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The Impact of physical exercise on college students' peer attachment: the Chain mediating effect of perceived social support and sense of school belonging

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Article

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Abstract

As a critical indicator of social development among college students, the quality of peer attachment directly influences individuals' interpersonal adaptation and mental health. Using a questionnaire survey method, this study administered the Physical Activity Rating Scale, Peer Attachment Questionnaire, Perceived Social Support Scale, and School Belonging Scale to investigate 518 college students. It aims to explore the mechanism underlying the effect of physical exercise on college students' peer attachment, with a focus on the chained mediating effect of perceived social support and school belonging. The results demonstrate the following:(1) Physical exercise, perceived social support, school belonging, and peer attachment are all significantly and positively correlated with each other.(2) Physical exercise positively predicts perceived social support and school belonging, and also exerts a direct positive predictive effect on peer attachment.(3) Perceived social support and school belonging play independent mediating roles in the relationship between physical exercise and peer attachment, respectively, and simultaneously form a chained mediating path between the two variables.The conclusions indicate that physical exercise not only directly affects the level of peer attachment among college students, but also indirectly promotes the healthy development of peer relationships by enhancing perceived social support and school belonging.

Introduction

At the college stage, peer attachment, as a key indicator of individual social development, is not only related to the quality of emotional bonds, but also exerts a profound impact on the sustainable development of mental health, interpersonal adaptation, and even academic achievement[1]. Originating from attachment theory, peer attachment is rooted in the theoretical framework that emphasizes individuals form internal working models through interactions with primary caregivers during early life, which further shape their approaches to establishing relationships and regulating emotions throughout their lifespan[2]. As individuals grow up, their attachment figures gradually shift from parents to peers. Particularly during college, a critical transitional period moving from family to society, peer relationships serve as a vital source for satisfying the need for belonging and obtaining emotional support [3].

Research demonstrates that secure peer attachment can significantly enhance individuals' perceived social support, alleviate loneliness, and provide an emotional buffer against academic and life pressures[4]. Conversely, the absence or ambivalence of peer attachment may lead to interpersonal alienation, emotional distress, and difficulties in social adaptation [5]. Nevertheless, amid intensifying academic competition and diversified social interaction patterns, some college students still face substantial challenges in establishing and maintaining in-depth peer relationships, and even exhibit phenomena such as interpersonal estrangement and emotional loneliness [6]. Against this backdrop, exploring ways to promote peer attachment through operable and universally inclusive campus activities carries important practical significance.Physical exercise, as a behavior integrating physical and mental functions as well as social interaction, is widely regarded as an effective vehicle for fostering

interpersonal connections. The social support buffering hypothesis highlights that individuals' subjective perception of supportive resources plays a pivotal role in their psychological adaptation[7]. Collective sports activities, in particular, create a social context for participants to collaborate with each other and share emotional resonance, thereby contributing to the improvement of their perceived social support.Meanwhile, school belonging, as an embodiment of the emotional bond between students and their institutions[8], may also act as a critical mediator in the relationship between physical exercise and peer relationships. Active participation in sports activities can strengthen students' identification with and sense of belonging to the campus, which in turn provides a secure foundation for them to invest more emotional resources in peer interactions[9].Based on the aforementioned theoretical perspectives, this study innovatively constructs a chained mediation model of "Physical Exercise–Perceived Social Support–School Belonging–Peer Attachment". It aims to systematically investigate whether physical exercise can promote the development of college students' peer attachment by enhancing their perceived social support and school belonging. This research not only helps clarify the mechanism through which physical exercise influences interpersonal functions from a psychosocial perspective, enriching the theoretical understanding of the formation and maintenance of peer relationships among college students, but also provides empirically grounded practical references for universities to promote the healthy social development of students through physical education and the creation of a supportive campus environment.

Theoretical Basis and Hypotheses

The Relationship Between Physical Exercise and Peer Attachment Among College Students

Peer attachment refers to an emotional attachment relationship characterized by mutual care, mutual warmth, and mutual support that individuals establish with peers of similar age [10]. As a vital emotional bond formed by college students during their campus life, it exerts a profound impact on their social development, mental health and academic achievement[3]. It mainly denotes the quality of interpersonal relationships established during interactions with peers, which is grounded in emotional security and support, and serves as a key indicator for measuring college students' social adaptation ability [1].

During the critical stage when college students gradually break away from their families of origin and step into a quasi-socialized environment, healthy and stable peer attachment can effectively buffer stress, facilitate identity formation, and shape positive interpersonal interaction patterns [11]. As a regulated physical activity featuring both physiological activation and social participation, physical exercise is regarded as a potential effective approach to promoting positive peer attachment [12]. Its mechanism of action is not a single direct effect, but is realized through diversified psychosocial processes.Firstly, from the perspective of direct interaction, physical exercise, especially team-based or group sports, creates a structured social interaction context for college students [13]. Relevant studies have demonstrated that college students who frequently participate in collective sports activities tend to have broader social networks. The "comrades-in-arms" camaraderie developed during these activities

can significantly enhance their sense of trust and closeness toward their peers [14].Secondly, physical exercise indirectly strengthens individuals' attractiveness in interpersonal interactions and their ability to maintain relationships by improving their internal psychological state. A large number of empirical studies have confirmed that regular physical exercise is an effective method to alleviate anxiety and depression, as well as to boost positive emotions and self-efficacy[15–16]. Individuals with more stable emotions, a more positive mindset and stronger beliefs in their own capabilities usually exhibit greater initiative, better empathy and stronger conflict resolution skills in interpersonal interactions[17]. These positive psychological traits and social skills make them more likely to be accepted and favored by peer groups, and also enable them to manage and maintain in-depth attachment relationships more effectively.Thirdly, the willpower qualities cultivated through long-term and regular participation in physical exercise, such as perseverance, self-discipline and resilience to setbacks, as well as respect for rules and teamwork, can be transferred to daily interpersonal interactions [18]. College students with these qualities are often regarded as reliable and trustworthy partners in peer relationships. Meanwhile, the shared challenges, successes and even failures experienced during sports can foster strong emotional resonance and collective memories. Such shared experiences act as a catalyst for strengthening group belonging and the special emotional bonds among members [13].To sum up, physical exercise not only directly increases opportunities for peer bonding by providing a specific social interaction context, but also lays a solid foundation for college students to develop and maintain secure and close peer attachment relationships through multiple pathways, including improving individual mental health, cultivating positive personality traits and creating shared emotional experiences [14–15]. Existing studies have supported this correlation from various perspectives, providing a theoretical basis and logical starting point for this research to explore its internal mechanism of action.Therefore, based on the above theoretical elaboration and literature review, this study proposes the following hypothesis:

H1: Physical exercise has a significant positive predictive effect on peer attachment among college students.

The Mediating Effect of Perceived Social Support

Perceived social support refers to an individual’s perception and evaluation of the availability and value of social support resources[19]. It emphasizes the subject’s subjective interpretation of and confidence in a supportive environment, rather than merely the existence of objective support. This internal psychological construct is crucial for understanding how individuals benefit from environmental interactions, particularly during the period of college life, which is replete with changes and challenges. Research demonstrates that a high level of perceived social support is not only a protective factor for mental health but also a key mediator in promoting the development of positive interpersonal relationships [20].

As a proactive social behavior, physical exercise provides college students with a unique context for establishing and strengthening social support. During regular physical activities, individuals not only engage in physical collaboration and interaction with others, but also deepen emotional communication

and mutual recognition through pursuing common goals, learning skills and cooperating as a team. This process can effectively enhance individuals' perception that they are embedded in a supportive network. Studies have confirmed that college students who participate in physical exercise regularly are more inclined to believe that they can obtain help and understanding from friends, classmates or groups when in need [21]. The formation of this belief partly stems from the inherent social attributes of physical activities and the positive group atmosphere they create [22].The enhancement of perceived social support, in turn, exerts a profound impact on college students' peer attachment. According to the main effect model of social support and attachment theory, individuals will develop a stronger sense of security and belonging when they are internally convinced that they possess a reliable social support system [23]. This psychological security serves as the foundation for establishing and maintaining high-quality intimate relationships. Specifically, students with high perceived social support tend to exhibit greater trust, more self-disclosure and stronger abilities to resolve interpersonal conflicts in interactions with peers [24]. They are more likely to regard peer relationships as stable and dependable, and thus more willing to invest emotions to form secure and close attachment bonds. Conversely, individuals with low perceived social support may hold a skeptical attitude toward the interpersonal environment, behave more withdrawn or anxious in interactions, and hinder the formation of deep attachment[25].Therefore, this study infers that physical exercise is unlikely to exert a direct effect on peer attachment. Instead, it first fulfills its psychosocial benefits by improving individuals' perception and evaluation of supportive resources in the environment—namely, perceived social support. In other words, physical exercise creates objective conditions and a practical field for the perception of social support, and it is this perceived support that becomes the direct psychological nourishment for nurturing secure and stable peer attachment relationships.Based on the above analysis, this study proposes the following hypothesis:

H2: Perceived social support plays a mediating role in the relationship between physical exercise and peer attachment among college students.

The Mediating Effect of School Belonging

School belonging refers to the emotional experience of being accepted, respected and recognized by students in the school environment. It represents an individual's emotional and identity-based identification with and attachment to their institution [8]. For college students, the university is not only a place for knowledge acquisition, but also a crucial context for their social development and the formation of emotional bonds. A high level of school belonging can facilitate positive psychological adaptation among students, enhance their willingness to participate in campus activities, and provide an important emotional foundation for them to establish stable and healthy peer relationships [26].Research indicates that the development of school belonging is not an isolated process, but is influenced by multiple individual and external resources. Among these, social support serves as a pivotal nourishment for fostering a sense of belonging. When students perceive support from classmates, friends or teachers, they are more likely to develop a communal sense of "we", thereby strengthening their

identification with and attachment to the university[27]. In other words, perceived social support may provide an important cognitive and emotional pathway for promoting school belonging. At the same time, school belonging itself has been proven to be a significant predictor of the quality of interpersonal relationships. Students with a strong sense of school belonging tend to exhibit greater social initiative, stronger interpersonal trust and more positive qualities in peer interactions, all of which contribute to the deepening of emotional attachment among peers[28].When examining school belonging within the framework of the relationship between physical exercise and peer attachment, its potential mediating role becomes increasingly clear. On the one hand, as a vital campus activity, physical exercise can indirectly promote students' identification with and attachment to the school environment by increasing social interaction and enhancing positive emotions [29]. On the one hand, once established, school belonging acts as a stable psychological resource that motivates individuals to seek and maintain high-quality peer bonds within the campus setting[30].Notably, there may be a progressive relationship between perceived social support and school belonging: the perceived support promoted by physical exercise is first transformed into a sense of school belonging, which in turn lays the foundation for deeper emotional attachment with peers. This constitutes a coherent psychosocial process. Based on the above analysis, this study proposes:

H3: School belonging plays a mediating role in the relationship between physical exercise and peer attachment among college students.

Meanwhile, integrating the aforementioned mediating effect of perceived social support, this study further hypothesizes that perceived social support and school belonging form a chained mediation mechanism in the pathway through which physical exercise influences peer attachment. That is, physical exercise helps college students obtain higher levels of perceived social support, which in turn enhances their sense of school belonging, and ultimately promotes the formation of closer emotional attachment with their peers. This hypothesized pathway integrates personal perception, emotional identification and interpersonal connection, attempting to more comprehensively reveal the internal process through which physical exercise exerts its psychosocial effects [3132].

The Chained Mediating Effect of Perceived Social Support and School Belonging

As an important campus activity, the social attribute of physical exercise provides college students with opportunities to establish a supportive interpersonal network. Research shows that regular participation in collective or cooperative physical activities can directly increase the frequency and quality of actual social support obtained by individuals[33]. More crucially, such interactive experiences, after undergoing an individual's subjective cognitive evaluation, will be internalized into relatively stable perceived social support—that is, the degree of social resources that individuals perceive as available for utilization[34]. Perceived social support is not only a cognitive judgment but also an important form of psychological capital, which can buffer stress and enhance an individual's sense of security and self-worth [35].

A high level of perceived social support serves as pivotal nourishment for fostering school belonging. School belonging refers to the emotional experience and psychological identification in which students feel accepted, respected, and cared for within the school environment[26]. When students perceive support from classmates and teachers through physical activities and other channels, they tend to evaluate the campus environment as friendly and safe, thereby more easily forming positive emotional bonds and identity identification with the school [36]. Numerous studies have confirmed that perceived social support is one of the key antecedent variables predicting school belonging among adolescents and college students[37].A strong sense of school belonging provides an ideal emotional and situational foundation for students to develop high-quality peer attachment. According to the expansion of attachment theory, the concept of a secure base can be extended from parent-child relationships to a broader social environment[38]. When students develop a strong sense of belonging to their school, the school becomes a “base” that provides safety and support. In this base, students will have greater confidence and willingness to explore and develop in-depth and lasting peer relationships[39]. Conversely, students lacking a sense of school belonging may feel isolated, thus exhibiting more avoidant or insecure tendencies in peer interactions [40].Based on the above chained mediating path constructed in this study, Hypothesis H4 is proposed:

H4: Perceived social support and school belonging play a chained mediating role in the relationship between physical exercise and peer attachment among college students.

The hypothesized research model is shown in Fig. 1.

Research Methods

Participants

This study adopted the convenience sampling method to recruit 520 college students from several universities in Liaoning Province as research participants. An online questionnaire was distributed via the Wenjuanxing platform. The questionnaire consisted of five sections: demographic information, level of physical exercise, quality of peer attachment, perceived social support, and school belonging. Multiple procedures were implemented to ensure voluntary participation and avoid coercion:A formal informed consent module was placed on the first page of the questionnaire, which clearly stated the research purpose, data usage and confidentiality protocols, and notified participants that they could withdraw voluntarily at any time without any negative consequences;The questionnaire link was voluntarily forwarded to eligible students by university counselors, and mandatory participation through collective notices or task assignments was strictly prohibited Participants were required to click “Agree to Participate” to access and complete the questionnaire; those who did not provide consent were unable to view the questionnaire content, ensuring that participation was entirely voluntary throughout the process.All participants in this study provided informed consent. Participants were required to meet the following criteria: full-time undergraduates aged 18–25 years, with no history of physical illness or mental disorders. During the data screening process, 48 invalid questionnaires were excluded due to

regular response patterns or incomplete responses. Ultimately, 472 valid questionnaires were retained, yielding a valid response rate of 90.76%.Among the valid sample, there were 226 male college students (47.9%) and 246 female college students (52.1%). The research protocol was reviewed and approved by the relevant institutional ethics committee of the university prior to implementation.

The demographic characteristics of the participants are presented in Table 1.

Research Instruments

Physical Activity Rating Scale

This study adopted the Physical Activity Rating Scale (PARS) revised by Liang Deqing (1994) to assess the physical exercise level of college students[41]. The scale consists of three dimensions, with one item for each dimension: exercise intensity (e.g., How intense is your physical exercise?), exercise duration (e.g., How many minutes do you spend on a single session of physical activity?), and exercise frequency (e.g., How many times do you engage in physical activity per month?).A 5-point Likert scale was used for scoring. Exercise intensity and exercise frequency were scored on a scale of 1 to 5, while exercise duration was scored on a scale of 0 to 4. The total physical exercise volume was calculated as the product of exercise intensity, exercise frequency, and exercise duration. A higher score indicates a greater volume of physical exercise. The Cronbach's α coefficient of this scale in the present study was 0.705.

Peer Attachment Scale

This study employed the peer attachment subscale of the Inventory of Parent and Peer Attachment (IPPA), which was developed by Armsden & Greenberg (1987) and translated and revised by Zhang Yingli (2011) [42]. This questionnaire contains 25 items covering three dimensions: peer trust (e.g., When we discuss problems, do my friends care about my opinions?), peer communication (e.g., I like to ask for my friends' opinions on things that matter to me?), and peer alienation (e.g., Talking about my problems with my friends makes me feel ashamed or stupid?). It was scored on a 5-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree), with the total score calculated as the sum of all item scores. The scale presented satisfactory construct validity in this study, and its Cronbach's α coefficient was 0.833 in the present research.

Perceived Social Support Scale

This study used the Perceived Social Support Scale (Revised 2006 Edition). The original scale was developed by Jiang Qianjin (1999) and later revised by Yan Biaobin et al[43]. The scale consists of 12 items, all rated on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). All items are positively scored, and the total score is obtained by summing the scores of all items. The scale covers three dimensions: family support (e.g., Can my family provide me with practical and specific help?), friend support (e.g., Can my friends truly help me?), and other support (e.g., When I encounter

problems, will some people such as teachers, classmates and relatives be there for me?). The Cronbach's α coefficient of this scale in the present study was 0.874.

School Belonging Scale

This study adopted the School Belonging Scale originally developed by Goodenow in 1993 and later translated and revised into Chinese by Zhang Yingxiao et al. in 2021 [44]. The item statements of the Chinese version were transformed from declarative sentences into rhetorical questions. The formal questionnaire was scored on a 6-point Likert scale, with scores ranging from 1 to 6 corresponding to the responses of “never” to “always” respectively. The Cronbach's α coefficient of this scale in the present study was 0.914.

Statistical Methods

The valid data were imported into SPSS 27.0 for analysis. Pearson correlation analysis, regression analysis, and serial multiple mediation analysis were conducted. The Bootstrap method with the Process macro was used to test the mediating effects in the serial multiple mediation analysis.When analyzing the indirect effects of variables with the Process macro, the specific settings were as follows: Model 6 was specified; the independent variable X was physical exercise, the first mediator M1 was perceived social support, the second mediator M2 was school belonging, and the dependent variable Y was peer attachment; the number of Bootstrap samples was set to 5000.

Results and Analysis

Common Method Bias Test

First, procedural controls were implemented to mitigate common method bias:1.Appropriate reverse-scored items were incorporated into the scales.2.The presentation order of the scales was randomized.3.Participants were instructed to complete the scales anonymously prior to administration.Second, the Harman’s single-factor test was utilized to examine the severity of common method bias in the dataset. The results showed that there were 10 factors with eigenvalues greater than 1. The first factor explained 19.482% of the total variance, a value below the 40% critical threshold. This demonstrates that the data of the present study does not exhibit severe common method bias.

Descriptive Statistics and Correlation Coefficients for All Variables

Correlation analysis was conducted using the mean scores of all variables. The results revealed that physical exercise was significantly positively correlated with perceived social support and sense of school belonging among college students, and also exhibited a significant positive correlation with peer attachment. Additionally, perceived social support was significantly positively correlated with both peer attachment and sense of school belonging, while sense of school belonging was significantly positively correlated with peer attachment. Gender, place of origin, age and major category showed no significant

correlations with physical exercise, peer attachment, perceived social support and sense of school belonging (see Table 2).

Testing of the Chain Mediation Effect

With physical exercise as the independent variable, peer attachment as the dependent variable, and perceived social support and school belonging as mediating variables, this study used SPSS 27.0 and the PROCESS 3.4 macro to test the chain mediating effect of perceived social support and school belonging in the relationship between physical exercise and peer attachment, after controlling for demographic variables such as gender. The results are presented in Table 3.The specific steps were as follows:First, taking peer attachment as the dependent variable, gender, place of origin, grade, and major category were entered to control for their potential influences on college students' peer attachment.Second, physical exercise was entered to establish the regression model, so as to examine the total effect of physical exercise on peer attachment after controlling for the covariates. It was found that physical exercise could positively and significantly predict peer attachment (β = 0.150, $p < 0.001$), indicating that Hypothesis H1 was supported.Third, perceived social support and school belonging were added into the model to test whether the two variables served as mediators between physical exercise and peer attachment, as well as whether a chain mediating effect existed.The results showed that physical exercise could significantly and positively predict sense of security (β = 0.085, $p < 0.001$), perceived social support could positively predict peer attachment (β = 0.074, $p < 0.001$), and school belonging could positively predict sense of security (β = 0.221, $p < 0.001$). Meanwhile, the test also revealed that physical exercise could significantly and positively predict perceived social support (β = 0.195, $p < 0.001$) and school belonging (β = 0.163, $p < 0.001$), and perceived social support could positively predict school belonging (β = 0.337, $p < 0.001$).In summary, there is a significant chain mediating effect of perceived social support and school belonging in the relationship between physical exercise and peer attachment, which supports Hypotheses H2 and H3 in this study.

A Bootstrap test with 5000 repeated samplings was conducted to examine the mediating effects and confidence intervals of perceived social support and sense of school belonging in the relationship between physical exercise and peer attachment, respectively (Table 4). The results showed that the total effect size of physical exercise on peer attachment was 0.150, and the 95% confidence intervals of the mediating effects of perceived social support and sense of school belonging did not contain 0 (LLCL = 0.099, ULCL = 0.201), indicating that the total effect of physical exercise on peer attachment and the mediating effects of the two variables were significant. The direct effect size of physical exercise on peer attachment (direct path) was 0.085, with its Bootstrap 95% confidence interval also excluding 0 (LLCL = 0.039, ULCL = 0.130), which demonstrated a significant direct effect of physical exercise on peer attachment, accounting for 56.66% of the total effect size.

As can be seen from the model, physical exercise significantly predicts peer attachment, with perceived social support and sense of school belonging exerting an indirect mediating effect in this relationship (involving three paths). The total indirect effect size was 0.065, and its Bootstrap 95% confidence interval

did not contain 0 $\mathrm{LLCL}=0.024,\mathrm{ULCL}=0.114$, accounting for 43.33% of the total effect. Specifically, the three mediating paths are as follows: the first mediating path (Path 1) was physical exercise → perceived social support → peer attachment, with an indirect effect size of 0.014, accounting for 21.53% of the total effect; the second path (Path 2) was physical exercise → sense of school belonging → peer attachment, with an indirect effect size of 0.036, accounting for 55.38% of the total effect; the third chain mediating path (Path 3) was physical exercise → perceived social support → sense of school belonging → peer attachment, with an indirect effect size of 0.014, accounting for 21.53% of the total effect. These results confirm that Hypothesis H4 of the study is supported.

Based on the above research results, the chain mediation model is presented in Figure 2.

Discussion

The Relationship Between Physical Exercise and Peer Attachment Among College Students

Physical exercise has a significant positive predictive effect on peer attachment among college students (H1). That is, the higher the level of physical exercise, the better the quality of peer attachment. This finding is consistent with the conclusions of existing studies [12], further confirming the positive role of physical exercise in improving the quality of interpersonal relationships among college students.

Physical exercise, especially team-based or collective activities, provides individuals with regular and structured social interaction scenarios. During joint participation in sports, college students gradually establish trust and emotional bonds through cooperation, communication, and emotional resonance [13]. Such interactions based on shared experiences not only increase the frequency of communication but also deepen mutual understanding and recognition, forming a realistic foundation for the development of peer attachment.Regular engagement in physical exercise helps alleviate anxiety and depression, while enhancing positive affect and self-efficacy [15]. The enhancement of these internal psychological resources enables individuals to be more proactive, inclusive, and adaptable in interpersonal interactions. College students with emotional stability and a positive mindset are often more likely to gain acceptance and trust from peers, and are more capable of maintaining in-depth relationships[16].From the perspective of attachment theory, the formation of secure attachment depends on individuals' experience of reliable support and emotional responsiveness within relationships[1]. The collective environment created by physical exercise naturally embodies an atmosphere of encouragement, mutual assistance, and empathy, which is inherently consistent with the function of a secure base required by the attachment system.Research has shown that college students who participate in team sports are more likely to find emotional support and a sense of belonging among their peers, thereby promoting the secure development of attachment relationships [14]. Meanwhile, the improved psychological resilience and emotion regulation abilities derived from physical exercise also help individuals remain stable when facing interpersonal conflicts or relationship fluctuations, thus

sustaining the continuity and quality of attachment[17].In summary, the promoting effect of physical exercise on college students' peer attachment is reflected not only in the objective social platforms and interaction opportunities it provides, but also in its shaping effect on individuals' internal psychological states and social competencies.

The Mediating Role of Perceived Social Support in the Relationship Between Physical Exercise and Peer Attachment Among College Students

This study examined the mediating role of perceived social support in the relationship between physical exercise and peer attachment among college students using a structural equation model. After controlling for variables including gender, place of origin, grade, and major category, the results showed that physical exercise not only had a direct positive predictive effect on peer attachment, but also exerted an indirect influence on peer attachment through the partial mediating role of perceived social support. These findings supported Hypothesis H2 that perceived social support plays a mediating role between physical exercise and peer attachment among college students. This conclusion is consistent with the results of numerous previous studies.The social support buffering model proposes that individuals' subjective perception of external support can act as a buffer between stress and health outcomes, and physical exercise is often regarded as an important way to promote social interaction and enhance perceived support [35]. Among college students, participation in collective physical exercise can significantly strengthen individuals' perception of social support, thereby facilitating the establishment and maintenance of interpersonal relationships [24]. Similarly, studies on youth physical activity and social function have also found that physical exercise indirectly strengthens the quality of peer bonds by improving participants' sense of social integration and perceived support[22]. Collectively, these studies confirm the chain relationship among physical exercise, perceived social support, and interpersonal relationships from different perspectives.

The Mediating Role of School Belonging in the Relationship Between Physical Exercise and Peer Attachment Among College Students

This study verified the mediating role of school belonging in the relationship between physical exercise and peer attachment among college students (H3). That is, physical exercise can promote the level of peer attachment by enhancing students' sense of school belonging. This conclusion partially supports the view in previous studies that school belonging acts as a bridge between physical activity and interpersonal relationships [29], and also provides a basis for understanding how physical exercise affects peer relationships through the path of emotional identity.As a comprehensive reflection of an individual's emotional connection and identity with the school, the formation of school belonging is significantly influenced by an individual's participation experience on campus. The present study found that physical exercise positively predicts school belonging, which is consistent with existing research findings. For example, participation in collective physical activities is often regarded as an important way to integrate into campus culture and strengthen collective identity [40]. Team cohesion and shared experiences formed in physical activities help students develop a "we" sense of community, thereby improving their sense of

belonging to the school. In addition, physical exercise is often accompanied by positive emotional experiences, such as a sense of accomplishment and pleasure. These emotional resources can enhance students' positive evaluation of the school environment and further strengthen emotional attachment [36].The promoting effect of school belonging on peer attachment is also confirmed in this study. A high level of school belonging provides students with an emotional secure base [26,] making them more willing to conduct interpersonal exploration in the campus environment and establish in-depth and stable peer relationships. Studies have shown that students with a strong sense of school belonging usually exhibit higher interpersonal trust, social initiative, and emotional investment [28], all of which lay the foundation for developing secure peer attachment. In addition, the experience of recognition and acceptance brought by a sense of belonging can meet individuals' need for relatedness, thereby prompting them to exhibit more supportive behaviors in peer interactions and strengthening emotional bonds with each other[8].School belonging plays an important mediating role between physical exercise and peer attachment among college students. This suggests that when educational practitioners promote students' interpersonal development through physical exercise, they should focus on creating an inclusive and supportive campus sports environment, enhancing students' sense of belonging in activities, so as to provide an emotional foundation for the healthy development of their peer relationships.

The Chain Mediating Role of Perceived Social Support and School Belonging

The Bootstrap test conducted in this study revealed that perceived social support and school belonging formed a significant chain mediating path between physical exercise and peer attachment among college students (Path 3: Physical exercise → Perceived social support → School belonging → Peer attachment). The indirect effect size was 0.014, accounting for 21.53% of the total effect, which supported Hypothesis H4. These findings are consistent with attachment theory, the social support buffering model, and relevant studies on school belonging, revealing the multi-stage psychosocial mechanism through which physical exercise promotes peer attachment from an integrated perspective.The establishment of the chain mediating effect first confirms the function of physical exercise as a platform for social interaction. Collective physical activities enhance individuals' subjective perception of social support through cooperation, encouragement, and shared goals, which echoes the social support buffering model proposed by Cohen [7], stating that individuals' perception of supportive resources can exert a psychological protective effect in stressful environments. Second, perceived social support further contributes to the formation of school belonging. Research has shown that when students perceive support from peers, teachers, or other school members, they are more likely to develop emotional identification with the school environment[8], thereby strengthening their "we" consciousness and sense of belonging[27]. In the present study, the significant positive predictive effect of perceived social support on school belonging ($\beta = 0.337$, $p < 0.001$) further supports this path.Attachment theory proposes that secure attachment relationships are often built on individuals' feelings of safety and acceptance in the environment[1]. A strong sense of school belonging enables

students to regard the campus as a reliable emotional space, thus becoming more willing to invest trust and affection in peer relationships [29]. In addition, school belonging indirectly promotes emotional intimacy among peers by enhancing students' social initiative and interpersonal trust [28]. The significant positive prediction of school belonging on peer attachment in this study ($\beta = 0.221$, $p < 0.001$) is also consistent with Osterman's [26]argument that belonging is closely associated with interpersonal functioning.Overall, the chain mediating path in this study integrates three stages: individual perception, emotional identification, and interpersonal bonding, reflecting the continuity and systematicity of the influence of physical exercise on peer attachment.

Conclusion

Physical exercise, perceived social support, school belonging, and peer attachment among college students are all positively correlated with each other.

Physical exercise positively predicts perceived social support, school belonging, and peer attachment.

Perceived social support and school belonging play independent mediating roles in the relationship between physical exercise and peer attachment, respectively.

Perceived social support and school belonging play a chain mediating role in the relationship between physical exercise and peer attachment.

Limitations and Future Directions

Although this study has preliminarily revealed the psychological mechanism through which physical exercise promotes peer attachment among college students via perceived social support and sense of school belonging, several aspects deserve further investigation. Future research may adopt longitudinal tracking or experimental intervention designs to more clearly clarify the causal relationships among variables.In terms of sample selection, the scope of regions and school types can be expanded to enhance the generalizability of the research findings. In addition, besides social support and sense of belonging, other psychological and social factors, such as emotion regulation strategies, interpersonal trust, and self-disclosure tendency, may also play mediating or moderating roles in the relationship between physical exercise and peer attachment. Future studies can incorporate more comprehensive variables to construct an integrated model.At the level of educational practice, it is also a worthwhile direction to explore in depth how to organically integrate physical exercise with the psychosocial support system and design campus activities that serve the dual functions of promoting sports participation and emotional bonding.Overall, physical exercise exerts multi-path and multi-level positive effects in advancing the healthy interpersonal development of college students. Subsequent research can be further carried out in two dimensions: deepening the underlying mechanisms and translating research findings into practical applications.

Declarations

Data availability

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.If anyone would like to request data from this study, please contact the corresponding author,Hongbo Zhao,hongbo1128@163.com

Author contributions

Z-Y C was responsible for the data analysis and writing of the original draft preparation. H-B Z was responsible for data analysis and methodology. Z-Y C was responsible for the conceptualization, writing, reviewing and editing the draft. H-B Z was responsible for the conceptualization, writing, reviewing and editing the draft, and funding acquisition. All authors have read and approved the final manuscript.

All authors confirm that the manuscript has been submitted solely to this journal and is not published, in press, or submitted elsewhere (including preprint servers). And all the research meets the ethical guidelines, including adherence to the legal requirements of the study country. All authors have seen the manuscript and approved to submit to your journal.

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Ethics approval and consent to participate

The design of this study followed the guidelines and regulations of the Declaration of Helsinki and approved by Ethics Committee of Liaoning Normal University (LL2025379),and all participants signed an informed consent form and were paid for their participation.

Compliance Statement

During the implementation of this study,it strictly adheres to the International Ethical Guidelines for Health - related Research Involving Human Subjects issued by the Council for International Organizations of Medical Sciences (CIOMS) and relevant Chinese scientific research ethics management measures and regulations. All aspects, such as the design of research methods and the collection and use of data, prioritize the protection of the rights, safety, and well - being of participants,ensuring that the research is carried out within a legal and compliant framework.

Consent for publication

Not applicable.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships.

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Tables

Table 1
Demographic Characteristics of the Participants(N = 472)

Demographic Variables	Category	Number	Percentage(%)
Gender	Male	226	47.9%
	Female	246	52.1%
Grade	Freshman	140	29.7%
	Sophomore	124	26.3%
	Junior	115	24.4%
	Senior	93	19.7%

Table 2
Correlations of Research Variables(n = 472)

Variable	1	2	3	4	5	6	7	8
Gender(1)	1							
Origin of Student (2)	0.017	1						
Grade(3)	0.039	-0.028	1					
Major(4)	0.070	-0.021	0.006	1				
Physical Exercise(5)	-0.044	-0.089	0.103*	0.003	1			
Peer Attachment(6)	0.065	0.024	-0.022	-0.013	0.250**	1		
Perceived Social Support(7)	0.010	0.030*	-0.013	0.040	0.154**	0.349**	1	
Sense of School Belonging(8)	-0.029	-0.040	0.002	0.019	0.216**	0.504**	0.404**	1
Note:* indicates P < 0.05,** indicates P < 0.01, the correlation is significant.								

Table 3 Mediation Regression Model for Perceived Social Support and Sense of School Belonging

Regression Equation		Overall Fit Indices			Significance of coefficients	
Dependent Variable	Independent Variable	R	R^2	F	β	t
Peer Attachment	Physical Exercise	0.271	0.073	7.371	0.150	5.833***
Perceived Social Support	Physical Exercise	0.168	0.028	2.734	0.195	3.511***
School Belonging	Physical Exercise	0.435	0.189	18.165	0.163	3.585***
	Perceived Social Support				0.337	9.018***
Peer Attachment	Physical Exercise				0.085	3.705***
	Perceived Social Support	0.555	0.308	29.517	0.074	3.695***
	Sense of School Belonging				0.221	9.638***

Note: ** indicates P<0.01, *** indicates P<0.001.

Table 4

Mediation Effects of Self-Esteem and Psychological Capital

Effect	**Path**	**Effect Size**	**Standard Error**	**LLCL**	**ULCL**	**Effect Ratio**
Total Effect		0.150	0.025	0.099	0.201	100%
Direct Effect	Direct Path	0.085	0.022	0.039	0.130	56.66%
Total Indirect Effect		0.065	0.022	0.024	0.114	43.33%
	Path1	0.014	0.007	0.003	0.030	21.53%
Indirect Effect	Path2	0.036	0.014	0.011	0.066	55.38%
	Path3	0.014	0.007	0.003	0.031	21.53%

Figures

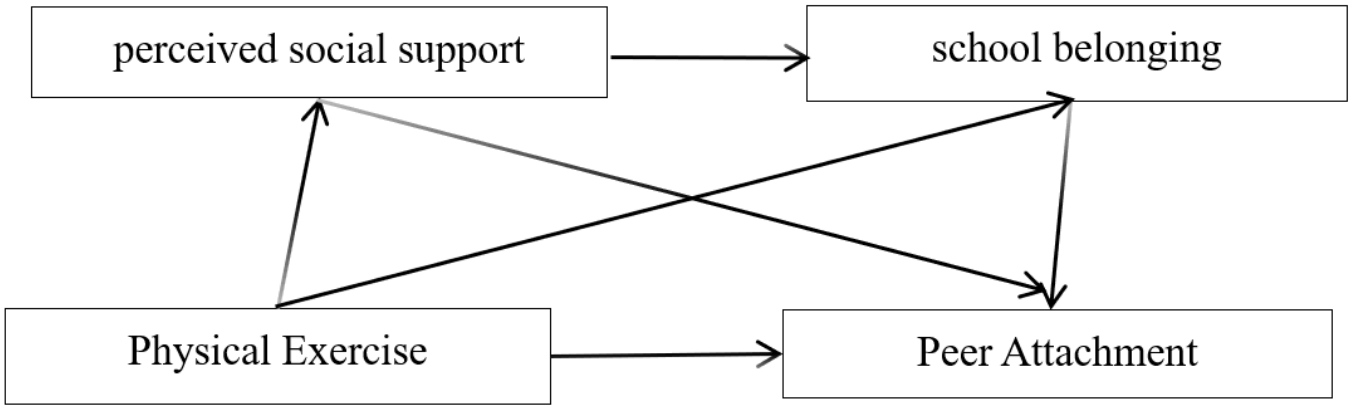


Figure 1

The Hypothesized Chained Mediation Model

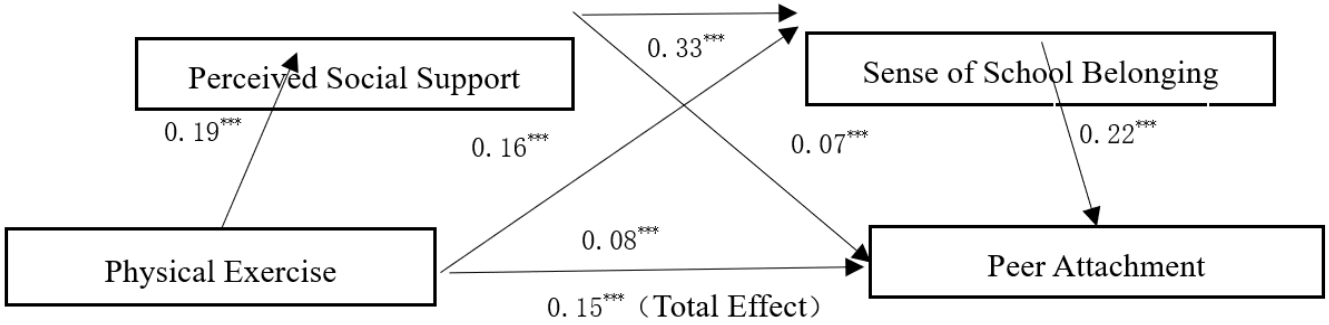


Figure 2

Chain Mediation Effect Model of Perceived Social Support and School Belonging