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Exploring the structural links between peer support, psychological resilience, and exercise adherence in adolescents: a multigroup model across gender and educational stages

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Abstract

Background This study explored the associations among peer support, psychological resilience, and exercise adherence in adolescents, paying particular attention to different gender groups and educational stages. Psychological resilience was regarded as a potential explanatory mechanism in the relationship between peer support and exercise adherence.

Methods A cross-sectional study with a mixed approach was conducted in Zhejiang Province, China (2023), involving a total of 2,137 adolescents (aged 10–18; 49.6% were girls), who completed three standardized questionnaires measuring psychological resilience, peer support, and exercise adherence. Semi-structured interviews were conducted with 21 students, teachers and parents.

Results Male students scored higher than female students in terms of psychological resilience, peer support, and exercise adherence ($p < 0.001$). Elementary and middle school students scored higher than high school students across three dimensions, with elementary school students also performing better than middle school students ($p < 0.001$). There was a positive association between peer support and exercise adherence, with psychological resilience shown as a potential mediating factor. Multi-group analysis revealed stronger direct associations between peer support and exercise adherence among males and middle school students. Qualitative interviews indicated that peer support influenced adolescents exercise adherence through multi-level mechanisms. The understanding of peer support and psychological resilience among adolescents developed progressively at different educational stages, and there were differences in the development trends of different genders. The interviews also showed that the match of peer skill levels was a key condition for the effectiveness of support, and that the victory experience in sports might help adolescents form a positive cycle. Peer support not only directly enhanced psychological resilience in sports scenarios, but also transferred the cultivated target concentration and emotional regulation ability to academic and life fields through the "springboard effect".

Conclusions This research emphasized the roles of peer support and psychological resilience in promoting exercise adherence among adolescents, which showed distinct pathways across different gender and developmental stages. The results highlighted the need to create a better peer support environment and improve psychological resilience.

Keywords Psychological resilience, Peer support, Exercise adherence, Educational stage, Gender difference

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Introduction

Background

Adhering to regular exercise plays an important role in promoting physical health [36]. The World Health Organization's [106] Global Status Report on Physical Activity noted that over 80% of adolescents and nearly 30% of adults worldwide did not meet the recommended levels of physical activity (World Health Organization, 2023). In China, the obesity rate among children and adolescents has increased from 0.2% in 1982 to 7.9% in 2020 [27], and by 2023, more than 28 million individuals younger than 18 years were reported to suffer from depression [30]. Although surveys have suggested that Chinese adolescents generally had a positive attitude towards exercise, their actual participation in physical activity remained significantly insufficient, with one-quarter of adolescents reporting no regular participation in physical activity [30, 123]. However, adolescence is a crucial period for the development of healthy exercise habits [55]. This not only reduces the obesity rate [12] and improves mental health [113] but also helps maintain and increase the frequency of exercise in future adulthood, thereby laying a solid foundation for the long-term development of physical and mental health [70, 83].

Adolescence is a crucial period for cognitive and emotional development, and also a high-risk period for the occurrence of psychological problems [107]. When facing psychological crises, the positive psychological traits shaped by innate genetics and the postnatal environment can play a better buffering role [4, 79]. Psychological resilience, which is a key positive psychological trait, enhances self-confidence and self-control [94, 99, 100]. Individuals with strong psychological resilience are more likely to adopt proactive coping strategies when faced with stress or setbacks, which enables them to overcome challenges more effectively [13].

During adolescence, peer influence (imitation and social reinforcement) becomes more obvious [40]. Meanwhile, adolescent rebellion often leads to a stronger tendency to resist parental authority and a more active interaction with peers who share similar knowledge and interests [22]. Peer support (e.g., emotional regulation assistance) plays a crucial role in promoting the mental health of teenagers. In the context of sports participation, peer encouragement can significantly increase their motivation to continue participating [70, 93, 94] and relieve exercise-related stress [76]. However, studies have shown that the level of peer support among Chinese teenagers in sports is relatively low, with limited peer involvement or encouragement [84, 94] and significant gender differences [119].

Social learning theory [5], particularly the model of triadic reciprocal determinism, asserts that behavior is shaped by dynamic interactions among personal, behavioral, and environmental factors. In this study, peer support is viewed as a key environmental factor that influences adolescents' cognition and behavior through modelling, reinforcement, and social interaction. On the other hand, self-determination theory [20] focuses on the impact of meeting basic psychological needs – autonomy, competence, and relatedness – on motivation and behavior. Peer support can enhance intrinsic motivation by meeting these needs. Psychological resilience, as an internal resource of an individual, reflects the adaptive satisfaction of these needs (such as coping with challenges and self-regulation). Therefore, the paths from peer support (environment) to psychological resilience (individual) and then to exercise adherence (behavior) integrate the core propositions of the two sets of theories.

There are close relationships among psychological resilience, peer support, and exercise adherence. Higher levels of psychological resilience enable adolescents to better cope with challenges encountered in sports, thereby enhancing their adherence to exercise. Regular participation in exercise is also supported by strong peer relationships, which in turn foster psychological resilience [69, 95]. Despite these obvious connections, research on the relationships among these three factors remains limited. Furthermore, the comparison between the gender and educational stages deserves further exploration. Therefore, on the basis of an empirical study of adolescents in City P, Zhejiang Province, this research aims to (1) expand the understanding of the relationships among psychological resilience, peer support and exercise adherence; (2) investigate differences in psychological resilience, peer support, and exercise adherence across educational stages (elementary, middle, and high school); and (3) investigate differences in psychological resilience, peer support, and exercise adherence across gender groups.

Literature review

Exercise adherence

Exercise adherence is a behavioral tendency to show persistent efforts during exercise, including three dimensions: regular exercise habits, the willpower and effort individuals exert, and positive emotional experiences [101]. Exercise adherence is of great significance for teenagers who are in a critical period of growth and development [36], such as reducing obesity [3] and regulating emotions [92]. The current exercise adherence of Chinese teenagers needs to be improved. A survey of 6,744 Chinese students conducted by Zhang and Dong [114] revealed that although adolescents had a moderate to high level of intrinsic motivation and exercise-related friendship, their exercise adherence remained

relatively low. Sports dropout among young people has also become a common problem worldwide, and as a result, understanding the predictors of adolescents' continuous participation in sports has received considerable attention in recent years [73, 117, 118].

At present, research on the influencing factors of exercise adherence among teenagers has been relatively abundant and has focused on two main aspects: individual factors and environmental factors. In terms of individual factors, the significant influences of psychological dimensions such as gender, motivation, personality, and perceived pleasure on exercise adherence have been confirmed [45, 41, 105, 108]. Among them, studies with motivation as the influencing factor are relatively common [15, 52, 67, 86]. In terms of environmental factors, support from parents and peers,hard environments, such as space facilities and technical support; and soft environments, such as school systems and social atmospheres, are important factors influencing exercise adherence [24, 41, 73, 77, 91, 102] because this may be related to increasing exercise opportunities and feedback frequency [71]. Among the influences of peer relationships, interpersonal relationship distress negatively predicts exercise adherence [103], whereas the quality of sports friendships can significantly predict exercise adherence [116].

Notably, the above factors do not exist in isolation. Instead, there are interactions among different influencing factors that jointly affect exercise adherence. Guo [39] reported that exercise motivation and self-efficacy had a chain mediating effect on the relationship between parental support and exercise adherence. Li [48] also reported that self-efficacy partially mediated the relationship between college students'willingness to use sports apps and exercise adherence. [23] reported that core beliefs could affect exercise adherence by affecting deliberate rumination under the influence of the exercise atmosphere. Reynolds and colleagues [63] explored the influence of sociocultural factors on the exercise behaviors and attitudes of adolescents and reported that adolescents were under pressure from the expectations of their parents and peers for exercise and the goals of fitness tracking technologies. These external pressures influenced their exercise habits. In addition, adolescents tended to imitate the exercise behaviors of their parents or peers, especially in social relationships, or to achieve the"ideal"body shape recognized by society. Overall, although current research is relatively abundant, gaps remain, particularly in terms of the interactions among different influencing factors and the comparative analysis of the influencing factors of exercise adherence across educational stages and gender groups [52, 71, 112]. Furthermore, many studies follow the environment-individual-behavior framework, which provides valuable references for the design of this study.

Peer support

Peer support refers to the emotional or material assistance provided by peers, often involving the sharing of life experiences, emotional support, and skill development, and it is a positive aspect of peer relationships [33]. As a critical component of social support, peer support can alleviate emotional problems in adolescents and encourage their participation in physical exercise [31, 47, 74, 78, 80, 89, 96]. Sheridan and colleagues [72] conducted a systematic review of 73 studies on social support for adolescent sports from 1990 to 2013 and reported that peer support played an important role in shaping the adolescent sports experience. Eliasson and Lundstrom [28] reported that physical activities helped adolescents build strong peer relationships, thereby promoting their mental health and social adaptation. Similarly, Papaioannou and colleagues [60] noted that peer support, such as the help of significant others, could encourage adolescents to develop self-regulation skills, establish exercise habits, and maintain prosocial motivations. Studies have shown that, compared with family support, peer support has better emotional reinforcement and demonstration effects, thereby promoting higher levels of physical activity among adolescents [58, 59]. Borowiec and colleagues [9] emphasized the crucial role of peer support in preventing sports bullying and reported that low levels of peer support significantly increased the likelihood of adolescents becoming victims or perpetrators of physical, verbal, and social bullying.

Peer support has also been proven to have a positive effect on mental health. [64] conducted a scope review and reported that peer support was associated with improved mental health, such as greater well-being, self-esteem and coping skills, as well as reduced depression, loneliness and anxiety. This effect has been observed among university students, nonstudent youth, and ethnic/sexual minorities, highlighting that peer support is an effective and accessible mental health resource with lower barriers than traditional mental health services. Furthermore, Suresh and colleagues [82] reviewed the role of peer support in strengthening mental health during the COVID-19 pandemic and noted that it had a positive effect on alleviating anxiety and depression during the crisis. In addition to physical activity and mental health, peer support is crucial for academic and social development [10, 61].

Draper and colleagues [25], after reviewing 30 studies conducted between 2000 and 2013, emphasized the lack of research on the influence of peers on

adolescents'dietary habits, physical activity and sedentary behavior, which clearly required further study. Although many studies have confirmed the positive impact of peer support on exercise participation, the psychological mechanism behind this impact has not been fully explored. Furthermore, research on peer support in sports has focused mostly on participation behaviors, with insufficient attention given to the impact of peer support on exercise adherence [47, 58, 80, 94, 119].

Psychological resilience

Psychological resilience refers to the ability to maintain healthy, positive and stable mental and physical functions after experiencing setbacks or trauma [2, 75, 87]. It consists of two major components: personal strength (goal focus, emotional control, positive cognition) and support strength (family support, interpersonal assistance) [43]. Psychological resilience has been a major and hot topic in the field of positive psychology in recent years, with extensive theoretical research conducted by scholars in the field. For example, Richardson [65] explored the process of psychological resilience, whereas Hunter and Chandler [44] proposed a hierarchical model of psychological resilience.

The relationship between psychological resilience and physical activity is close. Studies have shown that physical activity or exercise promotes psychological resilience by strengthening the self-regulatory mechanisms of the brain during adolescence [8]. Furthermore, a study by Wiedenman and colleagues [104] revealed that students who participated in sports activities in high school demonstrated greater exercise self-efficacy and psychological resilience in college. Dunston and colleagues [26] reported that the intensity of physical activity had an effect on the psychological resilience of college students, with higher-intensity activities leading to significant improvements in perseverance and resilience, whereas moderate-intensity activities did not have the same effect.

In current related studies, the psychological resilience of adolescents is mostly regarded as a mediating variable or moderating variable and focuses on mental health conditions [99, 124]. Many studies have focused on the influence of family factors on psychological resilience [53, 54, 117, 118]. For example, Wang and colleagues [98] noted that psychological resilience and gender could play a moderating role in the influence of family function on externalizing problem behaviors in early adolescence and that, compared with boys, girls'family function had a stronger impact on psychological resilience. Some scholars have also adopted a broader perspective of interpersonal relationships to examine the impact of psychological resilience [110]. Ren and colleagues [62] reported in a study of 572 college students that psychological resilience played a mediating role in the relationship between social support and posttraumatic stress disorder among college students. These findings indicate that the psychological resilience of adolescents is influenced by interpersonal relationships and has an impact on their mental health status.

These studies provide important insights for the design of this research. However, existing studies lack exploration of the relationship between psychological resilience and exercise adherence, particularly in terms of how resilience changes across educational stages and varies by gender. This study also incorporates psychological resilience as a mediating variable, focusing on how peer support (a form of social support) influences exercise adherence through its impact on psychological resilience.

Links from peer support, and psychological resilience, to exercise adherence

Peer support plays an important role in promoting teenagers'participation in sports activities. As a key factor influencing the exercise behavior of adolescents [6], peer support stimulates individuals'motivation to participate in various sports activities, thereby increasing exercise adherence [58]. Adolescents who perceive positive peer support tend to experience greater pride, happiness and self-confidence, thereby generating stronger motivation and reducing sports-related stress [76]. Many studies have examined social support, including peer support, as a key factor influencing exercise adherence, emphasizing the importance of interpersonal support in maintaining consistent physical activity [21, 88]. Notably, the research of Zou and colleagues [125] confirmed the mediating role of self-efficacy and self-regulation in enhancing exercise adherence through peer support, providing a valuable reference for this study.

The positive impact of peer support on exercise participation is not unique. Some scholars believe that for peer support to effectively promote sports participation, it must first meet basic psychological needs [111]. Intrinsic motivation and self-efficacy are regarded as mediators of the relationship between peer support and physical activity [7]. Furthermore, personal circumstances can affect the effectiveness of peer support in sports participation. For instance, Wang [96] reported that family economic differences affected the mechanisms of peer support, whereas Zhang [116] reported gender and age differences in how individuals experienced peer support.

Peer support can significantly enhance the psychological resilience of teenagers. Wang's investigation indicated that among various forms of social support, peer support had the greatest impact on psychological resilience, although there were age-related differences

[98]. Mecha and colleagues [56] further explained the positive effect of peer support on psychological resilience from the perspective of the psychological state of adolescents, indicating that their mental health has improved. However, more in-depth and diverse studies are needed to fill this research gap.

Psychological resilience significantly promotes exercise adherence in teenagers. Psychological resilience can serve as a buffer against adversity, thereby helping individuals manage negative emotions effectively [49, 50] and achieving greater adherence [52]. Feng and colleagues [32] reported that psychological resilience played a mediating role between parental autonomy support and exercise adherence, highlighting its importance in promoting exercise behavior among adolescents. Furthermore, Dai et al. [18] emphasized that grit, which is closely related to psychological resilience, positively affected exercise adherence, among which exercise self-efficacy played a mediating role. Finally, Gerber and colleagues [38] reported that adolescents who engaged in higher levels of physical activity reported greater mental toughness, a trait closely linked to psychological resilience. These studies emphasize that cultivating psychological resilience not only helps teenagers cope with challenges but also plays a crucial role in maintaining long-term exercise habits.

Identified gaps in the literature

Although previous studies have emphasized the influence of individual and environmental factors on exercise behavior, few studies have considered the developmental stages and gender differences in these pathways. However, adolescence is a highly dynamic period, and these demographic factors may mitigate the influence of peer and psychological variables on healthy behavior. Apart from that, in non-Western environments, especially East Asian cultures such as China, collectivist values and educational pressures may have different effects on the behavior of teenagers, and research in this area is relatively lacking. In this case, peer support may involve additional relationships or expectations of social consistency, which may change its psychological impact. Therefore, to address these gaps, this study proposes a structural model that integrates peer support, psychological resilience and exercise adherence while accounting for subgroup differences.

Research hypothesis

On the basis of the literature and theoretical frameworks, this study aims to explore the structural relationships among peer support, psychological resilience and exercise adherence. Given the cross-sectional nature of the data, causal conclusions cannot be drawn. Therefore, the hypotheses proposed below are intended to guide model checking and are exploratory:

H1: Psychological resilience is significantly positively associated with exercise adherence among adolescents.
H2: Peer support is significantly positively associated with psychological resilience among adolescents.
H3: Peer support is significantly positively associated with exercise adherence among adolescents.
H4: Psychological resilience plays a mediating role in the association between peer support and exercise adherence.
H5: Educational stages and gender influence the mediating role of psychological resilience in the association between peer support and exercise adherence.

Exploring relationships: a quantitative examination of peer support, psychological resilience, and exercise adherence

Method

Participants

Students from elementary, middle, and high schools in P city, Zhejiang Province, China, were selected via a cluster sampling method. A total of 2,400 paper questionnaires were distributed on the basis of voluntary participation. Of these, 2,312 were ultimately returned, yielding a response rate of 96.3%. After the questionnaires with incomplete responses were excluded, 2,137 valid questionnaires were retained, resulting in a valid response rate of 92.4%. The distribution of participants is detailed in Table 1.

This study examined gender-based differences among participants on the basis of the male and female categories provided in the demographic data. Importantly, this binary categorization was used to reflect the structure of the available dataset; it was not intended to overlook or exclude individuals whose gender identities extend beyond the male–female binary.

Measures

In this study, the selection of measurement scales mainly was guided by two main factors: (1) the consistency between the scale structure and the core variables of the conceptual model; and (2) empirical evidence supporting its reliability and validity, especially among Chinese adolescents.

Table 1 Demographic variables ($n = 2137$)

	Total Sample		Elementary School		Middle School		High School	
	($n = 2137$)		($n = 386$)		($n = 1030$)		($n = 721$)	
	(n)	(%)	(n)	(%)	(n)	(%)	(n)	(%)
Gender								
Male Group	1076	50.4	208	53.9	572	55.5	296	41.1
Female Group	1061	49.6	178	26.1	458	44.5	425	58.9

Peer support scale The Peer Support Scale was adapted from the Exercise Social Support Scale revised by Zhong and colleagues [122], which was built upon the Social Support for Exercise Behaviors Scale originally developed by Sallis and colleagues [68]. Zhong's version analyses and addresses the weaknesses and shortcomings of the original scale, making necessary improvements. In the original scale's research, the Exercise Social Support Scale demonstrated good reliability and validity, with χ^2/df $=3.286$ ($p < 0.001$), NFI $=0.938$, NNFI $=0.943$, CFI $=0.949$, RMSEA $=0.078$, SRMR $=0.086$, and Cronbach's α ranging from 0.75 to 0.94. This scale has been widely used to measure the social support dimension related to physical exercise among adolescents and has shown strong reliability and validity in adolescent populations, [37, 115, 51, 89].

In this study, the peer support dimension was selected and further modified on the basis of the research objectives and practical needs, with a focus on aspects such as companionship and encouragement. To ensure the scale's relevance and clarity, modifications were made on the basis of feedback from experts in adolescent psychology and sports education, as well as from adolescent participants. These modifications aimed to more accurately reflect the social dynamics of peer support in exercise settings, emphasizing companionship, encouragement, and positive experiences. The final version of the Peer Support Scale consisted of five items and employed a 5-point Likert scoring method ranging from "strongly disagree" (1) to "strongly agree" (5). The total scores were obtained by summing the scores of each item, with higher total scores indicating a higher level of peer support. Example items included "My peers are willing to discuss technical skills or experiences related to physical exercise with me," and "My peers encourage me when I feel fatigued during exercise."In this study, the five items on the Peer Support Scale loaded well onto a single factor, with a KMO value of 0.84, and Bartlett's test of sphericity yielded a chi-square value of 2254.99 ($p < 0.001$), accounting for 85.90% of the total variance. The confirmatory factor analysis indicated excellent model fit with the following indices: χ^2/df $=1.009$, CFI $=0.999$, NFI $=0.999$, GFI $=0.999$, RMSEA $=0.003$, suggesting good structural validity of the scale. The Cronbach's α was 0.85, indicating that the scale had a high level of internal consistency reliability.

Exercise adherence scale The Exercise Adherence Scale used in this study was developed by Wang and colleagues [101] and comprised three subdimensions, namely, effort investment, emotional experience, and behavioral habits. In the original research, the Exercise Adherence Scale demonstrated good reliability and validity, with χ^2/df $=2.896$, CFI $=0.945$, TLI $=0.932$, NFI $=0.919$, RFI $=0.900$, IFI $=0.945$, NCP $=140.298$, RMSEA $=0.08$, KMO $=0.935$, and Cronbach's α ranging from 0.875 to 0.924. This scale has been widely used in research related to exercise adherence in China and has shown high reliability and validity [39, 108].

The scale was maintained in its original form, consisting of 14 items that use a 5-point Likert scale ranging from "strongly disagree"(1) to "strongly agree"(5). Example items included "I am willing to set aside regular time to maintain physical exercise" and "I will try to eliminate distractions to stick with physical exercise." The scores for each item were summed to obtain a total score, with higher scores indicating stronger exercise adherence. In this study, 12 items of the Exercise Adherence Scale loaded well onto the three factors, with a KMO value of 0.93 and a Bartlett's test of sphericity yielding a chi-square value of 7169.06 ($p < 0.001$), accounting for 69.989% of the total variance. The confirmatory factor analysis showed a good model fit with the following indices: χ^2/df $=2.811$, CFI $=0.986$, NFI $=0.978$, GFI $=0.978$, RMSEA $=0.041$, suggesting good structural validity of the scale. The Cronbach's α was 0.92, indicating that the scale had a high level of internal consistency reliability.

Psychological resilience scale The Psychological Resilience Scale used in this study was based on the Adolescent Psychological Resilience Scale developed by Hu and Gan [43], which was designed to measure

adolescents'psychological resilience. In the original research, the Adolescent Psychological Resilience Scale demonstrated good reliability and validity, with χ^2/df = 2.52, RMSEA = 0.07 (< 0.08), CFI = 0.92 (> 0.90), GFI = 0.83 (> 0.80), AGFI = 0.81 (> 0.80), NNFI = 0.91 (> 0.90), and a test–retest internal consistency of 0.83. This scale has been widely used in studies involving adolescents in China and has consistently shown good reliability and validity [42].

In general, the scale aims to assess psychological resilience across five dimensions, namely, goal focus, interpersonal assistance, family support, emotional control, and positive cognition, with a total of 27 items. It uses a 5-point Likert scale ranging from "completely disagree"(1) to "completely agree"(5). Example items include "Failure always makes me feel discouraged" and "I find it difficult to control my unpleasant emotions." Higher scores indicate stronger psychological resilience in adolescents. In this study, 19 items of the Psychological Resilience Scale converged well onto the five factors, with a KMO value of 0.85 and Bartlett's test of sphericity yielding a chi-square value of 5511.99 ($p < 0.001$), accounting for 57.865% of the total variance. Items that did not align well with the theoretical dimensions or failed to show strong factor loadings were excluded on the basis of both the data analysis results and our theoretical understanding of psychological resilience. The confirmatory factor analysis showed a good model fit with the following indices: χ^2/df = 2.973, CFI = 0.953, NFI = 0.932, GFI = 0.960, RMSEA = 0.043, suggesting good structural validity of the scale. The Cronbach's α was 0.83, indicating that the scale has a high level of internal consistency reliability.

Data analysis

This study utilized IBM SPSS 27.0 and AMOS 26.0 statistical software for data analysis. After extreme values or data from irrelevant respondents were removed on the basis of the research objectives, the data were processed as follows: (1) exploratory factor analysis (EFA) was conducted via SPSS 27.0; (2) confirmatory factor analysis (CFA) was performed via AMOS 26.0; (3) the internal consistency of the scales was tested via SPSS 27.0; (4) common method bias was tested via Harman's single-factor method; (5) analysis of variance (ANOVA) was used to explore differences between different groups; (6) correlation and regression analyses were conducted to investigate the relationships among peer support, exercise adherence, and psychological resilience; and (7) multigroup structural equation modelling (SEM) was used to test a mediation model across different grade and gender groups.

Results

Common method bias test

Common method bias (CMB) is a type of systematic error that can significantly confound research results and potentially lead to erroneous conclusions. Since the data in this study were collected through self-reported scales, there was a possibility of common method bias being present. Therefore, Harman's single-factor test was employed to assess the presence of CMB. According to Podsakoff and Organ, if the variance explained by a single factor obtained through unrotated exploratory factor analysis is less than 50%, then CMB is not considered serious. In contrast, the commonly accepted threshold in China is 40% [85]. The test results indicated that eight factors had eigenvalues greater than 1, and the variance explained by the first factor was 30.09%, which is below the threshold value. These outcomes suggested that there was no significant common method bias present in this study.

Comparison of differences

Gender differences The differences in peer support, exercise adherence, and psychological resilience across gender groups (male and female) were analysed via independent sample t tests in SPSS. The results are presented in Table 2 and Fig. 1. Overall, significant differences were observed between gender groups in the dimensions of peer support ($p < 0.001$), exercise adherence ($p < 0.001$), and psychological resilience ($p < 0.001$). Male students scored higher than female students across all three dimensions.

Specifically, in the dimensions of peer support and exercise adherence, male gender group students scored significantly higher than female gender group students did ($p < 0.001$). The effect sizes, as measured by Cohen's d, were 0.405 for peer support, 0.358 for exercise adherence, and 0.174 for psychological resilience. According to Cohen's benchmarks, these values indicate moderate differences in peer support and exercise adherence and a small difference in psychological resilience, suggesting that male students may benefit more from social encouragement and structured physical activity environments.

Comparison across different educational stages One-way ANOVA was conducted to compare the differences in peer support, exercise adherence, and psychological resilience among the elementary, middle, and high school participants. The results indicated that there were highly significant differences across the different educational stages in all three dimensions ($p < 0.001$), as shown

Table 2 Independent samples T test results by gender groups

Category	Gender Groups	n	Mean	SD	*t*	*d*
Peer Support	Male	1076	3.512	1.054	9.356***	0.405
	Female	1061	3.089	1.037		
Exercise Adherence	Male	1076	3.511	0.967	8.283***	0.358
	Female	1061	3.171	0.926		
Psychological Resilience	Male	1076	3.466	0.656	4.010***	0.174
	Female	1061	3.349	0.683		

* Note: ***$p < 0.001$

in Table 3 and Fig. 2. The effect sizes, as indicated by η^2 values (0.075–0.118), are considered small to moderate according to Cohen's benchmarks, suggesting that the educational stage accounts for a meaningful proportion of the variance in peer support, exercise adherence, and psychological resilience. Multiple comparisons revealed that in the dimensions of peer support, exercise adherence, and psychological resilience, high school students scored significantly lower than both elementary and middle school students did ($p < 0.001$), whereas elementary school students scored significantly higher than middle school students did ($p < 0.001$). These results highlight the significant decline in peer support, exercise adherence, and psychological resilience as students progress from elementary to high school.

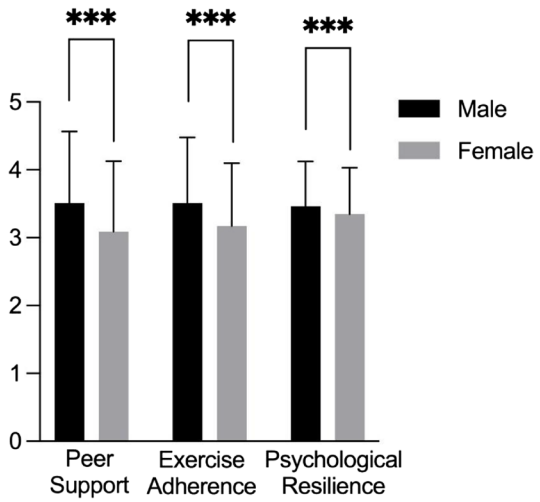

Fig. 1 Comparison of peer support, exercise adherence, and psychological resilience differences between gender groups ($n = 2137$). *Note: ***$p < 0.001$

Study of the relationships among peer support, exercise adherence and psychological resilience

Descriptive statistics and correlation analysis Overall, the participants exhibited average levels of peer support (3.302), exercise adherence (3.342), and psychological resilience (3.408). The analysis revealed highly significant correlations between peer support, exercise adherence, and psychological resilience ($p < 0.001$). Specifically, peer support was found to be positively correlated with both psychological resilience and exercise adherence; psychological resilience was also found to be positively correlated with exercise adherence. These findings indicate that higher levels of peer support are associated with stronger exercise adherence and better psychological resilience. The findings are detailed in Table 4.

Multiple regression analysis Multiple regression analysis was conducted with peer support and psychological resilience as independent variables and exercise adherence as the dependent variable, with gender serving as a control variable. The enter method was applied for

Table 3 Comparison of differences across educational stages

Category	Elementary ($n = 386$) Mean ± SD	Middle ($n = 1030$) Mean ± SD	High ($n = 721$) Mean ± SD	*F*	η^2
Peer Support	3.733 ± 1.102	3.401 ± 1.032	2.930 ± 0.976	86.261***	0.075
Exercise Adherence	3.830 ± 0.870	3.443 ± 0.926	2.937 ± 0.898	134.298***	0.112
Psychological Resilience	3.887 ± 0.660	3.349 ± 0.653	3.235 ± 0.582	142.829***	0.118

* Note: ***$p < 0.001$

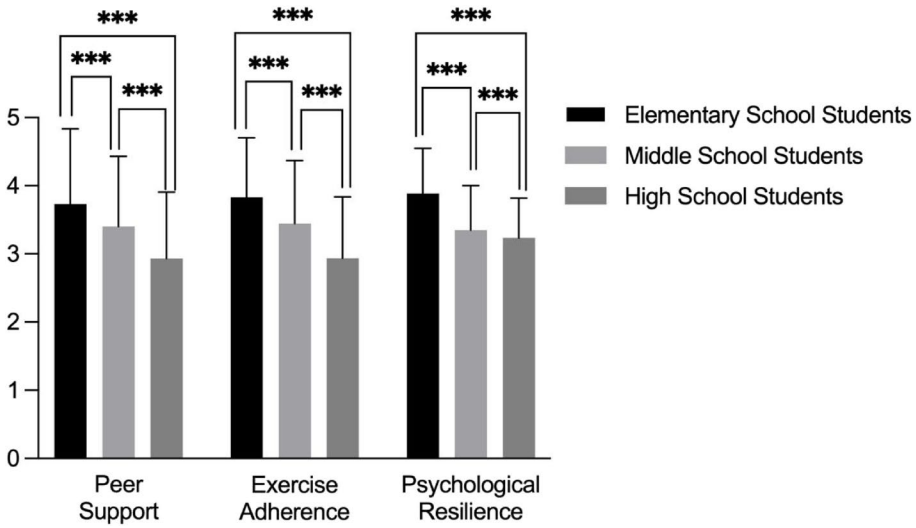

Fig. 2 Comparison of peer support, exercise adherence and psychological resilience differences among elementary, middle, and high school students ($n = 2137$). *Note: ***$p < 0.001$

variable input. The results are presented in Table 6, which can be found in the appendix. Overall, the model was found to be significant, with a good fit. Together, peer support and psychological resilience explained 53.0% of the variance in exercise adherence. Both psychological resilience and peer support were significantly associated with exercise adherence ($p < 0.001$), which is consistent with the hypothesized model structure (H1 and H3). Notably, peer support ($\beta = 0.586$) was more strongly associated with exercise adherence than was psychological resilience ($\beta = 0.226$), highlighting the potential importance of social context in adolescents' physical activity patterns.

Exploratory testing of a mediation pattern involving psychological resilience To explore the potential linking role of psychological resilience (M) in the association between peer support (X) and exercise adherence (Y), a structural equation model was tested via the Hayes' PROCESS macro in SPSS. Although the cross-sectional design does not allow for causal inference, the analysis aimed to examine whether the data were consistent with a mediation pattern. The structural equation model was constructed via the PROCESS macro plugin, and the mediation effect test model is illustrated in Fig. 3. The data were standardized, with gender included as a control variable. Model 4 was selected, with 5,000 bootstrap samples and a 95% bias-corrected confidence interval.

The analysis revealed that the total, indirect, and direct paths between peer support and exercise adherence had confidence intervals that did not include zero, indicating that the associations were significant. The indirect path via psychological resilience accounted for approximately 17.586% of the total association between peer support and exercise adherence, suggesting a partial mediation-consistent pattern. The pathway (peer support → psychological resilience → exercise adherence) was validated, as shown in Tables 7 and 8, which are presented in the appendix. These findings suggest that psychological resilience may function as a partial linking variable in the association between peer support and exercise adherence. The results are consistent with a mediation pattern in which higher levels of peer support are associated with greater psychological resilience, which in turn correlates with greater exercise adherence—thus supporting hypotheses H2 and H4. These findings imply that fostering psychological resilience may enhance the motivational benefits associated with peer support, particularly in efforts to encourage sustained physical activity.

Table 4 Descriptive statistics and correlation matrix of the study variables ($n = 2137$)

Variable	M	SD	Exercise Adherence	Psychological Resilience
Peer Support	3.302	1.067	0.699***	0.463***
Exercise Adherence	3.342	0.962	1	0.501***
Psychological Resilience	3.408	0.672		1

* Note: ***$p < 0.001$

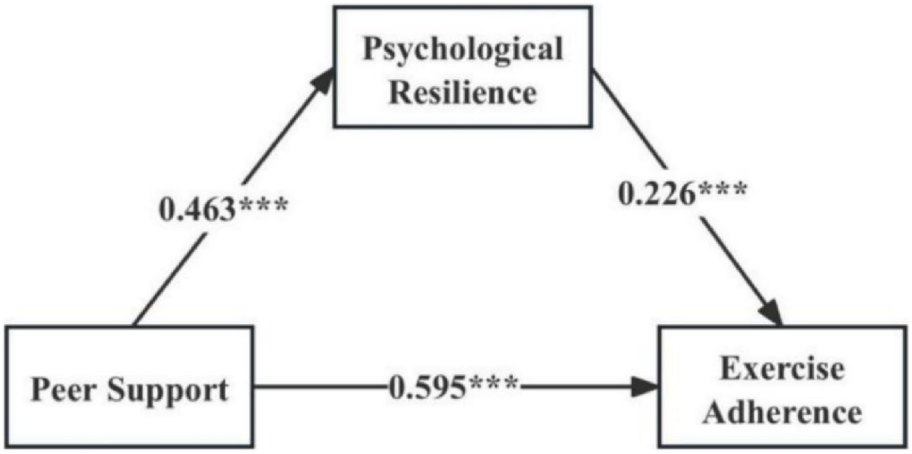

Fig. 3 Exploratory mediation-consistent model ($n = 2137$)

Multigroup structural equation models To evaluate the stability of the mediation model across grade groups, measurement invariance testing was conducted through a series of nested multigroup structural equation models. The invariance testing followed a sequential constraint approach: (1) Configural Invariance Model: No equality constraints were imposed, establishing a baseline model to verify structural consistency across groups. (2) Metric Invariance Model: Factor loadings were constrained equally across groups to test the equivalence of measurement indicators. (3) Structural Path Invariance Model: Structural path coefficients were constrained to be equal, and whether the relationships between latent variables differed by grade was examined. (4) Higher-Order Invariance: The covariance and residual variances of latent variables were progressively constrained to assess full invariance. Model fit was evaluated via the χ^2/df, Comparative Fit Index (CFI), and Root Mean Square Error of Approximation (RMSEA). Acceptable thresholds included $\chi^2/df < 3$, CFI > 0.90, and RMSEA < 0.08 [29, 121]. Invariance was supported if ΔCFI ≤ 0.01 between nested models [16].

Educational stage comparisons The unconstrained configural model demonstrated excellent fit ($\chi^2/df = 2.269$, CFI $= 0.932$, RMSEA $= 0.024$, as shown in Table 9 in the appendix), indicating that the proposed theoretical structure was well supported across different educational stages without imposing equality constraints. In the successive invariance tests, the changes in the CFI and other indices were within acceptable limits, providing a statistical foundation for the subsequent comparison of structural paths. Although chi-square differences were significant in more constrained models, the small changes in CFI suggested that comparisons of structural paths across grade groups remained valid, with the primary differences lying in the strength rather than the form of relationships.

The standardized path coefficients derived from the measurement weights model are summarized in Table 10, which can be found in the appendix. Peer support was positively associated with psychological resilience across all school levels, with slightly stronger effects observed in elementary ($\beta = 0.568$, $p < 0.001$) and middle school students ($\beta = 0.570$, $p < 0.001$) than in high school students ($\beta = 0.480$, $p < 0.001$). With respect to the direct associations between peer support and exercise adherence, middle school students presented the strongest link ($\beta = 0.587$, $p < 0.001$), followed by high school students ($\beta = 0.553$, $p < 0.001$), with elementary school students displaying the weakest direct effect ($\beta = 0.484$, $p < 0.001$). Additionally, the relationship between psychological resilience and exercise adherence was strongest among elementary school students ($\beta = 0.416$, $p < 0.001$), followed by high school ($\beta = 0.385$, $p < 0.001$) and middle school students ($\beta = 0.342$, $p < 0.001$). These results indicate meaningful variations in how peer support and psychological resilience influence exercise adherence across developmental stages, suggesting that social and psychological mechanisms shift as adolescents mature. The stronger association between peer support and exercise adherence in middle school suggests that this stage may be particularly responsive to peer-led interventions or programs that emphasize group-based encouragement. In contrast, the increasing role of psychological resilience in elementary and high school students implies that strategies promoting emotional regulation, goal setting, and positive cognition may be more effective in these groups.

Gender comparisons The fit indices for the nested models are presented in Table 11, which can be found in the appendix. The unconstrained model demonstrated good fit ($\chi^2/df = 2.652$, CFI $= 0.944$, GFI $= 0.925$, RMSEA $= 0.028$), indicating that the theoretical model

adequately explained the data across gender groups. Subsequent invariance tests revealed that the metric invariance model (ΔCFI = 0.000, $\Delta\chi^2 = 46.494$, $\Delta df = 27$, $p = 0.011$) did not significantly deteriorate in fit compared with the baseline model, supporting the equivalence of factor loadings across gender groups. Further constraints on structural paths (e.g., structural weights, covariances) yielded minimal changes in fit indices, suggesting partial invariance. Among the nested models, the measurement weights model emerged as the most parsimonious, balancing model fit and simplicity.

Table 12, located in the appendix, summarizes the standardized path coefficients for the male and female groups. Peer support was positively associated with psychological resilience in both groups, with a slightly stronger effect observed in female students ($\beta = 0.596$, $p < 0.001$) than in male students ($\beta = 0.562$, $p < 0.001$). Conversely, the direct association between peer support and exercise adherence was stronger among males ($\beta = 0.590$, $p < 0.001$) than females ($\beta = 0.507$, $p < 0.001$). Notably, psychological resilience was more strongly associated with exercise adherence in female students ($\beta = 0.412$, $p < 0.001$) than in male students ($\beta = 0.327$, $p < 0.001$). These findings suggest gender-specific dynamics in how peer support and resilience contribute to exercise adherence. These results imply that, while both genders benefit from peer support, the way it influences their exercise adherence differs. For males, peer support plays a more direct role, suggesting that group-based encouragement and social reinforcement might be particularly effective in supporting their exercise habits. In contrast, females appear to rely more on psychological resilience to maintain their adherence, highlighting the importance of fostering internal coping strategies and emotional regulation.

In-depth perspectives: qualitative insights into peer support, resilience, and exercise behaviors

As shown above, quantitative research has demonstrated the relationships between peer support, psychological resilience, and exercise adherence through data analysis. However, the specific nature of these relationships requires deeper exploration through qualitative research.

Research design

Semistructured interviews were carried out with 21 participants (students, parents, PE teachers, class teachers, and PE research staff) from representative elementary, middle, and high schools in P city, Zhejiang Province. The participants were purposefully selected via convenience and stratified purposive sampling methods to ensure diversity and representativeness (Table 5). The participants were first assessed for their background and context and were then selected on the basis of their ability to provide relevant insights into peer support, resilience, and exercise behavior in adolescents. For student participants under the age of 18, informed consent was obtained from their parents or legal guardians, and assent was obtained from the students. The participants were also informed of their rights, including voluntary participation and the option to withdraw at any time without penalty.

The interviews were recorded and transcribed verbatim, producing 144,939 words of qualitative data. To protect participant confidentiality, all interviews were anonymized, and identifying information was removed during transcription. Audio recordings were stored securely and accessed only by the research team. Thematic saturation was determined when no new themes emerged in the interviews, indicating that a comprehensive understanding of the research topics had been reached. The data were systematically coded via NVivo 14, resulting in 146 reference points organized into three core themes: peer support, psychological resilience, and students'perceptions of physical exercise.

The qualitative data were analysed via reflexive thematic analysis [11], which was chosen for its flexibility and depth in exploring patterns of meaning within the data. This approach allows for a nuanced understanding

Table 5 Interview subjects

Code	Identity	Educational Stages	School	Gender
ATM17	In-School Student	Elementary	T	Male
ATF2	In-School Student	Elementary	T	Female
AUM11	In-School Student	Elementary	U	Male
AUM5	In-School Student	Elementary	U	Female
AVM8	In-School Student	Middle	V	Male
AWF9	In-School Student	Middle	W	Female
AXM16	In-School Student	High	X	Male
AXF20	In-School Student	High	X	Female
AYF15	In-School Student	High	Y	Female
AZM10	In-School Student	High	Z	Male
BWF6	Parent	Middle	W	Female
BYF19	Parent	High	Y	Female
BXM21	Parent	High	X	Male
CTM7	PE Teacher	Elementary	T	Male
CUM8	PE Teacher	Elementary	U	Male
CVM12	PE Teacher	Middle	V	Male
CVM13	PE Teacher	Middle	V	Male
CZM18	PE Teacher	High	Z	Male
DVF3	Class Teacher	Middle	V	Female
DVF7	Class Teacher	Middle	V	Female
EM1	PE teaching-research staff	-	-	Male

of the interactions among peer support, psychological resilience, and exercise adherence, which are grounded in the participants'own experiences and perceptions. The six-phase framework was as follows: (1) familiarizing with the data through repeated reading of transcripts, (2) generation of initial codes on the basis of meaningful text segments, (3) searching for patterns and organizing codes into themes, (4) reviewing themes to ensure internal coherence, (5) defining and naming themes, and (6) producing the final report. Coding was conducted inductively and iteratively, and the themes were interpreted in light of the study's quantitative findings to enrich the understanding of how peer support influences resilience and adherence across different school stages and gender groups. Coding reliability was confirmed to be high (kappa =0.855), demonstrating excellent consistency between independent coders [14, 19].

Research results and analysis

Friendship as a source of motivation and resilience

The quantitative findings supported a positive association between peer support and exercise adherence, with psychological resilience emerging as a potential mediating factor. First, peer support creates a positive psychological environment for exercise adherence. In this environment, students actively overcome difficulties and choose to participate, especially when facing challenges. The encouragement and companionship of peers provide stronger support. Additionally, the enjoyment of being with peers can offset many unpleasant experiences, such as weather or fatigue. Furthermore, peer relationships act as a binding force, making individuals more resilient because they do not want their withdrawal to disappoint others.

> *"In my class, there are a dozen or so boys who truly enjoy playing football. However, sometimes when the weather is too hot, few people say it is too hot and are unwilling to leave. However, then, some other boys will say,'Do not worry; this bit of heat cannot stop us. If the two of you do not come, our sports activities cannot go on.'Then, those boys who were unwilling to go outside ended up joining. They are truly a team, capable of encouraging each other, which I think is quite nice."(CZM18)*
>
> *"The main reason is that when I see them not giving up despite difficulties, I feel embarrassed to give up myself."(AXM16)*

In the early stages, peer support is characterized primarily by emotional exchange and enjoyment-driven motivation, commonly referred to as "enjoyment-driven support." This shift in understanding corresponds with the increasing complexity of their social relationships and their developmental needs at different educational stages. For example, one student mentioned, "It is more enjoyable to play with peers, and I'm more motivated to play basketball." As adolescents age, peer support evolves to feature more instrumental qualities, as seen in the statement by a middle school student: "Training with stronger peers helps improve oneself," where support is increasingly used to enhance personal abilities and address external goals, such as academic and athletic achievements. In high school, the understanding of peer support becomes more multifaceted, incorporating both emotional support and a focus on peers' roles in emotional regulation and skill development. For example, a high school male student prefers to train only with peers of similar skill levels, stating, "Only then can true motivation be generated." Similarly, another female student explained, "When we do jump rope exercises together, it is not just about fitness, but also sharing everyday stories."

There are also gender differences in the understanding of peer support, with male students focusing more on competition and skill enhancement, whereas female students seek support through emotional and social interaction. This difference reflects the influence of traditional gender roles, with boys typically socialized to focus on competition and self-improvement, whereas girls are more often guided towards emotional exchange and the establishment of social bonds. Male students generally associate peer support with competition, viewing it as a means to improve their abilities. As a boy noted, "Training with stronger peers helps improve oneself." highlights a more instrumental and competitive understanding of peer support. In contrast, female students' understanding of peer support is more emotionally driven and influenced by gender roles. Many female students view peer support as a way to engage in emotional exchange and social bonding, as a girl saying, "It is more fun to exercise with classmates." However, societal gender expectations sometimes restrict female students'participation in sports, leading them to favour lower-intensity activities such as badminton or volleyball. As another girl mentioned, "Sometimes I play football with boys, but I feel a bit shy," reflecting how gender roles influence the way female students experience peer support.

The skill level differences among peers can significantly impact the effectiveness of peer support. In general, when peers have similar skill levels, support is more effective because it promotes continuous interaction in sports. Competing on a relatively equal basis helps boost motivation and confidence, making it easier to resonate with and learn from each other. In contrast, a significant skill gap can lead to a loss of interest for both parties.

"There is a girl in our class who assists the teacher in managing and organizing physical education classes. When playing table tennis, she often struggles to find an opponent because she plays better than most of the girls do, and some boys who are better than her are unwilling to play with her. Sometimes she says to me, 'I cannot find a partner to play table tennis with.' Then, a boy who had been playing badminton switched to playing table tennis. Among the boys, his table tennis skills are not particularly strong, but his level happens to match her. Every class, the two of them sweat so much from playing table tennis that their clothes become completely soaked. Occasionally, they will say to me, 'Please end class a little earlier; I need to grab a table tennis table.' Since we have a limited number of high-quality tables, they want to secure one early. Regardless of how hot the weather is, the two of them always play. Their skill levels are well matched, making the game more enjoyable. On the one hand, companions need to get along in terms of personality and temperament; on the other hand, their skill levels should be similar. Only then can they truly support each other."(CZM18)

"Running alone can be very dull. For example, one of the students who assisted me in managing and organizing physical education classes said that they always run as a group of three. He has relatively better stamina, whereas the other two are slightly weaker, so he encourages them. Before running, he wears a watch and sets a goal, saying, 'Today, let us run a certain number of laps,' and calculates the average time per lap. He constantly monitors the time with his watch and keeps pushing them. I think the three of them are quite happy running together, but if you're running alone, it is hard to keep going when you feel tired."(CZM18)

Overcoming difficulties, more than sports

Adolescents' understanding of psychological resilience evolves from basic adherence to more complex emotional regulation and strategic adaptation as they mature. In elementary school, resilience is primarily viewed as mechanical adherence. For example, a student stated, "Even if I miss the shot, I keep trying." As they grow older, especially in middle school, adolescents begin to associate resilience with goal orientation, seeing it not only as adherence but also as striving to achieve external goals, such as academic or athletic success. Another student noted, "I do sports to showcase my abilities and earn points." Furthermore, adolescents begin to develop self-regulation skills when faced with pressure, although their resilience is still largely driven by external factors, particularly academic and exam-related stress. In high school, their understanding of resilience becomes more nuanced and mature, with a focus on cultivating intrinsic motivation and combining emotional management with strategic optimization to cope with challenges. A student explained, "After failure, I adjust my training methods to avoid making the same mistakes," reflecting a broader understanding of resilience that includes not only adherence but also strategy adjustment and self-improvement in the face of setbacks.

There are also gender differences in how resilience is understood. Boys tend to associate resilience with physical endurance and willpower, viewing it as a demonstration of strength through ongoing challenges and confrontation. On the other hand, girls focus more on emotional support and environmental adaptation, especially in overcoming setbacks. As a girl mentioned, "Exercising with peers helps motivate me to keep going," underscoring the importance of emotional support and peer encouragement in fostering resilience among girls.

Peer support not only promotes psychological resilience in overcoming difficulties related to sports but also extends to students' lives, achieving a transfer of abilities, i.e., a springboard effect. This transfer, which occurs through sports, also forms a generally applicable skill set, including a focus on goals, emotional and cognitive regulation, and more, not limited to exercise participation.

"When my daughter was in middle school, her running score in eighth grade was still quite far from a perfect score on the exam, with a one-minute gap. Later, she continued training and working hard and eventually achieved a perfect score. Therefore, in terms of sports, I personally feel that she can handle pressure quite well. She has confidence in herself and is willing to improve. When she achieves certain results and sees the outcomes of her efforts, she realizes that as long as she works hard, she can definitely reach her goals. Moreover, this mindset not only helps her in sports but also benefits her studies."(BXM21)

"We hope that students not only improve their physical fitness in physical education classes but also experience the true value that sports can bring us—perseverance, team cohesion, and life lessons... I want students to understand that we will give our all to fight for a goal, to have the willpower and spirit to strive. This is what I hope to impart to them."(CTM7)

"If the spirit of sports can be reflected in the activities, such as sticking with an exercise like pull-ups even if they cannot reach a perfect score, and continuing to practice it, this spirit can actually extend to their studies as well."(DVF7)

The joy of victory, the adherence cultivator

Peer support promotes exercise adherence through psychological resilience, which is well realized in students' participation in sports under certain conditions. A crucial aspect is that students can experience the joy of victory in competition. The positive emotional experiences from winning help diminish the fatigue of competition and create pleasant memories, encouraging continued effort in pursuit of future victories, thus forming a positive cycle. Therefore, it is essential to help students find sports they excel at and experience the feeling of victory while also addressing the experience of failure in competitions so that students can face setbacks correctly.

> *"When I encounter my weaker events and others are better than me, I lose confidence."(AUM5)*
> *"Because many sports have wins and losses, with that competition, we naturally pursue victory. In the process of pursuing it, we experience enjoyment. Every sport has its own unique kind of fun."(CZM18)*
> *"Students feel happy when they win a basketball game. If a class wins a basketball match against another class, they might stay happy for a week, a semester, or even a whole school year."(CVM12)*
> *"A few days ago, my child told me about a volleyball test at school, where two students passed the ball back and forth. At first, she could not complete it, so she kept practising until her clothes were completely soaked. However, in the end, when she finally passed the test, she felt very happy and accomplished."(BYF19)*

Discussion

Peer support, exercise adherence and psychological resilience play important roles in students' long-term participation in sports and their physical and mental health development. This study revealed that the peer support, exercise adherence and psychological resilience of the adolescents investigated in P city, Zhejiang Province, were all at a medium level, which was relatively consistent with the findings of relevant studies by previous scholars. A study by Tan [84] that was based on surveys of adolescents in six cities within China's three major economic zones, Chen's research on exercise adherence, which involved 680 middle school students [15], and Sun's research on psychological resilience among 900 middle and high school students in two schools [81] reported similar moderate levels of peer support, exercise adherence, and psychological resilience among the surveyed students. This finding indicates that while there is a certain level of peer support, the ability to persist in exercise, and psychological resilience among current adolescents, there is still significant room for improvement.

The results of this study also supported H2, indicating that peer support in sports was positively associated with psychological resilience in adolescents. Gao [35] proposed that teenagers with better peer support could better receive positive reinforcement from friends and peers when encountering difficulties and setbacks and thus face bad situations with a more positive attitude and better treated life. The current study revealed that peer support in sports could also enhance psychological resilience in daily life. This association may be partially explained by an enhanced sense of identity fostered through participation in supportive peer environments. According to social learning theory, as the level of peer support increases, students are more likely to perceive themselves as active participants in sports from their peers' perspective. This perception fosters stronger identification with the positive effects of participating in sports [17], thereby proactively overcoming difficulties in exercise participation, focusing on personal goals, and actively regulating emotions and cognition, all of which enhance psychological resilience [66]. The important role and influencing factors of individual identity have been confirmed in the discipline of mathematics [57, 120], and this study revealed that it was very likely to hold true in sports participation. Additionally, the current study indicated that the impact of peer support in sports extended beyond exercise participation, indicating a transferable skill. Through this springboard effect, peer support in sports provides a supportive psychological atmosphere, gradually enhancing confidence, focus, and regulatory abilities, thereby fostering greater effort and adherence when facing challenges. These findings are highly consistent with social learning theory, which emphasizes that behavior is learned through observation, modelling and reinforcement in a social environment. In this study, peer encouragement and shared athletic goals, as social reinforcers, simulated and maintained adaptive behaviors such as emotion regulation and perseverance. This effect may be magnified in Chinese society, where collectivism emphasizes harmonious relationships and group cohesion, thereby enhancing the influence of peer relationships and common expectations in guiding behavioral participation.

The results of this study supported H3, suggesting that peer support was positively associated with exercise adherence; this outcome is consistent with previous research. In terms of academic performance, existing studies have shown that peer support promotes academic achievement [34, 49, 50]. Self-determination theory (SDT) can partially explain the findings of the current study, during physical exercise, peers can provide tangible support (such as sharing techniques or experiences) and emotional support (such as companionship and shared joy), thereby fulfilling the basic human need

for relatedness [20]. This, in turn, encourages students to actively participate in physical exercise and enhances their exercise adherence. Furthermore, high school students and girls are more dependent on resilience, indicating that they tend to internalize motivational regulation, which is consistent with the continuum of SDT from external motivation to intrinsic motivation. In this sense, psychological resilience may reflect the ability of adolescents to maintain their ability and autonomy under pressure. The current study revealed that a positive exercise-related psychological atmosphere under peer support effectively established a support model among peers and mitigated negative experiences in exercise participation. Influenced by conformity, this gradually became an implicit habit within the group. The findings of the current study also indicated that one important condition for the effectiveness of peer support was similarity in skill level, which facilitated resonance and equitable competition. Moreover, the associations identified in the structural model aligned with H1 and H4, indicating that psychological resilience was positively associated with exercise adherence and may function as a potential pathway through which peer support was related to adherence behavior.

This study revealed that boys scored significantly higher than girls in peer support and exercise adherence, consistent with findings by Guo [39] and Yu [109]. This might be due to the influence of gender role stereotypes. Parents and schools differ in the physical education of boys and girls from an early age, including the degree of emphasis on sports, project selection and guidance by gender. Gender socialization processes in many educational and family contexts tend to promote competitiveness and external recognition among boys and emotional regulation and empathy among girls. Gender schema theory suggests that children develop gender-related concepts on the basis of the information they receive from their environment. This leads to a more enthusiastic exercise atmosphere among boys than among girls, thereby affecting their exercise behavior habits, emotional experiences, and personal willingness to strive. For example, in interviews with male students, they often described exercise as a group-oriented competitive activity in which peer reinforcement and shared goals were the main motivations for participation.

Furthermore, the multigroup structural equation modelling across gender groups provided deeper insights. Peer support is positively associated with psychological resilience in both male and female students, among whom the relationship among female students is slightly stronger. This might reflect that in the current cultural and educational context, female teenagers are often socialized to attach importance to emotional support and interpersonal relationships. In contrast, peer support has a stronger direct connection with boys' adherence in exercising, suggesting that male teenagers may be more likely to respond to peer-based social reinforcement in maintaining physical activity. Furthermore, the psychological resilience of female students shows a stronger connection with exercise adherence, which may reflect that they rely more on internal psychological resources, such as emotional regulation and adherence, when maintaining physical participation. The qualitative research results revealed a similar situation: female participants often described "resilience" not only as adherence but also as emotional adaptability and the ability to regain calmness after emotional setbacks. These differences may reflect the process of gender socialization formed by culturally constructed norms: male adolescents tend to receive more external encouragement and recognition in sports environments, which may expand the direct impact of peer support on their physical activities. In contrast, female students may receive less external reinforcement, so they tend to make greater use of internal psychological resources to maintain their exercise behaviors.

Therefore, to promote intervention measures that adapt to different gender identities, the unique influencing factors of adolescent behavior must be taken into account. For those students who rely more on internal regulation (mainly those with a female identity), psychological resilience training can be incorporated into physical education, psychological counselling and other aspects, thereby enhancing their internal motivation by improving aspects such as self-regulation and resilience. For students who are more directly influenced by their peers (mainly those with a male identity), more peer competitive environments can be created in sports activities. At the same time, clear shared goals and recognition systems should be identified. In addition, it should be emphasized that specific intervention measures should be tailored to the individual, as every student has different interests. Moreover, attention should also be given to the fluid and performative nature of gender to ensure that the intervention measures include multiple gender identities and expressions beyond the binary.

In terms of differences in development stages, this study revealed that in the dimensions of peer support, exercise adherence, and psychological resilience, high school students were significantly lower than middle school students, and middle school students were significantly lower than primary school students. This might be because, from primary school to high school, academic and college entrance pressures gradually increase, resulting in a reduction in social activities and exercise time. Moreover, from the perspective of psychological development, primary school students are usually in a

stable growth environment and face less pressure. Middle school students are in the early to middle stages of adolescence and face certain psychological and social development challenges. High school students are in the late stage of adolescence and face more challenges related to self-identity and the establishment of values. Moreover, because they are regarded as "relatively mature", the level of psychological care provided by parents and teachers is relatively lower than that provided by middle schools and primary schools [46]. One study revealed that the psychological resilience of students in the second year of middle school was greater than that in the third year, which demonstrated the influence of academic pressure. Moreover, the psychological resilience status of teenagers was strongly affected by the disciplinary methods of parents and teachers [97].

This study also employed SEM to examine the consistency of the mediation pattern involving psychological resilience across elementary, middle, and high school students. Notably, middle school students showed the strongest direct relationship between peer support and exercise adherence. This discovery may reflect the high sensitivity of middle school students to peer relationships and their greater need for social acceptance and recognition. Furthermore, in the context of China's middle school physical education examinations, sports performance directly affects the evaluation of high school admissions. Therefore, students may experience more goal-oriented approaches and place greater emphasis on sports activities. Similar findings were also found in the interview content: middle school students often described exercise as a way to gain recognition and strengthen social bonds, and peer encouragement and shared goals were repeatedly described as their core motivations. Furthermore, many middle school students described "peer support" as a mutual sense of responsibility; for instance, exercising together meant"not letting teammates down". Therefore, their exercise adherence behaviors may be more susceptible to the influence of peer interactions and encouragement.

In contrast, elementary school students have a relatively weak direct response to peer support, which might be due to their greater reliance on family and school structures. The interviewed primary school students often emphasized happiness and praise from teachers rather than the influence of peers, which indicated that the supportive environment – rather than the norms of peers – was the main driving force for participation. Among high school students, the direct correlation between peer support and exercise adherence is relatively weak, which may be related to the enhancement of autonomy and independence as well as the development of self-regulation ability, which can reduce the reliance on peer recognition. Furthermore, at this stage, higher academic requirements and the pressure of college admission seem to limit opportunities for physical activities, potentially reducing the actual impact of peer dynamics. The interviews also revealed that older students often regarded time pressure, stress and internal motivation as the key determinants of their exercise behaviors. The changes from primary school to high school also reflect the shift from external motivation regulation to internal motivation regulation.

Importantly, although there are differences in the direct association with peer support, the mediating role of psychological resilience remains statistically significant at all educational stages. This discovery highlights the powerful role of resilience as a key psychological mechanism for teenagers' continuous exercise participation. In particular, at the elementary level, psychological resilience is more closely related to exercise adherence. This effect may be related to younger children's developmental sensitivity toward self-efficacy and coping skills [90, 125]. Children with greater adaptability can better cope with setbacks encountered in sports activities and remain engaged in difficulties. Therefore, intervention measures should be carefully customized according to the development characteristics of a specific developmental stage. For primary school students, intervention programs should emphasize resilience building through structured opportunities to overcome challenges and experience success in physical activities. For middle school students, maximizing peer interaction and peer-led physical activities can take advantage of the direct impact of the peer support observed at this stage. During the high school stage, as the direct effect of peer support decreases, intervention measures should particularly focus on enhancing psychological resilience and intrinsic motivation to maintain students'exercise behaviors. In addition, future research could consider adopting the motivational behavior classification system based on self-determination theory proposed by Ahmadi and colleagues [1]. Although it was initially applied in the teacher-student environment, its principles may also be related to peer-led interventions in the sports activity environment. For example, younger students may benefit more from competence-supportive behaviors, middle school students may respond better to relatedness-supportive behaviors, and high school students may be more receptive to autonomy-supportive behaviors.

In addition, this study revealed that the joy of victory could help form a reasonable self-perception, provide a goal and motivation for adherence, enhance self-confidence and the desire to pursue goals, and attract individuals to overcome difficulties constantly. Therefore, intervention measures should actively cultivate opportunities for students to experience success and recognition in a sporting environment.

Conclusion

Research has indicated that peer support is significantly associated with psychological resilience and exercise adherence. The research results are consistent with the partial mediation pattern, among which psychological resilience may serve as a psychological bridge connecting peer support and exercise adherence. Furthermore, psychological resilience demonstrates a transferable "springboard effect", which goes beyond merely participating in physical activities and influences a broader range of psychological and behavioral outcomes. These findings not only verify the existing theoretical assumptions but also provide new empirical insights, especially regarding the differences between gender groups and educational stages. Importantly, this research was conducted in a collectivist cultural context in which peer harmony and interpersonal cohesion were strongly emphasized.

Notably, significant variations emerge across gender groups and educational stages, indicating nuanced developmental pathways: peer support directly influences males' exercise adherence more strongly, whereas females rely more substantially on internal resilience mechanisms. Similarly, developmental stage analyses reveal that the mediating role of psychological resilience between peer support and exercise adherence significantly varies across elementary, middle, and high school students, highlighting the necessity of age-specific intervention strategies.

This study has several limitations that should be addressed in future research. First, the cross-sectional design and reliance on single-reporter data did not adequately meet the temporal order assumptions necessary for rigorous mediation analysis, potentially causing common method bias and limiting causal inferences. Therefore, future research should adopt longitudinal designs with multiple measurement points to better establish causal relationships and conduct deeper exploration using experimental or intervention-based methods. Furthermore, the sample of this study is geographically and demographically limited. Future research should incorporate the backgrounds of more diverse regions and participants – both quantitatively and qualitatively – to enhance generalization and capture a broader perspective of adolescents. Furthermore, although this study adopted a mixed approach, the measurement of peer support mainly relied on self-reported perceptions. Future research can benefit from the inclusion of data triangulation methods to mitigate potential social expectation biases and enhance the effectiveness of peer support assessments.

Appendices

Table 6 Regression coefficients of peer support and psychological resilience on exercise adherence ($n = 2137$)

Predictors	Exercise Adherence		
	β	***SE***	***t***
Constant		0.075	6.070***
Psychological Resilience	0.226	0.024	13.501***
Peer Support	0.586	0.015	34.454***
Gender: Male (Reference: Female)	0.040	0.029	2.674**
R^2	0.530		
F	802.624***		

* Note: $^{**}p < 0.01$, $^{***}p < 0.001$

Table 7 Analysis of the mediation effect of psychological resilience

Path Relationship	Standardized Effect Size	95% Confidence Interval	
		Lower Limit	Upper Limit
Total Effect			
Peer Support → Exercise Adherence	0.699	0.603	0.658
Indirect Effect			
Peer Support → Psychological Resilience → Exercise Adherence	0.105	0.086	0.125
Direct Effect			
Peer Support → Exercise Adherence	0.595	0.506	0.566

Table 8 Path coefficients of the mediation effect test model of psychological resilience

Path	Predictor	Outcome	Beta	SE
Peer Support → Psychological Resilience	Peer Support	Psychological Resilience	0.463***	0.012
Psychological Resilience → Exercise Adherence	Psychological Resilience	Exercise Adherence	0.226***	0.024
Direct Path: Peer Support → Exercise Adherence	Peer Support	Exercise Adherence	0.595***	0.015

* Note: $^{***}p < 0.001$

Table 9 Multigroup SEM fit indices comparison

Model	χ^2/df	CFI	GFI	RMSEA	$\Delta\chi^2$	Δdf	p	ΔCFI
Unconstrained	2.269	0.932	0.907	0.024	-	-	-	-
Measurement weights	2.242	0.931	0.905	0.024	75.787	54.000	0.027	-0.001
Structural weights	2.245	0.930	0.903	0.024	121.859	72.000	0.000	-0.002
Structural covariances	2.244	0.930	0.903	0.024	124.254	74.000	0.000	-0.002
Structural residuals	2.292	0.927	0.901	0.025	246.995	91.000	0.000	-0.005
Measurement residuals	2.755	0.893	0.869	0.029	1412.719	218.000	0.000	-0.039

Table 10 SEM path estimates across educational stages

Path	Elementary β	Middle β	High β
Psychological Resilience ← Peer Support	0.568***	0.570***	0.480***
Exercise Adherence ← Peer Support	0.484***	0.587***	0.553***
Exercise Adherence ← Psychological Resilience	0.416***	0.342***	0.385***

*** $p < 0.001$

Table 11 Multigroup SEM fit indices comparison

Model	χ^2/df	CFI	GFI	RMSEA	$\Delta\chi^2$	Δdf	p	ΔCFI
Unconstrained	2.652	0.944	0.925	0.028	-	-	-	-
Measurement weights	2.630	0.944	0.923	0.028	46.494	27.000	0.011	0.000
Structural weights	2.631	0.943	0.922	0.028	71.007	36.000	0.000	-0.001
Structural covariances	2.629	0.943	0.922	0.028	71.017	37.000	0.001	-0.001
Structural residuals	2.636	0.943	0.921	0.028	100.585	45.000	0.000	-0.001
Measurement residuals	2.877	0.931	0.910	0.030	561.213	108.000	0.000	-0.013

Table 12 SEM path estimates across gender groups

Path	Male β	Female β
Psychological Resilience ← Peer Support	0.562***	0.596***
Exercise Adherence ← Peer Support	0.590***	0.507***
Exercise Adherence ← Psychological Resilience	0.327***	0.412***

*** $p < 0.001$

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Declaration of generative AI and AI-assisted technologies in the writing process
The authors used ChatGPT to assist with translation and language polishing during manuscript preparation. In some instances, ChatGPT was also employed to help articulate and expand upon ideas originally developed by the authors. All AI-assisted outputs were critically reviewed, revised, and integrated by the authors to ensure clarity, originality, and academic integrity. The authors take full responsibility for the final content.

Authors' contributions
ML designed the study, analysed and interpreted the data, and was the primary contributor to writing the manuscript. YH contributed to the acquisition and analysis of the data and assisted in the drafting of the manuscript. MS supervised the study, provided critical revisions to the manuscript, and secured funding. All the authors read and approved the final manuscript.

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Data availability
The raw qualitative interview transcripts and quantitative datasets are not publicly available due to restrictions specified in the informed consent agreements. During the ethics approval process, participants explicitly request the confidentiality of their personal narratives, and only deidentified aggregated data may be used for research purposes. The supporting materials, including the survey questionnaire, are accessible via Moyan-Li@outlook.com.

Declarations

Ethics approval and consent to participate

All procedures involving human subjects were conducted in accordance with ethical standards, and the privacy rights of the participants were strictly observed. Informed consent was obtained from all the adult participants. For student participants under the age of 18, parental or guardian consent was secured along with student assent. The study was ethically approved by the Sports Science Experiment Ethics Committee of Beijing Sport University (Ethics Approval: 2020158H).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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