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How does physical exercise influence self-efficacy in adolescents? A study based on the mediating role of psychological resilience

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Abstract

Objective This study explores the influence of physical exercise on self-efficacy in adolescents, focusing on the mediating role of psychological resilience. By analyzing direct and indirect pathways, the study provides insights into the psychological mechanisms linking physical activity and self-efficacy.

Method Data were collected from 1,613 adolescent participants across 15 provinces in China using validated questionnaires to measure physical exercise, psychological resilience, and self-efficacy. Structural equation modeling (SEM) was used to test direct and mediated effects, while multi-group invariance testing examined gender differences.

Results Physical exercise significantly predicts both psychological resilience ($\beta = 0.410$, $p < 0.001$) and self-efficacy ($\beta = 0.220$, $p < 0.001$). Psychological resilience positively predicts self-efficacy ($\beta = 0.417$, $p < 0.001$). Mediation analysis revealed that psychological resilience partially mediates the relationship between physical exercise and self-efficacy, contributing 43.85% to the total effect. Multi-group analysis confirmed structural invariance across genders.

Conclusion Physical exercise enhances adolescents' self-efficacy both directly and indirectly through psychological resilience. It strengthens psychological resilience, which in turn boosts self-efficacy. These findings highlight the key role of physical activity in promoting resilience and building adolescents' confidence in their abilities.

Keywords Physical exercise, Psychological resilience, Self-efficacy, Adolescents, Structural equation modeling

Introduction

Adolescence is a critical stage of individual development, characterized by rapid physical growth, psychological maturation, and increasing academic and social pressures. This phase plays a foundational role in shaping lifelong health behaviors and psychological well-being, while also being a high-risk period for psychological development, with heightened vulnerability to stress and mental health issues [1, 2]. According to reports by the World Health Organization, adolescent populations are facing multiple mental health challenges, including anxiety, depression, and social isolation [3]. Therefore, identifying effective strategies to promote the physical and mental health of adolescents has become a priority for both researchers and policymakers.

Physical exercise is widely recognized as a cornerstone of adolescent health. In addition to its well-documented physical benefits, research shows that physical exercise is closely linked to improved mental health, including reductions in anxiety and depression, enhanced cognitive

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function, and overall well-being [4, 5]. Regular participation in physical activity not only promotes physical health but also provides a valuable context for developing life skills such as psychological resilience, self-regulation, and confidence—key abilities needed to navigate the complexities of modern life [6]. However, despite the significant impact of physical exercise on both physical and mental health, adolescent participation rates in physical exercise have been steadily declining worldwide, especially in developed countries and regions, raising concerns about the potential long-term negative effects of reduced physical activity on both physical and mental health [7, 8].

Self-efficacy, a critical psychological construct, has been widely studied in adolescent development. It refers to an individual's belief in their ability to accomplish specific tasks or achieve goals and is a key determinant of motivation, perseverance, and performance [9, 10]. High levels of self-efficacy are strongly associated with better academic achievement, improved social relationships, and greater resilience when facing challenges [11, 12]. Similarly, psychological resilience—the ability to positively adapt to stress or adversity—has emerged as a key factor in promoting mental health and well-being [13–15]. While both constructs are independently significant, their interaction and the mechanisms by which physical exercise influences mental health through these pathways remain underexplored.

Although existing research has shown the broad positive effects of physical exercise on mental health, there is still insufficient research into the mechanisms underlying these effects. Particularly in the context of adolescent psychological development, psychological resources such as adaptability to stress and confidence in task performance may play a crucial mediating role in the effects of physical exercise. However, there is a lack of in-depth analysis in the literature regarding how these psychological resources are influenced by external activities and the mechanisms of their action [16]. Understanding these mechanisms is essential for a comprehensive understanding of the role of physical exercise in adolescent psychological development.

From a theoretical perspective, the development of psychological traits depends not only on intrinsic characteristics but also on the influence of external activities. These activities provide adolescents with opportunities to experience challenges and growth, helping to cultivate positive psychological traits [17]. Further exploration of the mechanisms underlying the development of these psychological traits can shed light on the role of physical exercise in shaping adolescent mental health and provide essential theoretical support for promoting holistic development.

The primary aim of this study is to explore the mechanisms by which physical exercise influences psychological resilience and self-efficacy in adolescents. Through this research, we aim to provide new empirical support for theory and practice, revealing how physical exercise improves adolescent mental health by enhancing psychological resources. This will provide scientific evidence to inform more effective interventions to promote the physical and mental well-being of adolescents.

Literature review and research hypotheses

Physical exercise and self-efficacy in adolescents

Social Cognitive Theory was first proposed by Stanford University psychologist Albert Bandura [18]. This theory analyzes the social basis of thoughts and behaviors, emphasizing that individual behavior is influenced not only by personal factors but also by environmental and social factors [19]. In this framework, behavior, individuals, and the environment form a dynamic interactive relationship, where the intensity and pattern of interaction between any two factors vary depending on the specific behavior, individual characteristics, and environment. Bandura further expanded this theory, particularly in the context of health behaviors (including physical activity, healthy diet, etc.), by proposing a multidimensional causal model. He highlighted that individuals regulate their motivation and behavior through self-efficacy, outcome expectations, and perceived environmental supports and barriers [19].

Social Cognitive Theory provides a theoretical basis for understanding how physical exercise affects adolescents' self-efficacy. During physical activities, adolescents not only experience improvements in physical health but also develop self-efficacy through their participation. As a tool for holistic development, physical exercise enhances adolescents' self-awareness and promotes the development of their psychological, emotional, and social skills [20]. This is particularly important during adolescence, a stage of rapid physical and psychological growth, where shaping behavioral habits, developing emotional regulation, and understanding social roles significantly impact future quality of life [21, 22].

From a psychological perspective, physical exercise provides adolescents with diverse experiential contexts that help them develop positive self-perceptions [13, 24]. In these physical activities, adolescents often encounter challenging tasks such as improving physical skills, strategizing, or achieving team goals. Successfully completing these tasks not only provides immediate success experiences but also strengthens adolescents' perception of their abilities [25]. Unlike standardized assessments in academic settings, the feedback mechanisms in physical exercise are more dynamic and flexible. This unique feedback process helps adolescents gain intense psychological

stimulation through completing autonomous tasks and engaging in positive social interactions [26, 27].

Specifically, physical exercise promotes the enhancement of self-efficacy through multiple pathways. On one hand, the physiological benefits of exercise directly impact brain function. Research shows that exercise stimulates the secretion of brain-derived neurotrophic factor (BDNF), which not only enhances cognitive function but also improves emotional regulation and stress management [28, 29]. These physiological effects provide foundational support for psychological development, enabling adolescents to perform better in emotional control and goal perseverance [30–32]. On the other hand, the practical contexts provided by physical activities offer valuable psychosocial resources. For example, team sports help adolescents learn to build trust through cooperation and competition, fostering their role identity within the team and enhancing their positive self-perception [33].

Additionally, the structured goals and feedback mechanisms inherent in physical exercise play a crucial role in strengthening individual beliefs. Achieving physical goals often requires adolescents to overcome setbacks and failures, which helps them develop stronger self-regulation strategies when facing challenges. Research indicates that by persistently completing tasks, adolescents gain a heightened sense of mastery, thereby enhancing their self-efficacy [23]. Furthermore, the challenges presented by physical exercise are not only physical but also psychological. These psychological challenges include focusing attention, maintaining perseverance, and rebuilding confidence after failure [34, 35]. These resilience factors are closely related to adolescents' self-efficacy, helping them better cope with difficulties in physical exercise and develop stronger psychological resilience.

Based on the above analysis, this study proposes the following hypothesis:

H1 There is a significant positive correlation between physical exercise and self-efficacy in adolescents.

Physical exercise and psychological resilience in adolescents

Positive Psychology Theory was proposed by Seligman in 1998 [36]. This theory focuses on the inherent positive qualities and strengths of humans, suggesting that psychology should focus on human's latent constructive powers, virtues, and goodness, emphasizing the use of a positive mindset to understand psychological phenomena and issues. This, in turn, helps stimulate individuals' inner positive forces, maximizing personal potential and enhancing happiness [37]. Within this theoretical framework, physical exercise, as a positive lifestyle choice, not only has a significant impact on physical health but also has profound effects on psychological development through various mechanisms [38, 39].

This is particularly important during adolescence, a critical stage of rapid physical and psychological growth, where young people face multiple challenges such as academic pressure, social challenges, and the formation of self-identity [40]. Physical exercise provides adolescents with a unique context, helping them effectively alleviate these pressures and fostering the development of key psychological traits. In recent years, psychological resilience, as a core ability to cope with pressure and adversity, has become an important area of focus in how physical exercise influences adolescent mental health [41, 42].

Psychological resilience is defined as the ability to adapt and recover when facing challenges and stress [13–15]. Physical exercise provides unique support for the development of this ability. In physical activities, adolescents face challenges not only related to physical fatigue but also emotional regulation, coping with failure, and enduring competitive pressure [43]. These challenges require adolescents to mobilize internal resources to cope, thus cultivating their adaptability and laying a solid foundation for dealing with more complex situations in the future. Research shows that participation in structured physical activities significantly reduces adolescents' stress levels and improves their emotional regulation abilities when facing uncertainty [44]. Through repeated exposure to stress in physical exercise, adolescents learn various coping strategies, fostering a positive mindset towards challenges.

Physical exercise not only helps adolescents face failure but also provides experiences linked to success, deepening their understanding of the relationship between setbacks and growth [45]. For example, in team sports, adolescents learn to maintain patience, focus, and self-control under pressure, which are core elements of psychological resilience [46, 47]. Furthermore, the immediate feedback mechanisms in physical exercise further enhance adolescents' positive self-assessment of their abilities, strengthening their adaptability and self-efficacy. This improved self-perception extends beyond physical activities to other areas such as academics, family, and social interactions [48].

From a physiological perspective, physical exercise provides a solid foundation for psychological resilience through its regulation of neural and biological mechanisms. Research has found that exercise promotes the secretion of brain-derived neurotrophic factor (BDNF), enhancing the functionality of neural pathways involved in emotional regulation [49, 50]. This not only improves adolescents' immediate responses to stress but also provides support for the long-term accumulation of psychological resources. Additionally, physical activity helps regulate the hypothalamic-pituitary-adrenal (HPA) axis,

reducing excessive stress responses and improving emotional recovery under pressure [51, 52]. These physiological mechanisms not only enhance adolescents' immediate responses to short-term stress but also, by increasing brain plasticity, lay the foundation for the long-term development of psychological resilience.

Social support is another crucial pathway through which physical exercise promotes psychological resilience. During physical activities, adolescents gain a sense of belonging and support through interactions with peers and teams. This social experience enhances their sense of security when facing challenges [53]. Studies show that team sports not only improve individuals' cooperation skills but also play a critical role in conflict management and trust-building, which are essential for the multidimensional development of adolescents' psychological resilience [46, 47]. Through these processes, physical exercise goes beyond being a mere tool for physical fitness, becoming a comprehensive platform for cultivating psychological and social resources.

Based on the above analysis, this study proposes the following hypothesis:

H2 There is a significant positive correlation between physical exercise and psychological resilience in adolescents.

Psychological resilience and self-efficacy in adolescents

Self-Determination Theory, proposed by American psychologists Deci and Ryan in the 1980s, emphasizes the autonomy of individual behavior and the motivational processes involved [54]. This theory suggests that whether an individual's behavior is driven by intrinsic motivation largely determines the quality and sustainability of that behavior, with motivation being influenced by contextual and interpersonal factors [55]. Particularly during adolescence, when young people can experience a high degree of autonomy in physical exercise, this not only helps them improve their physical health but also promotes the development of psychological resilience, which in turn enhances self-efficacy. Physical exercise provides adolescents with a favorable environment that allows them to participate in self-directed activities, build confidence, and overcome challenges.

Psychological resilience is defined as the ability of individuals to effectively adapt and recover in the face of stress or adversity, and it is a core trait for maintaining mental health and fostering positive development in adolescents [14]. Adolescence is a critical period of physical and psychological development, during which young people experience multiple pressures from academic, family, and social environments. Psychological resilience provides them with the ability to cope with these pressures [56–58]. During this process, self-efficacy plays an important role. Self-efficacy refers to an individual's belief in their ability to complete tasks and achieve goals, and research shows a strong relationship between psychological resilience and self-efficacy [9, 10]. Psychological resilience helps adolescents enhance their ability to cope with failure, and through emotional regulation stability, it provides a foundation for the development of positive self-perception [59].

Specifically, psychological resilience indirectly shapes adolescents' positive self-evaluations by improving their ability to adapt to setbacks [60, 61]. For example, when adolescents face challenges, resilience enables them to mobilize internal resources, actively address problems, and find solutions under pressure. This process not only helps them regulate their emotions but also strengthens their confidence in their abilities through repeated successes [62]. Adolescents with higher levels of resilience often exhibit greater perseverance and goal-oriented behavior, traits that are closely associated with high levels of self-efficacy [63, 64].

Emotional regulation, a key component of psychological resilience, plays a crucial role in shaping self-efficacy [65, 66]. Effective emotional regulation allows adolescents to maintain a balanced mindset when facing failure or criticism, enabling them to focus on problem-solving and goal achievement [67]. For instance, when faced with setbacks in academic tasks, adolescents with higher resilience are more likely to adopt the mindset of "I can do better next time," which helps boost their confidence in completing tasks [68, 69].

Social support is also a key factor in the relationship between psychological resilience and self-efficacy. In physical activities, adolescents gain emotional and practical support through interactions with peers, family, and teachers. This support effectively alleviates feelings of isolation in stressful situations and enhances adolescents' sense of social role identity [52, 70, 71]. Research shows that team sports not only improve individuals' cooperation skills but also enhance their conflict management and trust-building abilities, all of which are essential for the multidimensional development of psychological resilience [46, 47]. Therefore, physical exercise not only improves adolescents' physical health but also, through mechanisms such as social support, emotional regulation, and teamwork, further promotes the development of their self-efficacy.

Based on the above analysis, this study proposes the following hypothesis:

H3 There is a significant positive correlation between psychological resilience and self-efficacy in adolescents.

The mediating role of psychological resilience

The significant role of physical exercise in promoting the physical and mental health of adolescents has been widely acknowledged. Its impact extends beyond direct improvements in physical health to indirectly enhancing psychological traits through complex mechanisms [72]. Psychological resilience, as a critical adaptive resource, has recently been identified as a potential mediating mechanism through which physical exercise contributes to psychological development [73]. It may act as a bridge between physical exercise and self-efficacy in adolescents, explaining how physical activity indirectly influences self-perception by fostering internal psychological resources.

Research indicates that physical exercise enhances psychological resilience through various mechanisms. Adolescents frequently experience processes such as overcoming challenges, coping with failure, and adjusting goals during physical activities. These experiences directly reinforce their ability to adapt to adversity [74, 75]. Additionally, immediate feedback and success experiences during exercise bolster adolescents' confidence in their abilities, further shaping their resilience to stress [76]. For instance, in team sports, adolescents develop emotional regulation skills and flexibility in addressing complex problems through competitive tasks and resolving collaborative conflicts, which are closely linked to the development of psychological resilience [77].

Psychological resilience supports the enhancement of self-efficacy through its core characteristics. From an emotional regulation perspective, resilience helps adolescents maintain stable emotional states in stressful situations. This stability allows them to focus on task objectives, thereby strengthening their confidence in completing tasks [78]. Studies have found that individuals with higher resilience are more likely to adopt proactive coping strategies, such as reevaluating problems or devising feasible solutions, which significantly enhance their self-evaluations [79]. Through this process, resilience not only mitigates the negative effects of stressful situations but also transforms these challenges into factors that enhance self-efficacy [80].

Further research suggests that psychological resilience can transfer the positive effects of physical exercise to other contexts, thereby broadly promoting adolescents' psychological development [81]. The coping abilities and success experiences cultivated in physical activities extend through resilience to academic, social, and other domains, enabling adolescents to face challenges in these areas with greater confidence and adaptability [82]. For example, experiences of competition and collaboration in physical activities can strengthen social cognition, enhancing psychological resilience and, in turn, improving social role recognition, which indirectly boosts self-efficacy [83].

Based on the above analysis, this study proposes the following hypothesis:

H4 Psychological resilience mediates the relationship between physical exercise and self-efficacy in adolescents.

Construction of an integrated theoretical hypothesis model

Based on the literature review and proposed hypotheses, this study constructs a theoretical hypothesis model, as illustrated in Fig. 1. The model aims to integrate existing research findings, optimize the relationships between hypotheses, and expand the theoretical framework for a more comprehensive understanding of the research topic.

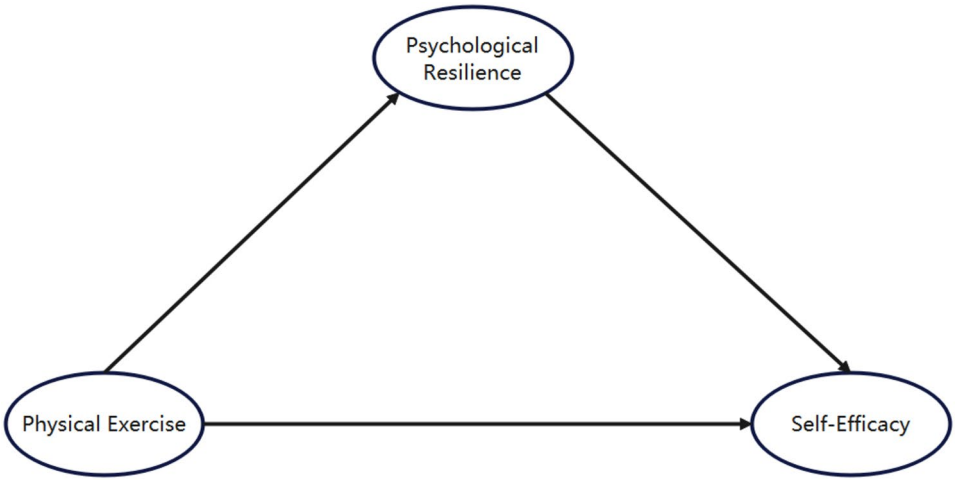

Fig. 1 Theoretical model of physical exercise and self-efficacy in adolescents: The mediating role of psychological resilience

Materials and methodology

Participants and data

Sample size justification

To ensure the robustness of the research design and the reliability of the results, the sample size was rigorously estimated using both G*Power analysis and established empirical rules in social science research.

Firstly, G*Power 3.1 software was utilized to conduct a power analysis for multiple regression. Assuming a medium effect size ($f^2 = 0.15$), a significance level of $\alpha = 0.05$, and a target statistical power of $1 - \beta = 0.80$, the analysis indicated a minimum requirement of 280 participants to detect statistically significant effects. This analysis ensures that the relationships among physical exercise, psychological resilience, and self-efficacy can be accurately assessed within the predefined statistical parameters.

Secondly, following the empirical rule of thumb in social science research, the recommended sample size is 10 to 15 times the total number of questionnaire items. The measurement instruments used in this study include the Physical Exercise Scale (3 items), the Psychological Resilience Scale (10 items), and the Self-Efficacy Scale (10 items), amounting to a total of 23 items. Accordingly, the required sample size is estimated to range from 230 to 345 participants (i.e., 23 items × 10 to 23 items × 15). This approach further ensures that the sample size is scientifically appropriate and comprehensive for the questionnaire design.

By integrating these two methods, the minimum sample size requirement for this study was determined to be 280 participants, while the ideal range based on the empirical rule was estimated to be between 230 and 345 participants. To enhance the statistical power and external validity of the research findings, data were ultimately collected from 1,613 adolescent participants. This substantially larger sample size not only exceeds the minimum requirements determined by power analysis and empirical guidelines but also provides ample data to support the analysis of relationships among the study variables.Furthermore, the design's inclusion of a sample size far exceeding the minimum requirement enhances the stability, generalizability, and representativeness of the findings across diverse demographic characteristics.

Table 1 Stratification by region and province in the sampling frame

Region	Province
Eastern China	Shanghai, Jiangsu, Shandong
Central China	Henan, Hubei, Hunan
Western China	Sichuan, Guizhou, Chongqing
Southern China	Guangdong, Guangxi, Hainan
Northern China	Beijing, Shaanxi, Liaoning

In conclusion, the sample size estimation in this study adheres to rigorous statistical and social science standards, and the large-scale data collection further strengthens the scientific validity and applicability of the research findings to a broader population.

Participant selection process

To ensure the representativeness of the research sample and minimize selection bias, this study adopted a stratified random sampling technique for participant selection. This method fully accounted for the socioeconomic and cultural diversity of different regions in China, combining stratification and randomization to construct a scientifically robust sampling framework encompassing a broad population.

The sampling framework covered middle and high school students from grades 7 to 12 across 15 provinces and cities in China, ensuring balanced distribution across age groups and educational stages. The sampling process consisted of the following steps:

First, China was stratified geographically and socioeconomically into five major regions (East, Central, West, Northeast, and South). This stratification was based on China's geographical diversity and varying levels of economic development, aiming to ensure sufficient representation of adolescents from different regions within the sample. Subsequently, three provinces or cities were randomly selected from each stratum to ensure balanced regional representation (see Table 1 for details).

Within the selected provinces or cities, several schools were randomly chosen as study sites. Specifically, representative middle and high schools were selected from both urban and rural areas within each region. Then, within each selected school, students who met the study's inclusion criteria were randomly chosen as participants. This multi-level randomization process not only reduced selection bias but also enhanced the broadness and balance of the sample across both school and student levels.

Random selection of schools and students To ensure the balance and representativeness of the sample, this study adopted randomized strategies for the selection of both schools and students, while fully considering geographical and demographic factors.At the school level, schools within each geographical stratum were selected using a random number generator. The number of selected schools in each region was proportional to the student population of that region. For instance, if a region accounted for 20% of the national student population, approximately 20% of the total sample schools were chosen from that region. This weighting approach ensured fairness and scientific rigor in the sample design by reflecting the distribution of students across regions. At the student level, random sampling was conducted using

a random number generator to select participants from grades 7 to 12 in each selected school. Specifically, participants were randomly chosen from the student rosters provided by the schools. This process ensured equal selection opportunities for every student, effectively reducing selection bias and enhancing the diversity and representativeness of the sample.

Exclusion of certain regions Due to logistical and practical constraints, some regions were excluded from the sampling framework of this study. For instance, Xinjiang and Tibet were excluded due to their remote geographical locations, limited transportation access, and the increased complexity of data collection and logistical operations associated with their cultural diversity. Similarly, Taiwan was excluded due to challenges in obtaining research permissions and uncertainty regarding participant cooperation.The exclusion of these regions may limit the applicability of the study's conclusions to these specific areas. However, the sampling framework included 15 provinces and cities from mainland China, representing the majority of adolescent populations across the country. This extensive coverage ensures broad generalizability and national representativeness. Although some regions were excluded, the remaining sample effectively covered China's major geographical, social, and cultural areas, offering strong support for the generalization of the study findings.

Data collection methods

To ensure the validity and reliability of the data, this study implemented a rigorous standardized procedure for data collection. The specific process is as follows:

Training of data collectors Before distributing the questionnaires, the research team conducted systematic training sessions for the participating physical education teachers and class advisors responsible for data collection. The training covered the explanation of the study objectives, the importance of random sampling, and the standardized procedures for questionnaire distribution and administration. Detailed instructions and scenario-based simulations ensured that data collectors could consistently implement the questionnaire distribution and supervision processes, minimizing the potential impact of human error on data quality.

Questionnaire distribution and completion The questionnaires were distributed and completed in a controlled environment during regular school hours to ensure a quiet and distraction-free setting. Physical education teachers and class advisors supervised the entire process to guarantee that students completed the questionnaires independently, without external influence. Upon completion, the questionnaires were immediately collected and securely sealed to prevent delays or potential data breaches, ensuring the timeliness and accuracy of the data.

Confidentiality and ethical pproval This study strictly adhered to the declaration of helsinki and relevant national and institutional ethical guidelines. The research protocol was reviewed and approved by the Ethics Committee of the School of Sports Training at Chengdu Sport University (Approval Number: CTYLL2024007).Since all participants were minors, dual consent was required before participation: oral informed consent from the students themselves and written consent from their parents or guardians. In some cases where logistical or access limitations made it impossible to obtain written parental consent directly, the ethics committee approved waivers based on specific circumstances, ensuring that the study adhered to ethical standards.

Data privacy and anonymity All data were processed anonymously to fully protect participants' privacy. The questionnaires did not collect any personally identifiable information, and data confidentiality was strictly maintained during analysis. Additionally, the research team employed encryption measures during data storage and sharing to further safeguard data security, ensuring the participants' rights and confidentiality were respected throughout the study.

Data processing

The survey spanned thirteen months, commencing on September 1, 2023, and concluding on September 30, 2024. A total of 1,800 questionnaires were distributed during this period. To ensure the accuracy of the data and the rigor of the research, a meticulous screening process was conducted on the returned questionnaires. Invalid questionnaires were excluded due to issues such as missing responses, erroneous entries, or fixed-pattern answering. Ultimately, 1,613 valid questionnaires were retained, resulting in a high effective response rate of 89.61%. During the screening process, predefined criteria were strictly followed, with incomplete responses or logically inconsistent answers being removed. This rigorous approach ensured the quality and completeness of the data. Detailed demographic information of the respondents is presented in Table 2.

Measurements

All measurement tools used in this study were based on established scales that have demonstrated good reliability and validity. The details of the specific measurement tools are as follows:

Physical exercise: Physical exercise was assessed using a scale developed by Liang Deqing et al. [84]. This

Table 2 The sample information

Basic information	Category	Frequency	Percentage	Cumulative percentage
Gender	Male	810	50.22%	50.22%
	Female	803	49.78%	100%
School stage	Middle school	782	48.48%	48.48%
	High school	831	51.52%	100%
Residence type	Rural	821	50.90%	50.90%
	Urban	792	49.10%	100%

Table 3 Scales used in this study

Scale	Author (Year)	Item quantity	Scoring
Physical exercise	Deqing Liang (1994)	3	5
Psychological resilience	Campbell-Sills & Stein(2007)	10	4
Self-efficacy	Kangcai Wang (2001)	10	4

scale consists of three items designed to measure the frequency and intensity of adolescents' participation in physical activities. It employs a 5-point Likert scale, ranging from 1 ("very poor") to 5 ("excellent"), with higher scores indicating higher levels of physical activity. Previous research has shown the scale to exhibit good reliability (Cronbach's $\alpha > 0.70$) and validity across different cultural contexts and populations. In this study, the scale demonstrated a Cronbach's α of 0.715.

Psychological resilience: Psychological resilience was measured using the scale developed by Campbell-Sills and Stein [85]. This scale contains 10 items aimed at evaluating individuals' ability to adapt and recover in stressful or adverse situations. The questionnaire uses a 4-point Likert scale, ranging from 1 ("not true at all") to 4 ("completely true"), with higher scores reflecting greater resilience. Previous studies have consistently reported high internal consistency (Cronbach's $\alpha > 0.80$) and structural validity across various age groups and cultural contexts. In this study, the scale achieved a Cronbach's α of 0.959.

Self-Efficacy: Self-efficacy was evaluated using the scale developed by Wang Kangcai [86]. This scale consists of 10 items designed to assess adolescents' belief in their ability to complete tasks. It uses a 4-point Likert scale, ranging from 1 ("does not match at all") to 4 ("completely matches"), with higher scores indicating stronger self-efficacy. This scale has shown good reliability (Cronbach's $\alpha > 0.80$) and validity in prior studies, effectively capturing the psychological characteristics of self-efficacy. In this study, the scale achieved a Cronbach's α of 0.961.

Summary: Table 3 provides an overview of the scales used in this study, including the number of items, scoring range, reliability coefficients, and standard deviations. The selection of these scales was based on their proven stability and applicability in relevant research fields, ensuring their effectiveness in capturing the key characteristics of the core variables in this study.

Data analysis procedures

To ensure methodological rigor, we employed various data analysis procedures. First, to assess common method bias, we applied Harman's single-factor test using principal component analysis [87]. The results showed that no single factor accounted for more than 40% of the total variance, indicating that common method bias was not a significant concern in this study.

Descriptive statistics, including means and standard deviations, were computed for the key variables—physical exercise, psychological resilience, and self-efficacy. These statistics provided an overview of the sample's characteristics, serving as a foundation for subsequent analyses. Internal consistency reliability was assessed using Cronbach's α coefficient, with all scales showing acceptable values (≥ 0.70), confirming the reliability of the measurement instruments [88].

Confirmatory Factor Analysis (CFA) was performed to validate the factor structure of the measurement model for each individual scale (physical exercise, psychological resilience, and self-efficacy). CFA was chosen because it allows for testing the structural validity of pre-established scales in the context of this study, ensuring that the measurement models appropriately fit the data. Initially, CFA was conducted for each scale separately to confirm that the factor structures of all scales remained consistent with their original designs. Specifically, we tested each scale's factor structure by assessing several key fit indices, including the χ^2/df ratio, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). The criteria for model fit were as follows: $\chi^2/df < 3.0$, $CFI > 0.90$, $TLI > 0.90$, $RMSEA < 0.08$, and $SRMR < 0.08$. The results confirmed that the factor structures of the individual scales were appropriate and provided a good fit to the data [89].

For the multi-factor model, we integrated the three constructs (physical exercise, psychological resilience, and self-efficacy) into a three-factor model. This model was assessed using the same fit indices to ensure that the constructs were distinct and the model was appropriately specified. The fit indices confirmed that the three-factor model provided a good fit to the data. To assess discriminant validity, we compared the three-factor model to alternative models, including a two-factor and a one-factor model. The three-factor model demonstrated superior fit compared to these alternatives, indicating that the three constructs were indeed distinct and appropriately measured.

Pearson's correlation analysis revealed significant relationships among the variables, providing preliminary

evidence for the hypothesized relationships, and suggesting psychological resilience's potential mediating role. Path analysis within the structural equation modeling (SEM) framework tested direct and indirect relationships [88], confirming the mediating effect of psychological resilience between physical exercise and self-efficacy.

To assess the significance of the mediation effects, we conducted effect size testing using the bootstrap method with 2,000 resamples. The use of the bootstrap method provides several key advantages, particularly in testing mediation effects. One major advantage is that it does not rely on the assumption of normality in the data, which is often violated in real-world data. Traditional methods, such as the Sobel test, assume normal distribution, which may not hold true in many situations, especially when dealing with small or skewed samples. The bootstrap method generates a large number of resampled datasets to estimate the indirect effects and calculates confidence intervals (CIs) for these effects. This allows for more robust and reliable conclusions about the significance of the mediation effect. By computing the confidence intervals for the indirect effects, we can assess whether the mediation effect is statistically significant. In this study, the 95% confidence intervals for the indirect effects did not include zero, indicating that the mediation effects were statistically significant and not due to chance [90].

Additionally, we performed multi-group invariance testing to ensure the consistency of the model across genders. This step was crucial to determine whether the hypothesized relationships hold true for both male and female adolescents. Multi-group analysis helps assess whether the same underlying model is appropriate for different groups, such as gender groups in this case, and whether the model parameters (such as factor loadings and residuals) are consistent across these groups. The model invariance was assessed by comparing the unconstrained and constrained models, and the results showed that the ΔCFI value was less than 0.01, confirming that the model fit was stable across gender groups. This indicates that the proposed relationships are consistent and generalizable across both male and female adolescents, further strengthening the robustness of our findings [91].

Result

Common method bias and multicollinearity test

To assess the potential impact of common method bias, a principal component analysis was conducted using Harman's single-factor test. Three factors with eigenvalues greater than 1 were extracted, with the largest factor accounting for 23.57% of the total variance, which is below the critical threshold of 40%. This indicates that common method bias is not a significant concern in this study, suggesting minimal interference with subsequent analyses.

Descriptive statistics, reliability, and construct validity of the measurement model

Table 4 presents the descriptive statistics, internal consistency reliability, and fit indices for the confirmatory factor analysis (CFA) of the key variables used in this study. The mean (M) and standard deviation (SD) of the variables indicate an appropriate range of variability, suggesting that the data is well-distributed for further analysis.

The internal consistency reliability of the variables was assessed using Cronbach's alpha (α). All variables demonstrated strong reliability, with α values exceeding the recommended threshold of 0.7. Specifically, occupational stress and work engagement achieved excellent reliability, with α = 0.944 and α = 0.943, respectively. Teacher competency showed good reliability with α = 0.838.

Construct validity was examined using CFA fit indices, including the Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Standardized Root Mean Square Residual (SRMR), and Root Mean Square Error of Approximation (RMSEA). The results indicate an excellent model fit for occupational stress and work engagement. Both variables achieved CFI and TLI values above the 0.95 cutoff (CFI = 0.973 and 0.983; TLI = 0.966 and 0.978, respectively). Furthermore, the SRMR values for occupational stress (0.021) and work engagement (0.016) fell below the recommended threshold of 0.08, and RMSEA values with 90% confidence intervals (CIs) were within acceptable limits (occupational stress: RMSEA = 0.075, 90% CI = [0.068, 0.082]; work engagement: RMSEA = 0.059, 90% CI = [0.052, 0.066]).

To further validate the measurement model, a comparison of alternative factor structures was conducted. Table 5 presents the fit indices for three models: the three-factor model (Physical Exercise [PE], Psychological Resilience [PR], and Self-Efficacy [SE]), the two-factor model (combining PE and PR into one factor, and SE as another factor), and the one-factor model (combining all three constructs into a single factor).

The three-factor model demonstrated the best fit, as indicated by its superior fit indices (χ^2 = 770.559, *df* = 227, CFI = 0.979, TLI = 0.977, SRMR = 0.021, RMSEA = 0.039,

Table 4 Descriptive statistics, internal consistency reliability, and fit indices for confirmatory factor analysis (CFA) of key variables

Variable	M	SD	α	CFI	TLI	SRMR	RMSEA (90%CI)
Teacher competency	24.023	21.271	0.838	-	-	-	-
Occupational stress	2.578	0.854	0.944	0.973	0.966	0.021	0.075 (0.068–0.082)
Work engagement	2.496	0.857	0.943	0.983	0.978	0.016	0.059 (0.052–0.066)

Table 5 Comparative fit indices for alternative factor structures of key constructs

Model	Factor	χ 2	*df*	△χ 2 (△*df*)	CFI	TLI	SRMR	RMSEA (90%CI)
Three-factor model	PE, PR, SE	770.559	227	-	0.979	0.977	0.021	0.039 (0.36 – 0.042)
Two-factor model	PE + PR, SE	2398.750	229	1628.191 (2)	0.917	0.908	0.065	0.077 (0.074–0.079)
One-factor model	PE + PR + SE	9945.823	230	9175.264 (3)	0.629	0.592	0.138	0.162 (0.159–0.165)

PE, Physical Exercise. PR, Psychological Resilience. SE, Self-Efficacy. All △χ 2 passed the significance test at 0.05 level

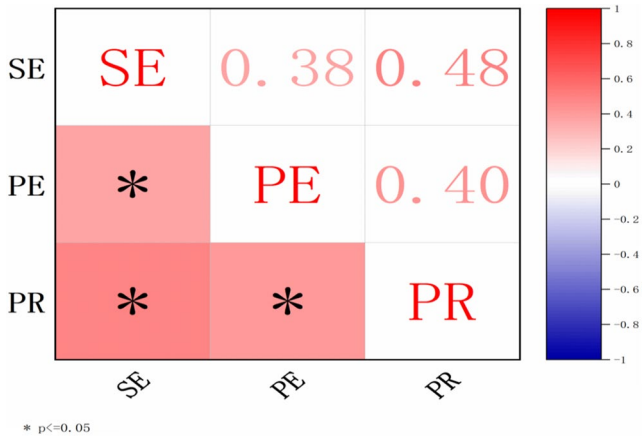

Fig. 2 Correlation matrix of key variables

90% CI = [0.036, 0.042]). These values exceeded the recommended thresholds (CFI and TLI > 0.95, SRMR < 0.08, RMSEA < 0.06), suggesting excellent model fit.

In comparison, the two-factor model showed a significant decline in fit ($\Delta\chi^2$ = 1628.191, Δdf = 2, CFI = 0.917, TLI = 0.908, SRMR = 0.065, RMSEA = 0.077, 90% CI = [0.074, 0.079]), indicating that combining PE and PR into a single factor does not adequately capture the distinctiveness of the constructs.

The one-factor model exhibited the poorest fit among the three models (χ^2 = 9945.823, df = 230, CFI = 0.629, TLI = 0.592, SRMR = 0.138, RMSEA = 0.162, 90% CI = [0.159, 0.165]), with all indices falling far below acceptable levels. This result underscores the importance of treating PE, PR, and SE as distinct constructs.

Overall, the three-factor model was confirmed as the best representation of the data, supporting the theoretical distinctions among Physical Exercise, Psychological Resilience, and Self-Efficacy. These findings provide strong evidence for the construct validity of the measurement model, justifying its use in the subsequent mediation analyses.

Correlation analysis among key variables

Figure 2 illustrates the correlation matrix of the key variables: Physical Exercise (PE), Psychological Resilience (PR), and Self-Efficacy (SE). The results reveal significant positive correlations among all three variables, providing preliminary evidence for their interconnectedness.

Specifically, PE is positively correlated with PR (r = 0.40, $p \le 0.05$) and SE (r = 0.38, $p \le 0.05$), indicating that higher levels of physical exercise are associated with greater psychological resilience and self-efficacy. Similarly, PR is positively correlated with SE (r = 0.48, $p \le 0.05$), suggesting that adolescents with higher psychological resilience also tend to report higher self-efficacy.

The correlation coefficients fall within a moderate range, consistent with theoretical expectations and indicating no multicollinearity issues. These findings further support the hypothesized relationships among the variables.

Table 6 Questionnaire model fitting indicators

Model Fit	χ 2/*df*	CFI	TLI	SRMR	RMSEA (90%CI)
Model	3.871	0.978	0.975	0.020	0.042 (0.039–0.045)

Test results of mediation effects

Model fit evaluation As shown in Table 6, the model fit indices indicate that the hypothesized mediation model fits the data well. The ratio of chi-square to degrees of freedom (χ^2/df = 3.871) is below the threshold of 5. Additionally, the CFI (0.978) and TLI (0.975) exceed the recommended cutoff of 0.95, while the SRMR (0.020) and RMSEA (0.042, 90% CI = [0.039, 0.045]) are within

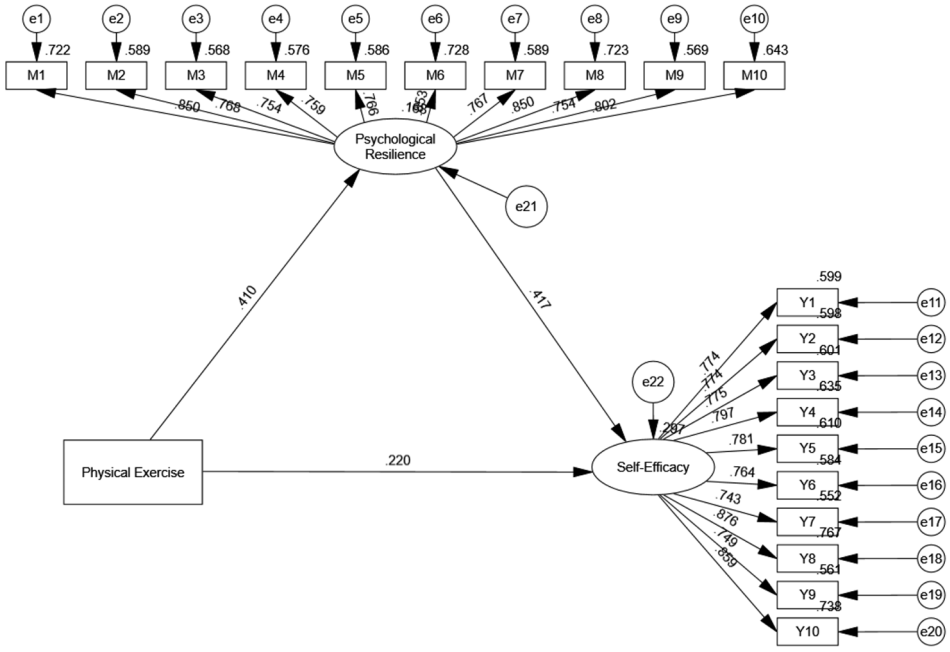

Fig. 3 Structural equation model illustrating the relationships among physical exercise, psychological resilience, and self-efficacy

Table 7 Total, direct and indirect effects in the multiple mediator model

Path	Estimated effect	Boot SE	*P*	Boot LLCI	Boot ULCI	Ratio
Direct effect						
PE→SE	0.220	0.024	0.001	0.179	0.261	56.41%
Indirect effects						
PE→PR→SE	0.171	0.015	0.000	0.146	0.196	43.85%
Total effect	0.390	0.021	0.000	0.358	0.425	-

PE, Physical Exercise. PR, Psychological Resilience. SE, Self-Efficacy. Boot LLCI, the lower bound of the 95% confidence interval. Boot ULCI, the upper limit of the 95% confidence interval (Percentile Bootstrap Method with Bias Correction). The Bootstrap sample size is set at 2000

acceptable ranges. These results confirm that the model is suitable for testing the hypothesized mediation effects.

Path coefficients and mediation analysis Figure 3 illustrates the structural equation model (SEM), highlighting the direct and indirect pathways among PE, PR, and SE. The standardized path coefficients show that PE positively predicts PR (β = 0.410, $p < 0.001$), PR positively predicts SE (β = 0.417, $p < 0.001$), and PE directly predicts SE (β = 0.220, $p < 0.001$). These relationships support the hypothesized mediation model.

Table 7 summarizes the direct, indirect, and total effects. The direct effect of PE on SE is significant (β = 0.220, $p < 0.001$), accounting for 56.41% of the total effect. The indirect effect of PE on SE through PR is also significant (β = 0.171, $p < 0.001$), contributing 43.85% to the total effect. The total effect of PE on SE is β = 0.390 ($p < 0.001$), indicating that PE influences SE both directly and indirectly through PR.

Hypothesis testing

H1 There is a significant positive correlation between physical exercise and self-efficacy in adolescents. Supported. As shown in Table 7, PE has a significant positive direct effect on SE (β = 0.220, $p < 0.001$).

H2 There is a significant positive correlation between physical exercise and psychological resilience in adolescents. Supported. Figure 3; Table 7 show that PE positively predicts PR (β = 0.410, $p < 0.001$).

H3 There is a significant positive correlation between psychological resilience and self-efficacy in adolescents. Supported. PR significantly predicts SE (β = 0.417, $p < 0.001$), as shown in Fig. 3; Table 7.

H4 Psychological resilience mediates the relationship between physical exercise and self-efficacy in adolescents. Supported. The mediation analysis (Table 7) confirms that PR partially mediates the relationship between PE and SE, with a significant indirect effect (β = 0.171, $p < 0.001$).

Table 8 Testing for structural invariance across gender

	χ 2/*df*	CFI	△CFI	TLI	△TLI	SRMR	RMSEA (90%CI)
Unconstrained	2.411	0.978	-	0.975	-	0.026	0.030 (0.027–0.032)
Measurement weights	2.339	0.978	0.000	0.976	+ 0.001	0.026	0.029 (0.026–0.031)
Structural weights	2.328	0.978	0.000	0.977	+ 0.002	0.027	0.029 (0.026–0.031)
Structural covariances	2.398	0.977	-0.001	0.975	0.000	0.027	0.029 (0.027–0.032)
Structural residuals	2.386	0.977	-0.001	0.976	+ 0.001	0.027	0.029 (0.027–0.032)

The findings demonstrate that physical exercise significantly enhances self-efficacy in adolescents both directly and indirectly via psychological resilience. The mediation model is well-supported, and all hypotheses are confirmed.

Testing for structural invariance across gender

To examine whether the measurement model is invariant across gender, a multi-group confirmatory factor analysis (CFA) was conducted. Table 8 presents the fit indices for the different levels of measurement invariance testing, including unconstrained, measurement weights, structural weights, structural covariances, and structural residuals models.

The results show that the unconstrained model fits the data well, with fit indices meeting the recommended thresholds ($\chi^2/df = 2.411$, CFI = 0.978, TLI = 0.975, SRMR = 0.026, RMSEA = 0.030, 90% CI = [0.027, 0.032]). Successive constraints on measurement weights, structural weights, structural covariances, and structural residuals did not significantly degrade model fit, as indicated by minimal changes in CFI ($\Delta CFI \leq 0.001$) and TLI ($\Delta TLI \leq +0.002$). Additionally, the RMSEA values remained consistent across all models (0.029–0.030).

These findings suggest that the factor structure, factor loadings, covariances, and residuals of the measurement model are equivalent across genders, supporting the structural invariance of the model. Thus, the relationships among physical exercise, psychological resilience, and self-efficacy can be meaningfully compared across male and female adolescents.

Discussion

Theoretical implications

This study confirms a significant positive correlation between physical exercise and self-efficacy (H1), emphasizing the core role of physical activity in enhancing adolescents' confidence, particularly in their ability to accomplish various tasks. This finding is consistent with research from South Korea and Spain [92, 93], which generally suggests that physical exercise fosters a sense of competence and control in adolescents, which are fundamental components of self-efficacy [9, 10, 58]. However, the unique contribution of this study lies in exploring the mediating role of psychological resilience in this relationship, filling a gap in the existing literature, particularly in research conducted in China and other specific regions.

Next, the study reveals a positive relationship between physical exercise and psychological resilience (H2). This finding aligns with existing theoretical frameworks, indicating that physical activity not only enhances adolescents' physical health but also strengthens psychological resilience by promoting emotional regulation and stress management [15]. This result is consistent with studies in Norway and certain regions of Japan [94, 95], which also suggest that physical exercise positively affects adolescents' psychological resilience. However, our study further explores how this effect manifests in different cultural contexts, particularly in coping with social, academic pressures, and life challenges.

Third, the study found a strong positive relationship between psychological resilience and self-efficacy (H3). This supports the view that resilience, as a personal resource, enhances adolescents' belief in their ability to achieve desired outcomes [9]. By emphasizing the critical role of resilience in the development of self-efficacy, this study extends existing literature.

Finally, through mediation analysis, this study validates the mediating role of psychological resilience in the relationship between physical exercise and self-efficacy (H4), providing new insight into the mechanisms by which physical exercise influences adolescents' self-efficacy. Our findings show that psychological resilience partially explains how physical exercise contributes to higher self-efficacy in adolescents, highlighting resilience as an important pathway through which physical activity positively affects self-efficacy.

Practical implications

The findings of this study have profound practical implications for educators, policymakers, and mental health professionals globally. The positive correlation between physical exercise, psychological resilience, and self-efficacy suggests that encouraging adolescents to engage in regular physical exercise can serve as an effective intervention to promote adolescents' mental health. Unlike traditional Western interventions that focus solely on mental health, our findings support the integration of physical activity into educational curricula, particularly

in regions facing multiple challenges, such as developing countries or areas with high academic pressures.

The significant mediating role of psychological resilience highlights the need for strategies that enhance resilience in educational and community programs. Programs that combine physical exercise with resilience-building strategies, such as stress management, emotional regulation, and coping strategies, may have a stronger impact on boosting adolescents' self-efficacy. This approach can be applied in various international contexts, providing a more comprehensive intervention model.

Furthermore, this study offers new insights for global public health policies that integrate physical activity and mental health initiatives. Given that physical exercise programs are often overlooked or underfunded, especially in countries with limited economic resources, our findings underscore the need for increased investment in youth physical activity programs, which not only promote physical health but also significantly enhance mental health.

Methodological strengths and limitations

Methodological strengths and limitations

This study has several methodological strengths. First, it employed a robust measurement model and conducted a multi-group confirmatory factor analysis (CFA) to test structural invariance across gender. The results indicate that the relationships among the key variables are consistent across male and female adolescents, which enhances the generalizability of the findings.

However, despite the significant findings, several limitations need to be addressed:

(1) Time span of the research design: This study employed a cross-sectional design, limiting the ability to establish causal relationships. While the significant path coefficients in the model suggest associations between variables, the design does not conclusively establish the long-term effects of physical exercise on psychological resilience and self-efficacy. Future research should adopt longitudinal designs to better understand the causal pathways through which physical exercise impacts adolescents' psychological development. Longitudinal studies would offer a clearer understanding of the long-term effects and developmental trajectories of these constructs.

(2) Subjectivity of data collection: The data were collected through self-reported questionnaires completed by adolescents, which may introduce social desirability bias or subjective evaluation errors. For example, participants might overestimate their physical activity or psychological adaptability. Future studies should incorporate objective measures such as activity trackers or standardized psychological tests to improve the accuracy and reliability of the data. This could provide more accurate insights into adolescents' exercise behaviors and their psychological states, reducing reliance on subjective reports.

(3) Regional representativeness of the sample: Although this study included participants from multiple regions across China, certain remote areas, such as Xinjiang and Tibet, were excluded due to logistical constraints. This exclusion could limit the representativeness and comprehensiveness of the results. Additionally, cultural differences may influence how physical exercise and psychological development are understood. Future research should aim to include a broader range of geographical regions and consider cross-cultural differences to provide a more comprehensive perspective on these relationships. By including adolescents from diverse cultural and regional backgrounds, future studies could enhance the generalizability of findings and explore how cultural factors shape the relationship between physical exercise, psychological resilience, and self-efficacy.

(4) Diversity of the sample: The study did not sufficiently analyze how the diversity of the sample—particularly factors such as gender, academic discipline, and socio-economic status—might impact the results. For example, the sample predominantly included urban adolescents, which may not fully capture the experiences of rural youth or those from diverse socio-economic backgrounds. Future research should explore how these demographic variables influence the relationships between physical exercise, psychological resilience, and self-efficacy, and aim to expand the sample to ensure greater diversity and representativeness. This will help mitigate biases related to sample homogeneity, and provide a more nuanced understanding of how different subgroups experience and benefit from physical exercise.

(5) Specific forms and intensity of physical exercise: This study did not differentiate between the various types and intensities of physical activities, which may result in overly generalized conclusions about the effects of physical exercise. Different forms of exercise, such as aerobic exercise, strength training, and team sports, may have differential impacts on psychological resilience and self-efficacy. Future research should distinguish between these forms and intensities to explore how each type may uniquely contribute to psychological development. Moreover, considering the use of wearable devices and physiological measurements could provide more granular data on the types and intensities of physical

activities adolescents engage in, enhancing the validity of findings.

Expanding the research perspective and practical application

In addition to the limitations mentioned above, we also recognize the value of incorporating new variables and innovative methods into future research. For example, expanding the research perspective by considering multilevel factors such as family, school, and social environments could provide deeper insights into how these factors interact with physical exercise to influence psychological resilience and self-efficacy. Including variables like family sports atmosphere, school physical education quality, and social sports culture may better explain how various environmental contexts shape adolescents' psychological outcomes. Applying ecological systems theory to analyze these interactions at multiple levels could further enrich the research framework.

Furthermore, we acknowledge the importance of integrating emerging technologies such as wearable devices (e.g., fitness trackers or smartwatches) and physiological measures (e.g., EEG, eye-tracking) in future studies. These technologies could provide more objective, reliable, and granular data on physical activity and its impact on adolescents' psychological processes. This approach could complement the subjective self-reports and improve data accuracy, offering physiological evidence to deepen our understanding of cognitive and emotional changes during physical exercise. Additionally, incorporating a longitudinal design would allow researchers to track adolescents over time, improving the ability to infer causal relationships and better understand how physical exercise influences psychological development in the long run.

Finally, practical application is an important area for future research. We envision future studies developing and implementing innovative intervention programs that combine physical exercise with psychological resilience training. These programs could be tested in real-world settings, such as schools and communities, to observe and analyze their feasibility and impact. This would help translate research findings into actionable recommendations for educational practice and policy, enhancing the relevance and practical value of the research.

Conclusion

This study examined the relationships between physical exercise, psychological resilience, and self-efficacy in adolescents, highlighting the direct and indirect effects of physical exercise on self-efficacy through psychological resilience. The findings show that physical exercise enhances adolescents' self-efficacy not only through improved physical fitness but also by fostering psychological resilience, which boosts confidence in facing challenges. These results suggest that physical exercise is not only a physical activity but also a psychological intervention that strengthens adaptability and stress management skills. Additionally, the study confirmed the robustness of the model across genders, indicating that physical exercise benefits both male and female adolescents similarly. Future research should explore the impacts of different exercise types and intensities on psychological development, utilize longitudinal designs to establish causal pathways, and consider cross-cultural perspectives to expand the generalizability of these findings.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

BP: Data collection, conceptualization and design of the study, writing– original draft, writing– review & editing. WSC: Data analysis, data curation, writing– original draft, writing– review & editing. TY: Data collection, writing– original draft, writing– review & editing. HSW: Writing– original draft, writing– review & editing.

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Data availability

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

Declarations

Ethics approval and consent to participate

This study strictly adhered to the declaration of helsinki and relevant national and institutional ethical guidelines. The research protocol was reviewed and approved by the Ethics Committee of the School of Sports Training at Chengdu Sport University (Approval Number: CTYLL2024007).Since all participants were minors, dual consent was required before participation: oral informed consent from the students themselves and written consent from their parents or guardians. In some cases where logistical or access limitations made it impossible to obtain written parental consent directly, the ethics committee approved waivers based on specific circumstances, ensuring that the study adhered to ethical standards.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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