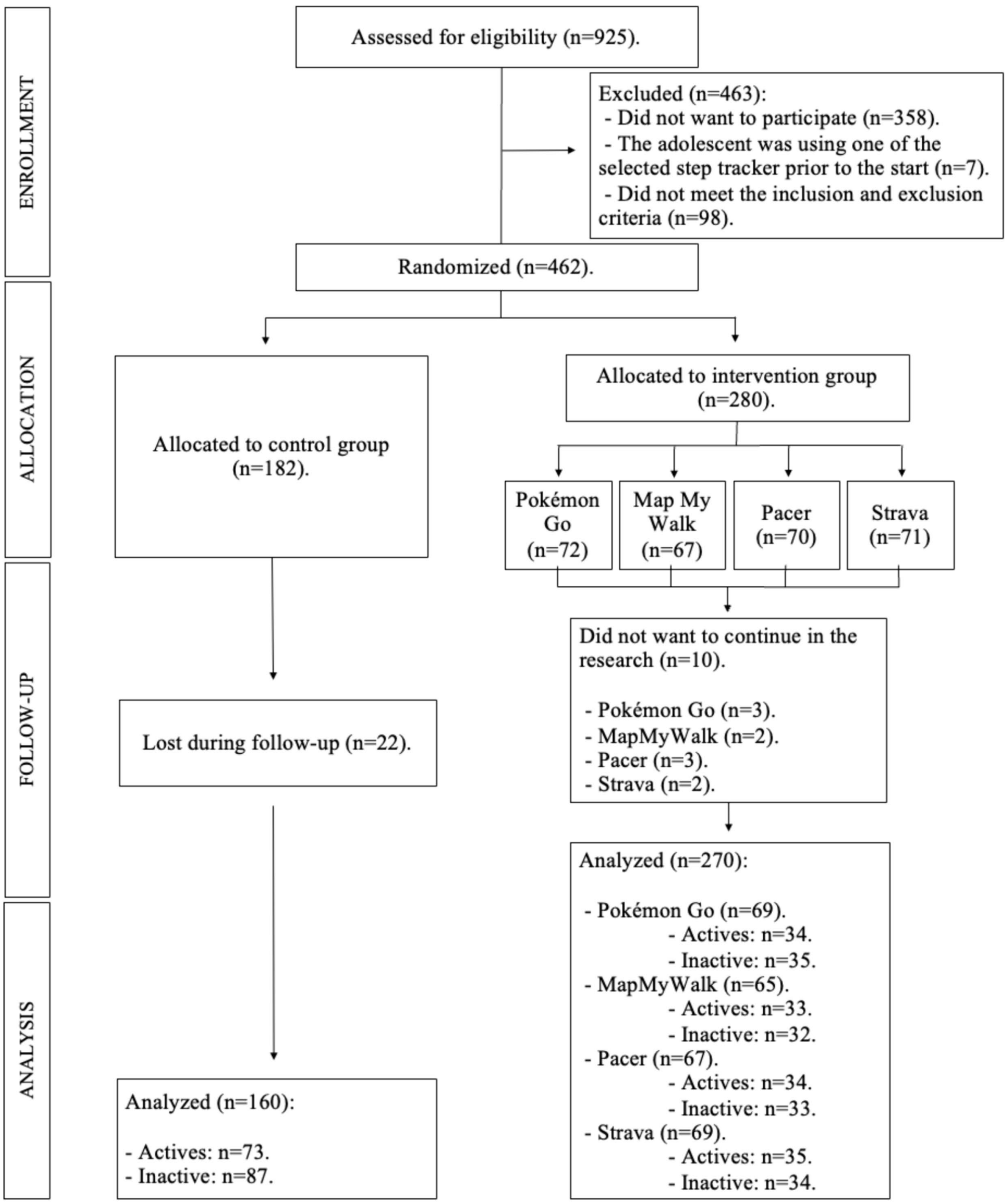

FIGURE 1
Flow diagram of the sample selection.

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2.3 Randomization and blinding

The randomization process was carried out by the principal investigator in the presence of other investigators not involved in the study, using a computer-generated random number table. For this purpose, the adolescents from each of the schools were randomized into EG and CG, so that in both schools there were adolescents from both groups, thus avoiding that the teaching plans proposed in each school in the physical education subject could contaminate the data. In addition, randomization was done by class, so that all adolescents belonging to that class became part of the CG or one of the EG groups. A second randomization was carried out in the EG to establish the step tracker mobile apps to be used by each of the classes (Strava, Pacer, MapMyWalk, PokémonGo). Four classes were randomly assigned to each application, achieving a homogeneous number of adolescents per step tracker mobile apps at the beginning of the intervention (Figure 1).

Pre-test measurements were performed after randomization. The researchers involved in the measurements were blinded as to which group each adolescent belonged to. They also did not know whether they were active or inactive at baseline, as this was determined after measurements for both EG and CG. In the post-test measurements, the researchers were blinded to whether the adolescents belonged to the EG or CG, to whether they were active or inactive before the start of the investigation, and to the score obtained by each adolescent in the pre-test measurements. The researchers in charge of monitoring the EG intervention were also blinded to the scores obtained by the adolescents in the measurements.

2.4 Instruments

The tests and instruments included are justified on the basis that previous research with mobile applications has shown significant changes in these variables (58, 61). However, the present study aims to determine whether there are differences in the effectiveness of the intervention in active and inactive adolescents. In addition, the inclusion of covariates in the present study will allow to determine whether gender, maturity status, app used and distance traveled with the app significantly influence the results, or whether the changes are the result of the intervention.

2.4.1 Questionnaire measurements

The "Physical Activity Questionnaire for Adolescents" (PAQ-A) was used to assess the level of physical activity in the adolescent population (65). This questionnaire is composed of 9 items. The arithmetic mean of the first eight items provides the final physical activity score. The ninth item allows to know if the adolescents had had any difficulty in performing physical activity during the week prior to completing the questionnaire. This questionnaire was used to determine active and inactive adolescents. Thus, adolescents were considered to be active when they scored 2.75 or higher on the PAQ-A, while they were considered inactive when they scored below 2.75 (55). This questionnaire was previously validated in an adolescent population and presents an intraclass correlation coefficient of 0.71 for the final score of the questionnaire (66).

AMD was assessed using the Mediterranean Diet Quality Index (KIDMED). This questionnaire is composed of 16 items that are completed with a 1 or 0 depending on whether the statement indicated is true (1) or not (0). Of the 16 items, 12 have a positive connotation (+1), favoring a good AMD, while four have a negative connotation (−1), hindering a good AMD. For this reason, the final score of the questionnaire ranges from 0 to 12 points, with a higher score referring to a better AMD. This questionnaire presents adequate reliability and reproducibility for use in the adolescent population ($\alpha = 0.79$ and kappa: 0.66) (67).

2.4.2 Kinanthropometric and body composition measurements

Adolescent body composition and anthropometry were measured by anthropometrists accredited by the International Society for the Advancement of Kinanthropometry (ISAK) (levels 3 to 4). The measurement consisted of body mass and height; triceps, thigh and leg skinfolds; and relaxed arm, waist, mid-thigh and leg girths (68). Kinanthropometric measurements were used to calculate the following variables: BMI, muscle mass, fat mass, sum of 3 skinfolds (triceps, thigh, and leg), corrected arm, thigh and calf girths, and waist-to-height ratio (waist girth/height) (69, 70).

All the measurements were performed following the protocol established by ISAK (68). A skinfold caliper (Harpenden, Burgess Hill, United Kingdom) with an accuracy of 0.2 mm was used to measure skinfolds; a Lufkin W606PM inextensible tape (Lufkin Industries) with an accuracy of 0.1 cm was used to measure girths; a TANITA BC 418-MA segmental scale (TANITA, Tokyo, Japan) with an accuracy of 100 g was used to measure body mass; and a SECA 213 stadiometer (SECA, Hamburg) with an accuracy of 0.1 cm was used to measure height. All instruments were calibrated prior to the pre- and post-test measurements. In the pre and post measurements, each anthropometrist measured the same subjects to minimize inter-rater error. Intra- and inter-evaluator technical measurement error (TME) was calculated in a subsample. For the basic measurements, the intra- and inter-evaluator TME was 0.03 and 0.05%, respectively; 1.23 and 1.99% for skinfolds, respectively; and 0.03 and 0.05% for perimeters, respectively.

The maturity offset was calculated according to the procedure established by Mirwald et al. and using gender-specific formulas: $-9.37 + 0.0001882 \times ((\text{height-sitting height}) \times \text{sitting height}) - 0.0022 \times (\text{age} \times (\text{height} - \text{sitting height})) + 0.005841 \times (\text{age} \times \text{sitting height}) - 0.002658 \times (\text{age} \times \text{weight}) + 0.07693 \times (\text{weight/height})$ (71). The result of the maturity offset equation is expressed in years from the age at peak height velocity (APHV) when the result is positive, and in years to the APHV when the result is negative (71).

2.4.3 Physical fitness test

Five researchers with previous experience in the supervision of physical fitness testing were in charge of the pre and post measurements. To avoid inter-rater bias, each test was assigned to a researcher and all adolescents were familiarized with the test prior to measurement.

The 20-m shuttle run test was used to assess the cardiorespiratory capacity of the participants (72). This is a maximal incremental test with high validity and reliability for use with adolescents (73). The test ends when the subject reaches exhaustion or is unable to complete the 20-m distance two consecutive times before the beep sounds. The last stage at which the subject finishes the test is used to predict maximal oxygen uptake (VO2 max) using the formula by Léger et al. (72).

To measure upper limb strength, two tests were carried out. First, the manual handgrip strength, which is considered a valid and reliable measurement in adolescents (74). The test requires adolescents to apply a maximum manual grip force with the elbow fully extended on a Takei Tkk5401, as this is the optimal position to produce the maximum force (75). All adolescents performed the test with both hands separately. Secondly, the push-up test was carried out. The test had a duration of 1 min. The number of final repetitions in which the elbow was fully extended and flexed during execution was counted (76).

Lower body power was measured using the countermovement jump (CMJ). The test was carried out on a force platform with a sampling frequency of 200 Hz (MuscleLab, Stathelle, Norway). The objective was to reach the highest vertical jump height. According to the guidelines in Barker et al., the hands were to be kept on the hips throughout the flight phase, the knees and ankles were to be fully extended and the adolescents were to keep their backs fully straight (77).

The curl-up test was used to assess the strength-resistance of the abdominal musculature. The adolescents had to perform as many trunk flexions as possible until they reached exhaustion, or until the end of 1 min. Those repetitions in which the upper back was no longer in contact with the ground were considered valid (78).

2.5 Measurement procedure

First, the adolescents completed the PAQ-A and the KIDMED. Subsequently, the kinanthropometric assessment was performed. Once finished, the adolescents were provided an explanation corresponding to the physical fitness tests and were familiarized with the execution of the handgrip, push up, CMJ, and curl up tests. Once the familiarization was completed, a progressive warm-up consisting of running and joint mobility involved in the physical fitness tests was performed, and two measurements of each of the tests were taken. The best score obtained was selected as the final value. Between repetitions of the same test, 2 min of rest were allowed, while 5 min were allowed between the different tests. The order in which the tests were conducted was randomized for each adolescent. Once the handgrip, push-ups, CMJ, and curl up tests were completed, a single repetition of the 20-m shuttle run test was performed, as this is a maximal incremental test whose fatigue may influence the performance of the rest of the tests. The recommendations by the National Strength and Conditioning Association (NSCA) were followed to establish the physical fitness assessment protocol, as it is based on the metabolic demands of each test, as well as the fatigue generated by the tests and the time required for recovery (79).

To minimize interference from possible contaminating variables, the pre- and post-test measurements were performed under as similar conditions as possible. Thus, to complete the PAQ-A and KIDMED questionnaires, a classroom in the school was used in which there was no noise, and the researchers only answered the adolescents' questions, but in no case did they influence their answers. The changing rooms of the sports hall were used for kinanthropometric measurements, and a stable temperature was maintained during all the measurements. The measurements were always taken between 8:30 a.m. and 2:30 p.m. using physical education class hours, so that each class group was measured in the pre- and post-test at the same time, to avoid the time of measurement inducing changes in kinanthropometric and body composition variables (80, 81). For the physical fitness tests, the covered sports pavilion was used to prevent the weather conditions from influencing the performance of the tests.

2.6 Mobile application intervention

The initial sample ($n = 462$) was divided into EG ($n = 280$) and CG ($n = 182$). The apps used by the EG adolescents were: Pokémon Go®, Pacer®, Strava®, and MapMyWalk®. For the use of the mobile applications, the adolescents carried their mobile device with them while walking the agreed distance for each day. The selection of this device was based on the fact that a high percentage of adolescents have a mobile device, but not all have watches or other wearables that could be used for the same purpose (82, 83).

Four different mobile apps were included to find out if there were significant differences between these when used by active and inactive adolescents. This is because previous research has shown that there may be small differences in the study variables when used in the general adolescent population (61). Four apps that included a high number of behavior change techniques were selected, based on previous studies, and that were available for android and apple, with the aim of finding out if there were differences between "similar" apps (84). In addition, the study design was not compromised as it is a small number of groups and covariates, being small the amount of information that can be lost during the execution (85). Since each school class consisted of a different number of adolescents, there were small sampling differences in EG adolescents at the beginning of the research (Pokémon Go: $n = 72$; MapMyWalk: $n = 67$; Pacer: $n = 70$; Strava: $n = 71$).

Prior to the start of the intervention, the adolescents of the EG were given a brief explanation of the application to be used and were shown how it worked and how to record the distance traveled. The adolescents then began the 10-week intervention in which they used the corresponding step tracker mobile apps after school hours a minimum of three times per week. Ten weeks was chosen because previous research has shown that interventions of short (6–12 weeks) and medium (12–26 weeks) duration are more effective than those of longer duration (more than 26 weeks) (86). Therefore, taking into account the academic year of the adolescents and the possibility to perform the pre- and post-test measurements, a duration of 10 weeks was chosen. The distance to be completed in each session was increased by 600 steps each week, starting with 7,100 steps per day in the first week and ending with 12,500 steps per day in the tenth week. This distance was used in previous research with step tracker mobile apps and was chosen because the target daily distance of the tenth week is the minimum distance established to stop being considered inactive (58, 87). Since the applications recorded the distance in kilometers, the adolescents were given the distance to be covered in kilometers (week 1: 4.57 km per session; week 10: 8.00 km per session), considering that 1 km corresponds to approximately 1,565 steps in this population (88). Regarding step tracker mobile apps, Pokémon Go was selected because it has been shown to be an effective game for increasing the level of physical activity and the number of daily steps in children and adolescents (89, 90); while Pacer, Strava and MapMyWalk were chosen because they include between 8 and 10 techniques for behavior change (84, 89, 90). The CG continued to attend physical education classes as normal and to perform the physical activity they were doing prior to the start of the investigation, but did not use any step tracker mobile apps. After 10 weeks of intervention, physical activity level, anthropometry, body composition and physical fitness of the CG and EG were measured again.

The use of the mobile applications was encouraged in the physical education course, with the adolescents who completed the intervention receiving up to one extra point in their final grade. This is similar to previous research and is due to the fact that rewards have been shown to be a great incentive to motivate adolescents in physical activity interventions (91, 92). Even so, not all EG adolescents completed the required distance each week, but they were not excluded from the research. These adolescents were measured at post-test and continued to be part of the *n* of the research. The intervention completion rate was different between applications. Of the 462 adolescents who initiated the study (Pokémon Go: $n=72$; Map My Walk: $n=67$; Pacer: $n=70$; Strava: $n=71$; CG: $n=182$), 430 completed the investigation (6.93% attrition). Of the adolescents who completed the research, 160 belonged to the control group (12.09% attrition), 69 to Pokémon Go (4.17% attrition), 65 to Map My Walk (2.99% attrition), 67 to Pacer (4.29% attrition) and 69 to Strava (2.82% attrition).

2.7 Statistical analysis

The normality of the variables was analyzed using the Kolmogorov–Smirnov test, and kurtosis and skewness analysis. As the data followed a normal distribution, parametric tests were used for analysis. Mean and standard deviation (M ± SD) were used as descriptive values for the sample. To analyze the differences in distance traveled depending on whether the adolescents were active or inactive, as well as on the mobile application used, a Student's *t*-test for independent samples and an ANOVA were used, respectively. Two Student's *t*-test for independent samples were performed to determine baseline differences in all the study variables between active and inactive adolescents, as well as between adolescents belonging to the EG and CG. A MANOVA was performed to analyze differences in the study variables between adolescents who were active and inactive and who belonged to the CG or EG. Subsequently, a MANCOVA was carried out including four covariates: gender (male or female), maturity (in years from the APHV), app used (Strava, Pacer, MapMyWalk, and Pokémon Go) and distance covered with the use of the app (based on steps taken during the study). An ANCOVA was performed to analyze whether the change observed in the EG between the pre- and post-test was significantly different from that observed in the CG, both in the active and inactive groups, including the covariate gender and maturity. And to analyze whether there were significant differences in the study variables between the different apps selected, firstly, a MANOVA was performed, taking into account the level of physical activity and the app used; and secondly, an ANOVA was performed to establish whether the change between pre-post in each app was significantly different from the change in the others. Partial Eta squared (η^2) was used to determine the effect size, and was defined as small: ES ≥ 0.10; moderate: ES ≥ 0.30; large: ≥ 1.2; or very large: ES ≥ 2.0, with an error of $p < 0.05$ (93). Statistical significance was established at $p < 0.05$. The statistical analysis was performed using the SPSS statistical package (v. 25.0; SPSS Inc., IL).

3 Results

The average distance traveled by the adolescents during the intervention was 146.73 ± 17.96 km. In the EG of active adolescents, the average distance traveled was 147.52 ± 19.24 km, while in the EG of inactive adolescents, the average distance traveled was 145.23 ± 16.78 km. Based on the application used, the average distance traveled by users was 146.91 ± 14.35 km on Pokémon Go, 148.27 ± 16.83 km on Strava, 148.64 ± 19.42 km on Pacer and 144.53 ± 17.65 km on MapMyWalk. There were no significant differences in distance traveled between the EG groups ($p=0.864$), nor between the different applications used ($p=0.657$).

At baseline, significant differences were found between active and inactive adolescents in physical activity level ($p<0.001$), AMD ($p=0.004$), corrected arm girth ($p=0.023$), corrected thigh girth ($p=0.002$), corrected calf girth ($p=0.003$), fat mass ($p<0.001$), sum of 3 skinfolds ($p<0.001$), muscle mass ($p<0.001$), VO2 max ($p<0.001$), handgrip (right: $p=0.003$; left: $p<0.001$), CMJ ($p=0.001$), curl up ($p=0.003$) and push up ($p<0.001$). No differences were found in body mass ($p=0.849$), height ($p=0.118$), waist-height ratio ($p=0.964$) or BMI ($p=0.430$).

By randomly dividing the active and inactive sample between EG and CG, the comparison between EG and CG at baseline showed no differences in physical activity level ($p=0.209$), body mass ($p=0.063$), height ($p=0.058$), BMI ($p=0.071$), waist/height ($p=0.997$), corrected arm girth ($p=0.512$), corrected thigh girth ($p=0.946$), corrected calf girth ($p=0.297$), fat mass ($p=0.083$), sum of 3 skinfolds ($p=0.065$), muscle mass ($p=0.781$), V02 max. ($p=0.144$), handgrip (right: $p=0.902$; left: $p=0.800$), CMJ ($p=0.950$), curl up ($p=0.893$) nor push up ($p=0.339$), but differences in AMD were found ($p<0.001$), with EG adolescents showing higher AMD before the start of the research.

3.1 Intra-group differences for active and inactive adolescents

Table 1 shows the differences between the pre- and post-test in the EG and CG of active and inactive adolescents. Thus, the EG of inactive adolescents showed a significant increase in the level of physical activity, as well as an increase in body mass, height, BMI, corrected arm girth, corrected thigh girth, muscle mass, Vo2 max, handgrip right and left hand, curl up and push up; while significantly decreasing the sum of 3 skinfolds after the intervention. As for the CG of inactive adolescents, a significant increase in physical activity level, body mass, BMI, corrected arm girth, corrected leg girth, muscle mass, Vo2 max and push-up was found after the 10-week period.

In the EG of active adolescents, a significant increase in body mass, height, corrected arm girth, corrected thigh girth, corrected leg girth, muscle mass, Vo2 max, handgrip right and left hand, CMJ, curl-up and push up was found; but the percentage of fat mass and the sum of 3 skinfolds decreased significantly after the training. In the CG of active adolescents there was a significant increase in body mass, height, BMI, corrected arm girth, corrected leg girth, muscle mass and handgrip left hand; however, the level of physical activity decreased significantly after the 10-week period.

TABLE 1 Pre and post-test differences in the physical activity level, adherence to Mediterranean diet, body composition and kinanthropometric variables, and physical fitness in active and inactive adolescents according to the group (intra-group differences).

Variable	Group	Pre	Post	Pre-post diff.	95% CI diff.	η²	*p*-value
Physical activity	EG-Inactive	2.19 ± 0.48	2.50 ± 0.52	−0.31 ± 0.05	−0.400; −0.221	0.105	<0.001
	CG-Inactive	2.17 ± 0.47	2.36 ± 0.71	−0.19 ± 0.06	−0.306; −0.070	0.024	0.002
	EG - Active	3.23 ± 0.35	3.21 ± 0.44	0.02 ± 0.05	−0.083; 0.126	0.001	0.688
	CG - Active	3.23 ± 0.39	3.03 ± 0.62	0.21 ± 0.06	0.091; 0.321	0.030	<0.001
AMD	EG-Inactive	6.49 ± 2.48	6.52 ± 2.40	−0.03 ± 0.22	−0.461; 0.402	0.001	0.894
	CG-Inactive	5.41 ± 2.44	5.39 ± 2.82	0.01 ± 0.29	−0.556; 0.581	0.001	0.965
	EG-Active	7.34 ± 2.31	7.25 ± 2.72	0.09 ± 0.26	−0.413; 0.592	0.001	0.728
	CG-Active	6.20 ± 2.59	6.10 ± 2.84	0.11 ± 0.28	−0.446; 0.663	0.001	0.701
Body mass	EG-Inactive	55.65 ± 13.23	56.60 ± 13.01	−0.95 ± 0.16	−1.270; −0.636	0.083	<0.001
	CG-Inactive	51.51 ± 9.29	52.14 ± 9.18	−0.63 ± 0.21	−1.046; −0.212	0.022	0.003
	EG-Active	55.23 ± 12.28	56.10 ± 12.18	−0.87 ± 0.19	−1.238; −0.501	0.053	<0.001
	CG-Active	53.42 ± 11.82	54.63 ± 11.71	−1.22 ± 0.21	−1.632; −0.803	0.079	<0.001
Height (cm)	EG-Inactive	162.23 ± 9.32	162.89 ± 9.14	−0.66 ± 0.14	−0.940; −0.389	0.055	<0.001
	CG-Inactive	160.07 ± 8.68	160.42 ± 8.77	−0.36 ± 0.19	−0.720; 0.006	0.010	0.054
	EG-Active	163.83 ± 8.79	164.67 ± 8.83	−0.84 ± 0.16	−1.159; −0.517	0.064	<0.001
	CG-Active	161.67 ± 8.81	162.60 ± 8.55	−0.38 ± 0.18	−1.289; −0.568	0.062	<0.001
BMI	EG-Inactive	21.07 ± 4.10	21.24 ± 3.96	−0.17 ± 0.06	−0.288; −0.043	0.018	0.008
	CG-Inactive	20.09 ± 3.24	20.29 ± 3.23	−0.20 ± 0.08	−0.365; −0.044	0.016	0.013
	EG-Active	20.55 ± 3.43	20.62 ± 3.30	−0.07 ± 0.07	−0.211; 0.074	0.002	0.344
	CG-Active	20.30 ± 3.43	20.57 ± 3.22	−0.27 ± 0.08	−0.426; −0.107	0.027	0.001
Waist-height	EG-Inactive	0.42 ± 0.05	0.42 ± 0.05	0.00 ± 0.00	−0.001; 0.004	0.004	0.193
	CG-Inactive	0.42 ± 0.04	0.42 ± 0.04	−0.00 ± 0.00	−0.005; 0.001	0.005	0.185
	EG-Active	0.42 ± 0.04	0.42 ± 0.04	0.00 ± 0.00	−0.001; 0.005	0.006	0.129
	CG-Active	0.42 ± 0.04	0.42 ± 0.04	0.00 ± 0.00	−0.001; 0.005	0.005	0.187
Corrected arm girth	EG-Inactive	20.69 ± 2.92	21.02 ± 2.66	−0.33 ± 0.08	−0.496; −0.168	0.040	<0.001
	CG-Inactive	20.30 ± 2.24	20.65 ± 2.21	−0.35 ± 0.11	−0.566; −0.127	0.024	0.002
	EG-Active	21.17 ± 2.61	21.69 ± 2.70	−0.52 ± 0.10	−0.704; −0.326	0.069	<0.001
	CG-Active	21.14 ± 3.01	21.56 ± 2.90	−0.42 ± 0.11	−0.629; −0.202	0.037	<0.001
Corrected thigh girth	EG-Inactive	38.71 ± 4.74	39.69 ± 4.63	−0.98 ± 0.20	−1.361; −0.593	0.061	<0.001
	CG-Inactive	38.24 ± 3.80	38.66 ± 3.54	−0.42 ± 0.26	−0.931; 0.095	0.007	0.110
	EG-Active	39.83 ± 4.54	40.73 ± 4.42	−0.90 ± 0.23	−1.341; −0.457	0.040	<0.001
	CG-Active	40.17 ± 5.96	40.65 ± 4.47	−0.48 ± 0.25	−0.982; 0.018	0.009	0.059
Corrected calf girth	EG-Inactive	28.65 ± 3.90	28.86 ± 2.82	−0.22 ± 0.16	−0.536; 0.102	0.005	0.182
	CG-Inactive	28.03 ± 2.23	28.56 ± 2.14	−0.53 ± 0.22	−0.958 -0.106;	0.015	0.015
	EG-Active	29.36 ± 2.73	29.93 ± 2.78	−0.57 ± 0.19	−0.935; −0.201	0.023	0.003
	CG-Active	29.31 ± 2.95	29.77 ± 2.88	−0.46 ± 0.21	−0.879; −0.048	0.012	0.029
Fat mass (%)	EG-Inactive	24.62 ± 10.84	24.12 ± 10.18	0.50 ± 0.29	−0.077; 1.076	0.007	0.089
	CG-Inactive	21.39 ± 9.21	21.40 ± 8.93	−0.01 ± 0.39	−0.780; 0.762	0.001	0.982
	EG-Active	20.32 ± 9.35	19.58 ± 8.66	0.75 ± 0.34	0.083; 1.411	0.013	0.028
	CG-Active	18.84 ± 10.51	18.26 ± 10.29	0.58 ± 0.38	−0.171; 1.331	0.006	0.130
Sum of 3 skinfolds	EG-Inactive	56.80 ± 28.42	54.96 ± 25.81	1.84 ± 0.78	0.314; 3.362	0.014	0.018
	CG-Inactive	47.79 ± 22.20	48.46 ± 21.87	−0.67 ± 1.04	−2.709; 1.365	0.001	0.517
	EG-Active	45.82 ± 23.60	43.94 ± 20.78	1.88 ± 0.89	0.121; 3.632	0.011	0.036
	CG-Active	42.10 ± 24.88	40.39 ± 23.19	1.72 ± 1.01	−0.267; 3.703	0.007	0.090

(Continued)

TABLE 1 (Continued)

Variable	Group	Pre	Post	Pre-post diff.	95% CI diff.	η^2	*p*-value
Muscle mass (kg)	EG-Inactive	17.40 ± 5.07	18.02 ± 4.96	−0.62 ± 0.11	−0.842; −0.393	0.071	<0.001
	CG-Inactive	16.94 ± 3.78	17.38 ± 3.74	−0.44 ± 0.15	−0.736; −0.136	0.021	0.005
	EG-Active	18.87 ± 4.79	19.67 ± 4.99	−0.81 ± 0.13	−1.066; −0.547	0.089	<0.001
	CG-Active	19.48 ± 5.06	19.99 ± 4.62	−0.51 ± 0.15	−0.802; −0.213	0.029	0.001
Vo2 Max	EG-Inactive	36.54 ± 4.29	37.50 ± 5.24	−0.95 ± 0.27	−1.476; −0.426	0.036	<0.001
	CG-Inactive	36.28 ± 3.94	37.05 ± 4.40	−0.77 ± 0.35	−1.458; −0.073	0.014	0.030
	EG-Active	40.02 ± 4.91	41.20 ± 5.63	−1.18 ± 0.31	−1.783; −0.577	0.041	<0.001
	CG-Active	40.93 ± 4.96	41.53 ± 4.82	−0.60 ± 0.36	−1.307; 0.099	0.008	0.092
Handgrip right hand	EG-Inactive	23.60 ± 7.80	24.92 ± 8.35	−1.33 ± 0.39	−2.092; −0.562	0.029	0.001
	CG-Inactive	23.13 ± 6.63	23.99 ± 6.90	−0.86 ± 0.51	−1.863; 0.151	0.007	0.096
	EG-Active	25.69 ± 7.26	27.38 ± 7.99	−1.69 ± 0.45	−2.580; −0.798	0.034	<0.001
	CG-Active	25.59 ± 7.62	26.48 ± 9.65	−0.89 ± 0.50	−1.877; 0.089	0.008	0.074
Handgrip left hand	EG-Inactive	21.94 ± 7.29	22.84 ± 7.10	−0.89 ± 0.30	−1.490; −0.292	0.021	0.004
	CG-Inactive	22.03 ± 6.11	22.40 ± 7.03	−0.37 ± 0.40	−1.159; 0.419	0.002	0.358
	EG-Active	24.43 ± 6.63	25.18 ± 7.64	−0.75 ± 0.36	−1.444; −0.049	0.011	0.036
	CG-Active	24.27 ± 7.15	25.26 ± 8.51	−0.99 ± 0.39	−1.760; −0.221	0.016	0.012
CMJ	EG-Inactive	20.89 ± 7.45	21.36 ± 8.60	−0.47 ± 0.68	−1.807; 0.869	0.001	0.491
	CG-Inactive	20.97 ± 6.85	21.88 ± 7.71	−0.91 ± 0.90	−2.674; 0.851	0.003	0.310
	EG-Active	23.50 ± 6.96	25.84 ± 6.22	−2.34 ± 0.79	−3.897; −0.780	0.022	0.003
	CG-Active	23.06 ± 8.08	23.14 ± 10.81	−0.08 ± 0.87	−1.802; 1.636	0.001	0.924
Curl up	EG-Inactive	19.25 ± 11.34	23.24 ± 9.79	−3.99 ± 0.93	−5.820; −2.165	0.045	<0.001
	CG-Inactive	18.00 ± 9.82	19.57 ± 10.52	−1.57 ± 1.21	−3.950; 0.811	0.004	0.196
	EG-Active	22.01 ± 11.55	25.91 ± 11.62	−3.90 ± 1.07	−6.006; −1.796	0.033	<0.001
	CG-Active	22.66 ± 12.25	24.32 ± 12.83	−1.66 ± 1.21	−4.039; 0.722	0.005	0.172
Push up	EG-Inactive	4.98 ± 7.62	6.43 ± 8.76	−1.45 ± 0.55	−2.534; −0.360	0.018	0.009
	CG-Inactive	5.40 ± 7.01	7.47 ± 8.19	−2.07 ± 0.72	−3.488; −0.642	0.021	0.005
	EG-Active	8.86 ± 10.85	10.89 ± 11.82	−2.03 ± 0.63	−3.272; −0.787	0.026	0.001
	CG-Active	10.27 ± 10.68	10.72 ± 11.11	−0.45 ± 0.73	−1.895; 0.989	0.001	0.537

BMI, body mass index; Sum of 3 skinfolds, summation of 3 skinfolds; Vo2 max, maximal oxygen consumption; CMJ, countermovement jump.

3.2 Influence of the covariates in the intra-group differences for active and inactive adolescents

Table 2 shows the influence of the covariates on the differences between pre and post of the different groups. The inclusion of the covariate gender showed significant influence on the EG evolution of inactive adolescents in the variables of physical activity, body mass, height, BMI, corrected arm girth, corrected thigh girth, muscle mass, sum of 3 skinfolds and all physical fitness variables, except CMJ. In the CG of inactive adolescents, the influence of this covariate was found in the evolution of level of physical activity, body mass, height, BMI, corrected arm girth, corrected leg girth, muscle mass, VO2 max and push-ups. In the EG of active adolescents, influence was observed in the evolution of body mass, height, corrected arm girth, corrected thigh girth, corrected leg girth, fat mass, the sum of 3 skinfolds, muscle mass and all the physical fitness variables. And in the CG of active adolescents, this covariate caused significant changes in the evolution of physical activity level, body mass, height, BMI, corrected arm girth, corrected thigh girth, corrected leg girth, muscle mass and handgrip. This covariate showed no influence on AMD in any of the groups analyzed.

The maturity covariate showed significant influence in EG of inactive adolescents in the evolution of body mass, height, BMI, corrected arm and thigh girths, muscle mass, handgrip right and left hand and push-ups. In the CG inactive, this covariates influenced in the evolution of body mass, BMI, corrected arm girth, muscle mass, handgrip right and left hands and push-ups. In the EG active, the influence of this covariate was observed in the evolution of body mass, height, corrected arm and thigh girths, muscle mass, handgrip right and left hands and push-ups. And in the CG active, the influence was significant in the evolution of body mass, height, BMI, corrected arm and thigh girths, muscle mass, handgrip right and left hands, and push-ups. However, this covariate did not show influence in the evolution of physical activity, AMD, waist-height, corrected calf-girth, fat mass, sum of 3 skinfolds, VO2 max., CMJ nor curl up (Table 2).

TABLE 2 Influence of the covariates gender, maturity, app used and distance covered with the app on the intra-group differences for active and inactive adolescents.

Variable	Group	Gender			Maturity			App used			Distance covered with the app		
		95% CI diff.	η^2	*p*-value	95% CI diff.	η^2	*p*-value	95% CI diff.	η^2	*p*-value	95% CI diff.	η^2	*p*-value
Physical activity	EG-Inactive	−0.410; −0.227	0.105	<0.001	−0.410; −0.225	0.035	0.341	−0.397; −0.187	0.070	<0.001	−0.406; −0.221	0.101	<0.001
	CG-Inactive	−0.308; −0.071	0.025	0.002	−0.301; −0.062	0.022	0.538	–	–	–	–	–	–
	EG - Active	−0.081; 0.128	0.001	0.658	−0.086; 0.125	0.000	0.714	−0.080; 0.170	0.001	0.484	−0.088; 0.125	0.001	0.729
	CG - Active	0.099; 0.337	0.032	<0.001	0.091; 0.328	0.030	0.402	–	–	–	–	–	–
AMD	EG-Inactive	−0.514; 0.371	0.001	0.752	−0.482; 0.402	0.000	0.857	−0.584; 0.429	0.000	0.765	−0.470; 0.421	0.001	0.914
	CG-Inactive	−0.563; 0.574	0.001	0.985	−0.492; 0.653	0.000	0.782	–	–	–	–	–	–
	EG - Active	−0.403; 0.604	0.001	0.695	−0.426; 0.583	0.000	0.759	−0.573; 0.631	0.000	0.924	−0.419; 0.606	0.001	0.721
	CG - Active	−0.403; 0.744	0.001	0.559	−0.381; 0.755	0.001	0.518	–	–	–	–	–	–
Body mass	EG-Inactive	−1.336; −0.687	0.088	<0.001	−1.394; −0.756	0.102	<0.001	−1.273; −0.533	0.056	<0.001	−1.311; −0.658	0.083	<0.001
	CG-Inactive	−1.059; −0.226	0.023	0.003	−0.983; −0.159	0.019	0.007	–	–	–	–	–	–
	EG-Active	−1.222; −0.485	0.051	<0.001	−1.238; −0.513	0.055	<0.001	−1.246; −0.368	0.033	<0.001	−1.274; −0.523	0.054	<0.001
	CG-Active	−1.553; −0.694	0.064	<0.001	−1.476; −0.641	0.060	<0.001	–	–	–	–	–	–
Height (cm)	EG-Inactive	−1.050; −0.491	0.071	<0.001	−1.086; −0.539	0.081	<0.001	−0.927; −0.283	0.010	0.076	−0.969; −0.400	0.055	<0.001
	CG-Inactive	−0.741; −0.024	0.011	0.037	−0.639; 0.066	0.007	0.111	–	–	–	–	–	–
	EG-Active	−1.126; −0.492	0.061	<0.001	−1.156; −0.535	0.069	<0.001	−1.145; −0.381	0.007	0.105	−1.184; −0.530	0.064	<0.001
	CG-Active	−1.128; −0.388	0.040	<0.001	−1.093; −0.378	0.041	<0.001	–	–	–	–	–	–
BMI	EG-Inactive	−0.292; −0.041	0.017	0.009	−0.317; −0.068	0.023	0.003	−0.313; −0.027	0.010	0.054	−0.290; −0.037	0.016	0.011
	CG-Inactive	−0.366; −0.043	0.016	0.013	−0.352; −0.031	0.014	0.020	–	–	–	–	–	–
	EG-Active	−0.211; 0.074	0.002	0.348	−0.211; 0.072	0.002	0.332	−0.244; 0.095	0.002	0.391	−0.212; 0.078	0.002	0.367
	CG-Active	−0.431; −0.098	0.025	0.002	−0.394; −0.068	0.020	0.006	–	–	–	–	–	–
Waist-height	EG-Inactive	−0.001; 0.004	0.006	0.142	−0.001; 0.004	0.005	0.183	0.000; 0.005	0.007	0.097	−0.001; 0.004	0.003	0.321
	CG-Inactive	−0.005; 0.001	0.004	0.200	−0.005; 0.001	0.005	0.180	–	–	–	–	–	–
	EG-Active	−0.001; 0.005	0.006	0.141	−0.001; 0.005	0.006	0.129	0.000; 0.006	0.009	0.064	−0.001; 0.004	0.004	0.203
	CG-Active	−0.001; 0.005	0.003	0.309	−0.001; 0.005	0.004	0.221	–	–	–	–	–	–
Corrected arm girth	EG-Inactive	−0.489; −0.152	0.035	<0.001	−0.510; −0.174	0.040	<0.001	−0.538; −0.157	0.012	0.065	−0.494; −0.156	0.036	<0.001
	CG-Inactive	−0.563; −0.124	0.024	0.002	−0.563; −0.122	0.024	0.002	–	–	–	–	–	–
	EG-Active	−0.707; −0.329	0.070	<0.001	−0.702; −0.321	0.068	<0.001	−0.759; −0.309	0.004	0.101	−0.701; 0.316	0.066	<0.001
	CG-Active	−0.656; −0.212	0.037	<0.001	−0.629; −0.188	0.034	<0.001	–	–	–	–	–	–

(Continued)

TABLE 2 (Continued)

Variable	Group	Gender			Maturity			App used			Distance covered with the app		
		95% CI diff.	η²	*p*-value	95% CI diff.	η²	*p*-value	95% CI diff.	η²	*p*-value	95% CI diff.	η²	*p*-value
Corrected thigh girth	EG-Inactive	−1.322; −0.535	0.053	<0.001	−1.345; −0.559	0.056	<0.001	−1.444; −0.552	0.004	0.137	−1.370; −0.579	0.058	<0.001
	CG-Inactive	−0.918; 0.109	0.006	0.122	−0.943; 0.087	0.007	0.103	–	–	–	–	–	–
	EG-Active	−1.354; −0.469	0.041	<0.001	−1.341; −0.451	0.039	<0.001	−1.452; −0.399	0.005	0.169	−1.348; −0.446	0.038	<0.001
	CG-Active	−1.081; −0.042	0.012	0.034	−1.062; −0.030	0.011	0.038	–	–	–	–	–	–
Corrected calf girth	EG-Inactive	−0.559; 0.095	0.005	0.164	−0.588; 0.065	0.006	0.116	−0.644; 0.096	0.005	0.146	−0.499; 0.157	0.003	0.307
	CG-Inactive	−0.963; −0.109	0.016	0.014	−0.941; −0.086	0.014	0.059	–	–	–	–	–	–
	EG-Active	−0.932; −0.196	0.023	0.003	−0.935; −0.195	0.011	0.073	−1.078; −0.203	0.011	0.054	−0.900; −0.152	0.020	0.006
	CG-Active	−0.871; −0.007	0.010	0.046	−0.840; 0.017	0.009	0.060	–	–	–	–	–	–
Fat mass (%)	EG-Inactive	−0.047; 1.136	0.008	0.071	−0.080; 1.102	0.008	0.090	−0.136; 1.204	0.006	0.118	−0.227; 0.957	0.004	0.226
	CG-Inactive	−0.768; 0.776	0.001	0.993	−0.789; 0.762	0.000	0.973	–	–	–	–	–	–
	EG-Active	0.070; 1.401	0.012	0.030	0.069; 1.409	0.012	0.051	−0.001; 1.582	0.010	0.051	−0.048; 1.300	0.009	0.069
	CG-Active	−0.275; 1.287	0.004	0.203	−0.214; 1.340	0.005	0.155	–	–	–	–	–	–
Sum of 3 skinfolds	EG-Inactive	0.332; 3.459	0.015	0.018	0.361; 3.486	0.015	0.076	0.058; 3.598	0.011	0.053	0.100; 3.239	0.011	0.037
	CG-Inactive	−2.697; 1.386	0.001	0.528	−2.755; 1.342	0.001	0.498	–	–	–	–	–	–
	EG-Active	0.103; 3.622	0.011	0.038	0.104; 3.645	0.008	0.118	−0.228; 3.956	0.008	0.081	−0.063; 3.513	0.009	0.059
	CG-Active	−0.441; 3.688	0.006	0.123	−0.434; 3.670	0.006	0.122	–	–	–	–	–	–
Muscle mass (kg)	EG-Inactive	−0.848; −0.386	0.068	<0.001	−0.846; −0.387	0.068	<0.001	−0.886; −0.364	0.022	0.106	−0.831; −0.368	0.064	<0.001
	CG-Inactive	−0.737; −0.135	0.021	0.005	−0.737; −0.135	0.021	0.005	–	–	–	–	–	–
	EG-Active	−1.067; −0.546	0.088	<0.001	−1.067; −0.546	0.089	<0.001	−1.125; −0.507	0.046	0.067	−1.055; −0.525	0.083	<0.001
	CG-Active	−0.814; −0.201	0.027	0.001	−0.810; −0.206	0.028	0.001	–	–	–	–	–	–
Vo2 Max	EG-Inactive	−1.696; −0.645	0.053	<0.001	−1.516; −0.438	0.036	0.084	−1.419; −0.200	0.020	0.009	−1.404; −0.312	0.027	0.002
	CG-Inactive	−1.508; −0.150	0.017	0.017	−1.413; −0.013	0.012	0.066	–	–	–	–	–	–
	EG-Active	−1.728; −0.546	0.040	<0.001	−1.789; −0.574	0.041	0.057	−1.719; −0.285	0.022	0.006	−1.724; −0.499	0.036	<0.001
	CG-Active	−0.921; 0.512	0.001	0.574	−1.291; 0.157	0.007	0.124	–	–	–	–	–	–
Handgrip right hand	EG-Inactive	−2.303; −0.743	0.036	<0.001	−2.125; −0.554	0.028	<0.001	−1.724; −0.939	0.020	0.103	−2.068; −0.488	0.025	0.002
	CG-Inactive	−1.892; 0.113	0.008	0.082	−1.886; 0.150	0.011	0.044	–	–	–	–	–	–
	EG-Active	−2.523; −0.749	0.032	<0.001	−2.659; −0.866	0.037	<0.001	−2.382; −1.259	0.025	0.062	−2.554; −0.737	0.031	<0.001
	CG-Active	−1.613; 0.407	0.003	0.241	−1.925; 0.094	0.006	0.035	–	–	–	–	–	–

(Continued)

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TABLE 2 (Continued)

Variable	Group	Gender			Maturity			App used			Distance covered with the app		
		95% CI diff.	η^2	*p*-value	95% CI diff.	η^2	*p*-value	95% CI diff.	η^2	*p*-value	95% CI diff.	η^2	*p*-value
Handgrip left hand	EG-Inactive	−1.595; −0.367	0.024	0.002	−1.490; −0.257	0.019	0.006	−1.891; −0.489	0.017	0.076	−1.527; −0.289	0.021	0.004
	CG-Inactive	−1.174; 0.404	0.002	0.338	−1.134; 0.464	0.002	0.040	–	–	–	–	–	–
	EG-Active	−1.420; −0.024	0.010	0.043	−1.469; −0.062	0.012	0.033	1.954; −0.287	0.021	0.069	−1.473; −0.049	0.011	0.036
	CG-Active	−1.652; −0.062	0.011	0.035	−1.832; −0.248	0.017	0.010	–	–	–	–	–	–
CMJ	EG-Inactive	−2.087; 0.652	0.003	0.303	−1.925; 0.767	0.002	0.398	−1.900; 1.242	0.000	0.681	−1.664; 1.097	0.001	0.687
	CG-Inactive	−2.714; 0.805	0.003	0.287	−2.240; 1.250	0.001	0.578	–	–	–	–	–	–
	EG-Active	−3.829; −0.714	0.020	0.004	−3.678; −0.605	0.005	0.106	−3.031; −0.296	0.013	0.073	−3.760; −0.584	0.018	0.007
	CG-Active	−1.487; 2.059	0.001	0.751	−1.684; 1.776	0.000	0.958	–	–	–	–	–	–
Curl up	EG-Inactive	−5.640; −1.897	0.039	<0.001	−5.053; −1.347	0.019	0.071	−6.166; −1.884	0.034	<0.001	−5.676; −1.879	0.038	<0.001
	CG-Inactive	−3.906; 0.856	0.004	0.209	−4.232; 0.515	0.006	0.125	–	–	–	–	–	–
	EG-Active	−6.065; −1.850	0.034	<0.001	−5.899; −1.718	0.012	0.134	−6.460; −1.423	0.024	0.002	−5.865; −1.557	0.029	0.001
	CG-Active	−4.474; 0.453	0.007	0.109	−5.002; −0.167	0.011	0.086	–	–	–	–	–	–
Push up	EG-Inactive	−2.745; −0.519	0.021	0.004	−2.836; −0.614	0.024	0.002	−2.460; 0.065	0.009	0.063	−2.525; −0.266	0.015	0.016
	CG-Inactive	−3.538; −0.693	0.022	0.004	−3.285; −0.427	0.017	0.011	–	–	–	–	–	–
	EG-Active	−3.227; −0.742	0.025	0.002	−3.348; −0.861	0.029	<0.001	−3.197; −0.241	0.014	0.053	−3.257; −0.715	0.024	0.002
	CG-Active	−1.637; 1.364	0.001	0.858	−1.560; 1.386	0.011	0.007	–	–	–	–	–	–

BMI, body mass index; Sum of 3 skinfolds, summation of 3 skinfolds; Vo2 max, maximal oxygen consumption; CMJ, countermovement jump.

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The covariate app used showed influence in the EG inactive in the involution of physical activity, body mass, VO2 max. and curl up, while in the EG active the differences were significant in the evolution of body mass, VO2 max. and curl up. And the inclusion of the covariable distance covered with the app showed significant influence on the EG of inactive adolescents in the evolution of the variable physical activity, body mass, height, BMI, corrected arm girth, corrected thigh girth, sum of 3 skinfolds, muscle mass and all the physical fitness test, except CMJ. In the EG of active adolescents, influence was observed on the evolution of body mass, height, corrected arm girth, corrected thigh girth, corrected calf girth, muscle mass and all the physical fitness test. Neither of the two covariates showed any influence on AMD in any of the groups analyzed (Table 2).

3.3 Inter-group differences (EG vs. CG) in intra-group differences for active and inactive adolescents

Table 3 shows the differences in the change showed by EG and CG in both the active and inactive adolescent groups. The results showed significant differences in the group of active adolescents in BMI, with the change observed being greater in the CG, with a significant effect of the covariates gender and maturity. In the case of the CMJ test for active group, a greater change was found in EG compared to CG, without influence of the covariates. No significant differences were found in the rest of the variables analyzed. Thus, the difference between the intra-group change in EG and CG was not significant for physical activity level and AMD. Neither was it significant for kinanthropometric variables or body composition (body mass, height, waist-height, corrected girths, fat mass, sum of 3 skinfolds or muscle mass), nor for fitness variables (VO2 max, handgrip left and right hands, curl-up or push-up). The covariates gender and maturity also showed no effect on the variables for which the analysis of change was not statistically significant.

3.4 Differences in the study variables in the groups of active and inactive adolescents according to the app used

Table 4 shows the pre-post differences for each of the variables according to the different mobile apps used by active and inactive adolescents. There was a significant increase in the level of physical activity in the inactive group with all the apps ($p < 0.001–0.032$). In body mass, there was an increase in Strava ($p < 0.001$), Pacer ($p = 0.003$) and MapMyWalk ($p = 0.007$) inactives, as well as in Pokémon Go ($p = 0.003$) and Strava ($p < 0.001$) actives. Significant increases occurred in all groups in height ($p < 0.001–0.049$), except in the MapMyWalk actives group ($p = 0.105$). In corrected arm girth there was a significant increase in Pacer ($p = 0.009$) and MapMyWalk ($p = 0.011$) inactives, as well as in Pokémon Go ($p < 0.001$), Strava ($p = 0.006$) and MapMyWalk ($p = 0.004$) actives. In the corrected thigh girth the significant increase occurred in the group of Strava ($p = 0.004$) and Pacer ($p < 0.001$) inactives, as well as in Strava actives ($p = 0.025$). And in corrected calf girth, a significant increase was recorded in the inactive Pacer ($p = 0.024$) and active Strava ($p = 0.012$). Only a significant decrease in fat mass ($p = 0.011$) and sum of 3 skinfolds ($p < 0.001$) was recorded in the inactive Pacer participants. In contrast, muscle mass increased significantly in all groups analyzed ($p < 0.001–0.049$). Regarding fitness tests, a significant increase in V02 max was found in Pacer inactive ($p = 0.001$) and Strava active ($p < 0.001$). Regarding the handgrip, there was an increase in the active and inactive Pacer ($p < 0.001$), as well as in the active Strava ($p = 0.010$). In curl-up, there was a significant increase in performance in those active and inactive on Strava ($p < 0.001$) and in those inactive on MapMyWalk ($p = 0.014$). And, in push-up, there was a significant improvement in those active ($p = 0.013$) and inactive ($p = 0.028$) from Pokémon Go. Despite the results obtained, Table 5 shows that the analysis of the change between the different applications did not show significant differences in any of the analyzed variables.

4 Discussion

4.1 Main results of the present research

The first objective of the present research was to analyze the differences in the level of physical activity, AMD, anthropometry, body composition, and physical fitness of active and inactive adolescents achieved by a 10-week program of after-school use of step tracker mobile apps promoted from the physical education subject. The results showed that there was no difference in the distance traveled by the adolescents with the use of the mobile application depending on whether they were active or inactive, nor depending on the app used. Regarding the perceived level of physical activity, there were significant increases in both inactive groups (EG and CG) and in the active CG, while in AMD there were no significant differences in either group between the pre- and post-test. In the kinanthropometric and body composition variables, the results showed significant increases in body mass, height, BMI, corrected girths and muscle mass in all the groups. Furthermore, in active and inactive adolescents, a decrease in fat mass and in the sum of 3 skinfolds was observed in the EGs. Regarding the physical fitness variables, the EGs of active and inactive adolescents showed improved performance in all the physical fitness tests, with the exception of the CMJ in the inactive group.

The second objective of the research was to determine the influence of gender, maturity, the app used, and the number of steps taken with the mobile apps on the study variables. Gender showed a significant effect on the kinanthropometric and body composition variables, physical fitness test and physical activity level of the active and inactive adolescents in CG and EG. The maturity status seemed to influence the body mass and height, the muscle mass variables and most physical fitness test in all the groups. According to the app used, this covariate influenced the level of physical activity of inactive adolescents, as well as the body mass, VO2 max and curl up of active and inactive adolescents. And the covariate distance covered with the app showed significant influence in the physical activity, body mass, height, BMI, corrected arm girth, corrected thigh girth, sum of 3 skinfolds, muscle mass and all the physical fitness test, except CMJ, on the inactive adolescents; as well as in the body mass, height, corrected arm girth, corrected thigh girth, corrected calf girth, muscle mass and all the physical fitness test on the active adolescents.

Despite the results obtained, the analysis of the change in the differences found in the study variables in the EG and CG in both the active and inactive groups showed that only the change in BMI was significantly greater in the CG than in the EG, with a significant

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TABLE 3 Inter-group differences (EG vs. CG) in the intra-group differences for active and inactive groups.

Variable	Group	Pre-post EG – pre-post CG				Gender covariate			Maturity covariate		
		Diff.	95%CI diff.	η^2	*p*-value	95%CI diff.	η^2	*p*-value	95%CI diff.	η^2	*p*-value
Physical activity	Inactives	−0.07 ± 0.07	−0.206; 0.072	0.003	0.343	−0.208; 0.071	0.003	0.337	−0.213; 0.069	0.003	0.314
	Actives	−0.11 ± 0.07	−0.256; 0.036	0.007	0.138	−0.262; 0.036	0.007	0.136	−0.265; 0.032	0.007	0.124
AMD	Inactives	0.27 ± 0.34	−0.395; 0.927	0.002	0.429	−0.409; 0.917	0.002	0.452	−0.357; 0.981	0.003	0.360
	Actives	0.04 ± 0.35	−0.655; 0.734	0.001	0.911	−0.700; 0.716	0.001	0.982	−0.610; 0.801	0.000	0.790
Body mass	Inactives	−0.40 ± 0.27	−0.932; 0.131	0.006	0.139	−0.972; 0.090	0.008	0.103	−1.038; 0.030	0.010	0.064
	Actives	0.46 ± 0.28	−0.096; 1.021	0.008	0.104	−0.211; 0.922	0.005	0.218	−0.227; 0.899	0.004	0.242
Height (cm)	Inactives	−0.22 ± 0.21	−0.628; 0.186	0.003	0.286	−0.686; 0.107	0.006	0.152	−0.768; 0.030	0.010	0.069
	Actives	0.08 ± 0.22	−0.347; 0.507	0.001	0.713	−0.526; 0.320	0.001	0.632	−0.522; 0.319	0.001	0.635
BMI	Inactives	0.02 ± 0.11	−0.206; 0.240	0.001	0.882	−0.210; 0.239	0.001	0.899	−0.235; 0.216	0.000	0.936
	Actives	0.26 ± 0.12	0.022; 0.491	0.014	0.032	0.011; 0.489	0.012	0.040	−0.013; 0.463	0.010	0.044
Waist-height	Inactives	0.00 ± 0.00	−0.001; 0.007	0.006	0.172	−0.001; 0.007	0.006	0.151	−0.001; 0.007	0.006	0.169
	Actives	0.00 ± 0.00	−0.004; 0.005	0.000	0.846	−0.004; 0.005	0.000	0.705	−0.004; 0.005	0.000	0.825
Corrected arm girth	Inactives	0.06 ± 0.15	−0.246; 0.356	0.001	0.720	−0.237; 0.367	0.001	0.672	−0.259; 0.350	0.000	0.769
	Actives	−0.05 ± 0.16	−0.368; 0.265	0.001	0.750	−0.346; 0.298	0.001	0.883	−0.385; 0.259	0.000	0.702
Corrected thigh girth	Inactives	−0.59 ± 0.36	−1.292; 0.105	0.008	0.095	−1.272; 0.129	0.008	0.110	−1.231; 0.181	0.006	0.144
	Actives	−0.49 ± 0.37	−1.220; 0.247	0.005	0.193	−1.174; 0.320	0.004	0.262	−1.147; 0.342	0.003	0.289
Corrected calf girth	Inactives	0.40 ± 0.30	−0.186; 0.990	0.005	0.179	−0.204; 0.976	0.005	0.199	−0.250; 0.939	0.004	0.255
	Actives	0.01 ± 0.31	−0.609; 0.626	0.001	0.978	−0.665; 0.594	0.001	0.913	−0.689; 0.565	0.000	0.846
Fat mass (%)	Inactives	0.36 ± 0.53	−0.684; 1.403	0.001	0.499	−0.657; 1.437	0.002	0.464	−0.677; 1.438	0.001	0.480
	Actives	−0.01;0.56	−1.108; 1.085	0.001	0.984	−1.047; 1.187	0.001	0.902	−1.102; 1.130	0.000	0.980
Sum of 3 skinfolds	Inactives	1.999 ± 1.41	−0.780; 4.778	0.006	0.158	−0.739; 4.841	0.006	0.149	−0.696; 4.933	0.007	0.140
	Actives	0.04 ± 1.48	−2.882; 2.958	0.001	0.979	−2.799; 3.152	0.001	0.907	−2.785; 3.154	0.000	0.903
Muscle mass (kg)	Inactives	−0.16 ± 0.20	−0.563; 0.249	0.002	0.447	−0.568; 0.248	0.002	0.441	−0.547; 0.275	0.001	0.516
	Actives	−0.33 ± 0.22	−0.752; 0.102	0.007	0.135	−0.767; 0.103	0.007	0.134	−0.733; 0.135	0.005	0.176
Vo2 Max	Inactives	−0.43 ± 0.45	−1.312; 0.453	0.003	0.339	−1.420; 0.316	0.005	0.212	−1.337; 0.451	0.003	0.331
	Actives	−0.57 ± 0.47	−1.492; 0.362	0.004	0.231	−1.818; 0.035	0.011	0.059	−1.525; 0.362	0.004	0.226
Handgrip right hand	Inactives	−0.39 ± 0.56	−1.491; 0.708	0.001	0.484	−1.544; 0.662	0.002	0.432	−1.407; 0.818	0.001	0.603
	Actives	−0.61 ± 0.59	−1.762; 0.550	0.003	0.303	−1.912; 0.440	0.005	0.219	−1.661; 0.687	0.002	0.415
Handgrip left hand	Inactives	−0.50 ± 0.43	−1.337; 0.341	0.004	0.244	−1.365; 0.319	0.004	0.222	−1.266; 0.430	0.003	0.333
	Actives	0.50 ± 0.45	−0.378; 1.385	0.004	0.262	−0.461; 1.335	0.003	0.339	−0.293; 1.496	0.005	0.187

(Continued)

TABLE 3 (Continued)

Variable	Group	Pre-post EG – pre-post CG				Gender covariate			Maturity covariate		
		Diff.	95%CI diff.	η^2	*p*-value	95%CI diff.	η^2	*p*-value	95%CI diff.	η^2	*p*-value
CMJ	Inactives	0.48 ± 0.69	−0.864; 1.830	0.001	0.481	−0.933; 1.765	0.001	0.545	−0.752; 1.972	0.002	0.379
	Actives	1.57 ± 0.72	0.151; 2.982	0.014	0.030	−0.052; 2.827	0.011	0.059	0.285; 3.159	0.016	0.069
Curl Up	Inactives	−2.48 ± 1.66	−5.735; 0.780	0.007	0.136	−5.676; 0.864	0.006	0.149	−5.145; 1.401	0.004	0.261
	Actives	−1.84 ± 1.74	−5.258; 1.588	0.003	0.292	−5.133; 1.843	0.003	0.354	−4.547; 2.360	0.001	0.534
Push Up	Inactives	0.69 ± 0.95	−1.181; 2.551	0.002	0.471	−1.298; 2.436	0.001	0.549	−1.539; 2.210	0.000	0.725
	Actives	−1.30 ± 1.00	−3.264; 0.658	0.005	0.192	−3.601; 0.381	0.007	0.113	−3.708; 0.248	0.009	0.086

BMI, body mass index; Sum of 3 skinfolds, summation of 3 skinfolds; Vo2 max, maximal oxygen consumption; CMJ, countermovement jump.

influence of the covariates gender and maturity; and that the changes in CMJ were greater in the EG than in the CG, with a significant influence of the covariate maturity. It should also be noted that, although there were differences between the changes caused by the four apps when analyzing pre-post intra-group differences, there were no inter-group differences in the changes generated by the different apps.

4.2 Explanation of the changes found in the study variables

According to the kinanthropometric and body composition variables, one of the main findings of the present investigation was the decrease in fat mass and in the sum of 3 skinfolds in active and inactive adolescents of the EGs, without significant changes in active and inactive adolescents of the CGs. This could lead to consider that the interventions with step tracker mobile apps can slightly reduce the accumulation of fat mass in the adolescent population, regardless of the initial level of physical activity of the adolescents. Thus, the increased physical activity performed by the adolescents in the EG would increase their energy expenditure, which would favor the loss of fat mass, as observed in previous research (94). However, it should be noted that the active adolescents in the EG did not report a significant increase in the physical activity performed. This could be due to the fact that when recording this variable by means of a self-completed questionnaire, these students did not perceive that going for a walk three times a week increased the daily physical activity performed.

In terms of muscle mass variables, both active and inactive EG and CG adolescents showed significant increases after the intervention, which leads to consider that the changes were not solely due to the intervention performed with the step tracker mobile apps. The fact that participants used aerobic applications where no strength-endurance training was performed leads one to believe that changes in muscle mass were not generated by the intervention (95). Therefore, a possible explanation for these results could be that the maturation process in which adolescents are immersed was the cause of the changes in muscle mass variables, which explains why changes in muscle mass variables also occurred in the CGs (96). Puberty is a key stage in adolescent musculoskeletal development, and is characterized by increases in the accumulation of sex steroid hormones such as testosterone or growth hormone (96–98). This increase in hormone concentration is highly correlated with increased muscle mass, as well as increased strength production (99–101).

Similarly, the observed changes in height and body mass in all the groups could be due to the maturational process (102). Previous research has shown that the maximum peak growth (APHV) occurs in girls between the ages of 11.4 and 12.2, and in boys between 13.8 and 14.4 years of age increasing in height during these ages at a rate of 9–10.3 cm per year (60, 103, 104). Body mass is also affected during this stage, increasing by 8.3 kg per year in girls and 9 kg per year in boys (105, 106). Furthermore, changes in height and body mass would be the cause of the changes in BMI, which would explain why this variable was modified in all groups. However, despite being a widely used index in previous scientific literature it does not allow distinguishing whether the changes are due to changes in fat mass or muscle mass (107, 108).

TABLE 4 Intra-group differences in the study variables in the groups of active and inactive adolescents according to the app used.

Variable	Group	Pokémon Go			Strava			Pacer			MapMyWalk		
		Diff.	η^2	p-value	Diff.	η^2	p-value	Diff	η^2	p-value	Diff.	η^2	p-value
Physical activity	Inactives	−0.33 ± 0.01	0.027	0.001	−0.38 ± 0.08	0.051	<0.001	−0.28 ± 0.09	0.026	0.001	−0.21 ± 0.10	0.012	0.032
	Actives	−0.01 ± 0.10	0.000	0.917	0.04 ± 0.10	0.001	0.648	0.12 ± 0.11	0.003	0.279	−0.09 ± 0.13	0.001	0.457
AMD	Inactives	−0.48 ± 0.48	0.003	0.311	−0.05 ± 0.39	0.000	0.905	0.43 ± 0.42	0.003	0.305	−0.21 ± 0.48	0.000	0.664
	Actives	1.03 ± 0.47	0.012	0.058	−0.42 ± 0.36	0.002	0.362	−0.26 ± 0.53	0.001	0.625	−0.33 ± 0.60	0.001	0.581
Body mass	Inactives	−0.56 ± 0.35	0.007	0.107	−1.25 ± 0.29	0.046	<0.001	−0.91 ± 0.31	0.022	0.003	−0.95 ± 0.35	0.019	0.007
	Actives	−1.04 ± 0.35	0.023	0.003	−1.33 ± 0.34	0.039	<0.001	−0.19 ± 0.39	0.001	0.629	−0.68 ± 0.44	0.006	0.125
Height (cm)	Inactives	−0.59 ± 0.30	0.010	0.042	−0.45 ± 0.26	0.008	0.049	−1.08 ± 0.27	0.041	<0.001	−0.47 ± 0.30	0.006	0.049
	Actives	−0.90 ± 0.30	0.023	0.003	−1.18 ± 0.29	0.041	<0.001	−0.77 ± 0.34	0.013	0.025	−0.39 ± 0.38	0.003	0.105
BMI	Inactives	0.04 ± 0.13	0.000	0.785	−0.34 ± 0.11	0.023	0.053	−0.09 ± 0.12	0.001	0.467	−0.20 ± 0.13	0.006	0.133
	Actives	−0.17 ± 0.13	0.004	0.195	−0.18 ± 0.13	0.005	0.153	0.32 ± 0.15	0.012	0.062	−0.16 ± 0.17	0.002	0.348
Waist-height	Inactives	−0.00 ± 0.00	0.000	0.830	−0.00 ± 0.00	0.001	0.529	−0.00 ± 0.00	0.011	0.250	−0.00 ± 0.00	0.001	0.551
	Actives	−0.00 ± 0.00	0.002	0.377	−0.00 ± 0.00	0.000	0.910	−0.00 ± 0.00	0.005	0.175	−0.00 ± 0.00	0.004	0.235
Corrected arm girth	Inactives	−0.29 ± 0.18	0.007	0.108	−0.24 ± 0.15	0.007	0.116	−0.42 ± 0.16	0.018	0.009	−0.46 ± 0.18	0.017	0.011
	Actives	−0.60 ± 0.18	0.029	<0.001	−0.48 ± 0.17	0.020	0.006	−0.33 ± 0.20	0.007	0.106	−0.66 ± 0.23	0.021	0.004
Corrected thigh girth	Inactives	−0.81 ± 0.42	0.010	0.055	−1.02 ± 0.36	0.021	0.004	−1.30 ± 0.38	0.030	<0.001	−0.57 ± 0.42	0.005	0.181
	Actives	−0.81 ± 0.42	0.010	0.052	−0.92 ± 0.41	0.013	0.025	−0.85 ± 0.47	0.008	0.073	−0.98 ± 0.54	0.009	0.068
Corrected calf girth	Inactives	−0.53 ± 0.35	0.006	0.131	0.53 ± 0.29	0.008	0.072	−0.71 ± 0.31	0.013	0.024	−0.40 ± 0.35	0.003	0.254
	Actives	−0.46 ± 0.34	0.005	0.182	−0.72 ± 0.34	0.005	0.012	−0.50 ± 0.39	0.004	0.199	−0.56 ± 0.44	0.004	0.206
Fat mass (%)	Inactives	0.37 ± 0.63	0.001	0.553	0.10 ± 0.53	0.000	0.846	1.44 ± 0.57	0.017	0.011	0.00 ± 0.63	0.000	0.996
	Actives	1.19 ± 0.62	0.010	0.056	0.20 ± 0.61	0.000	0.745	0.28 ± 0.71	0.000	0.695	1.50 ± 0.80	0.009	0.062
Sum of 3 skinfolds	Inactives	1.45 ± 1.66	0.002	0.384	0.93 ± 1.39	0.001	0.506	5.03 ± 1.49	0.029	<0.001	−0.63 ± 1.66	0.000	0.705
	Actives	3.18 ± 1.63	0.010	0.052	0.09 ± 1.60	0.000	0.958	0.92 ± 1.86	0.001	0.620	3.92 ± 2.10	0.009	0.063
Muscle mass (kg)	Inactives	−0.68 ± 0.25	0.020	0.006	−0.41 ± 0.21	0.010	0.047	−0.89 ± 0.22	0.041	<0.001	−0.48 ± 0.25	0.010	0.049
	Actives	−0.79 ± 0.25	0.026	0.001	−0.86 ± 0.24	0.034	<0.001	−0.65 ± 0.28	0.014	0.019	−0.90 ± 0.31	0.022	0.004
Vo2 Max	Inactives	−0.91 ± 0.57	0.007	0.113	−0.79 ± 0.47	0.008	0.093	−1.71 ± 0.52	0.031	0.001	−0.14 ± 0.58	0.000	0.804
	Actives	−0.98 ± 0.57	0.009	0.089	−2.13 ± 0.53	0.045	<0.001	−0.85 ± 0.64	0.005	0.182	−0.35 ± 0.75	0.001	0.642
Handgrip right hand	Inactives	−0.40 ± 0.84	0.001	0.633	−0.59 ± 0.69	0.002	0.395	−2.63 ± 0.74	0.031	<0.001	−1.39 ± 0.84	0.007	0.099
	Actives	−0.09 ± 0.82	0.000	0.913	−2.10 ± 0.81	0.017	0.010	−3.65 ± 0.94	0.037	<0.001	−1.32 ± 1.06	0.004	0.214
Handgrip left hand	Inactives	−0.41 ± 0.66	0.001	0.536	−0.20 ± 0.55	0.000	0.717	−1.82 ± 0.59	0.024	0.002	−1.08 ± 0.66	0.007	0.103
	Actives	−0.53 ± 0.65	0.002	0.414	−0.46 ± 0.64	0.001	0.472	−1.03 ± 0.75	0.005	0.167	−1.10 ± 0.84	0.004	0.192
CMJ	Inactives	−1.21 ± 1.49	0.002	0.415	−0.59 ± 1.22	0.001	0.629	−0.61 ± 1.32	0.001	0.646	0.45 ± 1.49	0.000	0.762
	Actives	−1.90 ± 1.46	0.004	0.195	−2.21 ± 1.44	0.006	0.126	−2.59 ± 1.67	0.006	0.123	−2.99 ± 1.89	0.006	0.115
Curl Up	Inactives	0.28 ± 1.95	0.000	0.888	−5.02 ± 1.62	0.060	<0.001	−1.31 ± 1.75	0.001	0.457	−4.93 ± 1.99	0.016	0.014
	Actives	−1.80 ± 1.92	0.002	0.349	−6.29 ± 1.89	0.059	<0.001	−2.35 ± 2.19	0.003	0.285	−0.56 ± 2.48	0.000	0.823
Push Up	Inactives	−2.62 ± 1.19	0.013	0.028	−0.98 ± 1.00	0.003	0.328	−1.03 ± 1.08	0.002	0.341	−1.21 ± 1.21	0.003	0.315
	Actives	−2.90 ± 1.17	0.016	0.013	−1.68 ± 1.15	0.006	0.144	−1.52 ± 1.33	0.003	0.254	−1.72 ± 1.50	0.003	0.253

BMI, body mass index; Sum of 3 skinfolds, summation of 3 skinfolds; Vo2 max, maximal oxygen consumption; CMJ, countermovement jump.

Therefore, based on the results concerning kinanthropometric and body composition variables, it seems that the 10-week intervention with step tracker mobile apps could generate changes only in fat variables. However, the changes in body mass, height, BMI, and muscle mass variables seem to be the result of changes caused by the maturation process in which adolescents are immersed. The results obtained in the present study support these assertions, since the inclusion of the covariate maturity showed influence on all the kinanthropometric and body composition variables, with the exception of fat mass and sum of 3 skinfolds.

Regarding the physical fitness variables, the EGs of active and inactive adolescents showed improved performance in all the physical

TABLE 5 Differences in the change between the pre and posttest in the study variables according to the app used.

Variables	Group	PokémonGo-Strava		PokémonGo-Pacer		PokémonGo-MapMyWalk		Strava-Pacer		Strava-MapMyWalk		Pacer-MapMyWalk	
		Mean Diff.	*p*-value	Mean Diff.	*p*-value	Mean Diff.	*p*-value	Mean Diff.	*p*-value	Mean Diff.	*p*-value	Mean Diff.	*p*-value
Physical activity	Inactives	0.11 ± 0.12	1.000	0.04 ± 0.12	1.000	0.00 ± 0.13	1.000	−0.07 ± 0.11	1.000	−0.11 ± 0.12	1.000	−0.04 ± 0.12	1.000
	Actives	−0.11 ± 0.13	1.000	−0.09 ± 0.14	1.000	0.02 ± 0.15	1.000	0.01 ± 0.13	1.000	0.13 ± 0.15	1.000	0.11 ± 0.16	1.000
AMD	Inactives	−0.51 ± 0.56	1.000	−1.04 ± 0.58	0.735	−0.30 ± 0.61	1.000	−0.53 ± 0.53	1.000	0.21 ± 0.56	1.000	0.74 ± 0.59	1.000
	Actives	0.55 ± 0.59	1.000	0.41 ± 0.65	1.000	0.65 ± 0.71	1.000	−0.15 ± 0.62	1.000	0.10 ± 0.69	1.000	0.25 ± 0.74	1.000
Body mass	Inactives	0.58 ± 0.44	1.000	−0.11 ± 0.46	1.000	0.43 ± 0.49	1.000	−0.69 ± 0.42	1.000	−0.15 ± 0.45	1.000	0.54 ± 0.47	1.000
	Actives	0.42 ± 0.47	1.000	−0.86 ± 0.52	0.971	−0.14 ± 0.57	1.000	−1.28 ± 0.50	0.105	−0.56 ± 0.55	1.000	0.72 ± 0.59	1.000
Height (cm)	Inactives	−0.14 ± 0.34	1.000	0.05 ± 0.36	1.000	−0.06 ± 0.38	1.000	0.19 ± 0.33	1.000	0.08 ± 0.35	1.000	−0.11 ± 0.36	1.000
	Actives	0.27 ± 0.36	1.000	−0.28 ± 0.40	1.000	−0.61 ± 0.44	1.000	−0.55 ± 0.38	1.000	−0.88 ± 0.43	1.000	−0.33 ± 0.45	1.000
BMI	Inactives	0.34 ± 0.19	0.645	0.07 ± 0.19	1.000	0.23 ± 0.20	1.000	−0.28 ± 0.18	1.000	−0.12 ± 0.19	1.000	0.16 ± 0.20	1.000
	Actives	0.06 ± 0.20	1.000	−0.48 ± 0.22	0.267	0.07 ± 0.24	1.000	−0.54 ± 0.21	0.100	0.01 ± 0.23	1.000	0.55 ± 0.25	0.271
Waist-height	Inactives	−0.00 ± 0.00	1.000	−0.01 ± 0.00	0.328	−0.00 ± 0.00	1.000	−0.01 ± 0.00	0.334	−0.00 ± 0.00	1.000	0.01 ± 0.00	1.000
	Actives	0.00 ± 0.00	1.000	−0.00 ± 0.00	1.000	−0.00 ± 0.01	1.000	−0.01 ± 0.00	1.000	−0.00 ± 0.00	1.000	0.00 ± 0.01	1.000
Corrected arm girth	Inactives	−0.05 ± 0.25	1.000	−0.00 ± 0.27	1.000	0.10 ± 0.28	1.000	0.04 ± 0.24	1.000	0.15 ± 0.26	1.000	0.11 ± 0.27	1.000
	Actives	0.01 ± 0.27	1.000	−0.11 ± 0.30	1.000	0.32 ± 0.33	1.000	−0.12 ± 0.28	1.000	0.31 ± 0.32	1.000	0.43 ± 0.34	1.000
Corrected thigh girth	Inactives	0.01 ± 0.59	1.000	0.42 ± 0.62	1.000	0.09 ± 0.65	1.000	0.41 ± 0.56	1.000	−0.10 ± 0.60	1.000	−0.51 ± 0.62	1.000
	Actives	−0.05 ± 0.63	1.000	0.02 ± 0.69	1.000	0.63 ± 0.76	1.000	0.07 ± 0.66	1.000	0.68 ± 0.73	1.000	0.62 ± 0.78	1.000
Corrected calf girth	Inactives	−1.13 ± 0.49	0.224	0.08 ± 0.51	1.000	−0.20 ± 0.54	1.000	1.21 ± 0.47	0.101	0.93 ± 0.50	0.621	−0.28 ± 0.52	1.000
	Actives	0.07 ± 0.52	1.000	0.10 ± 0.57	1.000	0.38 ± 0.63	1.000	0.03 ± 0.55	1.000	0.31 ± 0.61	1.000	0.28 ± 0.65	1.000
Fat mass (%)	Inactives	0.06 ± 0.87	1.000	−1.21 ± 0.91	1.000	0.37 ± 0.96	1.000	−1.27 ± 0.83	1.000	0.31 ± 0.88	1.000	1.58 ± 0.92	0.865
	Actives	1.55 ± 0.93	0.961	1.01 ± 1.01	1.000	−0.77 ± 1.12	1.000	−0.54 ± 0.97	1.000	−2.32 ± 1.08	0.332	−1.78 ± 1.16	1.000
Sum of 3 skinfolds	Inactives	0.73 ± 2.31	1.000	−3.65 ± 2.41	1.000	2.26 ± 2.54	1.000	−4.38 ± 2.19	0.467	1.53 ± 2.33	1.000	5.91 ± 2.44	0.157
	Actives	4.52 ± 2.45	0.665	2.75 ± 2.68	1.000	−2.17 ± 2.96	1.000	−1.77 ± 2.58	1.000	−6.69 ± 2.87	0.201	−4.93 ± 3.06	1.000
Muscle mass (kg)	Inactives	−0.36 ± 0.34	1.000	0.08 ± 0.36	1.000	−0.19 ± 0.38	1.000	0.44 ± 0.33	1.000	0.18 ± 0.35	1.000	−0.26 ± 0.36	1.000
	Actives	0.05 ± 0.36	1.000	−0.09 ± 0.40	1.000	0.50 ± 0.44	1.000	−0.14 ± 0.38	1.000	0.45 ± 0.43	1.000	0.59 ± 0.45	1.000
Vo2 Max	Inactives	0.02 ± 0.74	1.000	0.80 ± 0.77	1.000	−0.76 ± 0.81	1.000	0.79 ± 0.70	1.000	−0.78 ± 0.75	1.000	−1.57 ± 0.78	0.451
	Actives	1.15 ± 0.78	1.000	−0.13 ± 0.86	1.000	−0.63 ± 0.95	1.000	−1.28 ± 0.82	1.000	−1.78 ± 0.92	0.528	−0.50 ± 0.98	0.979
Handgrip right hand	Inactives	1.31 ± 0.91	1.000	1.55 ± 0.95	1.000	0.23 ± 1.00	1.000	0.23 ± 0.86	1.000	−1.09 ± 0.92	1.000	−1.32 ± 0.96	1.000
	Actives	2.21 ± 0.97	0.228	3.04 ± 1.06	0.079	0.92 ± 1.17	1.000	1.32 ± 1.02	1.000	−1.30 ± 1.13	1.000	−2.62 ± 1.21	0.307

(Continued)

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TABLE 5 (Continued)

Variables	Group	PokémonGo-Strava		PokémonGo-Pacer		PokémonGo-MapMyWalk		Strava-Pacer		Strava-MapMyWalk		Pacer-MapMyWalk	
		Mean Diff.	p-value	Mean Diff.	p-value	Mean Diff.	p-value	Mean Diff.	p-value	Mean Diff.	p-value	Mean Diff.	p-value
Handgrip left hand	Inactives	0.46 ± 0.71	1.000	0.62 ± 0.74	1.000	−0.03 ± 0.78	1.000	0.17 ± 0.67	1.000	−0.48 ± 0.72	1.000	−0.65 ± 0.75	1.000
	Actives	0.43 ± 0.75	1.000	0.86 ± 0.82	1.000	0.17 ± 0.91	1.000	0.43 ± 0.79	1.000	−0.25 ± 0.88	1.000	−0.69 ± 0.94	1.000
CMJ	Inactives	−0.31 ± 1.14	1.000	−0.08 ± 1.19	1.000	−0.25 ± 1.25	1.000	0.24 ± 1.08	1.000	0.06 ± 1.15	1.000	−0.18 ± 1.20	1.000
	Actives	1.26 ± 1.21	1.000	0.43 ± 1.32	1.000	0.36 ± 1.46	1.000	−0.83 ± 1.27	1.000	−0.90 ± 1.42	1.000	−0.07 ± 1.51	1.000
Curl Up	Inactives	5.05 ± 2.67	0.098	2.25 ± 2.79	1.000	4.57 ± 2.94	1.000	−5.80 ± 2.54	0.230	−3.48 ± 2.70	1.000	2.32 ± 2.82	1.000
	Actives	5.21 ± 2.84	0.101	1.39 ± 3.11	1.000	−1.05 ± 3.43	1.000	−6.82 ± 2.99	0.230	−9.27 ± 3.32	0.055	−2.45 ± 3.55	1.000
Push Up	Inactives	−1.36 ± 1.57	1.000	−1.53 ± 1.64	1.000	−0.70 ± 1.73	1.000	−0.17 ± 1.49	1.000	0.66 ± 1.59	1.000	0.83 ± 1.66	1.000
	Actives	−2.01 ± 1.67	1.000	−2.48 ± 1.83	1.000	−1.61 ± 2.02	1.000	−0.47 ± 1.76	1.000	0.40 ± 1.95	1.000	0.87 ± 2.09	1.000

BMI, body mass index; Sum of 3 skinfolds, summation of 3 skinfolds; Vo2 max, maximal oxygen consumption; CMJ, countermovement jump.

fitness tests, with the exception of the CMJ in the inactive group. In this case, the covariate maturity was shown to be determinant in the physical fitness tests related to muscular strength (handgrip and push-ups), but not in those of cardiorespiratory capacity or curl-up in which the distance covered with the app were more relevant. A possible explanation for these results could be that walking programs favor the strength-endurance of the abdominal muscles, as walking activates the core-stabilizing muscles, and could improve it after 10 weeks of intervention (109, 110). In terms of cardiorespiratory capacity, the use of aerobic applications based on walking would help increase performance in this test in both active and inactive adolescents, by including in the intervention, a weekly increase in the volume of walking to end in a daily distance equivalent to what an active adolescent should do (57). Differences were found in CMJ performance in the group of active adolescents, but the absence of these differences in the group of inactive adolescents could be due to the fact that this test requires a correct technical execution, which is present in many sports when performing vertical jumps (111, 112). This could indicate that in athletes with previous experience with this type of test, the improvements in vertical jump performance after the mobile app-based intervention were due to an improvement in lower limb strength (61). However, in inactive subjects, this improvement could be diluted by the lack of proper technique during the execution of the test by the participants.

The fact that all groups in the study improved handgrip and push-up performance, together with the fact that the covariate maturity showed influence in these tests, and the fact that mobile apps were not included for strength work, lead us to consider that the changes in these variables would be more related to the increase in muscle mass and strength as a result of the maturation process, than to the 10-week intervention (113). Therefore, another finding of relevance of the present investigation was that the fitness variables that could be most affected by the 10-week intervention were VO2 max and curl-up, while the rest of the variables seem to be more affected by the maturational process and associated changes in muscle mass.

It is also worth mentioning that the level of physical activity only showed significant changes in inactive adolescents. This could be because the perception of active adolescents, regardless of the volume of training completed, is that walking is not a sporting activity in the way that practicing a particular sport might be, so their perception is that the use of apps does not increase the physical activity performed. However, in the group of inactive adolescents, whose level of practice was lower, the inclusion of walking three times a week would be perceived as a substantial increase in the physical activity practiced.

Similarly, the absence of differences in AMD in either group is a relevant finding. The fact that the selected step tracker mobile apps did not include any type of nutritional guidelines could explain the results found, as previous studies using mobile nutrition applications have shown them to be effective in controlling intake, and in achieving changes in the anthropometry and body composition of adolescents (57, 114).

However, despite the results obtained, it should be noted that the results of the analysis of the change observed between EG and CG adolescents were only significant in BMI and CMJ for active participants, and the effect sizes of these changes were small in all the variables analyzed. More specifically, there was a greater body mass gain in the active CG, and a greater CMJ gain in the active

EG. Therefore, the evolution of most variables showed no significant change between the EG and the CG. On the one hand, this could be because longer interventions may be necessary to obtain differences in the changes between EG and CG (115). On the other hand, intensity, as opposed to distance, could be a stronger differentiating factor for generating changes in some of these variables (58, 116). Therefore, although some of the changes achieved during the research in the EG seem to be the result of the 10-week intervention with mobile applications, future research is needed to determine the real potential of this type of tool to increase physical activity and achieve substantial changes in kinanthropometric, body composition and physical fitness variables in the adolescent population.

4.3 Importance of the covariates included in the present research

The results obtained highlight the importance of the covariates included in the present study. The covariate gender seems to influence the level of physical activity, kinanthropometric and body composition variables, as well as physical fitness variables. Previous research has shown that the practice of physical activity of adolescent males tends to be higher than that of adolescent females (117). The results of the present research could indicate that step tracker mobile apps are a good strategy to increase physical activity practice in active and inactive females. These results are in line with previous research where it was observed that females used physical activity apps to a higher extent than males when their use was promoted in physical education classes (118). Regarding anthropometry and body composition, differences were observed in the muscle mass of all the groups analyzed, and in the fat mass of the EG. These results are consistent with those found in previous research, in which the muscle mass of adolescent males was higher than that of adolescent females (119). It is true that during the maturation process, steroid hormones increase in both males and females, but the accumulation is much greater in males, which generates greater increases in muscle mass (59, 120–122). In contrast, there is a greater accumulation of fat mass in females during puberty, which would be influencing the effects of the intervention program (59, 120, 121). Similarly, differences were significant in the majority of the physical fitness variables in the EG of active and inactive adolescents. It should also be noted that in the physical fitness tests related to body strength and cardiorespiratory capacity, the differences were significant according to gender in all groups. The greater development of muscle mass and strength of males with respect to females during puberty, as well as the greater cardiorespiratory capacity shown in previous research, could be the explanation for the results found (123). Another explanation could be that males generally practice more physical activity than females, so it is possible that this is the factor that causes a higher performance in all the fitness test in males (109).

The maturational process in which adolescents are immersed plays a very relevant role in the results of this research. As it has been observed, most of the changes in the variables of muscle mass, as well as in body mass, height and BMI are influenced by maturation. Similarly, the physical fitness variables related to strength, mainly handgrip and push-ups present a similar influence. This is due to hormonal changes and muscle mass development that occur during puberty (122). However, the fact that the changes in the level of physical activity, fat mass variables, VO2 max and curl up were not affected by this covariate, suggests that the intervention generates changes in these variables.

A significant finding was that the app used has been shown to influence the level of physical activity of inactive adolescents, as well as kinanthropometric and body composition, and physical fitness variables for both active and inactive adolescents. Specifically, the results showed differences in physical activity level, body mass, height, corrected perimeters, fat mass, sum of 3 skinfolds, muscle mass, V02 max, handgrip, curl up and push up when analyzing each of the mobile apps individually. However, the change in these variables between the different mobile apps was not significant, so there were no different effects between apps. These results show that the applications, even if they have different techniques for behavior change (84), can have similar effects. This is relevant because step-counting apps, such as Strava, Pacer and MapMyWalk, as well as gamified apps, such as Pokémon Go, can be effective with both active and inactive adolescents. These results are similar with previous research in which differences were seen in the study variables, mainly body mass, handgrip and curl up, depending on the application used (61), but bring the great novelty that the change produced between apps in these variables is not significant. Furthermore, the fact that the selected application shows different effects on the increase in physical activity depending on the level of physical activity is very relevant. That said, it would be important for future research to analyze the differences between interventions delivered with different apps in the longer term, to see if the fact that some of them are gamified may have an influence on the psychological variables that lead to greater use of them in the longer term, as has been seen in research in other fields (124, 125).

And, regarding the covariate distance covered with the use of the apps, the results showed a significant influence on the kinanthropometric and body composition variables both in active and inactive adolescents. This could indicate that the greater the distance covered with the application, the greater the changes achieved in the anthropometry and body composition of adolescents, regardless of whether or not they regularly practiced physical activity. These results are of great relevance, as they would indicate that the completion of a 10-week aerobic training program using step tracker mobile apps for its quantification would be effective in producing improvements in anthropometry and body composition in this population, at least for the reduction in fat mass, which would follow the line of previous research that used step tracker mobile apps (58). Similarly, the distance traveled with the use of the step tracker mobile apps showed an influence on all physical fitness variables, regardless of whether the adolescents were active or inactive before starting the research. It is logical to think that regardless of the previous level of practice, the improvements would be greater in adolescents who completed a longer distance with the use of step tracker mobile apps, as they would be more active, allowing them to obtain a greater physical fitness, as shown in previous research (58).

4.4 Differences and similarities of the results found with respect to previous scientific evidence

The main contribution of the present investigation with respect to previous scientific evidence is that active and inactive adolescents after the use of mobile applications for 10 weeks could show changes in fat mass, cardiorespiratory capacity and the strength-endurance of the abdominal muscles. It is true that previous research had shown the benefits of physical activity interventions, and more specifically of interventions with mobile applications, on these variables in the adolescent population (58). In this regard, previous research have shown a decrease in fat variables, as well as an improvement in performance in physical fitness tests, such as CMJ, curl-up, push-up or handgrip, after the interventions (46, 61). This is similar to the results obtained in the present research; however, the main contribution of this study and which had not been observed in any previous study is that the results are equally significant for previously active and inactive adolescents, with no significant differences between these groups, this study being novel in that sense. In addition, the fact that curl-up and cardiorespiratory capacity were not influenced by maturity is also new to this study and could indicate the effects of the intervention on these variables.

The improvement in other physical fitness variables as handgrip and push-up after intervention with step-tracking mobile apps also follows the line of previous research (61). However, this study provides two main novelties. The first is that both active and inactive adolescents belonging to the GE and the CG showed benefits in these tests. The second is that the maturity covariate was shown to significantly influence these variables. Therefore, this is the first study that shows the effect that maturity could play in the changes obtained in tests related to upper limb strength in this type of intervention. It is logical to think of the effect of maturity since this intervention did not include upper limb strength work, but in previous investigations this argument was used to justify the changes and in none of them was the influence statistically demonstrated.

Another novelty of the present study is that the increases in the level of physical activity occurred only in the group of inactive adolescents. Previous studies have shown that the implementation of step-tracker app-based interventions could increase self-perceived physical activity in adolescents (126). However, no previous study had examined the influence of adolescents' previous activity level on this change. The present novel study is novel in this respect. Furthermore, the absence of differences in AMD after intervention with step tracker mobile apps had been also observed in previous research (115).

In addition, the inclusion of the covariates gender, maturity, app used and distance traveled with the app and their effect on the study variables allows us to learn more about the changes that can actually be caused by the 10-week intervention with step tracker mobile apps. Previous studies have suggested that the effects of step-tracker intervention could depend on gender, the app used or the distance traveled with it (61, 118). However, in the case of the app used, the changes in the study variables when comparing between the different mobile applications were not significant, so there was no greater effect of one app on the others in either the active or inactive group. For its part, it has been shown that maturation could have a significant influence on the effects of physical exercise on anthropometric variables, body composition or physical fitness (120). However, this is the first research to analyze the effects of these factors according to whether the adolescents were active or inactive.

According to the results obtained in the present investigation, H1 in which indicated that the use of mobile step-tracking apps will be more effective on the study variables in inactive adolescents, since their level of physical activity is lower than that of active ones, can be partially rejected. This is because the changes occurred in both active and inactive adolescents, with the exception of the level of physical activity, in which only inactive adolescents perceived a greater improvement after the intervention, and the CMJ test, where significant changes were found only in the active adolescents. Regarding H2 in which indicated that gender, maturity, app used and the number of steps taken with the mobile apps will influence the changes produced in the study variables after the use of the mobile apps, it can be accepted. This is because all four covariates were shown to influence the study variables, mainly gender and maturity, although in the case of the app used there were no significant differences when considering the change produced by each of the apps.

4.5 Limitations and future directions

The present investigation is not without limitations. The sample was selected by convenience, by choosing the compulsory secondary schools with the largest number of adolescents in the geographical area of study. The level of physical activity was assessed using the PAQ-A questionnaire, which is a subjective measure of physical activity, which could influence the results obtained. It is also important to note that this questionnaire only records the physical activity of the last week, which might not give an overall picture of the subject's level of physical activity. In addition, the PAQ-A classifies subjects as active or inactive, without providing an intermediate range between the two conditions of physical activity. In addition, although the results of the KIDMED questionnaire did not show changes in adolescent AMD, other instruments should be used to assess adolescent caloric intake, as it could significantly influence changes in the anthropometry and body composition in this population.

In view of the limitations present in the research, the following lines of future research are proposed: (a) it would be important to complement the subjective information on perceived physical activity obtained by means of questionnaires with an objective measure. This could be carried out by accelerometry, or by means of wearable devices that allow the collection of data on physical activity throughout the day; (b) the use of mobile applications that include strength-endurance exercises would allow to know whether the effect of the maturational process is the cause of changes in muscle mass variables and fitness tests, or whether these are also modified by appropriate training; (c) interventions that include nutritional and physical activity guidelines are more effective than those that isolate one of these behaviors (97). Considering the absence of changes in AMD with the present intervention, future studies should use mobile step-tracking apps that track both physical activity and nutrition, or that include recommendations in both areas, as the results could be superior to those found in the present investigation; (d) future research should address the effect of the step-tracker apps on the results found, as it could be very relevant to decrease the time of physical inactivity in adolescents; (e) should also be examined in depth as to whether the distance traveled may be a more important determinant factor in an inactive or active group; and (f) this is the first study using the mobile apps and dividing the results according to the previous physical activity level of the adolescents, so the results should be taken with caution and future research is needed to corroborate them.

4.6 Practical implication

The following practical applications are derived from this research: (a) the step tracker mobile apps can be a very useful tool to be used in physical education classes, or promoted in the field of health, to increase the level of physical activity of inactive adolescents; (b) the use of mobile app step trackers can be a useful tool to favor the perception of competence, autonomy and social relationships in relation to physical activity. This could increase the satisfaction of the basic psychological needs of adolescents, which could be especially important among inactive adolescents. Thus, the use of mobile apps for the promotion of physical activity could lead to an improvement in the basic psychological needs of adolescents and, therefore, to greater adherence to the practice of physical activity; (c) the improvement in the fat variables after the intervention, both in the group of active and inactive adolescents, leads to consider these interventions as effective in improving body composition, which is decisive due to the increase in the rate of overweight and obesity in the adolescent population, especially among inactive adolescents, and could be a tool of great interest for the promotion of public health; (d) the use of rewards from the physical education class seems to be a useful strategy to increase participation and gain benefits from the intervention. This could be due to the fact that this external factor influences external regulation, which would affect adolescents' motivation. Therefore, if the use of apps is promoted from the physical education subject with an increase in the grade, initial adherence to the program may benefit; and (e) the present study demonstrates the benefits of the use of mobile applications in both active and inactive adolescents, which is fundamental to combat the negative perception that currently exists toward the use of mobile devices in this population. This leads to the view that it is not so much the time spent using the devices that is really harmful, but the apps used.

5 Conclusion

Regardless of the initial level of physical activity, the use of step tracker mobile apps in out-of-school hours, promoted from the subject of physical education, resulted in significant improvements in fat variables and in cardiorespiratory capacity and curl-up performance of adolescents aged 12–16 years old. The evolution of the rest of the kinanthropometric and body composition variables, as well as the physical fitness variables, seem to be more strongly influenced by gender and maturity status than by the physical exercise intervention. It should be noted that although both active and inactive adolescents in the EG used the step tracker mobile apps during the intervention period, only adolescents who were inactive before the start of the study perceived improvements in their level of physical activity. In addition, the app used and the distance covered with the apps seem to be influential in the results. Therefore, mobile step tracking apps may be a useful alternative to obtain improvements in fat variables and in some of the physical fitness variables, but the results obtained should be taken with caution because it is the first research to be carried out dividing adolescents according to their previous level of physical activity.

Data availability statement

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

Ethics statement

The studies involving humans were approved by Institutional committee of the Catholic University of Murcia (code: CE022102). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

NG-C: Formal analysis, Investigation, Writing – original draft, Writing – review & editing. AM-O: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. LM: Investigation, Writing – original draft, Writing – review & editing. LA-C: Conceptualization, Funding acquisition, Investigation, Project administration, Writing – original draft, Writing – review & editing. RV-C: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing.

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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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Psychological needs, self-efficacy, motivation, and resistance training outcomes in a 16-week barbell training program for adults

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Background: Despite extensive research on the relationship between psychological factors and aerobic training, there remains a gap in understanding these relationships within resistance training (RT), particularly barbell-based RT. This study aimed to examine the associations between basic psychological needs, behavioral regulation, self-efficacy, and a longitudinal barbell-based RT program for adults.

Methods: Forty-three adults (*M* age = 45.09 ± 10.72) were recruited from the Competitive Edge resistance training program at a medical fitness center in Northwest Montana. The study followed an 18-week schedule: 8 weeks of training, 1 week of active recovery, and 8 additional weeks of training.

Results: The results reveal several significant findings. First, the basic psychological need for competence significantly increased from baseline ($M = 5.06$) to post-program ($M = 5.30$), ($p = 0.017$). Second, the composite score of the BREQ-3 significantly predicting muscular strength improvements in the deadlift ($\beta = 3.64$, $p = 0.039$). Third, both mastery ($p = 0.021$) and resilience ($p = 0.007$) self-efficacy subscales increased from baseline to post-program. Fourth, exploratory analyses indicated that the reasons to exercise scale predicted increases in muscular endurance with the weight management ($\beta = 10.016$, $p = 0.046$) and solitude ($\beta = 6.792$, $p = 0.037$) subscales.

Conclusion: These findings highlight the importance of psychological factors in predicting strength outcomes and muscular endurance, suggesting that psychological interventions may complement physical training to maximize benefits. This research contributes valuable insights into how psychological factors influence training outcomes, potentially guiding future interventions and program designs to better support strength development and endurance in resistance training contexts.

KEYWORDS

strength training, affective responses, barbell training, women's health, inclusion

Introduction

Resistance training (RT) is a crucial form of exercise for adults of all ages, with training benefits observed among diverse populations (Centers for Disease Control and Prevention, 2006). It is even backed by public health agencies, with the Centers for Disease Control (CDC) advising that individuals aged 18–64 engage in muscle-strengthening activities at least twice a week. Despite its significance for promoting healthy adulthood, RT experiences less emphasis, adherence, and popularity compared to aerobic training. Only 31% of adults meet the recommended guidelines for strength training (Elgaddal et al., 2022). Among this 31%, only 6.8% adhere exclusively to strength training guidelines, while 24.2% meet both aerobic and anaerobic training guidelines. Furthermore, despite the importance of psychological factors to RT initiation, improvements, and adherence, there is a lack of multidisciplinary studies assessing the relationship between RT and psychological factors. Rather, the studies that exist regarding psychology and RT typically only assess single joint exercises, single sessions, machine-based RT exercises (e.g., bicep curls), or competitive athletes. To our knowledge, this is the first study to examine basic psychological needs, self-efficacy, reasons for exercises, and RT strength improvements in adults enrolled in a longitudinal RT program.

Importantly, women are significantly underrepresented in exercise science research. A recent systematic review found that only 8.8% of studies concentrate on women compared to 70.7% focusing on men, with just 20.5% of studies including both genders (Paul et al., 2023). These research deficits translate to observed behaviors, with only 20% of women reporting participation in RT (Centers for Disease Control and Prevention, 2006). A recent study revealed a striking contrast, indicating that for every woman using free weights in a gym, there were 27 men doing the same (a 27 to 1 ratio) (Haines et al., 2008). The American College of Sports Medicine identifies the perception of time and effort required as a significant barrier to resistance training among female adults (Hurley et al., 2018). Gender dimorphisms exist in motivation to strength train as well. Men have unique motivations for strength training, including physical health, sport or performance goals, physical appearance, and social factors (Ashton et al., 2015). Key motivators for men also encompass concerns about physical appearance, social inclusion, health benefits, and sport/performance improvements (Ashton et al., 2015). Women, however, may experience more potentially negative motivators, such as avoiding criticism from healthcare or fitness professionals, or following trends in social media or pop culture (Vasudevan and Ford, 2022). Additionally, women are often likely to be motivated by objectives centered on enhancing physical appearance, attractiveness, achieving muscle toning, and managing weight through weight loss or weight management approaches (Nuzzo, 2023). Importantly, in adults, valuing a variety of goals can lead to better self-motivation and higher levels of physical activity (Martinez Kercher et al., 2022). More specifically, research underscores the significance of aligning exercise with personal values and the supportive role of social environments in maintaining physical activity levels (Lev-Arey et al., 2024).

Participation in strength training is influenced by psychological factors such as self-efficacy and psychological needs. Self-efficacy is defined as an individual's belief about their capabilities that can either aid or hinder exercise behaviors (Bandura, 1997). It can be influenced through successfully completing tasks (i.e., mastery experiences/performance accomplishments using tracking logs), hearing and seeing others' experiences and successful application of strategies (i.e., modeling/vicarious experiences), social persuasion (i.e., having other individuals tell you that you can adopt the behavior), and reduction of stress and physical/emotional arousal (i.e., self-pacing activity that challenges one without creating anxiety) through education on technique. Research shows that self-efficacy, composed of measures of mastery, resilience, and physical ability, mediates the relationship between mindset and exercise frequency (Orvidas et al., 2018), suggesting that self-efficacy is important for exercise adherence in adults (Rhodes et al., 2017).

Self Determination Theory (SDT) may be a useful tool to analyze the effects of self-efficacy and other psychological factors on exercise behavior (Teixeira et al., 2012). SDT highlights three fundamental psychological needs: competence, autonomy, and relatedness (Ryan and Deci, 2000). Autonomy refers to self-direction and freedom in decision-making. Competence is about feeling capable and effective in tasks. Relatedness involves meaningful social connections and a sense of belonging. When these needs are met, individuals experience heightened self-motivation and improved mental health (Ryan and Deci, 2000). Likewise, factors such as autonomy and competence in strength training promote adherence (Martinez Kercher et al., 2022). Conversely, unmet needs can lead to reduced motivation and diminished well-being, including decreased/lack of participation in exercise (Martinez Kercher et al., 2022). In comparison, with the large amount of literature regarding aerobic exercise, relatively few studies have examined the relationship between evidence-based psychological factors and RT outcomes. To our knowledge, this is the first study to examine psychological needs for exercise, motivation to exercise, and RT outcomes in a longitudinal study of general population adults using compound barbell exercises. Furthermore, a strength of this study is the deliberate recruitment and inclusion of women in RT research.

The overarching goal of this study was to examine the relationship between psychological needs, behavioral regulation, self-efficacy, and a longitudinal barbell-based RT program for adults. This study had three objectives. The primary objective was to explore the longitudinal influence of 16-weeks of RT on psychological factors (e.g., basic psychological needs, self-efficacy, behavioral regulation in exercise) from baseline to post-program. We hypothesized that psychological factors would increase post-program compared to baseline. The secondary objective was to assess the influence of psychological factors on muscular strength and muscular endurance. We hypothesized that more positive psychological factors would predict greater gains in muscular strength and endurance testing outcomes. Finally, the exploratory objective was to assess the reasons for exercise (REx) scale. To do this, we tested if there were changes in reasons to exercise from baseline to post program, and if any REx subscales predicted changes in muscular strength and endurance testing outcomes.

Methods

Sample and setting

Participants were recruited from a RT program called Competitive Edge (CE), at an 8,000+ member medical fitness center in Northwest

Montana. RT sessions took place in a semi-private turf area within the medical fitness center. 68% of the participants did not have a history of playing sports and were classified as novices/beginners (Haff and Triplett, 2016) based on previous RT experience. A convenience sample of 43 adults (M age = 45.09 ± 10.72) enrolled in Competitive Edge including 81.8% females (n = 35) and 18.2% males (n = 8) were recruited into this quasi-experimental study using a pretest-posttest design. 36 adults completed the 16-week study.

Design

The study was conducted over the course of 18 weeks. The week 0 pre-screening assessments were followed by 8 weeks of training, 1 week of suggested active recovery at week nine, then another 8 weeks of training. For clarity, we designated the initial 8 weeks of training as weeks one through eight, and the subsequent 8 weeks as weeks nine through sixteen.

Program

The Competitive Edge barbell program consisted of professionally supervised exercise, self-selected loads, and a small group atmosphere. The Competitive Edge barbell approach accommodated participants of any skill level. RT programming and protocols followed recommendations from the National Strength and Conditioning Association (NSCA) for optimal athletic development (Haff and Triplett, 2016). Coaches were certified by either NSCA, USA Weightlifting, and/or the American College of Sports Medicine. The classes were structured in an 8-week session with clients attending 2–3 classes per week. Each training group consisted of 4–9 participants. RT sessions lasted for approximately one-hour. Within each 8-week session there were two 4-week phases, each emphasizing muscular hypertrophy or strength development. We changed the phase every 4 weeks in accordance with NSCA-recommended phase principles and to avoid the 'honeymoon' effect (Rodgers et al., 2009). Within each 4-week phase there were three workouts: Day 1, Day 2, and Day 3 (see Supplemental File 1 for sample 4-week phase). Clients were encouraged to attend at least two workouts per week (either Mon, Wed or Tue, Thu) with an additional Day 3 workout also advised for Fridays or Saturdays. RT sessions included the following: (1) a 5–10 min warm-up consisting of various dynamic movements; (2) a muscle activation/coordination exercise; (3) a compound power exercise typically using barbell (e.g., hang clean); (4) a compound strength-based exercise typically using a barbell (e.g., squat); (5) multiple supporting exercises; (6) a challenging and camaraderie-building exercise called a "finisher." These warm-ups were different each of the 3 days and changed each phase to avoid monotony.

Measures

Physical activity, demographics, resistance training background questionnaire (PADRTBQ)

Participants reported their age, gender, ethnicity, and resistance training background using the Physical Activity, Demographics, and Resistance Training Background Questionnaire (PADRTBQ). Participants were asked about their exercise-related habits, such as resistance training history, time elapsed from starting with barbell training (in months), weekly frequency of barbell training, types of other regular physical exercises, and hours spent in other exercise modalities in a week. Classification of training status was based on the National Strength and Conditioning Association Guidelines (e.g., Beginner = 0–6 months; Intermediate = 8–12 months; and Advanced = over a year).

Physical activity readiness questionnaire (PAR-Q)

Participants completed the PAR-Q (Canadian Society for Exercise Physiology, n.d.) before beginning the program. The PAR-Q is a tool designed to assess an individual's readiness for engaging in physical activity. It consists of a series of questions focused on identifying any potential health risks that could be exacerbated by increased physical activity. The questions address key areas such as cardiovascular health, joint and bone issues, and overall physical condition. Respondents answer "yes" or "no" to each question, with any "yes" responses indicating the need for further medical evaluation before participating in physical activities. The PAR-Q is valued for its simplicity, ease of administration, and effectiveness in ensuring the safety of individuals starting new exercise routines.

Attendance and retention

Coaches recorded attendance for every class. Participants that attended one, two, or three times a week represented the completion of 8, 16, or 24 possible sessions attended for one, 8-week program or 16, 32, 48 sessions over 16-weeks, respectively.

Self-efficacy

Self-efficacy was assessed using the Resistance Training Self-Efficacy scale (RT-SE) (Jones et al., 2016) to assess participants' beliefs related to mastery experiences, physical capability, and resilience. The RT-SE scale considers a wider range of factors related to overall self-efficacy in resistance training, including exercise-specific confidence, belief in program adherence, managing fatigue, progressing in exercises, and overcoming barriers.

Psychological needs

The Psychological Needs Scale for Exercise (PNSE) is a fundamental tool for assessing individuals' psychological experiences in the realm of exercise. It comprises three core components: competence, autonomy, and relatedness. Competence pertains to an individual's confidence and perceived ability in executing exercises, overcoming challenges, and attaining fitness goals. Autonomy reflects one's sense of control and freedom in designing exercise routines, setting goals, and aligning activities with personal preferences and values. Relatedness assesses feelings of connection, support, and understanding within exercise environments, encompassing social interactions, relationships with peers or trainers, and a sense of belonging.

Reasons to exercise (REX)

The Reasons to Exercise (RE_X) Scale-2 was used to assess the reasons people exercise at baseline and post-program. The RE_X-2 scale contains nine factors represented by 36 items including: (a) fitness; (b) competition; (c) solitude; (d) social; (e) appearance; (f) weight management; (g) health concerns; (h) mood enhancement; (i) preventative health. Items included a standardized stem (i.e., "To you, how important is this reason for exercising and/or being physically active?") followed by content statements evaluated using a 6-point Likert scale, ranging from 1 to 6 (*not at all important* to *extremely important*). The validity and reliability of the RE_X-2 demonstrated good psychometric properties in adult exercisers (Martinez Kercher et al., 2022).

Behavioral regulation

The Behavioral Regulation in Exercise Questionnaire-3 (BREQ-3) (Markland and Tobin, 2004) was used to assess the type of self-determined motivation ranging from amotivation to the most intrinsic form of motivation (i.e., relative autonomy) at baseline and post-program. The BREQ-3 measures external, introjected, integrated, identified, and intrinsic forms of regulation of exercise behavior using a 5-point Likert scale, ranging from 0 to 4 (*not true for me* to *very true for me*). The validity and reliability of the BREQ-3 has demonstrated good psychometric properties with adult exercisers (Markland and Tobin, 2004). In line with previous literature, a single score was computed by summing subscale scores to provide an index of the degree to which respondents felt self-determined to measure 'relative autonomy index' (RAI) (Martinez Kercher et al., 2022).

Resistance training intentions

Participants were asked to complete questions regarding intentions to continue RT in barbell. Participants' intentions were assessed at Week 0, 8, and 17 using the following items: "Rate how likely you are to train in CE over the next 8 weeks;" "I intend to engage in barbell at least 2 times a week for the 8-week session;" and "I intend to engage in barbell at least 3 times a week for the 8-week session." Each item has a Likert scale of 1 to 7, with anchors ranging from "Very unlikely" to "Very likely." The two items will be analyzed individually.

Strength testing

Participants completed RT muscular strength and endurance testing at baseline and post-program. Exercises to assess muscular strength used a barbell and included the deadlift, front squat, and hang clean. For the muscular strength tests, participants completed a 3–5 repetition maximum set that was used to calculate a 1 rep max following NSCA guidelines (Table 1). Muscular endurance was assessed with a maximum push-up test. To account for differences in body mass, we calculated a relative strength index that summed participants total predicated 1RM loads for the deadlift, front squat, and hang clean then divided that sum by their body weight (e.g., [200 + 100 + 75]/170 lbs. = strength index).

TABLE 1 Power and strength-based compound barbell exercises used in programming.

Complex power	Complex strength
Hang clean*	Back squat
Power clean	Deadlift*
Snatch	Front squat*
Split Jerk	Bench press*
Hang High Pull	Split squat
Push press	Hex Bar Deadlift

*Exercises that will be included in the 3–5 RM (estimated 1 RM) testing to identify exercise intensity and workload.

Procedure

Participants were asked to come to the medical fitness center on two separate occasions to collect measures before (Week 0) and after (Week 17) their 16-week barbell program. On the first visit, following a verbal and written explanation of the nature involved in the study, a written informed consent was obtained in accordance with the principal investigator's Institutional Review Board. Once the participants provided informed consent, participants were asked to complete two questionnaires, the PAR-Q and a health history to determine the presence of contradictions to exercise, with a specific focus on orthopedic, cardiovascular, and pulmonary conditions that would preclude participation in the research study. Additionally, participants completed the PADRTQ.

On the first and last visit, the PADRTBQ, RT intentions, and questionnaires were collected from the participants. Following collection of psychological measures, participants' anthropometrics and body composition were measured. During their first visit, participants underwent a familiarization session to teach them how to navigate through their workout sheet and where to report psychological measures, as well as how to record load (weight) lifted.

Participants were responsible for self-selecting their loads during lifts. However, it is a pseudo self-selected process because they were in a supervised setting where the coach may or may not encourage them to lift heavier or lighter. Generally, the coaches were encouraged to allow the participants to self-select, but through building the coaching relationship coaches often had the power to influence the weight lifted. We felt this supervised self-selected load approach would lead to an enhanced sense of autonomy within the lifter while utilizing the coach's judgment and experience in the process.

Data analysis

Data analysis was conducted using SPSS (Corp, 2024) and R Studio (2023.12.0 + 369) (RStudio Team, 2024). We conducted thorough data screening, including checks for missing data, outliers, and assessing univariate and multivariate normality. Internal reliability for each construct was measured using Cronbach's alpha. Descriptive statistics were utilized with frequencies and percentages calculated for categorical variables and means along with standard deviations computed for continuous variables. Our analysis of outcome measures involved mixed model regressions and two-sample t-tests. Additionally, a sensitivity analysis was performed on participants who completed strength testing at both baseline and post-program to detect any systematic differences between these groups.

Results

Descriptive statistics

Table 2 shows the descriptive statistics for the final sample of adults (that completed the psychological measures) ($n = 43$). The sample was 100% white/Caucasian.

TABLE 2 Participant characteristics.

Variable	Male (n = 8)		Female (n = 35)	
Age	43.62 ± 10.47		45.42 ± 10.90	
Education (n%)				
Some high school	0%		2.80%	
Trade/vocational certification	12.50%		0%	
Some college credit	25%		2.80%	
Associate degree	0%		8.50%	
Bachelor's degree	25%		42.80%	
Some graduate school	0		2.80%	
Master's degree	37.50%		34.20%	
Doctorate degree	0%		5.70%	
Body composition (M, SD)	Pre-program	Post-program	Pre-program	Post-program
Skeletal Muscle Mass (SMM)	79.77 ± 15.89	64 ± 9.7	59.10 ± 6.02	61.85 ± 4.34
Body Mass Index (BMI)	24.95 ± 3.59	24.8 ± 1.2	26.0 ± 3.94	26.78 ± 4.64

TABLE 3 Strength testing outcomes (pre-program n = 27, post-program n = 29).

Variable	Pre (Mean ± SD)	Post (Mean ± SD)	Change (Mean ± SD)
1 RM hang clean	99.28 ± 32.5	101.78 ± 31.83	10.00 ± 6.41
1 RM front squat	116.2 ± 39.1	121.37 ± 39.77	11.31 ± 13.10
1 RM deadlift	198.2 ± 50.9	197.24 ± 51.34	−0.26 ± 14.09
Max pushup reps	20.1 ± 21.6	24.04 ± 19.18	4.3 ± 8.11

Data presented as means in lbs. (SD); 1RM is a predicted 1 rep max from actual 3–5 rep max test.

Strength testing

There were $n = 27$ participants who completed baseline strength testing and $n = 29$ who completed post-program strength testing. The sample who completed the post-program strength testing showed improvements in the amount of weight lifted (pounds) in their predicted 1RM for the front squat, hang clean, and deadlift. There were no significant changes in body weight, body fat mass, or skeletal muscle mass. For the strength index, which controls for participants' body weight, there was an average increase of 0.21 ($SD = 1.96$).

Resistance training (RT) intentions

At the start of the program, mean intention to continue to attend barbell for another 8-weeks at least 2 times and/or 3 times a week was 6.6 (±0.16) and 4.8 (±0.31) on a 7-point scale ranging from 1 to 7. After completing 16-weeks in the program, participants reported a mean intention to continue to attend barbell for another 8-weeks at least 2 times and/or 3 times a week was 6.2 (±0.29) and 4.4 (±0.43) on a 7-point scale. There was no significant change in intention to continue training RT ($p > 0.05$).

Changes in psychological factors

The primary objective was to explore potential changes in psychological factors pre- to post-program. Welch two sample t-tests were conducted for all measures of interests (e.g., psychological needs, self-efficacy, BREQ-3). Table 3 shows all t-test results.

Additionally, linear regressions were conducted to evaluate if attendance in the Competitive Edge program influenced changes seen in competence, identified regulation, mastery, and resilience. Total attendance did not significantly predict any of the significant psychological factors. Table 4 shows all regression results.

Psychological factors predicting RT outcomes

The secondary objective was to assess if baseline psychological factors predicted total muscular strength outcomes. Linear regressions were conducted between each psychological scale (e.g., BPN, BREQ, SE) and their subscales with changes in strength index. No significant results were seen. Additionally, we sought to assess if baseline psychological factors predicted muscular endurance (total number of push-ups performed) outcomes. Linear regressions were used to explore these relationships. No significant predictors emerged. Table 5 shows model results.

Moreover, baseline composite scores of psychological factors were compared to each lift tested (e.g., deadlift, front squat, and hang clean). The analysis found that the baseline basic psychological needs score significantly predicted the change in one-rep max (1RM) deadlift ($\beta = 3.64$, $p = 0.039$). Table 6 shows all regression results.

TABLE 4 *T*-test results for psychological factors pre vs post.

Psychological factor	Pre-mean	Post-mean	*t*-value	DF	*p*-value
Basic psychological needs					
Autonomy	5.34 ± 0.57	5.52 ± 0.57	1.356	79.37	0.178
Competence	5.06 ± 0.84	5.3 ± 0.73	1.479	79.83	0.017*
Relatedness	5.26 ± 0.74	5.33 ± 0.66	0.422	79.97	0.673
Behavioral regulation exercise questionnaire					
Identified regulation	3.49 ± 0.49	3.24 ± 0.53	−2.190	79.97	0.0313*
Amotivation	0.11 ± 0.35	0.11 ± 0.28	0.012	78.77	0.989
Intrinsic motivation	3.25 ± 0.66	3.26 ± 0.66	0.004	79.42	0.996
Integrated regulation	3 ± 0.90	3.07 ± 0.86	0.392	79.78	0.695
Introjected Regulation	2.36 ± 0.99	2.26 ± 0.87	−0.443	79.91	0.658
External regulation	0.43 ± 0.49	0.44 ± 0.50	−0.056	79.08	0.954
Self-efficacy					
SE-physical	7.72 ± 2.25	8.24 ± 1.61	1.215	76.10	0.227
SE-mastery	8.27 ± 1.96	8.89 ± 1.08	2.402	66.44	0.021*
SE-resilience	7.99 ± 1.93	8.61 ± 1.10	2.852	67.99	0.007*

TABLE 5 Linear regression results for significant psychological factors.

Model	Coefficient	Std. error	*t*-value	*p*-value
BPN-competence	0.016	0.012	1.312	0.197
SE-mastery	0.019	0.018	1.020	0.314
BREQ-identified regulation	0.004	0.008	0.480	0.633
SE-resilience	0.011	0.019	0.599	0.552

TABLE 6 Linear regression results for psychological factors and change in strength.

Predictors	*F*-statistic	Adjusted R^2	*P*-value
Muscular strength			
BPN subscales	0.884	−0.008	0.457
BREQ subscales	0.971	−0.004	0.458
SE subscales	0.745	−0.018	0.531
Muscular endurance			
BPN subscales	0.414	−0.171	0.746
BREQ subscales	0.578	−0.267	0.739
SE subscales	1.253	0.059	0.347

Reasons to exercise

Lastly, the exploratory analysis sought to examine the RE_X measure. At the start of the program, participants' top three reasons for exercising were for (1) preventative health ($M = 5.3 \pm 0.79$), (2) mood enhancement ($M = 5.1 \pm 0.78$), and (3) fitness ($M = 5.1 \pm 0.61$). Competition ($M = 2.5 \pm 0.12$) was the least important reason people had for participating in exercise. After 16-weeks, participants reported (1) mood enhancement ($M = 5.1 \pm 0.84$), (2) preventative health ($M = 5.1 \pm 0.99$), and (3) fitness ($M = 5.1 \pm 0.62$) as their primary reasons for exercising. Competition remained the least important reason for exercising. We conducted two-sample *t*-tests to see if any subscales changed from pre- to post-program. No significant changes were seen. Table 7 shows all *t*-test results.

Additionally, analyses were conducted to see if any baseline RE_X subscales predicted changes in muscular strength. No significant predictors were found. However, looking at muscular endurance, the subscale weight management ($\beta = 10.016$, $p = 0.046$) was a significant predictor of increases in endurance. Likewise, the subscale solitude had a positive relationship with muscular endurance ($\beta = 6.792$, $p = 0.037$). Table 8 shows all regression outcomes.

Lastly, to explore the REx measure with changes in strength, we tested the baseline composite score was tested against changes in 1RM. The linear regression found that the composite REx score

TABLE 7 Regression results for 1RM and baseline psychological factor scores.

Predictors	F-Statistic	Adjusted R^2	P-value
Deadlift 1RM Δ			
Pre BPN-score	0.312	−0.051	0.585
Pre BREQ-score	5.209	0.231	0.039*
Pre SE-score	0.343	−0.049	0.567
Front squat 1RM Δ			
Pre BPN-score	0.312	−0.051	0.585
Pre BREQ-score	0.276	−0.054	0.607
Pre SE-score	4.309	0.191	0.058
Hang clean 1RM Δ			
Pre BPN-score	0.031	−0.074	0.856
Pre BREQ-score	0.577	−0.031	0.461
Pre SE-score	0.483	−0.038	0.498

TABLE 8 RE_X subscale pre vs pos.

REx subscale	Pre-mean	Post-mean	t-value	DF	p-value
Social	3.92 ± 1.03	3.92 ± 1.06	−0.021	78.592	0.982
Weight management	4.24 ± 1.18	3.92 ± 1.21	−1.207	78.733	0.231
Health concerns	3.0 ± 1.28	3.18 ± 1.22	0.668	79.768	0.505
Appearance	4.24 ± 1.08	3.96 ± 1.20	−1.107	76.728	0.271
Mood enhancement	5.12 ± 0.78	5.13 ± 0.85	0.036	77.497	0.971
Solitude	3.66 ± 1.33	3.73 ± 1.32	0.211	79.273	0.833
Competition	2.48 ± 1.34	2.69 ± 1.48	0.669	76.970	0.505
Physical health	5.25 ± 0.79	5.11 ± 1.00	−0.695	72.041	0.488

significantly predicted changes in hang clean strength ($\beta = 1.146$, $p = 0.036$). Table 9 shows all regression results for REx score and changes in strength (Table 10).

Discussion

While there has been a plethora of studies conducted assessing the relationship between psychological factors and aerobic training (Reed and Buck, 2009; DiLorenzo et al., 1999; King et al., 1989), there is a gap in our understanding of the association between psychological factors and participation in RT, and more specifically, barbell-based RT. The overarching goal of this study was to examine the relationship between basic psychological needs, behavioral regulation, self-efficacy, and a longitudinal barbell-based RT program for adults. The present study had 4 key findings. First, the basic psychological need of competence increased from baseline to post-program. Second, for behavioral regulation the identified regulation subscale, increased from baseline to post-program; and the behavioral regulation composite score of the BREQ-3 predicted muscular strength increases in the deadlift. Third, for the self-efficacy subscales, both mastery and resilience increased from baseline to post-program. Fourth, from an exploratory standpoint, the reasons to exercise scale predicted increases in muscular endurance and muscular power. Taken together, our data empirically support multiple positive relationships between psychological factors and longitudinal barbell-based RT programming for adults while calling for more exercise psychology research on barbell-based RT.

The first key finding was a significant increase in participants' sense of competence from pre- to post-program. Competence is one of the three basic psychological needs posited by the psychological needs mini-theory of self-determination theory and is a critical component of sustaining intrinsic motivation and multiple positive behavioral and health outcomes (Ryan and Deci, 2000; Deci and Ryan, 1985), including exercise adherence and overall well-being. Many of the exercises included in the RT program are traditionally seen as complex, challenging, and intimidating, especially in a population with limited RT experience. Thus, increasing participants' competence in these compound movements (e.g., deadlift, front squat, hang clean) is an important achievement. Studies of sport and exercise have found mixed results in improving basic psychological needs, as competence is a relatively stable construct that takes time to change (Ryan and Deci, 2000). Longitudinal studies have demonstrated increased competence pre- to post-program for aerobic training programs, but there is a strong need for more research on psychological responses to RT (Cavarretta et al., 2019; Goldfield et al., 2015). There have been mixed results about the association of RT exercises to competence and these studies are often of short duration, assessing single-joint or upper extremity RT exercises (e.g., leg curl, bicep curl, bench press), and are often in

TABLE 9 Linear regression results for REx subscales and change in strength.

REx subscales	β	SE	t-value	p-value
Muscular strength, adjusted $R^2=0.008$, $p=0.423$				
Social	−0.301	0.327	−0.920	0.364
Weight management	−0.230	0.336	−0.686	0.497
Health concerns	0.550	0.283	1.944	0.060
Appearance	−0.071	0.381	−0.185	0.854
Mood enhancement	−0.130	0.573	−0.228	0.821
Solitude	0.159	0.313	0.509	0.613
Competition	0.255	0.270	0.947	0.350
Physical health	−0.162	0.496	−0.328	0.745
Muscular endurance, adjusted $R^2=0.634$, $p=0.115$				
Social	4.025	1.919	2.098	0.103
Weight management	10.016	3.505	2.858	0.046*
Health concerns	1.810	1.296	1.397	0.234
Appearance	−5.148	3.054	−1.686	0.167
Mood enhancement	−4.903	3.770	−1.301	0.263
Solitude	6.792	2.216	3.065	0.037*
Competition	1.880	1.453	1.294	0.265
Physical health	7.157	4.614	1.551	0.195

TABLE 10 Linear regression results for baseline REx score and change in strength.

Predictors	F-statistic	Adjusted R^2	P-value
Pre-REx-score			
Deadlift 1RM Δ	2.818	0.114	0.117
Front squat 1RM Δ	0.381	−0.046	0.547
Hang clean 1 RM Δ	5.432	0.240	0.036*

competitive athletes, younger populations, or populations with pre-existing health conditions (O'Dowd et al., 2022; Collins et al., 2019). However, to our knowledge, this is the first study to show an improvement in competence from pre- to post- program from a longitudinal barbell-based RT program for adults. The distinction between stationary machines and single joint exercises compared to barbell-based RT exercises is important because barbell-based RT may have added benefits, including but not limited to functional strength, balance, coordination, core activation, greater hormonal responses, and joint health (Paoli et al., 2017; Suchomel et al., 2018). An important aspect of the RT program in the present study worth highlighting is the role of perceived feedback as a source of competence. For instance, in line with psychological needs, individuals often judge their competence through different sources of motivation than they use to judge their performance ability (Ryan and Deci, 2000). In this RT program, participants received a variety of rich, intentional information about their progress, including coach feedback and an individualized tracking sheet to promote self-comparison and degree of strength performance improvement over time. This feedback may support self-awareness and a sense of accomplishment related to speed or ease of learning challenging new RT exercises, improvements in amount of effort exerted, and week-to-week improvement (Martin and Nikos, 2007). Therefore, self-determination highlights the role of feedback as a social factor that influences motivation and behavioral outcomes. While the barbell-based movements used in the present program are relatively challenging, this study provides evidence that adult participants enrolled in a 16-week RT program can significantly increase their sense of competence.

The second area of key findings was related to motivation through behavioral regulation. The identified regulation subscale of the BREQ-3 increased from baseline to post-program and the BREQ-3 composite score predicted muscular strength increases in the deadlift. Identified regulation, defined as identified benefits of exercise (e.g., "I value the benefits of exercise"), is an important improvement because it is associated with long-term exercise adherence (Teixeira et al., 2012). Compared to integrated regulation, identified regulation represents the lower limit of autonomous motivation in which participation is regulated by goal values or the importance of behavioral outcomes (Teixeira et al., 2012; Ryan and Deci, 2000). This finding is important, but may be related to characteristics of the sample in that the majority of the participants were likely in the action or maintenance stages of change as they have joined an RT program; thus, this finding may not have been representative in a population distributed across different stages of change. Literature supports the concept that people's behavioral regulation generally becomes more intrinsic over time (Kwasnicka et al., 2016), but to our knowledge this is the first study to demonstrate increased intrinsic motivation in a longitudinal barbell-based RT program for adults. Taken together with the first finding of increased competence pre- to post-program, increased identified regulation suggests that a longitudinal RT program has many positive effects on psychological outcomes. With long-term exercise adherence and lifestyle benefits in mind, other RT programs may be well-served to target these psychological factors, in addition to the more traditionally sought after physiological outcomes (e.g., strength/physiological improvements).

Another key outcome related to behavioral regulation was that the BREQ-3 composite score predicted strength increases in deadlift, the most fundamental and emphasized barbell-based exercise in the current RT program. Deadlifts, or hip hinging, are a fundamental exercise to many other barbell-based movements (e.g., hang clean, power clean, hang snatch) and they also are, arguably, one of the most important functional movements for activities of daily living (e.g., bending over, picking things up off the ground). This finding further supports the notion of potentially focusing program design on not only on physiological improvements (e.g., strength gains), but also attempting to design RT programs to target intrinsic motivation, as defined within the behavioral regulation continuum identified within the BREQ-3.

The third key finding was an increase in self-efficacy subscales pre- to post-program, including resilience and mastery. Increases in resilience have been seen in other research, where exercise, broadly defined, served as a mediator for resilience during the COVID-19 pandemic (Lancaster and Callaghan, 2022). In terms of resilience, Lancaster and Callaghan (2022) findings indicated that those who exercised during the pandemic were able to increase their resilience versus those who were sedentary. Indeed, the effect of RT on psychological function are well-supported with empirical evidence demonstrating exercise ensures healthy brain functioning (Deslandes et al., 2009). Moreover, the increase in resilience is also seen in research exploring military training, where RT is prescribed not only for physical readiness, but for psychological preparation as well (Szivak and Kraemer, 2015). Expanding on existing literature, our study extends the observed improvements in resilience resulting from long-term barbell-based RT among adults. Our findings, in conjunction with previous research, highlight resistance training as a valuable tool not only for the general population but also for individuals undergoing specialized training, enabling them to better cope with life stressors. Additionally, our findings add to physical activity literature specifically highlighting that participation in a 16-week barbell-based RT program has an important association to changes in perceived feelings of self-efficacy among a group of adults who may have built up preconceived belief that resistance training leads to increased likelihood of injury. To combat that potential preconceived notion, in this study we found that adults reported a greater sense of efficacy in their ability to "execute a lift safely" and/or perform complex, barbell-based RT exercises without feeling like they will get injured. Future resistance training programs could prioritize resilience enhancement to offer greater advantages to participants both within and outside gym environments.

Similar to the resilience subscale, the mastery subscale showed a significant increase from pre- to post-program. The mastery subscale primarily captures individuals' confidence in mastering new skills, indicating that participants felt more prepared and capable of learning and taking on unfamiliar tasks. This may be compared to research exploring self-efficacy in a RT context (Dionigi, 2007), which found that in healthy adults, RT offered enhanced perceptions of mastery which led to greater feelings of self-efficacy. The varied psychological improvements seen from pre- to post-program in the current study suggest substantial benefits from exercise aside from the clear physical benefits. These improvements in self-efficacy, combined with previously discussed findings of increased competence and identified regulation from pre- to post-program warrant further rigorous investigation in longitudinal barbell-based RT programming for regular adults.

The final key finding was the reasons to exercise (RE_X) scale predicted increases in muscular endurance and muscular power. Specifically, two subscales, weight management and seeking solitude, were significant predictors of increased push-up repetitions seen post-program. Weight management's influence on exercise has been explored previously, with females citing it as their primary motivation for engaging in fitness routines (Kim and Cho, 2013). Notably, this motivation tends to be more prevalent in female populations (Yang, 1994), which aligns with our study where 81% of participants were female. This prevalence likely contributed to the observed trend of weight management serving as a motivator for enhancing muscular endurance. Moreover, seeking solitude predicted gains in muscular endurance. There is extremely limited research of the relationship between pursuing solitude and RT, but this exploratory finding warrants further investigation. Those who are motivated by solitude may particularly benefit from barbell-based RT as it takes a high degree of focus to perform movements like the deadlift or front squat, in comparison to activities like jogging, cycling, or single joint machine-based exercises (e.g., leg extensions). Further, the RE_X composite score predicted muscular power (i.e., 1RM hang clean). Similar to previous research that found multiple valued reasons were associated with greater physical activity levels (Martinez Kercher et al., 2022), participants in the present study with a greater number of highly valued reasons for exercise were more likely to increase their hang clean performance. Further research exploring the specific effects of weight management, solitude, and reasons for resistance training could provide valuable insights into optimizing exercise interventions for both physical and psychological health outcomes.

In conclusion, barbell-based RT remains a relatively untapped exercise option compared to aerobic training (e.g., running, cycling) or stationary machines (e.g., leg extension, bicep curl) and our study provides evidence for important associations between psychological factors, RT programming, and RT outcomes. Moreover, these findings hold the potential to guide future research and practical applications within exercise science, especially in crafting programs that cater to the holistic well-being of individuals participating in RT. Notably, our study had a substantial representation of women in the sample. Consequently, the insights gleaned from this research could be particularly beneficial for women. Moving forward, there's an opportunity for further work to develop targeted programs that can benefit women, who are often underrepresented in exercise science, gym settings, and research as whole, thereby fostering inclusivity and equity in society.

The present study must be interpreted within its limitations. First, there was a lack of generalizability from the study sample in that the population was primarily White, self-selected into the program (i.e., more motivated and financially stable than the regular population), and had the financial means to afford small group RT programming. Second, while this study was a pragmatic longitudinal assessment of an existing barbell-based RT program, the lack of a control group limits the internal validity of the findings and must be considered as the findings represent correlation rather than causation. Lastly, while also a strength of the study, the sample was made of primarily women, so the findings are not necessarily generalizable to men. Despite these limitations, this study adds relevant evidence emphasizing the importance of combining exercise psychology in exercise performance-based studies to help develop a more comprehensive understanding of human motivation in barbell-based RT contexts. After all, human performance exists within a psychological context as humans have important thoughts, feelings, and motivations that influence their behaviors.

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 humans were approved by Logan Health Medical Center, Institutional Review Board Coordinator Logan Health Medical Center 310 Sunnyview Lane Kalispell, MT 59901 (406) 858-6854 WKGRPIRB@logan.org. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

VM: Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing, Conceptualization, Project administration, Resources, Supervision, Validation. JW: Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. JG: Formal analysis, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. LP: Conceptualization, Investigation, Methodology, Project administration, Resources, Writing – review & editing. BR: Conceptualization, Investigation, Methodology, Project administration, Resources, Supervision, Writing – review & editing. KB: Conceptualization, Investigation, Methodology, Project administration, Resources, Writing – review & editing. DD: Investigation, Methodology, Project administration, Resources, Writing – review & editing. KK: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

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

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Effects of perceived variety-support on middle school students' learning engagement in physical education: the mediating role of motivation

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Introduction: High engagement in physical education (PE) could effectively develop students' motor competence and promote physical activity, which was significantly important for students' physical and mental health. Researches had shown that motivation was an important factor in explaining students' learning engagement, and variety-support as the fourth independent psychological need was a potential factor influencing students' learning motivation. However, there was a lack of empirical research evidence on the effect of perceived variety-support on middle school students' learning engagement in PE and the influencing mechanisms. This study aimed to investigate the direct effect of perceived variety-support on learning engagement in PE and the mediating effect of motivation in PE on the relationship.

Methods: A cross-sectional study was conducted and 587 middle school students from Liaoning province filled the paper-and-pencil questionnaires adopting perceived variety-support in PE scale (PVSPES), utrecht work engagement scale-student (UWES-S), and perceived locus of causality in PE scale, which had been proved to have good reliability and validity (294 boys and 293 girls, Mage=13.47 $\pm$ 0.94).

Results: The results showed three variables were significantly positively correlated with each other ($r = 0.323$-0.562 $p < 0.01$) and perceived variety-support in PE could not only directly promote middle school students' learning engagement in PE but also indirectly through the mediating effect of motivation in PE.

Discussion: Therefore, in order to better promote students' participation in PE class, we should pay more attention to satisfy students' varied PE learning needs and stimulate students' autonomous learning motivation.

KEYWORDS

perceived variety-support, learning engagement, motivation, physical education, middle school students

1 Introduction

The advancement of digital technology and artificial intelligence has undoubtedly increased convenience but also led to an increase in screen exposure. This, in turn, has caused sedentary behaviors and resulted in a lack of physical activity (Nakshine et al., 2022).

A pooled analysis of 298 school-based surveys, encompassing 1.6 million participants aged 11–17 years, showed that 81% of school-going students in this age group were insufficiently physically active, indicating that the vast majority of these students are not meeting the current physical activity guidelines (Guthold et al., 2020).

Maintaining a physically active lifestyle during school years is critical for their overall health and mental well-being, including reduced sedentary behavior, improved scoliosis outcomes, enhanced cardiorespiratory and muscular fitness, healthy weight management, and positive effects on psychological health (Almahmoud et al., 2023; Jiang et al., 2023; Martinko et al., 2023). Physical education (PE) could be regarded as a powerful influence in promoting school-aged students' physical activity (Wallhead and Buckworth, 2004).

As an indispensable school subject with course goals defined by curriculum standards, schools and PE teachers in China have been encouraged to include "health aims" into the physical and health education curriculum. These "health aims" focus on enhancing students' physical and mental health and helping them adapt effectively to their external environment (Ji, 2022). Similarly, many countries have paid attention to reforming their physical and health education curricula to include these "health aims" (OECD, 2019). One of the key strategies for achieving these "health aims" is promoting physical activity through PE. Recent global evidence indicates that comprehensive school-based physical activity programs, especially those integrated into the PE curriculum, are more successful in promoting physical activity. Additionally, a supportive school environment is a crucial component of the adolescent physical activity system (van Sluijs et al., 2021). Therefore, greater emphasis needs to be placed on the PE curriculum in schools.

There was a global consensus that PE is the most important subject for students to learn motor skills, acquire communication and cooperation skills, and develop excellent personalities and values (McLennan and Thompson, 2015).

High-quality PE promoted motor literacy, equipped students with the motor skills necessary for lifelong physical activities (Whitehead, 2013), and provided potential evidence of a significant increase in physical activity levels among school-going students (Ha et al., 2019). The two main focal points of PE were PE teachers and students, and the attainment of high-quality PE inevitably predicated students' learning engagement in PE lessons (Fredricks et al., 2004). Learning engagement is a positive, fulfilling state of mind related to learning, characterized by vigor, dedication, and absorption. It also reflects the degree of students' efforts in learning, understanding, and mastering knowledge and skills (Schaufeli et al., 2002b). Vigor refers to the state in which students are fully energized in the learning process, willing to put in effort, and highly involved in learning; dedication refers to the state in which students have full enthusiasm for learning and are fully devoted to learning; and absorption refers to the state in which students concentrate on learning and enjoy the fun of learning (Ni and Wu, 2011). In the present middle school PE classroom teaching, due to the absence of attention to students' subjective consciousness, the lack of emotional interaction between students and teachers, as well as among students, the low novelty and challenge of teaching content, tedious teaching methods and means, and other factors, students have low energy and enthusiasm in PE classes and show a low level of learning engagement (Zhang et al., 2020).

Low levels of learning engagement in PE directly lead to reduced exercise intensity and insufficient physical activity, which, over time, contribute to physical inactivity and negatively impact physical and mental health. Therefore, there is an urgent need to explore effective operational programs to improve students' learning engagement in PE.

Improving students' motivation for PE learning, especially intrinsic motivation, could inspire students to learn and improve their focus on learning. Research has shown that learning engagement is highly correlated with intrinsic motivation (Kuo et al., 2020; An et al., 2022; Alemayehu and Chen, 2023). According to self-determination theory (SDT), an individual's participation in an activity may be motivated by relative self-determination or autonomy, and/or by more controlled motivation (Ryan et al., 2009), which indicates that stimulating students' motivation in PE had positive integrative benefits for enhancing students' learning engagement behaviors such as increased vigor, increased emotional engagement, and improved concentration. In addition, previous studies has indicated that when teaching and learning elements align with the psychological needs of students for autonomy, competence, and relatedness, students' motivation, achievement, and well-being will be significantly enhanced, and it may have a positive impact on students' learning.

The provision of variety-support was put forward as a potential influencing factor of one's motivation in PE, the effects of which on physical activity had been proven to be positive, and increasing the variety-support provided for PE could increase an individual's motivation of sport participation and enjoyment of sport (Juvancic-Heltzel et al., 2013). It has been reported that variety-support was the provided activity or environmental elements of variety with given contexts. Moreover, variety-support or non-support would probably facilitate (or hinder) subsequent variety experiences (Eather et al., 2022). In PE, variety-support was comprised of the provision of diverse teaching methods, sports equipment, curriculum contents, lesson topics, venues for classes, etc. Variety-support could maximize the positive impact of exercise on health and well-being by improving emotional reactions in sports contexts (Mandolesi et al., 2018). In addition, it has been pointed out that variety-support perceived by students in PE could influence their physical activity level (Sylvester et al., 2016b), predict physical activity behaviors (Sylvester et al., 2014a), and increase indices of exercise-related well-being (Sylvester et al., 2016a).

SDT emphasizes that individuals are sufficiently intrinsically motivated to participate in physical activity when three basic psychological needs (the need for competence, the need for autonomy, and the need for relatedness) are fulfilled (Teixeira et al., 2012). Sylvester et al. (2014b) extended this theory by suggesting that variety-support could be considered a fourth independent basic psychological need that influences motivation to participate in physical activity. Similarly, Abós et al. (2021) found that perceived task diversity predicted adolescents' autonomous motivation in PE classes (Abós et al., 2021). Therefore, further research is needed to better understand students' PE learning engagement and provide the rationale for new initiatives in students' PE learning.

Perceived variety-support is currently considered an independent element that promotes motivation and behavior in physical activity; however, empirical research on this topic is relatively limited.

Moreover, studying middle school students' learning engagement in PE is crucial for improving both their physical literacy and PE core literacy, and research on the middle school students' learning engagement in PE also lacked new conceptual support. Consequently, this study aimed (1) to determine the relationships between perceived variety-support, motivation, and learning engagement in school PE settings and (2) to investigate the possible mediating effect of motivation in PE on the relation between perceived variety-support and learning engagement in PE among middle school students, in an effort to provide additional support for promoting middle school students' learning in PE, advancing the achievement of high-quality PE, and increasing the physical activity levels of adolescents.

2 Methods

2.1 Participants and procedures

A convenience sample of 611 students from a middle school in Fuxin Province was used for this study, where mandatory PE classes were offered three times a week, each lasting 40 min throughout the school year. The PE classes in this study mainly referred to the junior high school PE and health curriculum in China's compulsory education stage. To ensure voluntariness and confidentiality of participants in the study, students and their parents were required to provide written informed consent. The cross-sectional data for this study were collected over approximately 2 weeks in October 2023. With the assistance of the head teacher, students completed paper-and-pencil questionnaires during their self-study class. After excluding invalid questionnaires—those with missing information, inconsistent answers, or significant deviations from typical responses—we analyzed responses from 587 students, yielding a valid response rate of 96.1%. Among the respondents, there were 294 boys (50.1%) and 293 girls (49.9%), with 242 (41.2%) students in the first year, 153 (26.1%) in the second year, and 192 (32.7%) in the third year of junior high school. The age range of the students was from 12 to 16 years (Mage = 13.47 ± 0.94).

2.2 Instruments

2.2.1 Perceived variety-support in PE

The Perceived Variety-Support in PE Scale (PVSPES) was developed and evaluated by Eather et al. (2022) to assess individual variety-support in PE, which had been shown to have good internal consistency, factorial validity, and test–retest reliability and to be suitable for use with adolescents (Eather et al., 2022). To ensure the content validity of the scale, first, two PE scholars majoring in PE Curriculum and Pedagogy were invited to translate the scale into Chinese, followed by proofreading, discussion, and integration. Second, two more PhD students majoring in English were invited to translate the Chinese version of the scale back into English and then compare it with the original scale accordingly. Finally, the four discussed the Chinese version of the scale together and finalized it. The final revised Chinese version was piloted before the formal study and proved to be adaptable. The scale included eight items and was a brief unidimensional scale measuring variety-support in PE activity, instruction, and environment (e.g., "In PE, my teacher provides a range of different sports equipment for me to use the term, e.g., bats, balls, hoops, racquets, nets"). Each question was scored on a 4-point Likert scale, ranging from 1 = never to 4 = always. The higher the score, the higher the level of the student's perceived variety-support in PE. In the present study, the scale had good reliability (Cronbach's $\alpha = 0.850$) and ideal validity ($\chi 2/df = 2.481$, GFI = 0.982, AGFI = 0.963, NFI = 0.972, IFI = 0.983, RMSEA = 0.050).

2.2.2 Learning engagement in PE

The Utrecht Work Engagement Scale-Student (UWES-S), originally developed by Schaufeli et al. (2002a) and later revised and sinicized by Fang et al. (2008), was adopted to measure middle school students' learning engagement in PE. Combined with the characteristics of PE teaching and learning in middle school, "study" was replaced by "study in PE lessons." For example, "When studying, I feel strong and vigorous" was replaced by "When studying in PE lessons, I feel strong and vigorous." The 17-item scale was divided into three dimensions, including vigor (6 items, e.g., "I can continue for a very long time when I am studying in PE lessons"), dedication (5 items, e.g., "I find my studies in PE lessons to be full of meaning and purpose"), and absorption (6 items, e.g., "Time flies when I'm studying in PE lessons"). A 5-point Likert scale was used to measure the degree of students' learning engagement in PE, ranging from 1 = strongly disagree to 5 = strongly agree. Higher scores indicated higher levels of students' learning engagement in PE.

In this study, the Cronbach's α for each dimension was as follows: 0.901 for vigor, 0.923 for dedication, and 0.884 for absorption, and the Cronbach's α for the whole scale was 0.956, which showed good reliability. A confirmatory factor analysis was conducted and showed that the structural validity of the scale was adequate ($\chi^2/df = 2.883$, GFI = 0.938, AGFI = 0.911, NFI = 0.961, IFI = 0.974, RMSEA = 0.057).

2.2.3 Motivation in PE

The degree of middle school students' self-determined motivation in PE was assessed by adopting the Revised Perceived Locus of Causality in PE Scale (PLOC-R) revised by Vlachopoulos et al. (2011). The scale can indicate the extent to which middle school students choose to take part in PE for different purposes. In accordance with the same translation and revision process as for PVSPES, this study finalized the Chinese version of the PLOC-R, which includes nineteen items. The scale consisted of five factors: motivation (four items, e.g., "I take part in PE, but I really do not know why"), external regulation (three items, e.g., "I take part in PE because in this way I will not get a low grade"), introjected regulation (four items, e.g., "I take part in PE because I would feel bad if the teacher thought that I am not good at PE"), identified regulation (four items, e.g., "I take part in PE because it is important to me to do well in PE"), and intrinsic motivation (four items, e.g., "I take part in PE because PE is enjoyable"). The subjects responded using a 7-point Likert scale, with 1 indicating strongly disagree, 7 signifying strongly agree, and 4 serving as the neutral midpoint. A Relative Autonomy Index (RAI) was formed as an indication of individual differences in the degree of self-determination of his/her behavior. The RAI score was obtained by multiplying each item score by a given weight: motivation was given a weight of −3, external regulation −2, introjected regulation −1, identified regulation +1, and intrinsic motivation +2. Then, the sum of all products ranged from −39 to 15, with a higher RAI score signifying more self-determined motivation. In the present study, the Cronbach's α of five dimensions was as follows: 0.907 for motivation, 0.855 for external regulation, 0.874 for introjected regulation, 0.820 for identified regulation, and 0.956 for intrinsic

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motivation. The Cronbach's α of the whole scale was 0.830, representing good internal consistency. Meanwhile, the scale had good validity ($\chi2$/df = 2.902, GFI = 0.933, AGFI = 0.906, NFI = 0.956, IFI = 0.971, RMSEA = 0.057) in the present study.

2.3 Data analysis

Before statistical analysis, the common method deviation test and normal distribution test were conducted using SPSS 26.0. In this study, data were collected by filling out paper-and-pencil questionnaires, and several scales were used simultaneously. There were differences in subjects' grades and classes. Therefore, common method deviation required attention. To control for potential common method deviation, the Harman single-factor analysis was conducted to test the possibility of systematic errors. The results showed that, in the principal component analysis without varimax rotation, there were six factors with eigenvalues greater than 1. The variance explanation rate of the first factor without rotation was 32.576%, which is less than the 40% critical value, indicating that the common method deviation in this study was within acceptable limits. Moreover, all variables were tested to fit a normal distribution.

SPSS 26.0 was employed to conduct a reliability analysis of three scales, presenting Cronbach's α for each scale, as well as descriptive statistics including mean scores and standard deviations (SD) for the three variables. Additionally, independent-samples T-tests and one-way analyses of variance were performed alongside Pearson's correlation analysis. Amos 26.0 was utilized to carry out a confirmatory factor analysis (CFA) to assess the factorial validity of the three scales. The mediating effect serves to analyze the influence process and mechanisms through which independent variables affect dependent variables, establishing itself as an essential statistical method for examining relationships among multiple variables (Wen et al., 2022). In this study, the SPSS 26.0 PROCESS macro was applied to evaluate the significance of the mediating effect, while Bootstrap methods were employed to calculate mediation effect sizes.

3 Results

3.1 Descriptive characteristics

Table 1 presents the descriptive characteristics of 587 samples and the differences in gender and grade for each variable. The mean scores for perceived variety-support in PE, learning engagement in PE, and motivation in PE were 2.807 (SD = 0.703), 3.650 (SD = 0.832), and 0.938 (SD = 9.411), respectively. There were no gender differences in perceived variety-support in PE and motivation in PE; however, boys showed high levels of learning engagement in PE ($p < 0.001$). Additionally, there were no significant grade differences in learning engagement or motivation in PE, although first-year students reported lower levels of perceived variety-support compared to second- and third-year students ($p < 0.001$).

3.2 Correlations between research variables

Table 2 presents the results of Pearson's correlation analysis between research variables. Perceived variety-support in PE was significantly positively correlated with learning engagement in PE ($r = 0.408$, $p < 0.01$) and motivation in PE ($r = 0.323$, $p < 0.01$). Learning engagement in PE was significantly positively correlated with motivation in PE ($r = 0.562$, $p < 0.01$).

3.3 Mediating effect analysis

Table 3 displays the results of the mediating effect test. The results showed that the positive predictive effect of perceived variety-support in PE on learning engagement in PE was significant (standardized path coefficient = 0.435, SE = 0.038, $p < 0.001$). Even after adding motivation in PE as a mediating variable, the direct positive effect of perceived variety-support on learning engagement in PE remained significant (standardized path coefficient = 0.265, SE = 0.036, $p < 0.001$). Perceived variety-support in PE had a significant positive predictive effect on motivation in PE (standardized path coefficient = 0.365, SE = 0.040, $p < 0.001$), and motivation in PE had a significant positive predictive effect on learning engagement in PE (standardized path coefficient = 0.468, SE = 0.035, $p < 0.001$). In addition, the total effect of perceived variety-support in PE on learning engagement in PE was 0.435 (Bootstrap 95%CI = [0.351, 0.521]). The direct effect was 0.265 (Bootstrap 95%CI = [0.184, 0.348]), accounting for 60.92% of the total effect. The mediating effect of motivation in PE was 0.170 (Bootstrap 95%CI = [0.123, 0.225]), accounting for 39.08% of the total effect. The 95% confidence interval of Bootstrap did not contain 0 (see Table 4). Therefore, middle school students' perceived variety-support in PE could positively affect learning engagement in PE, but middle school students' motivation in PE also had a mediating effect on perceived variety-support in PE and learning engagement in PE (see Figure 1).

4 Discussion

The purposes of this study were (1) to examine the relationships between perceived variety-support, motivation, and

TABLE 1 Descriptive characteristics of the sample.

Gender		*t*	*p*	Grade		
Boys (*n* = 294)	Girls (*n* = 293)			Junior 1 (*n* = 242)	Junior 2 (*n* = 153)	Junior 3 (*n* = 192)
2.831 (0.728)	2.782 (0.677)	0.841	0.401	2.548 (0.679)	3.022 (0.693)	2.962 (0.636)
3.775 (0.891)	3.525 (0.748)	3.682	**<0.001**	3.621 (0.810)	3.753 (0.840)	3.603 (0.850)
1.432 (10.003)	0.443 (8.767)	1.273	0.203	1.562 (8.729)	1.040 (10.088)	0.072 (9.662)

A p-value of less than 0.001 signifies a statistically significant difference.

learning engagement in PE among middle school students and (2) investigate the potential mediating effect of motivation in PE on the relationship between perceived variety-support and learning engagement. The results highlighted the significantly positive correlations between perceived variety-support, motivation, and learning engagement in PE and showed that perceived variety-support in PE could not only positively and directly predict learning engagement in PE but also positively and indirectly predict through the mediation of motivation in PE.

First, research has shown that middle school students' engagement in PE is positively correlated with perceived variety-support in PE classes, which is consistent with the findings of previous studies (Martinek et al., 2019; Otundo and Garn, 2019). Students exhibited noticeable differences in their PE learning, reflecting a wide range of individual needs. The inherent disparities in motor competence among individuals, coupled with varying interests in sports, created a significant level of diversity in students' PE learning abilities. The provision of variety-support by teachers in PE classes fostered student engagement, creating a conducive classroom environment and fostering harmonious teacher–student relationships. This, in turn, addressed the diverse learning needs of students (Furrer and Skinner, 2003). Otundo and Garn (2019) highlighted the predictive effects of situational interest and need-supportive teaching on students' interest and engagement. This finding further demonstrated that when students' learning attitudes and behaviors in PE were driven by their interests, their learning process became more autonomous, voluntary, comprehensive, and sustainable (Kirch et al., 2021). The introduction of variety in PE classes highlighted diverse motor competencies and movement skills, allowing students to experience a wide range of movements, games, and sports cultures. With careful planning, PE lessons offering a variety of sports equipment, locations, activities, curriculum goals, engaging teaching methods, and groupings can effectively cater to students' diverse needs (Bertills et al., 2019). This approach generates interest in learning and sustainably motivates students to focus on PE learning in the classroom.

Second, the study confirmed that motivation in PE mediates the relationship between perceived variety-support and learning engagement. Sylvester et al. (2014a) found that perceived variety indirectly predicts physical activity behavior through autonomous motivation, aligning with our findings. Research indicated that variety, novelty, choice, and effort-based praise enhanced autonomous motivation toward PE (White et al., 2021), and motivation predicted intentional behavior participation (Ryan and Deci, 2017). The self-determination theory (SDT) revealed the extent to which and the manner in which various contextual factors influenced individuals' exercise behavior, particularly through psychological experiences (Lange et al., 2011). Embedded within SDT, it is highlighted that people universally possessed innate basic psychological needs, and the degree to which these needs were satisfied within the social environment subsequently influenced individuals' behavior, mediated by autonomous motivation. Specifically, autonomous and intrinsic motivation led to more adaptive outcomes in PE classes, including learning enjoyment and physical activity intentions (Vasconcellos et al., 2020), boosting student engagement. Therefore, variety-support in PE that satisfied students' psychological needs sparked their intrinsic motivation to learn PE, further promoting engagement behaviors. This insight aided physical educators in designing high-quality PE sessions. Additionally, Tang and Ma (2023) emphasized that teaching content and learning/practicing modes shape students' fundamental learning experiences in PE. The more the teaching content aligned with students' learning needs, the more choices of sports equipment and venues were available, along with novel and interesting learning/practicing modes, the higher the student engagement in PE lessons (Tang and Ma, 2023). However, it is unrealistic to address all students' needs simultaneously in terms of teaching content and facilities in PE classes. Thus, careful design of learning and practicing methods is crucial, as it facilitates the

TABLE 2 Correlations between research variables.

Variables	1	2	3
1. Perceived variety-support in PE	1		
2. Learning engagement in PE	0.408**	1	
3. Motivation in PE	0.323**	0.562**	1

**$p < 0.01$.

TABLE 3 Path coefficients of the mediation model.

IV	DV	M	Effect of IV on M		Effect of M *n* DV		Effect of IV on DV		Effect of IV on DV adding M	
			Coeff	SE	Coeff	SE	Coeff	SE	Coeff	SE
Perceived variety-support in PE	Learning engagement in PE	Motivation in PE	0.365***	0.040	0.468***	0.035	0.435***	0.038	0.265***	0.036

IV = independent variable; DV = dependent variable; M = mediator; ***$p < 0.001$.

TABLE 4 Values of total, direct, and indirect effects.

	Value	Proportion	95%CI	
			Lower	Upper
Total effect	0.435		0.351	0.521
Direct effect	0.265	60.92%	0.184	0.348
Indirect effect	0.170	39.08%	0.123	0.225

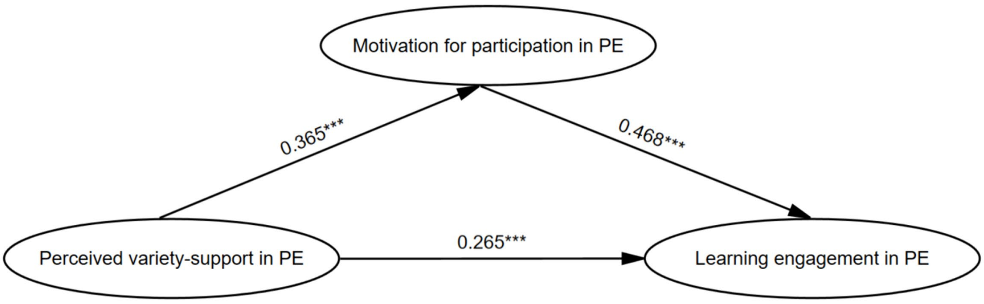

FIGURE 1
Path model of perceived variety-support in PE affecting learning engagement in PE.

presentation, connection, and transition of knowledge and skills, intensifies learning challenges, maintains student motivation (Light, 2014), mitigates teaching–learning conflicts (Kinder et al., 2020), and ensures student engagement in PE lessons.

Finally, these findings has certain implications for school-based interventions. On the one hand, schools should implement high-quality PE to promote students' participation in PE classes and foster a lifelong pursuit of a physically active lifestyle, which includes providing students with adequate opportunities for physical activity, conducting systematic professional training for PE teachers, being equipped with a complete evaluation and supervision system, and creating a dynamic PE atmosphere. On the other hand, PE teachers should provide students with variety-support in the PE curriculum and teaching to greatly satisfy the students' needs for PE learning and promote active participation of students in PE classroom learning. For example, PE teachers should provide students with more space for independent practice, management, and choice to create an exploratory learning atmosphere, and they should also formulate more abundant and humanized teaching contents and learning goals according to individual differences (Zhang et al., 2020). It is also recommended to focus on selecting novel learning and practicing methods in pedagogical practice that stimulate students' motivation and increase their interest in learning independently (Lentillon-Kaestner and Roure, 2019).

5 Conclusion

Studying how physical educators provide variety-support in PE and its impact on students' motivation to learn PE lessons was of interest in understanding the poor performance of some middle school students in PE. This study concluded the direct effect of perceived variety-support on middle school students' learning engagement in PE and the indirect motivation in PE on the relationship between perceived variety-support and learning engagement. On the one hand, gaining a better understanding of high learning engagement in PE was crucial to increase and guarantee the provision of variety-support in PE. On the other hand, high levels of autonomous and intrinsic motivation to learn PE made students perform more behaviors of learning engagement in PE lessons (Leo et al., 2022).

6 Limitations and implications for future research

This study provides empirical evidence to support the development of high-quality PE and the enhancement of students' engagement in PE lessons. However, there are some limitations in this study. First, the present study depended on students' ability to accurately reflect on their previous PE experiences to define the relationships between the variables. Alternative methods other than questionnaire surveys, which may better capture students' perceptions of variety-support, motivation, and learning engagement in PE, should be considered. In future studies, interviews can be conducted to explore students' interpretations of reconstructed descriptions of their school PE experiences, providing a deeper understanding of their engagement in PE class. Longitudinal studies are also recommended to analyze the development process of students' perceived variety-support, motivation, and learning engagement in PE.

Second, PE classes can differ significantly across different countries, and this study only focused on the junior high school PE and health curriculum in China's compulsory education stage. Future studies could include comparative experimental studies to explore the impact of perceived variety-support on students' learning engagement across different curriculum modes, determining whether these effects are consistent across diverse educational contexts.

Furthermore, it would be important to determine whether this effect is consistent across different curriculum models. Finally, this study focused solely on the direct relationship between perceived variety-support, motivation, and learning engagement within the school PE context. However, there may be multiple mediating or moderating factors at play in practice. Future research should incorporate a broader range of variables to better understand the complex processes through which perceived variety-support affects learning engagement.

Data availability statement

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

Ethics statement

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of Beijing Sport University on October 10, 2023. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MM: Writing – original draft, Resources, Investigation, Funding acquisition, Conceptualization. HC: Writing – original draft, Software, Methodology, Investigation, Formal analysis. RX: Writing – review & editing, Software, Methodology, Formal analysis. QW: Writing – review & editing, Validation, Supervision, Data curation, Conceptualization.

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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 between family factors and physical activity clustering in preschool children: a cross-sectional study

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Objective: This study aimed to examine the association between family factors and physical activity (PA) clustering in preschool children.

Methods: Preschoolers' PA and sedentary behavior (SB) were assessed consecutively for 7 days using ActiGraph accelerometers based on the cutoff counts developed by Pate et al. Information about children, their parents, and their families was collected using questionnaires. We developed a two-step approach to clustering PA both inside and outside of kindergarten. The Euclidean distance metric was utilized to distinguish between groups, while the Schwarz–Bayesian criterion was applied to identify the most optimal sub-group model. A one-way ANOVA was used to assess the clustering effect, and logistic regression was used to analyze the influencing factors of different clustering.

Results: We collected data from 291 preschool children aged 3 to 6 years and divided them into three clusters—Inactive (50.2%), Active in kindergarten (26.8%), and Active outside kindergarten (23.0%)—with significant differences in PA and SB, revealing distinct temporal and spatial clustering patterns (silhouette coefficient = 0.3, $p < 0.05$). Furthermore, preschooler activity levels correlated significantly with factors including gender (OR = 0.35, 95% CI: 0.19–0.66), age (OR = 1.05, 95% CI: 1.00–1.10), birth weight (OR = 1.79, 95% CI: 1.16–2.76), paternal age (OR = 1.01, 95% CI: 1.00–1.02), and maternal income (OR = 0.68, 95% CI: 0.48–0.96).

Conclusion: This study shows that the family environment or parents significantly influence the PA of preschool children. Older fathers may promote preschool children's PA through greater educational focus and financial stability, while higher maternal income can provide more opportunities and resources for preschool children to engage in active lifestyles. Thus, it is suggested that families providing more attention and exercise opportunities for preschool children's education can help improve their PA levels in the future.

KEYWORDS

physical activity, sedentary behavior, preschool children, family factors, clustering, parents

Introduction

Technological progress and the ease of transportation have brought plenty of convenience to human life but have decreased physical activity (PA) and increased sedentary behavior (SB) (1). This kind of trend in physical inactivity is recognized as "a global non-communicable disease prevalent in both developed and developing countries" (2). The World Health Organization (WHO) identifies it as the fourth leading risk factor for worldwide mortality (3). In addition, several studies have demonstrated that PA is essential for preschool-aged children's health and mental wellbeing (4, 5). It significantly contributes to bone growth (6), the development of motor skills (7), and the building of self-esteem (8). The first 2000 days of life, from conception to age five, is when substantive learning about health-related behaviors occurs throughout life (9). Therefore, PA is essential throughout one's life, and it is particularly crucial to foster it in preschool children whose habits are more malleable and receptive to change (10).

However, Lu (11) found that in Tianjin, China, preschool children engaged in only 6.6% of their day (both in and out of school) in moderate-to-vigorous physical activity (MVPA), and just 28% of them met the recommended levels of PA (32% of boys and 22% of girls). Currently, a significant portion of the population, including over 23% of adults and 80% of adolescents, are failing to achieve adequate levels of PA (1). Establishing healthy patterns of PA and SB from an early age is crucial for forming lifelong habits (10). Therefore, it is imperative to initiate interventions with preschool children to foster these habits and provide constructive guidance to enhance their health.

The pivotal role of family dynamics in shaping an individual's health, particularly in the context of PA, has been underappreciated in the scientific discourse. In a decision tree analysis of preschoolers' physical fitness, four factors affecting young children's physical fitness are related to parents (12). The study of Watanabe advocates for public health interventions aimed at reducing childhood overweight/obesity by promoting measures such as lowering parental screen usage within families (13). Parents exhibit potential categorizations in their approach to children's PA (14). This highlights a gap in the nuanced understanding of how family characteristics influence young children's health through PA. The family environment profoundly influences children's developmental trajectory, underscoring the critical importance of well-calibrated family-based interventions. However, the efficacy of previous studies has been hindered by a lack of detailed consideration of the diverse family factors of preschool children (15, 16). This oversight has led to interventions that are not sufficiently targeted, thereby reducing their potential to enhance preschoolers' development significantly. Therefore, it becomes imperative to discern and address the family determinants that significantly influence the PA engagement of young children.

Cluster analysis is an unsupervised learning process used to find groupings/clusters of natural observations based on inherent characteristics within the data. It is an exploratory statistical method in statistics, widely used in medicine, biology, finance, and other fields. Some researchers have applied cluster analysis to identify behavioral patterns, physique, PA, dietary habits, etc. (17, 18). We hypothesize that preschool children's PA performance has temporal and spatial distribution characteristics, and family factors influence PA performance differently. Therefore, this study aims to utilize a cross-sectional study to categorize the temporal and spatial characteristics of preschool children's unsupervised PA performance and discuss the impact of diverse family factors on their PA levels. The findings in this study are expected to enhance the practical application of physical education in family settings for preschool children.

Materials and methods

Study design

This cross-sectional study is a baseline data analysis from *The Physical Activity of Preschool Children Study* (Funding Number: 21BTY088). Recruitment was conducted through public welfare projects of Jiangxi Provincial Sports Bureau. The study's leader negotiated with the kindergarten and obtained the consent of the kindergarten. Parent meetings are held with the support of the kindergarten. The benefits and associated risks of the study are carefully explained to the participant's parents or legal guardians. A physical activity test was objectively measured using ActiGraph accelerometers, with the support of parents and kindergarten teachers. The questionnaires were distributed and collected with the assistance of Jiangxi Sports Science Medical Center, Nanchang Sports Bureau, and the kindergarten teachers. The study was approved by the Ethics Committee of FJNU (Fujian Normal University, ethics approval number: 19FJTK0051). Consent can be withdrawn from the study by participants and their parents or legal guardians at any time without explanation (Figure 1).

Participants

A total of 330 preschool children were recruited from seven kindergartens in Nanchang, China, based on the regional economic

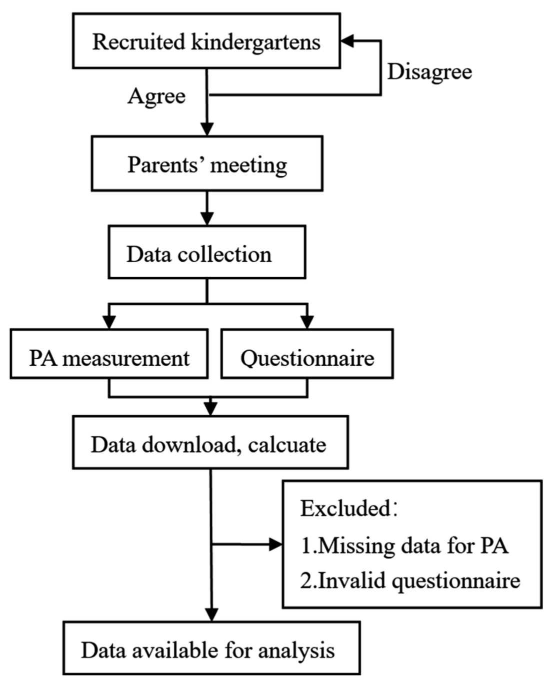

FIGURE 1
Flowchart of procedures for data acquisition of the study.

development levels and the stratified sampling principle. All the parents/guardians of potential participants were fully informed of the study protocol and purpose during the parent–teacher meetings held in the seven kindergartens. The inclusion criteria for this study were (1) children aged 3 to 6 years old, (2) healthy and maintaining a typical lifestyle during the measurement period, (3) children without impairment, and (4) children's parents or legal guardians provided informed consent. Finally, 330 children were eligible to participate in this research. According to the relevant data screening criteria, the movement behavior test data for 39 children were incomplete, or the questionnaire responses were deemed unqualified (incomplete answers, logical inconsistencies, or missing information). Therefore, the final group consisted of 291 children (boys, 57%).

Physical activity

PA was measured over 7 consecutive days during waking hours using ActiGraph accelerometers (GT3X+, ActiGraph, Pensacola, FL, United States) placed on the right hip. Data collection was conducted at 15 s intervals, and PA was categorized into light physical activity (LPA) or MVPA based on the cutoff counts developed by Pate et al. for preschool children (19). LPA was delineated by 800 to 1,679 counts per minute (CPMs), whereas MVPA was characterized by counts equal to or exceeding 1,680 CPMs. SB corresponds to less than or equal to 799 (20). PA/SB inside the kindergarten refers to the period that children are engaged in activities while at kindergarten (e.g., from 9 am to 5 pm). PA/SB outside the kindergarten refers to the period before and after the school day. The rest day PA and SB refer to when children wake up until they sleep on rest days. Data from individual participants would be eligible for inclusion in the analyses if they have been recorded engaging in monitored PA for at least 3 days, including 1 weekend day, with each day accounting for a minimum of 8 h (21).

Before starting the data monitoring, the researchers, supported by the kindergarten principal, conducted a parent–teacher meeting to provide a comprehensive explanation of the study's objectives and pertinent details to the participants' parents. They were informed that the ActiGraph accelerometers should be worn continuously throughout the day, with the only exceptions being times designated for bathing, swimming (non-waterproofing), and sleeping. During the testing period, parental cooperation was needed for device placement and removal. All recruited parents signed the informed consent forms. After collecting data from the ActiGraph accelerometers, the data were analyzed with ActiLife (Version 6.13.3). For the preschool children whose data were missing or did not meet the requirements, the corresponding supplementary test was conducted with the consent of their parents. The researchers recorded children's daily kindergarten attendance times and processed the time nodes in ActiLife to obtain PA and SB durations inside and outside kindergarten on weekdays and off days.

Questionnaires

The parents of the participating preschool children were asked to complete a questionnaire to provide relevant information (Table 1). The questionnaire was designed based on the questions from studies by Zhao (22), which had been previously validated and tested for reliability. After distributing the questionnaire to the parents, they completed it and returned it the following day for collection by the research team.

Statistical analyses

IBM SPSS Statistics 25.0 software was utilized for statistical analysis. The cluster analysis encompassed six variables that evaluated the temporal and spatial aspects of preschool children's PA, including PA and SB inside/outside the kindergarten (working day) and on rest day. A two-step cluster analysis used the Euclidean distance measure for group differentiation and the Schwartz–Bayes criterion to determine the optimal sub-group model. The two-step cluster analysis was deemed reliable for identifying the number of subgroups, the probability of individual classification into these subgroups, and the reproducibility of findings across clinical and various other datasets (23). In the pre-clustering phase, a sequential approach was used to preliminarily cluster cases by identifying dense regions within the attribute space under analysis. Subsequently, these preliminary clusters were statistically consolidated step by step until they formed a single comprehensive group (24).

Logistic regression was conducted to examine the impact of family factors, including continuous and categorical variables, on the clustering of preschool children. In logistic regression, different PA clusters were used as dependent variables, family factors were used as independent variables, and the reference category was set as Inactive. Continuous variables were presented as mean ± standard deviation and were evaluated using a one-way analysis of variance with the Tukey–Kramer *post-hoc* test. Normal distribution was assessed using the D'Agostino–Pearson test. A two-sided p-value of <0.05 was considered statistically significant in all analyses.

Results

Characteristics of preschool children

The characteristics of 291 participants (166 boys and 125 girls) who had complete data on PA and completed questionnaires by parents are shown in Table 2. The descriptive characteristics of preschool children's various PA and SB are shown in Table 2. According to the PA measurement results, compared to girls, boys had significantly less SB than girls, while boys had substantially higher LPA, MVPA, and total physical activity (TPA) than girls.

Cluster analysis

The two-step cluster analysis reported a three-cluster classification as the optimal solution for the data considered in this study, with a silhouette coefficient of 0.3. There were significant differences in PA and SB among the three groups ($p < 0.05$), which showed good clustering results. Three clusters were identified and descriptively labeled according to their dominant features: (1) Inactive, (2) Active in kindergarten, and (3) Active outside kindergarten. The characteristics of these three clusters are shown in Figure 2 and Table 3.

TABLE 1 Specific content and variable assignment of the questionnaire.

First-level indicators	Second-level indicators	Variable types	Variable assignment
preschool children	Birth weight (kg)	Continuous	
	Birth length (cm)	Continuous	
	Months of age (m)	Continuous	
Parenting	Caregivers	Classification	1 = Parental care/2 = Grandparent care/3 = Parents and grandparents care together
	Daily sleep time (hour)	Continuous	
	Feeding patterns[a]	Classification	1 = Breastfeeding/2 = Artificial feeding/3 = Mixed feeding
	Whether to attend early education?[b]	Classification	1 = YES/2 = NO
Parents and family	Parental age (month)	Continuous	
	Parental BMI	Continuous	
	Parental education level	Classification	1 = Junior high school and less/2 = Vocational high school/technical secondary school/3 = High school/4 = Junior college/Higher vocational college/5 = College education
	Parental enjoys sports	Continuous	1 = Love/2 = A little love/3 = General/4 = Do not love/5 = Dislike
	Parental exercise frequency (day/week)	Continuous	1 = Everyday/2 = 5–6 times a week/3 = 3–4 times a week/4 = 1–2 times a week/5 = Never
	Parental occupation	Classification	1 = Managers/2 = Professionals/3 = Clerical support workers/4 = Services and sales workers/5 = Skilled agricultural, forestry, and fishery workers/6 = Plant and machine operators and assemblers/7 = Armed forces occupations/8 = Elementary occupations
	Parental income (CNY/month)	Classification	1 = ≤ ¥ 3000/2 = ¥ 3,001– ¥ 5000/3 = ¥ 5,001– ¥ 8000/4 = ¥ 8,001– ¥ 10,000/5 = ¥ 10,001– ¥ 15,000/6 = ≥ ¥ 15,001
	Marital status	Classification	1 = Married/2 = Unmarried[c]

To improve the accuracy of statistical analysis, the age of preschool children and parents in this study was calculated accurately to "month".
[a]Feeding patterns from birth to 4 months of age.
[b]Early education is a "fitness center" or "interest class" for infants and young children that offers specialized courses, such as early education in music and early reading.
[c]Unmarried includes a single parent who has not remarried and the mother is raising the child, a single parent who has remarried, and the father is raising the child, a single parent who has remarried, and the mother is raising the child, and other conditions.

Cluster 1: Inactive. This is the largest cluster, comprising 50.2% of participants ($n = 146$). It was characterized by significantly higher SB in kindergarten on weekdays, SB outside the kindergarten on weekdays, and SB on the rest days and less PA.

Cluster 2: Active in kindergarten. This second cluster comprised 26.8% of participants ($n = 78$) and was characterized by a high level of PA in kindergarten on weekdays and less SB.

Cluster 3: Active outside kindergarten. This smallest cluster comprised 23.0% of participants ($n = 67$) and was characterized by a high level of PA outside the kindergarten on weekdays and rest days.

In contrast to the Inactive cluster, on weekdays in the kindergarten, children within the Active in kindergarten cluster exhibit a significantly higher level of PA, with an average difference of 52.42 min and a notably lower amount of SB, averaging a 47.24 min reduction. The Active outside kindergarten cluster also demonstrates a modest increase in PA, with an average difference of 8.91 min, and a slight decrease in SB, averaging 6.29 min less. Curiously, on weekdays outside the kindergarten, the PA levels of these two active clusters are comparable, with averages of 102.25 and 105.7 min, respectively, which substantially surpass the PA levels of the Inactive cluster. These findings suggest that the Active outside kindergarten cluster becomes more active once they return home, in contrast to their activity levels within the kindergarten environment. Conversely, the Active in kindergarten cluster is observed to be more active at kindergarten than at home.

On rest days, when all children are away from the kindergarten, both active clusters exhibit a pronounced increase in PA compared to the Inactive cluster, with average differences of 73.28 and 90.17 min, respectively. This underscores the fact that the Active outside kindergarten cluster stands out as the most active group when not in a kindergarten setting.

Family factors

Logistic regression was carried out by taking the PA clusters as the grouping variable and the family factor as the independent variable. The results showed that the five elements were significantly correlated among different clusters (Table 4). Compared to the Inactive cluster, the activity factors of preschool children were related to gender, age, and birth weight. Specifically, gender emerged as a significant negative predictor, with a regression coefficient (B) of −1.05, indicating that girls are more likely to be categorized within the Inactive than boys, with an odds ratio (OR) of 0.35 and a 95% confidence interval (CI) ranging from 0.19 to 0.66, which suggests a diminished likelihood transitioning from the Inactive to Active in kindergarten and Active outside kindergarten for girls. The regression coefficient for age (Months of age) was positive (B = 0.05), indicating a gradual increase in the odds of shifting from Inactive to Active in kindergarten and Active outside kindergarten with each additional month of age, with an OR of 1.05 and a 95% CI from 1.00 to 1.10. Birth weight demonstrated a significant positive association, with a regression coefficient of

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TABLE 2 Characteristics of the analyzed sample.

Variables	Boys (n = 166)	Girls (n = 125)	Total (n = 291)	p for sex
Age (month)*	60.09 (7.8)	57.93 (7.2)	59.23 (7.4)	0.073
BMI (kg/m^2)	16.37 ± 1.72	16.02 ± 1.24	16.22 ± 1.54	0.053
SB (min)	534.33 ± 66.89	550.77 ± 73.33	541.39 ± 70.08	**0.047**
LPA (min)	108.16 ± 23.58	101.90 ± 24.90	105.47 ± 24.31	**0.03**
MVPA (min)	76.67 ± 28.02	63.26 ± 24.81	70.91 ± 27.46	**0.000**
TPA/PA (min)	184.83 ± 48.00	165.17 ± 46.06	176.38 ± 48.09	**0.001**
SB in kindergarten (min/weekday)	266.87 ± 29.52	273.87 ± 28.13	269.88 ± 29.09	**0.042**
PA in kindergarten (min/weekday)	84.84 ± 29.89	77.66 ± 25.78	81.76 ± 27.19	**0.026**
SB outside the kindergarten (min/weekday)	253.52 ± 55.67	257.52 ± 52.85	255.24 ± 54.42	0.535
PA outside the kindergarten (min/weekday)	90.81 ± 27.83	82.80 ± 24.73	87.37 ± 26.79	**0.011**
SB (min/rest day)	549.30 ± 94.42	568.82 ± 95.72	557.68 ± 95.31	0.084
PA (min/rest day)	194.01 ± 64.60	170.27 ± 58.83	183.82 ± 63.19	**0.001**
Birth weight (kg)	3.41 ± 0.56	3.50 ± 0.87	3.45 ± 0.71	0.29
Birth length (cm)	50.78 ± 4.63	50.91 ± 3.78	50.84 ± 4.28	0.806
Caregivers				0.920
Independent parental care	36	24	60	
Independent grandparent care	4	4	8	
Parents/grandparents/babysitters care together	126	97	223	
Daily sleep time (hour)	10.27 ± 1.20	10.41 ± 1.43	10.33 ± 1.31	0.371
Feeding patterns				0.099
Breastfeeding	86	55	141	
Artificial feeding	48	36	84	
Mixed feeding	32	34	66	
Early education				0.748
Yes	23	19	42	
No	143	106	249	
Age of father (month)	434.72 ± 65.93	430.13 ± 69.83	432.75 ± 67.55	0.567
Age of mother (month)	407.39 ± 50.69	401.70 ± 53.15	404.94 ± 51.75	0.355
Father's BMI (kg/m^2)	23.61 ± 2.68	23.38 ± 3.11	23.51 ± 2.87	0.504
Mother's BMI (kg/m^2)	21.16 ± 2.29	20.87 ± 1.97	21.03 ± 2.16	0.272
Father's education level				0.984
Junior high school and less	26	19	45	
Vocational high school/technical secondary school	37	31	68	
High school	47	33	80	
Junior college/Higher vocational	50	35	85	
College education	6	7	13	
Mother's education level				0.937
Junior high school and less	27	19	46	
Vocational high school/technical secondary school	37	27	64	
High school	42	39	81	
Junior college/Higher vocational	56	34	90	
College education	4	6	10	
Father enjoys sports	2.66 ± 0.81	2.66 ± 0.75	2.66 ± 0.79	0.988
Mother enjoys sports	2.87 ± 0.67	2.90 ± 0.69	2.89 ± 0.68	0.705

(Continued)

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TABLE 2 (Continued)

Variables	Boys (n = 166)	Girls (n = 125)	Total (n = 291)	p for sex
Father exercise frequency	3.58 ± 1.11	3.78 ± 1.10	3.67 ± 1.11	0.119
Mother exercise frequency	3.84 ± 1.10	3.96 ± 1.10	3.89 ± 1.10	0.372
Father's occupation				0.662
Managers	18	17	35	
Professionals	22	16	38	
Clerical support workers	14	7	21	
Services and sales workers	37	32	69	
Skilled agricultural, forestry, and fishery workers	3	1	4	
Plant and machine operators and assemblers	2	3	5	
Armed forces occupations	3	1	4	
Elementary occupations	67	48	115	
Mother's occupation				0.894
Managers	19	9	28	
Professionals	14	16	30	
Clerical support workers	12	13	25	
Services and sales workers	49	32	81	
Skilled agricultural, forestry, and fishery workers	1	0	1	
Plant and machine operators and assemblers	0	1	1	
Armed forces occupations	1	0	1	
Elementary occupations	70	54	124	
Father's income (CNY/month)				0.272
≤3,000	1	5	6	
3,001 ~ 5,000	2	3	5	
5,001 ~ 8,000	42	21	63	
8,001 ~ 10,000	95	59	154	
10,001 ~ 15,000	21	31	52	
≥15,001	5	6	11	
Mother's income				0.591
≤3,000	24	19	43	
3,001 ~ 5,000	10	7	17	
5,001 ~ 8,000	69	45	114	
8,001 ~ 10,000	54	43	97	
10,001 ~ 15,000	6	9	15	
≥15,001	3	2	5	
Parental marital status				0.887
Married	162	123	285	
Unmarried	4	2	6	

*, median (interquartile range, IQR). Bold fonts indicate a P value less than 0.05, a factor with significant gender differences.

0.58, suggesting that higher birth weight is associated with an increased likelihood of belonging to Active in kindergarten and Active outside kindergarten rather than the Inactive one, with an OR of 1.79 and a 95% CI from 1.16 to 2.76. Although the effect of paternal age (Age of father) was less pronounced, the positive regression coefficient of 0.01 indicates a slight increase in the odds of moving away from the Inactive with each additional year of the father's age, with an OR of 1.01 and a 95% CI from 1.00 to 1.02. Maternal income (Mother's income) was negatively associated with the likelihood of being Inactive with a regression coefficient of −0.39, indicating that higher maternal income is associated with a decreased likelihood of the child being Inactive, with an OR of 0.68 and a 95% CI from 0.48 to 0.96. These findings elucidate the multifaceted determinants that influence an individual's propensity for PA clustering and provide potential targets for interventions aimed at promoting active lifestyles.

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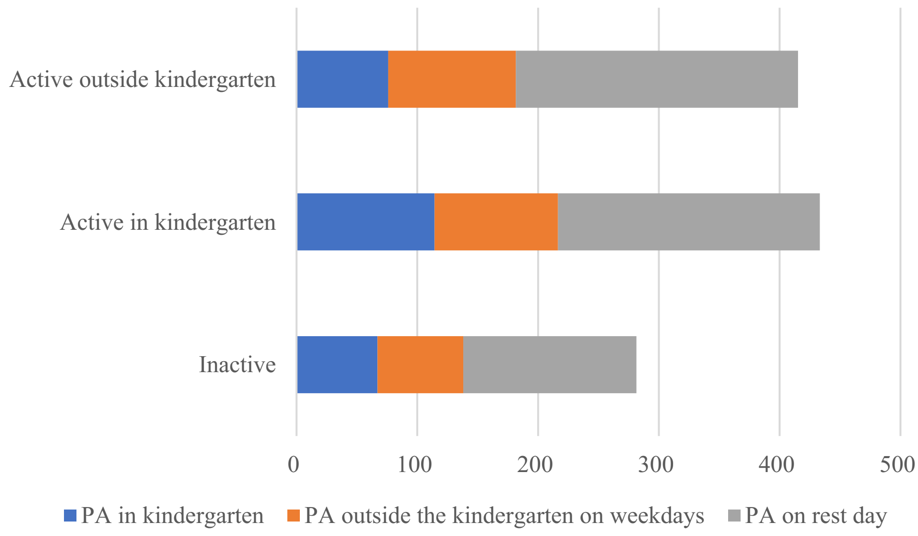

FIGURE 2
Bar graph of clustering.

TABLE 3 Descriptive of the different clusters.

	Inactive	Active in kindergarten	Active outside kindergarten
Sex: *n* (%)			
Boys	66 (45.2)	52 (66.7)	48 (71.6)
Girls	80 (54.8)	26 (33.3)	19 (28.4)
SB in kindergarten on weekdays	285.37 ± 18.61	232.95 ± 22.30*	279.08 ± 12.19*#
PA in kindergarten on weekdays	67.04 ± 17.56	114.28 ± 21.69*	75.95 ± 16.10*#
SB outside the kindergarten on weekdays	262.82 ± 52.06	237.14 ± 52.06*	259.78 ± 57.98#
PA outside the kindergarten on weekdays	71.01 ± 18.87	102.25 ± 26.03*	105.70 ± 19.65*
SB on the rest days	600.81 ± 81.27	496.04 ± 86.08*	535.48 ± 87.49*#
PA on the rest days	143.41 ± 40.77	216.69 ± 58.16*	233.58 ± 50.45*

*, $p < 0.05$ compared to the inactive cluster; #, $p < 0.05$ compared to the active in kindergarten cluster.

Discussion

This study explored the relationship between preschool children with different PA characteristics and their family factors to provide a reference for the combination of their physical education and family education. We found significant differences in the clustering of PA inside and outside the kindergarten among the different clusters ($p < 0.05$), indicating a strong clustering effect. This suggests that preschool children's PA exhibits clustering characteristics both temporally and spatially. Furthermore, in addition to the gender, age, and birth weight of preschoolers, in the family setting, the father's age and the mother's income may play some potential roles in the preschool children's PA initiative.

Cluster analysis was adopted in this study, and it was found that cluster analysis could be applied to the natural observation grouping of PA in and outside the kindergarten with good results. The results showed that the silhouette coefficient of cluster analysis was 0.3, and there were significant differences among the groups. From a statistical perspective, clustering analysis and evaluation can adopt the average silhouette coefficient, which ranges from −1 to 1. The closer the coefficient is to 1, the better the clustering effect; conversely, the closer it is to −1, the worse the clustering effect (25). Therefore, the silhouette coefficient of this study is 0.3, which indicates that the clustering effect was good and reached a reasonable level. In addition, the clustering effect is not uniform from different professional perspectives. It is reasonable to summarize and explain, put forward a conceptual model of decision information, and express decision information according to data characteristics from a professional perspective to facilitate information analysis and processing (26). Therefore, this study achieves good clustering results from both statistical and professional fields and provides a basis for further policy decision-making, which includes implementing targeted family education, engaging healthcare providers, and tailoring interventions to different PA occurrence settings.

PA performance and self-factors

According to our survey, boys were more active than girls. Similar to this study, previous studies have shown that boys were more active

TABLE 4 Logical regression results.

Factors	B	SE*	Wald	p	OR (95%CI)
Sex	−1.05	0.32	10.55	**0.000**	0.35 (0.19–0.66)
Months of age	0.05	0.02	4.02	**0.04**	1.05 (1.00–1.10)
Birth length	−0.03	0.04	0.62	0.43	0.97 (0.91–1.04)
Birth weight	0.58	0.22	6.93	**0.001**	1.79 (1.16–2.76)
Daily sleep time	0.15	0.12	1.46	0.23	1.16 (0.91–1.48)
Age of father	0.01	0.00	4.89	**0.03**	1.01 (1.00–1.02)
Age of mother	−0.01	0.01	1.51	0.22	0.99 (0.98–1.00)
Father's BMI	−0.08	0.06	2.01	0.16	0.92 (0.83–1.03)
Mother's BMI	−0.06	0.08	0.56	0.45	0.95 (0.82–1.10)
Feeding patterns	0.29	0.20	2.12	0.15	1.34 (0.90–1.97)
Caregivers	0.04	0.18	0.05	0.83	1.04 (0.73–1.48)
Early education	−0.58	0.47	1.50	0.22	0.56 (0.22–1.41)
Father exercise frequency	0.03	0.20	0.02	0.88	1.03 (0.70–1.52)
Mother exercise frequency	−0.11	0.19	0.35	0.55	0.89 (0.62–1.30)
Father enjoys sports	−0.25	0.24	1.04	0.31	0.78 (0.49–1.26)
Mother enjoys sports	0.01	0.27	0.00	0.96	1.02 (0.60–1.73)
Father's education level	−0.11	0.22	0.26	0.61	0.90 (0.59–1.37)
Mother's education level	0.19	0.24	0.63	0.43	1.21 (0.76–1.93)
Father's income	0.01	0.19	0.00	0.98	1.01 (0.70–1.45)
Mother's income	0.39	0.18	4.70	**0.03**	0.68 (0.48–0.96)
Father's occupation	−0.01	0.07	0.01	0.92	0.99 (0.87–1.14)
Mother's occupation	−0.05	0.08	0.50	0.48	0.95 (0.82–1.10)
Parental marital status	0.00	0.43	0.00	1.00	1.00 (0.43–2.31)

*, standard error. The bold font indicates that the *P* value is less than 0.05, indicating that the influence of this factor on the clustering of children's physical activity is significant.

and participated in PA than girls (27). In addition, the PA of preschool children gradually increases with age, but the increase of boys was significantly more than that of girls (28). Studies showed that the emphasis on inclusion and description of gender differences was a scientific trend and a shift in research methodology due to differences in physiology, nutrition, and exercise metabolism between men and women (29). However, the preschool period is crucial for forming children's gender consciousness (30). At approximately age 2, preschool children become aware of biological differences between boys and girls. By the age of 2–3, most preschool children can express their gender very clearly. At approximately age 4, preschool children's gender awareness stabilizes, and they begin showing their "gender identity" through more apparent behaviors. Boys may be more likely to play with cars or soldiers fighting, while girls may be more likely to play with dolls or build houses. However, this more varied behavior may represent a difference in PA. Therefore, the results suggested that gender was also an essential factor in preschool, and future interventions and plans should be more targeted to compare the effects of different genders.

This study also showed a significant correlation between preschool children's birth weight and PA clustering. However, there appears to be no direct causal relationship between the two. Studies have shown that gender, the record of preterm birth, and kindergarten can explain differences in average daily PA, intermediate school PA, and percentage of MVPA, with 44.7, 29.1, and 65.2% variation, respectively (31). The PA of pregnant women in the third trimester influences the baby's birth weight (32). To some extent, both infants' birth weight and PA performance are indirectly or directly related to mothers because infants' birth weight is related to mothers' nutrition and PA during pregnancy. In this study, the PA performance of preschool children acquiring different clusters was closely associated with parents and family environment, which may be the mediating factor of significant correlation between preschool children's birth weight and different clusters.

These findings suggest that future interventions and policies should be designed with a gender-sensitive approach to promote PA among preschool children. This includes developing targeted programs, encouraging girls' participation, and providing various activities catering to different interests. In addition, there is a need to enhance prenatal health education for mothers to improve birth outcomes, which can indirectly influence children's PA levels.

PA performance and family factors

This study showed that the father's age and the mother's income are important factors influencing children's PA clusters. Preschoolers with older fathers tended to be more active, whether in or outside kindergarten, than preschoolers with younger fathers. Indeed, the effects were small but significant, with better neurodevelopment outcomes for children born to older parents (33). At the same time, other studies have shown that older fathers have an increased risk of having a child with low weight, intensive care unit admission, epilepsy, and musculoskeletal abnormalities (34, 35). Therefore, we need to view the results carefully. But, in general, older fathers, who tend to be more focused on their children's education, are better off financially and more assertive, which can affect young children's character development and healthy lifestyles. Although no studies have shown that the father's age has a direct and significant relationship with the PA performance of young children, studies have shown that fathers' sense of responsibility for family expenses is related to their participation in PA activities with their children (36). This involvement helps cultivate children's active participation in these activities, thereby promoting their PA levels both inside and outside the kindergarten. This is one of the important reasons for the difference in PA between the clusters of "Active in kindergarten" and "Active outside kindergarten" compared to the "Inactive" cluster. It is worth noting that no significant disparity in activity levels was observed between the two Active clusters inside or outside the kindergarten. This could primarily be attributed to a father's pivotal role in shaping a child's character and habits. This influence is fundamental in fostering an active lifestyle and encouraging the development of a proactive personality in the child. Therefore, this study also highlights potential areas for future interventions to consider the father's age of preschoolers.

According to the family system theory, PA and SB of family members influence each other (37). Previous studies showed that parents' PA habits (15) and feeding styles (38) have varying degrees of influence on children's PA. Parents' attitudes, behaviors, and parenting styles profoundly impact children's health behaviors, including PA (39). In this study, parents' exercise behavior, liking for physical exercise, and feeding patterns did not significantly affect PA clustering. Previous studies have also shown that parents' exercise behavior does not directly impact children's physical health but may indirectly affect children's behavior (PA) (40). Previous studies have focused more on children's PA time rather than their specific performance in temporal and spatial tasks. This may explain why parents' exercise behavior and attitudes did not have a significant influence in two key areas. One area was the indirect influence, with the mediating variables warranting further discussion. The other area, that this study focused on, was related to the temporal and spatial characteristics of children's PAs, which may minimize the statistical gap between these factors, resulting in no significant impact.

Furthermore, this study also showed that the mother's income was another factor affecting the PA clustering of children. The higher the mother's income, the more time the child spends in PA, and the more likely the child is to be active, both "Active in kindergarten" and "Active outside kindergarten." However, in Oda Malmo's study, no significant correlation exists between parents' or family income and MVPA (Activity level at leisure) (41). On the contrary, it is inconsistent with the results of this study. Malmo studied leisure time MVPA, while this study is the average daily total PA in, out of, or on rest days. This may be attributable to the differences in the intensity and type of PA.

In addition, the WHO states that preschool children need 60 min of MVPA daily and 180 min of TPA daily. This study pays more attention to the TPA of children, so there are differences in the duration of PA. In this study, the activity level during leisure can be understood as the time spent out of the park or on rest days. From the perspective of comprehensiveness, this study focuses on the whole PA of preschool children, including its temporal and spatial characteristics. Therefore, a new field has been opened in the total PA time of young children and PA performance in different environments, finding that young children's PA is associated with maternal income. The results of the National Health and Examination Survey (NHAES) (2012) showed that family income was negatively correlated with the gross motor development of 3- to 5-year-old children (42). It can be explained that young children's PA was a mediator between family income and physical health or athletic ability. Family income and socioeconomic status are directly related to parents' parenting behavior and lifestyle, while PA and SB among family members influence each other. Therefore, the strong correlation between family income and athletic ability observed in the NHAES results implies a specific correlation between family income and preschool children's PA.

Based on these analyses, the mother's income is crucial in shaping the child's PA initiative through economic means and lifestyle choices. This financial empowerment can significantly broaden the horizon of PA options for children, fostering an environment that encourages an active lifestyle. Conversely, a lower income might limit these opportunities as the family may face constraints in accessing facilities or affording the costs associated with organized sports or activities. This economic barrier could reduce the child's exposure to diverse forms of PA, potentially leading to a more sedentary routine. In addition, the mother's income can indicate the family's socioeconomic status, which is known to influence health behaviors and outcomes. Families with higher incomes may have better access to information about the importance of PA and the means to prioritize and integrate it into their daily lives. This can create a cycle of health-conscious behavior that benefits the child's PA levels. Therefore, higher maternal income significantly encouraged children in the "Active in kindergarten" and "Active outside kindergarten" clusters to be more active both in and out of kindergarten, compared to those in the "Inactive" cluster.

Parental and family factors are numerous and intertwined. However, if family environmental factors can be classified in a targeted manner to improve children's PA performance, intervention measures for different aspects could be proposed. This approach would be constructive for improving children's PA. Similarly, related studies on PA intervention in preschool children deserve long-term, in-depth discussion.

Thus, this study suggests that policy recommendations should consider the influential roles of paternal age and maternal income on preschool children's PA levels. In response to these results, interventions can be more effective in encouraging positive habits in preschoolers, underscoring the importance of considering the family environment when developing strategies to improve children's overall physical health. Interventions can be designed to support older fathers in actively engaging with their children, harnessing their potential, and fostering positive lifestyle and character development in their children. Training is also provided to young parents to enhance their knowledge and practical ability in PA parenting. In addition, this finding highlights the importance of maternal income, suggesting that higher income levels are associated with increased opportunities for children to engage in PA. These insights point to addressing socioeconomic disparities as an important issue, which in the case of sports is reflected in promoting equitable access to public sports resources. Future measures should consider expanding the input of public sports resources. Then, there should be a focus on the role of family and community support in creating an environment that fosters an active lifestyle from an early age. Similarly, training should be provided to community sports workers and parents to ensure that all children can participate in PA, which is both enjoyable and beneficial to their health and development.

Strengths and limitations

To our knowledge, this study represents a pioneering effort to examine the temporal and spatial dynamics of preschool children's PA and its intricate relationship with the family environment. This innovative approach provides a fresh perspective that could substantially enrich the research landscape. Despite its strengths—such as the novel research scope, a comprehensive analysis that blends quantitative and qualitative insights, and a broad sample base that bolsters the findings' robustness—the study has its limitations. The regional bias of our sample may hinder the generalizability of our results, and the cross-sectional design limits our ability to establish causality. However, these limitations do not diminish the study's potential to inform and inspire future interventions and policy development. The findings can guide the creation of targeted interventions sensitive to the specific contexts of the regions studied, thereby increasing the likelihood of their success. Moreover, the insights can inform policymakers to foster environments conducive to PA, advocating for accessible community facilities and family-oriented initiatives. Recognizing the limitations of a cross-sectional approach, future research should embrace longitudinal designs to elucidate the causal pathways and long-term impacts of family influences on children's PA.

Conclusion

In summary, this study demonstrated the associations between family factors and PA clustering in preschool children through a cross-sectional study. Three clusters were obtained with distinct differences in PA and SB levels, namely, "Inactive," "Active in kindergarten," and "Active outside kindergarten." The results indicated that the father's age and the mother's income are noteworthy in the temporal and spatial manifestation of PA in preschool children. This suggested that families could promote preschool children's PA through greater educational focus and financial stability and provide more opportunities and resources for preschool children to engage in active lifestyles. This study underscores the significant influence of the family environment and parental behaviors on the PA of preschool children. By innovatively examining the temporal and spatial dimensions of family impact, the research opens avenues for future studies to implement and assess additional interventions. These interventions could include guiding parents to focus more on their children's physical education and could offer more opportunities and platforms for children to engage in physical activities, thereby fostering an environment conducive to enhancing their PA levels.

Data availability statement

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

Ethics statement

The studies involving humans were approved by Ethics Committee, Fujian Normal University. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

TH: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. GZ: Funding acquisition, Methodology, Project administration, Resources, Supervision, Visualization, Writing – review & editing. JF: Funding acquisition, Resources, Supervision, Writing – review & editing. SS: Data curation, Writing – review & editing. WL: Data curation, Formal analysis, Resources, Writing – review & editing. ZH: Data curation, Methodology, Software, Writing – review & editing. DC: Data curation, Software, Writing – review & editing. RC: Data curation, Formal analysis, Software, Writing – review & editing.

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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 effects of procrastination on physical activity among Chinese university students: the chain-mediated effects of time management disposition and exercise motivation

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Objectives: Grounded in self-determination theory (SDT), the procrastination-health model, and the mechanism model of exercise persistence, this study examined the effects of procrastination on physical activity and the mechanism of its action in Chinese college students.

Design: This study employed a cross-sectional design.

Methods: A total of 957 Chinese university students (Mage = 20.26, SD = 1.07) completed questionnaires. The Aitken Procrastination Questionnaire, the Adolescent Time Management Dispositions Scale (ATMDS), the Modified Physical Activity Motivation Measure-Revised (MPAM-R), and the Physical Activity Rating Scale (PARS-3) were used to measure procrastination, time management disposition, exercise motivation, and physical activity.

Results: Procrastination, time management disposition, exercise motivation, and physical activity were each significantly correlated, and procrastination was a significant negative predictor of physical activity. The mediating effect of time management disposition and exercise motivation in the effect of procrastination on physical activity was significant, and the mediating effect accounted for 44.65% of the total effect. Three paths were specifically included: first, the separate mediating effect of time management disposition, second, the separate mediating effect of exercise motivation, and third, the chain mediating effect of time management disposition and exercise motivation.

Conclusion: This study reveals the mechanism of action by which procrastination influences physical activities through time management disposition and exercise motivation in Chinese college students. The findings provide guiding recommendations for further promoting greater participation in physical activities among college students.

KEYWORDS

procrastination, physical activity, time management disposition, exercise motivation, college students

1 Introduction

Since the 21st century, physical inactivity has become the fourth most important risk factor for death globally after hypertension, smoking, and hyperglycemia (Bull et al., 2020). A recent study found that nearly one-third (31%) of the world's adult population, or approximately 1.8 billion adults, are physically inactive (Strain et al., 2024). A large number of studies have demonstrated the effects of active physical activity on physical and mental health, such as preventing cognitive decline, improving musculoskeletal function, and alleviating anxiety, depression, and other negative emotions (Guo et al., 2020; Zhang et al., 2020; Liu, 2020; Puts et al., 2017; Josefsson et al., 2014; Singh et al., 2023), and lowering the incidence of chronic non-communicable diseases such as type 2 diabetes and cardiovascular disease (John-Henderson et al., 2021). The college student population is a group at the forefront of new technologies and ideas in society, representing youth and vitality, and is a major driver of social progress. However, a large number of studies have shown that during the transition from adolescence to early adulthood, there is a sharp decline in physical activity (Kwan et al., 2012; Telama and Yang, 2000), followed by sedentary behavior (Bull et al., 2020), obesity (Jebeile et al., 2022), etc., which seriously affects the physical and mental health of college students. Currently, various countries have begun to actively adopt various ways to promote physical activity participation. In China, policy documents such as the "14th Five-Year Plan for Sports Development," "Physical Activity Guidelines for the Chinese Population (2021)," and "Opinions on Deepening the Integration of Physical Education and Sports to Promote the Healthy Development of Adolescents" have been issued one after the other, which have provided a scientific basis for the physical activity of different groups of people. Many Chinese scholars have made suggestions on the promotion of comprehensive health development of adolescents from personal, interpersonal, environmental, and policy perspectives. There are also many Chinese scholars who have conducted research on promoting the overall healthy development of adolescents and avoiding the potential health risks brought about by insufficient physical activity from personal, interpersonal, environmental, and policy perspectives (Wu and Yang, 2023). Therefore, as physical activity is an important way to maintain the physical and mental health of college students, it is of great practical significance to explore the factors affecting college students' physical activity and promote college students' active participation in physical activity on this basis.

Previous research has found that procrastination is a very common personality trait and behavioral tendency in modern society (Kim and Seo, 2015). Some scholars believe that procrastination is a behavioral tendency related to the degree of aversion to what is to be done and the fear of failure (Wolters, 2003), which belongs to the failure of self-regulation (Steel, 2007), and is a kind of avoidance behavior toward tasks. Some scholars believe that procrastination is a personality trait characterized by a consistent and persistent delay in starting or completing a task (Ferrari and Tice, 2000). Procrastination is defined as a novel and plausible perspective to explain failures of self-regulation in the context of health behaviors (Kroese and de Ridder, 2016). Procrastination has been found to be a representative problematic behavior in college students' learning that can directly or indirectly affect college students' academic performance through factors such as academic anxiety and stress (Kim and Seo, 2015; Manchado Porras and Hervias Ortega, 2021; Zhao et al., 2022). In addition, procrastination produces problems related to problematic cell phone use, Internet addiction, and more (Gong et al., 2021). The procrastination-health model states that procrastination affects health not only through stress but also indirectly through delayed health behaviors and disease prevention (Sirois et al., 2003). For example, bedtime procrastination is a sign of a lack of self-regulation, which can lead to sleep deprivation and affect the quality of sleep (Exelmans and Van den Bulck, 2021; Kroese et al., 2014). Physical activity is a healthy behavior in which people can be physically active enough to enhance their fitness and have a positive emotional experience, but engaging in strenuous physical activity may produce an unpleasant experience, which then may lead to procrastination (Ren et al., 2023; Shi et al., 2021). Research indicates that college students with a high tendency to procrastinate often struggle with self-management of exercise. They tend to have less clarity in their intentions and planning for physical activity, leading to increased randomness and inertia in their exercise behaviors, which negatively impacts their overall exercise performance. Therefore, reducing procrastination behavior among college students can help to promote active physical activity among college students. Overall, procrastination, a common personality trait and behavioral tendency among college students, has a significant impact on their health behaviors (e.g., physical activity), but it is unclear how procrastination can influence intrinsic psychological factors that can promote physical activity among college students. Previous studies have found a strong relationship between time management disposition and exercise motivation and physical activity; therefore, the present study intends to examine whether procrastination can have an effect on physical activity through the mediation of time management disposition and exercise motivation. Based on this, this study proposes the first hypothesis:

> *H1*: Procrastination has a negative and significant effect on physical activity.

1.1 The mediating role of time management dispositions

Time management tendency is the psychological and behavioral characteristics of individuals in terms of the function and value of time, and the way they use time, which includes three dimensions: the sense of time value, the sense of time control, and the sense of time efficacy (Huang and Zhang, 2001b). Higher time management disposition indicates that individuals are more certain of the value of time, have higher awareness and ability to monitor time in their study and life, and have more confidence in their own time management. It has been shown that time management is positively related to perceived time control, job satisfaction, and psychological and social adjustment and negatively related to stress (Claessens et al., 2007; Häfner et al., 2014) and directly affects job performance, academic achievement, and procrastination behavior (Wolters and Brady, 2021). Numerous studies have shown that time management is directly linked to variables closely related to the quality of life, such as healthy eating and physical activity (Indreica et al., 2022), and is a very worthwhile personal factor to consider (Connelly et al., 2015; Das and Evans, 2014; Heard et al., 2017). Strong time management skills are essential for ensuring regular participation in physical activity (Zhu, 2018). Conversely, a lack of time and irrational allocation and utilization of time are significant factors that can affect weight loss (Delahanty et al., 2019) and adversely affect overall performance in physical activities (Rebar et al., 2019). Self-regulation theory suggests that performing healthful activities requires a certain level of time regulation and self-control and that the tendency to procrastinate on time commitment for physical activity is related to the ability to self-manage time (Codina et al., 2020). College students are in the sensitive period of social adaptation and development, but also a critical period of personality and executive function improvement, procrastination, once formed, will become a relatively stable personality trait of the individual. Procrastination individuals tend to have lower self-control ability is lower, difficult to better manage and allocate time, is very likely to affect the participation of physical activities. Therefore, a second hypothesis is proposed:

> *H2*: Time management disposition has a significant mediating effect between procrastination and physical activity, that is, procrastination reduces physical activity by reducing the level of time management disposition.

1.2 The mediating role of exercise motivation

Exercise motivation is the internal psychological motivation that inspires and sustains individuals to engage in physical activity. Self-determination theory (SDT) is a motivational process theory about individual self-determination behavior, which is widely used in the fields of education (Behzadnia et al., 2023), management (Huang et al., 2023), sports (Liu, 2020), etc. This theory suggests that an individual's motivation is on a continuum from intrinsic motivation to extrinsic motivation and non-motivation (Behzadnia et al., 2018) and that intrinsic motivation positively influences adherence and persistence of behavior (Deci and Ryan, 1985). Exercise motivation is the direct impetus that drives individuals to engage in physical activity; it explains that individuals can satisfy certain needs by engaging in physical activity and reflects the reasons why individuals want to participate in physical activity. According to the source of motivation (internal/external) and its effect on exercise behavior (strong/weak), it can be classified as ability motivation, health motivation, fun motivation, social motivation, and appearance motivation (Chen et al., 2013). There are a number of studies that have examined exercise behavior from the perspective of self-determination theory, and these studies have validated the role of exercise motivation as a predictor of exercise behavior (Thogersen-Ntoumani and Ntoumanis, 2006). At the same time, the satisfaction of basic needs can stimulate more self-determined motivation. Exercise motivation can directly affect sedentary behavior (Esmaeilzadeh et al., 2022), social adaptation (Chen et al., 2022), etc., and different levels of exercise motivation are also capable of positively influencing the short-term emotional benefits of physical activity (Zhang et al., 2019). The effect of procrastination on behavioral execution and persistence cannot be ignored but also indirectly affects behavior through the mediating role of psychological variables that are directional to behavior. Individuals with high procrastination tend to respond to events with higher levels of discretion and inertia, which can reduce the degree of self-determination in physical exercise motivation (Wang et al., 2015). In addition, procrastination is manifested as a deviation between behavioral intention and actual behavior. Behavioral intention is a motivational factor for an individual to engage in a particular behavior, reflecting the level of effort an individual is willing to put in, and is a direct factor in behavioral decisions. Therefore, procrastination may affect the occurrence of physical activity behaviors by reducing physical activity motivation. Based on the above, this study proposes the third hypothesis:

> *H3*: Exercise motivation has a significant mediating effect between procrastination and physical activity, that is, procrastination reduces physical activity by reducing the level of exercise motivation.

1.3 Chain mediation of time management disposition and exercise motivation

Both time management disposition and exercise motivation can serve as internal psychological traits of individuals that promote the onset and persistence of exercise behavior (Li et al., 2021). The mechanism model of exercise persistence emphasizes the important role of exercise motivation in the generation and persistence of exercise behavior, pointing out that physical activity is realized through the path of "social environment → individual →cognitive decision-making → commitment →behavior," in which exercise motivation is the direct antecedent of the psychological mechanism of exercise commitment, which can be determined by the formation of behavioral intentions and produce actual physical activity (Chen et al., 2006). In addition, exercise motivation also acts as an important mediator in personality traits and emotional benefits of exercise (Jiang et al., 2015), and perceived social support and exercise behavior (Hui et al., 2022). Among them, personality traits are considered to be important determinants of exercise motivation. Previous research has shown that there is also a strong link between these two internal resources, with time management positively predicting achievement motivation (Song and Chen, 2016; Yang et al., 2014). Time management disposition involves an individual's awareness of the meaning of time, from which the individual develops a behavioral tendency in time management. In the field of sports, individuals with high levels of time management disposition have strong self-control and a correct perception of the positive effects of self-imposed physical activity on their health and thus are likely to show strong exercise motivation. However, few studies have considered the combined effects of time management disposition and exercise motivation when focusing on the influencing factors of physical activity. Therefore, based on hypotheses H1, H2, and H3, this study proposes a fourth hypothesis:

> *H4*: Time management disposition and exercise motivation have a chain-mediated effect between procrastination and physical activity, that is, procrastination reduces physical activity by sequentially reducing time management disposition and exercise motivation.

Based on this, this study aims to explore the influence of procrastination on college students' physical activity and also analyze the chain-mediated role of time management disposition and exercise motivation between procrastination and physical activity, so as to provide a reference for exploring the influence mechanism of college students' physical activity to promote college students' active participation in physical activity. The chain mediation model is shown in Figure 1.

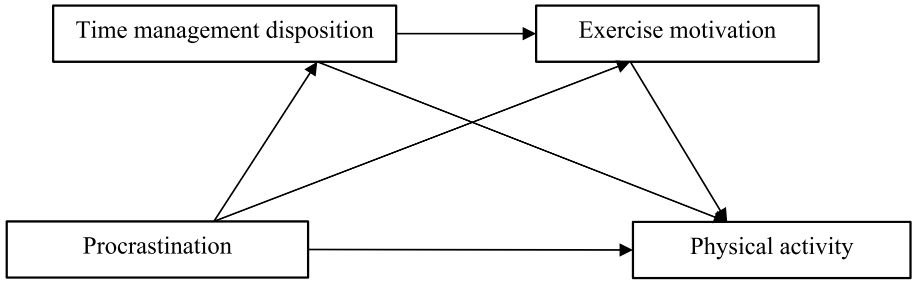

FIGURE 1
Hypothetical model of the relationship between procrastination, time management tendencies, exercise motivation, and physical activity in college students.

2 Materials and methods

2.1 Participants and procedures

The study was conducted on Chinese college students in six schools in the cities of Beijing, Shanghai, and Zhengzhou, following the principle of convenience sampling. All subjects were able to participate in school studies and sports activities normally and had no significant physical or mental diseases. A total of 1,022 questionnaires were recovered from the survey, and 957 questionnaires met the requirements after elimination to ensure the accuracy of the data, with an effective rate of 93.64%. The subjects who participated in the survey were divided by gender, 411 male (42.947%) and 546 female (57.05%) students; and by grade, 299 freshmen (31.24%), 264 sophomores (27.59%), 245 juniors (25.60%), and 149 seniors (15.57%). The mean age of the participants was 20.26 years (SD = 1.07; min = 18, max = 23). The questionnaires were rejected on the basis of the following: (1) the answer time was less than 240 s and more than 900 s; (2) the answer to the reverse question was contradictory; and (3) the answers were all consistent or had a certain pattern (e.g., "11111…" or "123123…").

The questionnaires were distributed and collected through the Questionnaire Star platform, a professional online survey tool known for its speed, ease of use, and low cost, making it widely used in surveys and research in China. The study was approved by the Ethics Committee of East China Normal University in China (HR515-2019), and according to the requirements of the ethical review system, this study did not require participants to sign an informed consent form for ethical review, even so, information about the content of the questionnaire and a reminder stating that the survey was anonymous and that the results would be used only for scientific research and would not pose any risk to their daily lives. At the same time, participation in the survey was completely voluntary, and participants could abandon or terminate the questionnaire at any time during the administration process according to their own wishes.

2.2 Methodology

2.2.1 Aitken procrastination questionnaire

The Aitken Procrastination Questionnaire, revised by Chinese scholars Xiaoli Chen, Xiaoyang Dai, and Qin Dong, was used to assess the procrastination behavior of college students. Students responded to the 19-item of the Aitken procrastination questionnaire (e.g., "I always wait until the last minute to do things"). Students responded to a scale ranging from 1 (*not conforming at all*) to 5 (*conforming completely*). In this study, Cronbach's α was 0.847, and the validated factor analysis fit indices were as follows: χ^2/df = 5.929, GFI = 0.908, AGFI = 0.833, TLI = 0.865, NFI = 0.862, CFI = 0.882, RMSEA = 0.072, SRMR = 0.0734, KMO = 0.897, and Bartlett's test showed $p < 0.001$. These results indicate good reliability and validity of the scale.

2.2.2 Adolescence time management disposition scale (ATMDS)

The Adolescence Time Management Disposition Scale (ATMDS) developed by Chinese scholar (Huang and Zhang, 2001a) was used as a tool to evaluate adolescents' personality traits in terms of time mastery and control. This scale assesses time management disposition in three dimensions, namely, the sense of time value (10 items, e.g., "I think the saying 'An ounce of time is worth an ounce of gold' is true"), the sense of time control (24 items, e.g., "I always spend a lot of time doing important work"), and the sense of time efficacy (10 items, e.g., "I always test my plans against the accomplishment of my goals"), with a total of 44 items. The items were rated using a 7-point scale (1 = *not conforming at all* and 7 = *conforming completely*). The higher the score, the stronger the time management disposition, and the better the ability to rationally manage and utilize time. In this study, Cronbach's alpha was 0.939, and the fit index of validated factor analysis fit indices were as follows: χ^2/df = 5.047, GFI = 0.807, AGFI = 0.787, TLI = 0.813, NFI = 0.789, CFI = 0.823, RMSEA = 0.065, SRMR = 0.0824, KMO = 0.956, and Bartlett's test showed $p < 0.001$. These results indicate good reliability and validity of the scale.

2.2.3 The simplified version of the motives for physical activities measure-revised scale (MPAM-R)

Students' exercise motivation was assessed through the Simplified Version of the Motives for Physical Activities Measure-Revised Scale (MPAM-R), which was revised by Chinese scholar Chen et al. (2013). The MPAM-R assesses college students' exercise motivation in five dimensions, namely, health motivation (three items, e.g., "I want to be fit"), appearance motivation (three items, e.g., "I want to lose weight"), fun motivation (three items, e.g., "I want to participate in entertaining activities"), ability motivation (three items, e.g., "I want to gain new motor skills"), and social motivation (three items, e.g., "I want to meet some new friends"). The items were rated using a 5-point scale (1 = *not conforming at all*, 5 = *conforming completely*). In this study, Cronbach's α was 0.952, and the validated factor analysis fit indices were as follows: $\chi^2/df = 8.651$, GFI = 0.893, AGFI = 0.856, TLI = 0.933, NFI = 0.937, CFI = 0.943, RMSEA = 0.089, SRMR = 0.040, KMO = 0.964, and Bartlett's test $p < 0.001$. These results indicate good reliability and validity of the scale.

2.2.4 Physical activity rating scale (PARS-3)

Students' physical activity was assessed through the Physical Activity Rating Scale (PARS-3), which was revised by Chinese scholar Liang (1994). Participants were asked to rate the frequency (e.g., "How many times a month do you do the above physical activities"), duration (e.g., "How many minutes at a time do you perform physical activity at the above intensities"), and intensity (e.g., "How intensely do you exercise") of their bodily movements from 1 to 5. The total score for physical activities was the product of the scores on frequency, duration (minus 1), and intensity. The scale has good psychometric properties and has been widely used for young adults in Chinese culture (Feng et al., 2015; Ge and He, 2022). In this study, the amount of exercise was used as an assessment index of participants' physical activity. Cronbach's α in this study was 0.952.

2.3 Data analyses

In this study, SPSS 26.0 and Amos 23.0 were used to process and analyze the recovered questionnaire data. First, internal consistency analysis and validation factor analysis were used to test the reliability and validity of the scales. Second, descriptive statistics and correlation analysis were used to examine the relationship between procrastination, time management disposition, exercise motivation, and physical activity. Third, the SPSS Process 3.3 plug-in was used, and the Bootstrap method was chosen to analyze the indirect effect of procrastination affecting the amount of physical activity (chain-mediated effect of time management disposition and exercise motivation). Setting the independent variable (X) = procrastination, mediating variable (M1) = time management disposition, mediating variable (M2) = exercise motivation, control variables = gender, and dependent variable (Y) = physical activity, selecting Model 6 based on templates, and repeating the sample of 5,000, with the default 95% confidence interval, to conduct the analysis of the chained mediation model effect. In addition, AMOS 26.0 was used in this study to validate the reasonableness of the model, and the results showed good model fit indicators for the hypothesized model: $\chi^2/df = 2.145$, CFI = 0.996, TLI = 0.993, RMSEA = 0.035, and SRMR = 0.0169.

3 Results

3.1 Common methodology bias control and testing

Since all the data in this study came from the self-reports of Chinese university students, the results may be affected by common methodological biases. Therefore, measures such as separating different questionnaires, reverse scoring some questions, and emphasizing the confidentiality of data were taken for prior procedural control during the study design and data collection process. In addition, the study used the Harman one-way test (Podsakoff et al., 2003) to conduct a *post-hoc* statistical test for common method bias. The results showed that a total of 19 factors had an eigenroot greater than 1, and the variation explained by the first factor was 24.99%, which was less than the critical value of 40%, indicating that the common method bias was not significant (Tang and Wen, 2020).

3.2 Diagnosis of multicollinearity

If the tolerance is less than 0.1 or the variance inflation factor (VIF) is more than 10, the independent variables may have multicollinearity. In this study, the tolerance values and the VIF values of each variable ranged from 0.708 to 0.779 and from1.284 to 1.413, respectively, indicating that there is no problem of multicollinearity among the variables, which will not affect the interpretation of the results of the regression analysis.

3.3 Descriptive statistics and correlation analysis

Table 1 shows descriptive statistics (i.e., mean and standard deviation) of variables. In addition, the results of the correlation matrix between variables are shown. The results of the study can be visualized quite well: Procrastination showed a significant negative correlation with time management disposition, motivation to exercise, and physical activity, and a significant positive correlation was found between time management disposition, motivation to exercise, and physical activity.

3.4 The relationship between procrastination and physical activity among college students: a chain mediation effect test

To test the hypothesized model, the SPSS PROCESS macro developed by Hayes was used to conduct a chained mediation effect analysis, and model 6 was selected for the chained mediation effect test (Hayes, 2018). Bootstrap sampling was set to repeat the extraction 5,000 times to test the significance of the mediation effect, based on whether the 95% confidence interval contained 0. If the confidence interval did not contain 0, it meant that the mediation effect was significant, and if it contained 0, it meant that the mediation effect was not significant, and the mediation effect of time management disposition and exercise motivation between procrastination and physical activity level was analyzed using gender and age as control variables.

As shown in Table 2 and Figure 2, procrastination significantly negatively predicted physical activity ($\beta = -0.271$, $p < 0.001$); procrastination significantly negatively predicted time management disposition ($\beta = -0.494$, $p < 0.001$), and time management disposition significantly and positively predicted physical activity ($\beta = 0.094$, $p < 0.001$); procrastination significantly and negatively predicted exercise motivation ($\beta = -0.261$, $p < 0.001$), and time management disposition significantly positively predicted exercise motivation ($\beta = 0.278$, $p < 0.001$); when procrastination, time management disposition, and exercise motivation were entered into

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TABLE 1 Descriptive statistics and correlation analysis results for each variable.

		M (SD)	1	2	3	4	5	6	7	8	9	10	11	12
1	Procrastination	50.602 (9.289)	1	−0.491**	−0.324**	−0.484**	−0.494**	−0.406**	−0.405**	−0.331**	−0.379**	−0.343**	−0.388**	−0.251**
2	Time management disposition	147.585 (20.808)	−0.491**	1	0.792**	0.956**	0.926**	0.406**	0.393**	0.388**	0.361**	0.323**	0.383**	0.257**
3	The sense of time value	36.448 (5.9)	−0.324**	0.792**	1	0.607**	0.652**	0.454**	0.434**	0.384**	0.428**	0.379**	0.441**	0.161**
4	The sense of time control	77.462 (11.786)	−0.484**	0.956**	0.607**	1	0.861**	0.313**	0.305**	0.326**	0.266**	0.240**	0.289**	0.254**
5	The sense of time efficacy	33.675 (5.257)	−0.494**	0.926**	0.652**	0.861**	1	0.396**	0.383**	0.374**	0.355**	0.314**	0.375**	0.265**
6	Exercise motivation	59.268 (10.578)	−0.406**	0.406**	0.454**	0.313**	0.396**	1	0.918**	0.855**	0.945**	0.905**	0.927**	0.230**
7	Health motivation	11.989 (2.27)	−0.405**	0.393**	0.434**	0.305**	0.383**	0.918**	1	0.713**	0.852**	0.808**	0.810**	0.217**
8	Ability motivation	11.377 (2.307)	−0.331**	0.388**	0.384**	0.326**	0.374**	0.855**	0.713**	1	0.751**	0.690**	0.738**	0.229**
9	Fun motivation	11.964 (2.228)	−0.379**	0.361**	0.428**	0.266**	0.355**	0.945**	0.852**	0.751**	1	0.826**	0.877**	0.196**
10	Appearance motivation	11.827 (2.399)	−0.343**	0.323**	0.379**	0.240**	0.314**	0.905**	0.808**	0.690**	0.826**	1	0.787**	0.203**
11	Social motivation	12.111 (2.421)	−0.388**	0.383**	0.441**	0.289**	0.375**	0.927**	0.810**	0.738**	0.877**	0.787**	1	0.203**
12	Physical activity	15.911 (16.063)	−0.251**	0.257**	0.161**	0.254**	0.265**	0.230**	0.217**	0.229**	0.196**	0.203**	0.203**	1

**$p < 0.01$.

the equation at the same time, procrastination significantly negatively predicted physical activity ($\beta = -0.150$, $p < 0.001$), and both time management disposition and exercise motivation positively predicted physical activity ($\beta = 0.094$, $p < 0.001$; $\beta = 0.233$, $p < 0.001$).

The results show (Table 3) that after controlling for gender, procrastination was able to exert an effect on physical activity not only through the separate mediating effects of time management disposition and exercise motivation but also through the chained mediating effect of time management disposition → exercise motivation (none of the three paths of the mediating effect had Bootstrap 95% confidence intervals that included 0). Specifically, the mediating effect works in the effect of procrastination on physical activity through three paths: (1) indirect path 1 (procrastination → time management disposition → physical activity), with an effect value of −0.060, accounting for 22.14% of the total effect; (2) indirect path 2 (procrastination → exercise motivation → physical activity), with an effect value of −0.040, accounting for 14.76% of the total effect; (3) indirect path 3 (procrastination → time management disposition → exercise motivation → physical activity), with an effect value of −0.039, accounting for 7.75% of the total effect. The total mediated effect value was −0.021, accounting for 44.65% of the total effect.

The results of the two-by-two comparison of the indirect effects of the different mediating pathways are shown (Table 3): No significant differences were found between the separate mediating effect of time management disposition and the separate mediating effect of exercise motivation and the chained mediating effect of time management disposition → exercise motivation (Bootstrap 95% confidence intervals for Comparison 1 and Comparison 2 included 0). The separate mediating effect of exercise motivation was significantly higher than the chained mediating effect of time management disposition → exercise motivation (Bootstrap 95% confidence intervals for Comparison 3 did not include a value of 0).

4 Discussion

Based on the self-determination theory, the procrastination-health model, and the mechanism model of exercise persistence, this study investigated the effects of procrastination on college students' physical activity and revealed the mechanisms by which procrastination affects physical activity through intrinsic psychological factors (time management disposition and exercise motivation). The results of the study further reveal the internal mechanisms by which

TABLE 2 Regression analysis of the chain-mediated model.

Regression equation variable		Overall fit index of the equation			Significance of regression coefficients		
Outcome variable	Predictor variable	R	R^2	F	β	SE	t
Physical activity		0.355	0.126	68.862***			
	Gender				−0.252	0.985	−8.313***
	Procrastination				−0.271	0.053	−8,930***
Time management disposition		0.492	0.242	152.460***			
	Gender				−0.038	1.188	−1.332
	Procrastination				−0.494	0.063	−17.462***
Exercise motivation		0.482	0.232	95.974***			
	Gender				0.106	0.609	3.718***
	Procrastination				−0.261	0.037	−7.965***
	Time management disposition				0.278	0.017	8.520***
Physical activity		0.406	0.165	46.894***			
	Gender				−8.513	0.972	−8.760***
	Procrastination				−0.150	0.061	−4.260***
	Time management disposition				0.094	0.027	3.442***
	Exercise motivation				0.233	0.051	4.534***

The values of each variable in the model were standardized before being substituted into the equation; ***$p < 0.001$.

procrastination affects physical activity among college students and can provide suggestions and guidance for improving procrastination and promoting physical activity among college students.

4.1 Characteristics of procrastination, time management disposition, exercise motivation, and current status of physical activity among college students

The study examined the effects of procrastination, time management disposition, and exercise motivation on physical activity among Chinese college students based on a health-related model combined with a maturation scale. The results of the descriptive statistics show that Chinese college students currently have a high overall level of procrastination but a high degree of time management, and although they have strong exercise motivation, the amount of physical activity is low, which is a worrying situation. It can be seen that college students are able to manage and utilize their time more reasonably and have a tendency to participate in sports activities, but there are certain problems in the process of transforming exercise motivation into actual physical activity behavior accompanied by a certain procrastination tendency. This is more consistent with existing research (Wang, 2016). In addition, even if college students want to participate in sports activities for some reason, the diversified recreational facilities brought about by the rapid development and popularization of information technology and intelligent technology, as well as the global pandemic of the new crown epidemic in recent years, are also important factors that lead to the limitation of the transformation of exercise motivation into actual sports activities.

4.2 The role of college student procrastination in cutting down on physical activity

The results of the study show that there is a significant negative correlation between college students' procrastination and their participation in sports activities, that is, the higher the degree of procrastination, the fewer college students participate in sports activities, and the results of the regression analysis further proved that procrastination has a significant negative predictive effect on exercise behavior, which is consistent with the research hypothesis. From a practical point of view, procrastination, as a kind of delayed behavioral tendency, acts as an obstacle factor in the transition from "knowing" to "doing." The deeper the degree of procrastination, the deeper the degree of procrastination, leading to a decline in individual physical activities, such as physical exercise, leisure activities, social interaction, and other behaviors. The deeper the obstacles, the more the individual's physical activities such as physical exercise, leisure activities, and social interactions. According to the theory of planned behavior, individual behavior is influenced by behavioral intentions, attitudes, subjective norms, and a sense of behavioral control (Ajzen, 2011). In the context of college students, engaging in physical activity behavior requires a combination of factors, such as the individual's cognitive attitude toward exercise, their grasp of the difficulty of

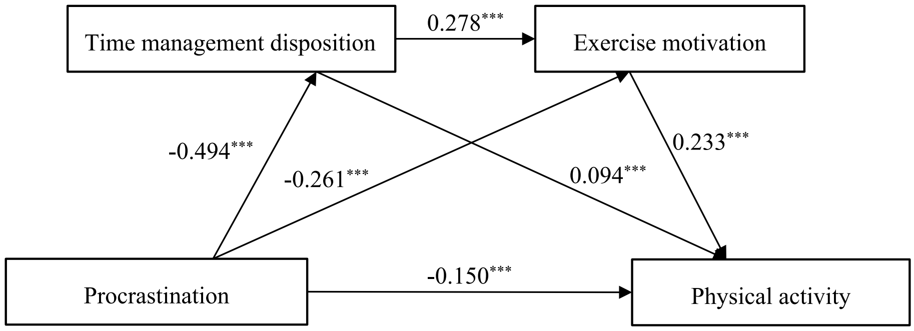

FIGURE 2
Model diagram of the effect of time management disposition and exercise motivation. ***$p < 0.01$.

TABLE 3 Chained mediation model effect test.

Effect	Pathway relationship	Efficiency value	95% confidence interval	Percentage of total effect
Total effect		−0.271***	[−0.331, −0.212]	
Total indirect effect		−0.121***	[−0.162, −0.081]	44.65%
Direct effect	Procrastination → physical activity	−0.260***	[−0.379, −0.140]	
Path 1	Procrastination → time management disposition →physical activity	−0.060***	[−0.103, −0.017]	22.14%
Path 2	Procrastination → exercise motivation → physical activity	−0.040***	[−0.061, −0.021]	14.76%
Path 3	Procrastination → time management disposition → exercise motivation → physical activity	−0.021***	[−0.033, −0.011]	7.75%
Comparison 1	Path 1 – Path 2	−0.020	[−0.075, 0.034]	
Comparison 2	Path 1 – Path 3	−0.039	[−0.086, 0.009]	
Comparison 3	Path 2 – Path 3	−0.019	[−0.038, −0.003]	

***$p < 0.001$.

carrying out the exercise, and external evaluative pressures regarding their own exercise activities. Research has shown that procrastination negatively correlates with an individual's willingness to engage in physical activity (Sirois, 2004). In other words, although college students may have positive attitudes toward physical activity and be encouraged by external environmental factors, as well as have the ability to carry out the behavior, they may still be affected by procrastination, which may diminish their willingness to exercise. From the perspective of time discounting, individuals with procrastination tendencies are more likely to succumb to short-term temptations than to commit themselves to volitionally demanding tasks, so procrastinators are more likely to choose long-term volitional goals such as recreation and leisure that provide instant gratification, as well as physical activities (Song et al., 2015). Therefore, if there are more relaxing ways of leisure in daily life, college students may procrastinate or just give up participating in sports and join other recreational activities, which may be an important reason why procrastination directly affects college students' sports activities.

4.3 Mediating effects of time management disposition and exercise motivation

It has been found that procrastination can influence physical activity through the separate mediating effects of time management disposition and exercise motivation and the chain mediating effect of time management disposition-exercise motivation, respectively. Time management involves a series of episodic behaviors such as setting goals, making plans, assigning priorities, allocating time, and providing feedback on results and is a psychological and behavioral characteristic of individuals in their approach to the function and value of time and the way they use it (Macan et al., 1990). Individuals with higher time management disposition tend to be able to allocate their time and tasks appropriately, which, in turn, leads to positive physical activity; conversely, individuals with lower time management disposition will increase the development of maladaptive behaviors and psychological problems, such as problematic cell phone use and academic anxiety (Zhang et al., 2021). At the same time, some researchers believe that procrastination is an externalized manifestation of a failure of self-regulation and a decline in self-control (Li et al., 2020; Deci and Ryan, 2008) and that individuals with procrastination have perceptions that time is of little value, that time does not need to be monitored, and that this negatively affects time management disposition. This shows that college students with higher levels of procrastination possess lower levels of time management disposition and therefore lower physical activity participation, that is, time management disposition mediates between procrastination and physical activity (Hypothesis H2 holds). In addition to this, it was found that procrastination can have an effect on physical activity through the mediating role of exercise motivation (Hypothesis H3 holds). According to self-determination theory, individuals are innately endowed with the expectation of self-actualization and development, and their behavioral motivation is a dynamic continuum from outside to inside (Deci and Ryan, 2008). Previous research has similarly identified the important mediating role of exercise motivation in the influence of many individual traits, such as self-enhancement (Zhou et al., 2022), exercise identity (Dong and Mao, 2020a), and perfectionism (Dong and Mao, 2020b), on physical activity, and has also been recognized as an important determinant of exercise motivation. Therefore, exercise motivation, as an important psychological resource for promoting physical activity, can effectively alleviate the lack of physical activity participation caused by negative individual traits such as procrastination. It can be seen that ameliorating procrastination tendencies is an effective strategy to cultivate good exercise habits among college students, which can effectively stimulate the degree of self-determination of exercise motivation and promote physical activity among college students to a certain extent.

This study also found that procrastination can influence college students' physical activity through the chain mediation of time management disposition → exercise motivation (Hypothesis H4 holds). It has been found that individuals with stronger time management disposition and motivation to exercise tend to have higher levels of physical activity (Li et al., 2021), both of which are psychologically motivating factors for individuals to engage in physical activity and exercise adherence (Guo and Mao, 2023), and can be influenced by individual characteristics. Higher procrastination leads individuals to exhibit higher levels of discretion and inertia in their behavior in response to events, resulting in less self-determined and more non-self-determined levels of motivation for physical activity, and may even persist in an unmotivated state of participation. At the same time, there is a positive relationship between time management disposition and individual motivation; individuals with a stronger time management disposition tend to have higher achievement motivation. Procrastination can negatively impact exercise motivation by decreasing time management disposition, which is not conducive to college students' participation in physical activity (Wang et al., 2023). Thus, procrastination is also able to influence exercise behavior through the chain-mediated effects of time management disposition and exercise motivation.

4.4 Practical significance

This study explored in depth the relationship between college students' procrastination and physical activity, examined the internal role mechanism of time management disposition and exercise motivation in the impact of procrastination on physical activity, constructed a chain mediation model of college students' physical activity influencing factors, and provided a practical basis for reducing the occurrence of college students' procrastination and promoting active participation in physical activity. According to the results of the study, educational authorities and educators should strengthen the cultivation of college students' time management ability and utilize the aggregation effect of society, family, school, peers, and other multi-party systems to build a good ecology of sports activities and to stimulate college students' motivation to participate in sports activities. As college students at an important stage of their lives, they should take the initiative to overcome and improve procrastination and other undesirable behaviors, improve their ability to plan their time rationally, actively participate in and adhere to sports activities by adopting goal-setting and other methods, and establish a sense of "lifelong sports," to promote the all-around healthy development of the body and mind.

4.5 Research shortcomings and prospects

There are some shortcomings in this study. First, the use of a self-reporting scale to assess procrastination and time management disposition may have the situation that there is a discrepancy between self-evaluation and the actual behavior of the subjects due to their strict demands on the self. Second, in response to the COVID-19 pandemic, governments generally adopted closure measures, and although this had no significant impact on the collection of our questionnaires, this unexpected event objectively reduced the amount of time people spent participating in physical activity, which may have had an impact on the results of this study. Future studies might be able to conduct a longitudinal study using pre-pandemic control group data to reveal the specific impact of this event on the results of the study. In addition, in terms of measurement, more objective measures such as accelerometers could be used in the future to compensate for the lack of self-reported data.

5 Conclusion

In conclusion, this study has shown that procrastination can significantly and negatively predict physical activity among Chinese university students. Time management disposition and exercise motivation can individually mediate the effect of procrastination on physical activity. Procrastination can have an effect on Chinese university students' physical activity through the chain mediation of time management disposition and exercise motivation.

Based on the research findings discussed above, this study offers the following recommendations for improving physical activity among university students: First, it is important to address the adverse effects of procrastination among college students. Regular health education can be conducted by means of relevant courses to enhance their understanding of the harms associated with procrastination and to cultivate their ability to manage and apply time scientifically. Second, it is essential to enhance the construction of places for physical activities, promote healthy lifestyles and sports concepts, provide convenient exercise resources and guidance for college students, increase their motivation to exercise, and promote their active participation in physical activities.

Data availability statement

The datasets presented in this article are not readily available because the data presented in this study are available on request from the corresponding author. These data are not publicly available because they are part of an ongoing study, which requires maintaining confidentiality and integrity to ensure the validity of future, more in-depth research findings. Requests to access the datasets should be directed to yangjianxz@sina.com.

Ethics statement

The studies involving humans were approved by the Ethics Committee of East China Normal University in China. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

YZ: Data curation, Investigation, Software, Writing – original draft. MT: Methodology, Writing – review & editing, Conceptualization. JY: Funding acquisition, Resources, Writing – review & editing. YX: Project administration, Writing – review & editing. ZL: Validation, Writing – review & editing. LW: Visualization, Writing – review & editing.

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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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