



OPEN The chain mediating role of perceived social support and cognitive reappraisal in the relationship between physical exercise and adolescent social anxiety

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In order to explore the effects of physical exercise on adolescents' social anxiety and its intrinsic mechanism of action, the present study was based on the theory of psychosocial adaptation and constructed a hypothetical model with the chain mediation of perceived social support and cognitive reappraisal. The Physical Activity Rating Scale, the Interaction Anxiety Scale, the Perceived Social Support Scale, and the Cognitive Reappraisal Scale in the Emotion Regulation Scale were used to administer questionnaires to 505 adolescents, and the mediating effects were tested by structural equation modeling. The results showed that (1) physical exercise significantly and negatively predicted the level of social anxiety in adolescents ($\beta = -0.467, P < 0.001$); (2) perceived social support and cognitive reappraisal played independent mediating roles between physical exercise and social anxiety, respectively, with the effect value of 24.28% and 3.47%; (3) physical exercise could indirectly reduce social anxiety through the chain mediating path of perceived social support and cognitive reappraisal, and the chain mediating path of social anxiety could indirectly reduce social anxiety, indirectly reducing social anxiety, with a chain effect percentage of 13.29%. The study suggests that physical exercise not only directly relieves adolescents' social anxiety, but also forms a multilevel protective psychological mechanism by enhancing the individual's ability to perceive social support, which in turn promotes the use of positive emotion regulation strategies. The results of the study provide theoretical and practical basis for improving adolescent mental health through physical activity interventions, and suggest the integration of social support systems and cognitive training to enhance the effectiveness of interventions.

Keywords Physical exercise, Social anxiety, Perceived social support, Cognitive reappraisal

The World Health Organization (WHO) and other international organizations are highly concerned about adolescent mental health issues. From a developmental perspective, adolescence represents a critical period of psychological development, where dual challenges in identity formation and academic pressures can easily trigger mental health problems¹. Among common mental health issues in adolescents, social anxiety stands out for its high prevalence. Social anxiety refers to intense feelings of worry, nervousness, or fear triggered by exposure to specific interpersonal situations, often accompanied by avoidance behaviors². This psychological state not only diminishes adolescents' subjective well-being but also disrupts normal learning and social interactions. In severe cases, it may trigger depressive moods and even suicidal tendencies^{3–6}. Among various factors influencing mental health, the therapeutic effects of physical exercise have gained widespread recognition in both academic and practical circles. However, existing research predominantly focuses on single mediation pathways, with insufficient exploration of mechanisms involving multivariable synergistic effects. Particularly lacking is systematic examination of the "social support-cognitive regulation" continuum as a sequential psychological process.

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Therefore, this study constructs a chain-mediated model—“physical exercise → perceived social support → cognitive reappraisal → social anxiety”—based on psychosocial adaptation theory. This theory emphasizes that individuals achieve positive adaptation by integrating internal and external resources: physical exercise, as a key pathway to promoting adaptation, not only enhances individual physiological and psychological resources but also expands environmental support by creating social opportunities. This model comprehensively depicts the psychosocial adaptation process—from perceiving environmental resources (perceived social support) to optimizing personal resources (cognitive reappraisal)—ultimately achieving adaptation in social contexts. It provides a systematic framework for understanding the underlying mechanisms through which physical exercise influences social anxiety.

Research hypotheses

Physical exercise and the predictive effect of social anxiety in adolescents

Physical exercise is an activity in which individuals perform physical exercises according to their own needs through various physical means for the purpose of enhancing physical fitness, improving health, promoting physical and mental development, and improving physical functioning⁷. According to the affective effects theory, emotional experiences generated during physical exercise can improve or even alleviate negative emotions such as depression, anxiety, and stress⁸. From a physiological perspective, physical exercise promotes the secretion of neurotransmitters like catecholamines and endorphins. These substances are closely associated with positive emotions and pleasant moods, helping to stimulate cognitive thinking and emotional experiences, thereby reducing anxiety and stress⁹. Additionally, physical exercise can indirectly alleviate adolescents' social anxiety levels by enhancing their sense of self-efficacy¹⁰. Evidence-based medical research further indicates that physical exercise positively impacts adolescent social anxiety: those who regularly engage in physical exercise exhibit lower levels of social anxiety, followed by occasional exercisers, while non-exercisers demonstrate the highest levels of social anxiety¹¹. In summary, a certain association exists between physical exercise and social anxiety. Based on this, Hypothesis H1 is proposed: Physical exercise can negatively predict social anxiety in adolescents.

Mediating effects of perceived social support

Perceived social support refers to an individual's subjective perception of the actual social support received, which is the psychological satisfaction and emotional feelings resulting from the individual's feeling of being understood and supported¹². According to the main effect and buffering effect models of social support, perceiving encouragement and support from others not only alleviates negative emotions but also plays a crucial role in individuals' mental health development^{13,14}. Physical exercise, as a common social activity, provides adolescents with opportunities for peer interaction, helping them gain more peer support in sports settings^{15,16}. As highlighted by the primary effect model of social support, individuals' positive perceptions of their social relationship quality enhance self-efficacy, maintain positive emotional states, and reduce the risk of psychological and behavioral problems¹⁷. Therefore, perceived social support can be regarded as a crucial psychological resource that mitigates the negative impact of stressful events on physical and mental health, significantly lowering individuals' levels of social anxiety¹⁸. In summary, physical exercise enhances adolescents' perceived social support, which in turn may further reduce their social anxiety. Based on this, Hypothesis H2 is proposed: Perceived social support mediates the relationship between physical exercise and adolescents' social anxiety.

Mediating effects of cognitive reappraisal

Cognitive reappraisal is an adaptive emotion regulation strategy in which an individual achieves emotion regulation by changing his or her perception and understanding of events¹⁹. According to embodied cognition theory, the body is an integral component of the cognitive system. Therefore, physical exercise, as a form of bodily activity, can directly influence an individual's cognitive processes²⁰. In practice, maintaining regular physical exercise requires adolescents to continually overcome inertia and avoidance tendencies. This process prompts them to actively engage in cognitive adaptation and reappraisal of their health beliefs and participation motivations²¹, thereby making them more inclined to employ cognitive reappraisal strategies to cope with stressful life events²². On the other hand, the cognitive-behavioral model of social anxiety posits that its core cause lies in individuals' excessive preoccupation with others' negative evaluations²³. Cognitive reappraisal, as a positive emotion regulation strategy, has been shown to effectively alleviate social anxiety. Conversely, individuals who rarely employ cognitive reappraisal are more prone to social anxiety due to heightened worry about social situations²⁴. In summary, physical exercise may influence adolescents' social anxiety levels by promoting the development of cognitive reappraisal abilities. Based on this, Hypothesis H3 is proposed: Cognitive reappraisal mediates the relationship between physical exercise and adolescents' social anxiety.

Chain mediation of perceived social support and cognitive reappraisal

In the process by which physical exercise influences adolescents' social anxiety, perceived social support and cognitive reappraisal each play a simple mediating role. However, these two mediating variables are not independent of each other but are intrinsically linked: Perceived social support, as a subjective yet tangible psychological resource, can promote individuals to more frequently employ cognitive reappraisal—a positive emotion regulation strategy—when facing stress^{25,26}. Specifically, when individuals perceive higher levels of social support from their environment, their internal psychological capital is strengthened, thereby enhancing their capacity and willingness to flexibly employ cognitive reappraisal in stressful situations. Based on this, physical exercise can not only directly elevate adolescents' perceived social support levels, thereby enhancing their cognitive reappraisal ability, but this enhanced ability will ultimately contribute to alleviating their social

anxiety. Therefore, we propose Hypothesis H4: Perceived social support and cognitive reappraisal mediate the relationship between physical exercise and adolescents' social anxiety in a chain-like manner.

As a result, the research hypothesis model was constructed as shown in Fig. 1.

Research objectives and methods

Research object

Using stratified random sampling, students from junior high, high school, and university levels in Liaoning (36%), Shandong (30.7%), and Chongqing (33.3%) were selected as participants. Prior to distributing the questionnaires, informed consent forms were provided to all survey subjects. Questionnaires were administered only after subjects acknowledged the information and obtained consent from both themselves and their parents. A total of 560 questionnaires were distributed. Fifty-five invalid questionnaires were removed: (1) extreme responses (2) incomplete responses (3) short response time (completed and submitted within 50 s). Among them, 20 questionnaires with extreme responses and 35 questionnaires with short response time were deleted. Finally, 505 valid questionnaires were collected, yielding a response rate of 90.18%. Among respondents, 242 were male (47.9%) and 263 were female (52.1%); 212 were only children (42%) and 293 were non-only children (58%). Regarding household socioeconomic status: - Monthly income $\leq$ 5,000 RMB: 142 households (28.1%) - Monthly income 5,001–15,000 RMB: 276 households (54.7%) - Monthly income $>$ 15,000 RMB: 87 households (17.2%). The sample age range was 12–22 years.

Research tools

Physical activity rating scale

The Physical Activity Rating Scale revised by Liang Deqing et al. was used, aiming to examine the indicators of intensity, time, and frequency of subjects' participation in physical activities in the past month²⁷. Each index was scored on a 5-point Likert scale, with physical exercise = intensity $\times$ (time-1) $\times$ frequency, and was categorized according to the total score as small exercise $\leq$ 19 points, medium exercise = 20 to 42 points, and large exercise $\geq$ 43 to 100 points, with a total of three grades, which were used as the evaluation indexes of the subjects' sports activities. In this study, the Cronbach's Alpha coefficient for the scale was 0.685. This coefficient reflects the internal consistency reliability of the scale. Although the value is slightly below the commonly used threshold of 0.7, it is justified for two reasons: First, the core function of this scale is to objectively describe physical exercise behavior through multiple dimensions (intensity, duration, frequency). Each item corresponds to a distinct behavioral dimension, and the behavioral heterogeneity across dimensions may result in slightly lower internal consistency. Second, a review of past application studies of this revised scale shows that its Cronbach's Alpha coefficient generally falls within the 0.65–0.75 range, consistent with the measurement characteristics of this type of behavioral assessment scale. Third, this study employs an adequate sample size ($n = 505$). A larger sample can partially compensate for the slight deficiency in reliability coefficients. Moreover, the scale's construct validity has been validated in previous research, making it suitable for measuring physical exercise levels in this study.

Social anxiety scale

The subjective feelings of social anxiety were measured using the Interaction Anxiety Scale developed by Leary using the Clinical Experience Method²⁸. The scale consists of 15 items across a single dimension. It employs a 5-point Likert scale, with items 3, 6, 10, and 15 reverse-scored while the remaining items are forward-scored. Higher scores indicate greater severity of social anxiety. In this study, the Cronbach's Alpha coefficient for the scale was 0.921, indicating extremely high internal consistency reliability and strong homogeneity among items. This confirms the scale's ability to reliably measure the core dimension of adolescent social anxiety.

Perceived social support scale

The Chinese version of the Perceived Social Support Scale developed by Zimet²⁹ and revised by Jiang Qianjin et al.³⁰ was used, with a total of 12 items, including three dimensions: family support, friend support, and other

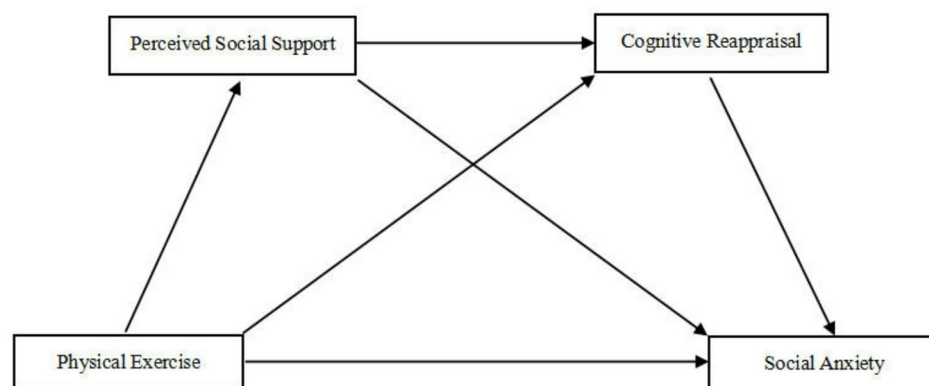


Fig. 1. Hypothetical model.

support, and a 5-point Likert scale was used, with higher scores on the dimensions indicating a higher degree of perceived social support. In this study, the Cronbach's Alpha coefficient for the scale was 0.960, indicating excellent internal consistency reliability. This demonstrates the scale's ability to reliably capture individuals' subjective perceptions of social support.

Emotion regulation scale

The cognitive reappraisal scale from the revised emotion regulation scale by Wang Li et al.³¹ was used, which consists of 10 entries, and the cognitive reappraisal scale consists of 6 entries, including 1, 3, 5, 7, 8, and 10. A 5-point Likert scale was used, with higher scores indicating a higher frequency of using cognitive reappraisal strategies. In this study, the Cronbach's Alpha coefficient for the scale was 0.963, indicating excellent internal consistency reliability. The item design effectively reflects individuals' use of cognitive reappraisal strategies.

Research methods

During the data processing phase of the survey questionnaire, Excel tools were first employed to complete the entry and organization of raw data. Invalid questionnaires with non-standard responses were filtered out based on predefined criteria to ensure the accuracy of the foundational data. For the valid data after preliminary processing, subsequent statistical analysis was conducted using SPSS statistical software and its PROCESS add-on. Specifically, Harman's single-factor analysis was first applied to examine whether common method bias existed in the data, thereby eliminating systematic errors at the methodological level. Subsequently, Pearson correlation analysis was employed to delve into the strength and direction of associations among core variables. Furthermore, leveraging the built-in Bootstrap sampling program within the PROCESS add-on, the significance of chained mediating effects was tested, providing evidence to validate the indirect causal mechanisms between variables.

Research results and analysis

Common method bias test

To eliminate potential common method bias in the questionnaire survey, Harman's one-factor test was employed. Using SPSS 27.0, unrotated principal component extraction was performed on all core variables. Results indicated five factors with eigenvalues greater than 1, with the first factor explaining 45.74% of variance below the 50% critical threshold³². This confirms no significant common method bias in the data. Subsequent analyses will further mitigate potential bias through methods such as controlling variables.

Descriptive statistics

Descriptive statistical analysis indicates that the sample comprised 505 students, including 242 males (47.9%) and 263 females (52.1%). This suggests a relatively balanced representation of male and female adolescents among survey participants. Regarding grade levels, junior high school students constituted the largest group with 256 participants (50.7%), followed by senior high school students at 207 (41%), and college students at 42 (8.3%), as shown in Table 1.

Differences in physical exercise, social anxiety, perceived social support and cognitive reappraisal among adolescents of different genders were analyzed using independent samples t-test. The results showed that boys were better than girls in physical exercise, while girls had higher levels of social anxiety than boys, but girls were better than boys in perceived social support and cognitive reappraisal, as shown in Table 2.

ANOVA one-way analysis was used to analyze the differences in physical exercise, social anxiety, perceived social support and cognitive reappraisal among adolescents at different educational stages. The results showed that there was no significant difference between adolescents of different stages in the dimension of physical exercise, while in the dimension of social anxiety, adolescents of different educational stages showed significant differences. There was no significant difference between adolescents of different stages in terms of perceived social support and cognitive reappraisal. As shown in Table 3.

Correlation analysis of variables

Pearson correlation analysis was conducted on all variables. The results revealed a significant positive correlation between physical exercise and perceived social support as well as cognitive reappraisal. All three variables showed a significant negative correlation with social anxiety, as shown in Table 4. Since gender was significantly correlated with physical exercise and social anxiety, and there was also a significant correlation between educational stage and social anxiety, both were studied as control variables in the regression analyses conducted later.

Demographic variables	Classification	Quantities	Proportion
Gender	Male student	242	47.9%
	Female student	263	52.1%
Educational stage	Middle school	256	50.7%
	High school	207	41%
	University	42	8.3%

Table 1. Distribution of demographic variables among survey participants.

	Gender	M ± SD	t	p
Physical exercise	Male	27.93 ± 21.87	5.282	<0.001
	Female	18.28 ± 18.95		
Social anxiety	Male	2.55 ± 0.78	-3.236	0.001
	Female	2.78 ± 0.77		
Perceived social support	Male	3.55 ± 0.94	-1.666	0.096
	Female	3.67 ± 0.79		
Cognitive reappraisal	Male	3.61 ± 0.98	-1.327	0.185
	Female	3.72 ± 0.84		

Table 2. Independent samples t-tests for physical exercise, social anxiety, perceived social support, and cognitive reappraisal. ** $P < 0.01$, *** $P < 0.001$.

Core Variable	Educational Stage	M ± SD	F	P
Physical exercise	Middle school	22.58 ± 19.19	0.225	0.798
	High school	23.58 ± 23.02		
	University	21.55 ± 20.81		
Social anxiety	Middle school	2.56 ± 0.76	4.886	0.008
	High school	2.77 ± 0.78		
	University	2.80 ± 0.84		
Perceived social support	Middle school	3.67 ± 0.85	1.507	0.223
	High school	3.53 ± 0.87		
	University	3.67 ± 0.93		
Cognitive reappraisal	Middle school	3.68 ± 0.92	0.796	0.451
	High school	3.62 ± 0.89		
	University	3.81 ± 0.94		

Table 3. ANOVA single-factor analysis of physical exercise, social anxiety, perceived social support, and cognitive reappraisal.

	Physical exercise	Social anxiety	Perceived social support	Cognitive reappraisal
Physical exercise	1			
Social anxiety	-0.473***	1		
Perceived social support	0.322***	-0.578***	1	
Cognitive reappraisal	0.332***	-0.560***	0.827***	1

Table 4. Correlational analysis of physical exercise, social anxiety, perceived social support, and cognitive reappraisal. * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Mediation analysis

First, the overall fit of the chained mediation model was examined. The results indicate that all model fit indices are satisfactory: $\chi^2/df = 3.825$, CFI = 0.891, GFI = 0.870, AGFI = 0.840, TLI = 0.883, NFI = 0.858, RMSEA = 0.075. This demonstrates that the chained mediation model fits the data well and is acceptable.

To examine the effect of physical exercise on social anxiety and its mediating mechanism, gender and educational level were first included as control variables in the model. The independent variable physical exercise was then introduced. Results indicated that physical exercise significantly and negatively predicted social anxiety ($\beta = -0.467$, $P < 0.001$), confirming that the overall effect of physical exercise on social anxiety holds after controlling for irrelevant variables and validating Hypothesis H1. Subsequently, mediating variables were added to the model. The analysis revealed: on one hand, physical exercise significantly and positively predicted perceived social support ($\beta = 0.359$, $P < 0.001$) and cognitive reappraisal ($\beta = 0.077$, $P < 0.01$), and perceived social support significantly and positively predicted cognitive reappraisal ($\beta = 0.803$, $P < 0.001$); On the other hand, perceived social support ($\beta = -0.314$, $P < 0.001$) and cognitive reappraisal ($\beta = -0.217$, $P < 0.001$) both significantly negatively predicted social anxiety, while physical exercise's direct prediction of social anxiety remained significant ($\beta = -0.275$, $P < 0.001$). All paths met significance criteria, confirming the validity of both the independent mediations by perceived social support and cognitive reappraisal, as well as their chained mediation. This validates Hypotheses H2 and H3, as shown in Table 5.

To validate the reliability of the mediating effect, a Bootstrap test (with 5000 samples and percentile confidence intervals) was employed to analyze the total effect, direct effect, and mediating effect of physical exercise on

Equation of regression		Significance of regression coefficients			Overall fit index		
Result variable	Variable of prediction	β	t	p	R	R ²	F
Social anxiety	Physical exercise	−0.467	−11.679	0	0.492	0.242	53.363
	Gender	0.030	0.750	0.454			
	Educational stage	0.131	3.352	<0.001			
Perceived social support	Physical exercise	0.359	8.392	0	0.360	0.130	24.948
	Gender	0.160	3.720	<0.001			
	Educational stage	−0.051	−1.214	0.225			
Cognitive reappraisal	Physical exercise	0.077	2.808	0.005	0.831	0.691	279.080
	Perceived social support	0.803	30.107	0			
	Gender	0.016	0.600	0.549			
	Educational stage	0.042	1.691	0.091			
Social anxiety	Physical exercise	−0.275	−7.579	0	0.681	0.464	86.344
	Perceived social support	−0.314	−5.319	0			
	Cognitive reappraisal	−0.217	−3.686	<0.001			
	Gender	0.111	3.251	0.001			
	Educational stage	0.115	3.488	<0.001			

Table 5. Regression analysis of the mediating model between perceived social support and cognitive reappraisal in physical exercise and social anxiety.

Effect	Trails	Effect value	Standard error	95% confidence interval	Effect ratio
Total effect		−0.0173	0.0015	[−0.0202, −0.0144]	100%
Direct effect	Direct path	−0.0102	0.0013	[−0.0128, −0.0076]	58.96%
Total indirect effect		−0.0071	0.0011	[−0.0093, −0.0051]	41.04%
	Ind1	−0.0042	0.0010	[−0.0064, −0.0024]	24.28%
Indirect effect	Ind2	−0.0006	0.0003	[−0.0013, −0.0001]	3.47%
	Ind3	−0.0023	0.0008	[−0.0039, −0.0009]	13.29%

Table 6. Analysis of the mediating effects of perceived social support and cognitive reappraisal in the relationship between physical exercise and social anxiety.

social anxiety. Results indicate: The total effect value of physical exercise on social anxiety is −0.0173, with a 95% confidence interval [−0.0202, −0.0144] that does not include zero, indicating a significant total effect. The direct effect of physical exercise on social anxiety was −0.0102, with a 95% confidence interval [−0.0128, −0.0076] also excluding zero, confirming a significant direct effect (accounting for 58.96% of the total effect). Furthermore, the confidence intervals for the mediating effects of perceived social support and cognitive reappraisal both excluded zero, further validating the significance of the mediating effects, as shown in Table 6.

Further validation of the indirect pathway through which physical exercise influences social anxiety: Results indicate a total indirect effect value of −0.0071 (accounting for 41.04% of the total effect), with its 95% confidence interval [−0.0093, −0.0051] excluding zero. This indicates a significant overall indirect mediating effect, achieved through three specific pathways: First, “Physical Exercise → Perceived Social Support → Social Anxiety” (Path 1, effect value −0.0042, accounting for 24.28%); second, “Physical Exercise → Cognitive Reappraisal → Social Anxiety” (Path 2, effect size −0.0006, accounting for 3.47%); third, “Physical Exercise → Perceived Social Support → Cognitive Reappraisal → Social Anxiety” (Path 3, chain effect size −0.0023, accounting for 13.29%). The effects of all three paths met the criterion that their confidence intervals did not include zero, confirming that both the independent mediation and chain mediation of perceived social support on cognitive reappraisal were established, thereby validating research hypothesis H4.

Based on the above findings, the chain mediation model was derived as shown in Fig. 2.

Discussion

The effect of physical exercise on social anxiety in adolescents

The findings of this study indicate that physical exercise exhibits a significant negative correlation with social anxiety among adolescents. Furthermore, after incorporating mediating variables, the negative predictive effect of physical exercise on social anxiety remains significant, supporting Research Hypothesis H1 and aligning with the conclusions of Stubbs et al.³³. Regarding the underlying mechanisms, physical exercise not only directly improves social anxiety by promoting the secretion of neurotransmitters such as catecholamines and endorphins³⁴, but also indirectly alleviates anxiety through psychosocial pathways like enhancing self-efficacy and psychological capital³⁵. However, the alleviating effects of physical exercise vary across different groups:

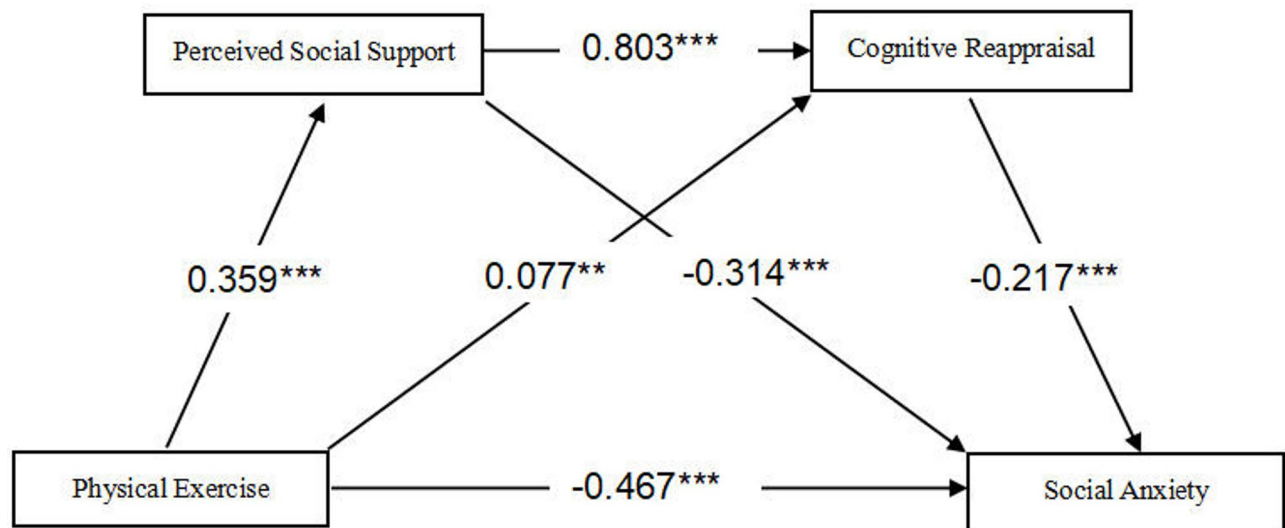


Fig. 2. A chain mediation effect model of perceived social support and cognitive reappraisal.

although males exhibited significantly higher levels of physical exercise than females, their social anxiety levels were lower. This discrepancy may be related to societal expectations regarding emotional expression between genders, differences in participation patterns, and coping strategies. simultaneously, despite no significant differences in physical exercise levels among adolescents across educational stages, their social anxiety intensifies with increasing educational level, suggesting developmental factors like academic pressure and identity transitions may significantly influence anxiety states³⁶. Furthermore, while most studies support the positive effects of physical exercise on anxiety, these effects are moderated by exercise type, intensity, and frequency. Some studies even suggest that high-intensity exercise may temporarily increase anxiety experiences³⁷, indicating that future interventions should emphasize individualized program design to achieve optimal benefits.

Mediating effects of perceived social support between physical exercise and social anxiety

This study validated the mediating role of perceived social support between physical exercise and adolescent social anxiety, supporting Hypothesis H2. The findings align with Cohen et al.'s³⁸ perspective that social support, as a vital psychological resource, can mitigate the adverse effects of stressful events. However, data analysis revealed group differences warranting further exploration: Although females scored higher than males on perceived social support, their social anxiety levels were significantly higher. This seemingly contradictory finding may reflect the complex influence of gender socialization on anxiety perception and expression—females may be more sensitive to interpersonal evaluations, and even when perceiving higher support, they may experience heavier emotional burdens when coping with social situations. Concurrently, data across educational stages indicate that while junior high students exhibit comparable levels of perceived social support to college students, their social anxiety levels are significantly lower. This discrepancy may stem from differences in dominant support sources and their psychological functions across developmental stages. The study reveals that the psychological benefits of social support are not linear or singular, but are jointly moderated by individual developmental stage, gender roles, and the match between support sources and contexts. Therefore, future research should further examine the conditional mechanisms of social support effectiveness and its differentiated pathways across groups to avoid oversimplifying its underlying mechanisms.

Mediating effects of cognitive reappraisal between physical exercise and social anxiety

The findings confirm that cognitive reappraisal mediates the relationship between physical exercise and adolescent social anxiety, supporting Hypothesis H3. This aligns with Gross et al.'s³⁹ theoretical perspective that cognitive reappraisal serves as an adaptive emotion regulation strategy. However, in-depth analysis of group differences revealed that although females scored higher than males on cognitive reappraisal, their levels of social anxiety were significantly higher. This seemingly contradictory result may reflect gender differences in the effectiveness of emotion regulation strategy use: while females are more inclined to employ cognitive reappraisal, their heightened sensitivity to evaluation in social situations may diminish the mitigating effects of this strategy. Additionally, while no significant differences in cognitive reappraisal were observed across educational stages, social anxiety intensified with increasing grade levels. This partially contradicts Giles et al.'s⁴⁰ findings that exercise enhances cognitive reappraisal, suggesting the anxiety-reducing effects of cognitive reappraisal may be moderated by stage-specific developmental stressors. Furthermore, the study found a relatively small mediation effect size for cognitive reappraisal (3.47%), contrasting with Hofmann et al.'s⁴¹ report of its significant predictive role for social anxiety. This discrepancy may stem from partial attribution of its effects to the perceived social support pathway within the chained mechanism examined here. These findings indicate that the role of cognitive reappraisal in the process of physical exercise influencing social anxiety is not isolated but intertwined with

gender characteristics, developmental stages, and other psychological mechanisms. Future research will further explore its boundary conditions for effectiveness and group applicability.

Chain-mediated effects of perceived social support and cognitive reappraisal between physical exercise and social anxiety in adolescents

This study employed a chain mediation model to reveal the multifaceted pathways through which physical exercise influences adolescents' social anxiety, confirming that perceived social support and cognitive reappraisal play crucial chain mediating roles. Findings indicate that physical exercise not only directly predicts social anxiety negatively ($\beta = -0.467$) but also exerts effects through independent mediating pathways of perceived social support (24.28% of variance explained) and cognitive reappraisal (3.47% of variance explained), as well as a chained pathway involving both perceived social support and cognitive reappraisal (13.29% of variance explained). This mechanism indicates that physical exercise not only enhances adolescents' perceived social support levels but also forms a complete pathway from external resource perception to internal cognitive restructuring by improving their cognitive reappraisal abilities. Specifically, physical exercise promotes perceived social support levels by providing social interaction contexts ($\beta = 0.359$), while high perceived social support creates favorable conditions for employing cognitive reappraisal strategies ($\beta = 0.803$), ultimately jointly alleviating social anxiety. This study offers a new theoretical perspective for comprehensively understanding the underlying mechanisms through which physical exercise influences adolescents' social anxiety, while also providing empirical evidence for designing multi-level, sequential psychological intervention programs in the future.

Conclusions

This study reveals the alleviating effect of physical exercise on adolescents' social anxiety and its underlying mechanisms. Data analysis leads to the following conclusions: (1) Significant correlations exist among physical exercise, social anxiety, perceived social support, and cognitive reappraisal. (2) Physical exercise negatively predicts adolescents' social anxiety. (3) Physical exercise indirectly negatively predicts adolescents' social anxiety through perceived social support and cognitive reappraisal. This mediating effect encompasses three pathways: individual mediating effects of perceived social support and cognitive reappraisal, as well as a chain mediating effect from perceived social support to cognitive reappraisal.

Limitations and future directions

This study has several limitations. First, the sample primarily originated from Liaoning, Chongqing, and Shandong provinces; future research should expand the sampling scope to enhance the generalizability of findings. Second, the cross-sectional design precludes establishing causal relationships. Subsequent studies could employ six-month or one-year longitudinal follow-ups, or design standardized physical exercise interventions lasting 12 weeks with three sessions per week at moderate intensity to validate temporal relationships among variables. Additionally, this study did not examine other potential mediating variables such as self-esteem and coping styles: physical exercise may alleviate social anxiety by enhancing body self-esteem, or by improving problem-focused coping to promote cognitive reappraisal strategies. Future research could construct integrated models incorporating pathways such as "physical exercise $\rightarrow$ self-esteem $\rightarrow$ social anxiety" and "physical exercise $\rightarrow$ coping styles $\rightarrow$ cognitive reappraisal $\rightarrow$ social anxiety" to more comprehensively elucidate the psychological mechanisms through which physical exercise influences adolescents' social anxiety.

Data availability

Data is provided within the manuscript or supplementary information files.

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Author contributions

BTQ was responsible for the data analysis and writing of the original draft preparation. JY was responsible for data analysis and methodology. BTQ was responsible for the conceptualization, writing, reviewing and editing the draft. JY was responsible for the conceptualization, writing, reviewing and editing the draft, and funding acquisition. All authors have read and approved the final manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Ethical approval

The design of this study followed the guidelines and regulations of the Declaration of Helsinki and approved by Ethics Committee of Liaoning Normal University (LL2025090), and informed consent was obtained from all subjects and their legal guardians.

Informed consent

Informed consent was obtained from all subjects involved in the study.

Additional information

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