

RESEARCH

Open Access



A study on the relationship between high school students' sleep quality, physical exercise, academic stress, and subjective well-being

Ruirui Cheng¹, Lei Yang¹ and Suh-Jung Kang^{2*}

Abstract

Objective This Research explores the intermediary function of academic stress and sleep quality in the connection between physical exercise and subjective well-being among high school students.

Methods This Research conducted an online survey through random sampling with a sample of 540 (males = 310, females = 217; grade 10 = 159, grade 11 = 190, grade 12 = 178) high school students to explore the intermediary function of academic stress and sleep quality between physical exercise and subjective well-being. The participants were surveyed using PSQI, the Subjective Well-Being Scale, the ESSA, and PSQI. SPSS Statistics 26 was used to conduct reliability and validity tests, descriptive statistics, and correlation analysis. Mediation analysis was conducted utilizing Model 6 from the PROCESS 4.0 plugin.

Results (1) Physical exercise shows a significant positive correlation with subjective well-being, and the direct impact of physical exercise on subjective well-being is also significant. (2) Physical exercise adversely affects academic stress and positively influences sleep quality. Academic stress negatively impacts sleep quality and subjective well-being, while sleep quality positively influences subjective well-being. (3) Academic stress and sleep quality serve as significant mediators between physical exercise and subjective well-being. The mediation effect encompasses two indirect paths: In one aspect, physical exercise has an indirect impact on subjective well-being through its influence on academic stress; in another aspect, physical exercise indirectly affects subjective well-being via the chain mediation effects of academic stress and sleep quality.

Conclusion Physical exercise can directly influence the subjective well-being of high school students. Additionally, physical exercise can indirectly impact their subjective well-being through academic stress, and it can also indirectly influence their subjective well-being through the chain mediation effect of academic stress and sleep quality. Based on these findings, it is recommended that schools provide more opportunities for physical exercise, integrated with psychological counseling and sleep management, to help students effectively alleviate academic stress, thereby enhancing their overall well-being.

*Correspondence:
Suh-Jung Kang
suhjkang@163.com

Full list of author information is available at the end of the article



© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by-nc-nd/4.0/>.

Keywords Subjective well-being, Physical exercise, Academic stress, Sleep quality

Introduction

Subjective well-being (SWB) is a key psychological trait in positive psychology, referring to a person's comprehensive assessment of their life quality according to their own criteria [1]. It's highly subjective and consists of two components: life satisfaction and emotional experience. Emotional experience can be further divided into the increase of favorable emotions and the reduction of unpleasant emotions [2]. Research shows that SWB is crucial for both physical and mental health [3, 4]. It not only enhances overall happiness in adolescents but also strengthens psychological resilience, helping them better cope with the various challenges in their academic and personal lives [5, 6]. However, recent studies have revealed an overall drop in adolescents' SWB, with this trend being particularly pronounced among high school students [7, 8]. This decline has garnered significant attention from researchers, as a decrease in SWB may not only impact academic performance but also exacerbate mental health issues, potentially creating a negative cycle [9]. During high school, students' psychological development transitions from semi-maturity and immaturity to full maturity. During this period, they experience intense emotional fluctuations and often face significant academic stress (AS), which can lead to psychological issues such as anxiety [10] and depression [11], severely impacting their physical and mental well-being [12]. The latest report from the World Mental Health Organization indicates that approximately 14% of adolescents worldwide are affected by mental disorders [13]. In China, high school students face immense AS, particularly due to the highly competitive college entrance examination system, which significantly impacts their psychological well-being and sleep quality (SQ) [14]. Excessive academic workload and exam preparation stress result in most high school students getting less than eight hours of sleep, with limited opportunities for physical exercise (PE), contributing to increasingly severe mental health issues [15, 16]. Against this backdrop, PE has emerged as a non-pharmacological intervention offering a new pathway to alleviate AS and improve psychological well-being.

The direct impact of physical exercise on SWB

PE is a conscious activity in which individuals actively transform and enhance their own well-being. It encompasses various forms of activity, including fitness exercises, recreational sports, health and rehabilitation exercises, and mental and intellectual training. Previous studies have demonstrated that PE is essential for improving SWB [17, 18]. Through regular PE, individuals can enhance their physical fitness while also boosting

the release of neurotransmitters like endorphins, which help combat depression, improve mood, reduce negative emotions, and increase positive emotions. This combined enhancement of both physiological and psychological aspects positions PE as a key avenue for improving SWB [18, 19]. Self-Determination Theory (SDT) is a fundamental framework for understanding motivation and SWB. According to SDT, PE can fulfill individuals' basic psychological needs, particularly autonomy, competence, and relatedness [20]. Jetzke and Mutz [20] found that PE has a notable positive impact on SWB. PE can meet individuals' needs for autonomy and a sense of control, thereby leading to positive emotional experiences and higher SWB. Additionally, during PE, individuals experience social interactions that allow them to perceive greater social support and develop a positive self-assessment, thereby enhancing their SWB [21]. Thus, PE not only brings improvements at both physiological and psychological levels but also fulfills individuals' multi-layered needs through social interaction, making it an effective means of boosting SWB.

The mediating role of academic stress

AS denotes the stress and unease that stem from the pressures imposed by school, family, and society throughout the learning journey [22]. An increase in AS is often accompanied by the emergence of mental health issues. Existing research indicates that when students face heavy academic workloads and exam pressures, they often struggle to experience joy and a sense of accomplishment in life. This directly impacts their SWB, involving overall life contentment and the experience of positive feelings [23, 24]. The greater the AS, the stronger the feelings of unhappiness, and individuals may experience more negative emotions [25]. If this state persists, individuals are likely to develop learned helplessness, which in turn reduces their SWB. Jiang et al. [26] also indicated that AS can influence adolescents' SWB through self-regulation and parent-child conflict. An increase in AS ultimately leads to a decline in SWB. This indicates that excessive AS can reduce SWB.

PE also holds a significant position in alleviating AS. Studies have indicated that combining moderate-intensity exercise with psychological training aids individuals in managing psychological stress more effectively and promotes mental health [27]. Through consistent PE, students can effectively manage stress, release negative emotions, and ultimately enhance their SWB [28, 29]. For instance, Demir and Barut [30] found that through engaging in PE, individuals can not only manage stress efficiently but also strengthen psychological resilience,

helping to eliminate negative emotions like anxiety and improve SWB. This suggests that AS serves as a mediator between PE and SWB. By alleviating AS, PE can indirectly enhance individuals' SWB, thus becoming an effective approach to improving mental health and increasing well-being.

The mediating role of sleep quality

SQ issues, including sleeplessness, recurring nightmares, late nights, and inadequate rest [31], are considered key factors affecting high school students' mental health and academic performance. Currently, sleep problems are widespread among adolescents, with 75% of high school students reporting that their sleep duration is significantly less than the recommended 8 h [32]. Insufficient sleep leads to poor sleep hygiene, frequent sleep problems [33], and a high prevalence of sleep disorders [34], making overall SQ concerning. High school students need adequate energy to efficiently complete academic tasks, but poor SQ often results in daytime drowsiness, fatigue, sleepiness, lack of concentration, memory decline, and low mood [35, 36]. These issues are frequently accompanied by mental health challenges like anxiety and depression [37]. Research has found that insufficient sleep increases the likelihood of emotional deficits [38]. Further research by Wang et al. [37] found that sleep may be closely associated with the prefrontal cortex, which is responsible for emotion regulation and cognitive functions. Adequate sleep helps maintain a positive emotional state, encouraging the expression of positive feelings while minimizing negative ones, thereby enhancing individuals' SWB. This suggests that improving SQ can enhance individuals' SWB.

PE significantly influences the enhancement of SQ. Research has demonstrated that engaging in PE can diminish the occurrence of anxiety, improve SQ, and be especially beneficial for adolescents who experience daytime sleepiness [39, 40]. Additionally, PE can increase the production of melatonin, regulate the sleep-wake cycle, and help with faster sleep onset [41]. An appropriate level of exercise intensity can lead to physical fatigue, prompting the brain to respond by extending deep sleep duration [42]. However, excessive physical exertion and overly frequent high-intensity activities may lead to difficulty falling asleep or even insomnia [43]. Tomás et al. [44] found that exercise habits are essential for high school students' sleep; appropriate PE can prevent declines in SQ, though the timing of exercise should be managed carefully. Research on college students has also shown that PE helps improve SQ, further enhancing SWB [45]. This indicates that SQ mediates the relationship between PE and SWB, as PE can indirectly promote SWB by improving SQ.

Analysis of the serial mediating effect of AS and SQ on high school students' SWB

Previous studies have found that AS has a significant impact on SQ [46]. The greater the AS, the poorer the SQ [47]. Gündoğan [46] found in research on college students that AS can not only directly affect SQ but also indirectly influence it through academic burnout. Deng et al. [48], in an investigation concerning Chinese teenagers, also found that as AS increases, adolescents' SQ significantly decreases [42]. This possibly related to the underlying consequences of unpleasant emotions, including worry and restlessness, which interfere with normal sleep cycles, ultimately resulting in poorer SQ. Research focusing on high school students has further revealed the specific characteristics of the relationship between AS and SQ. Compared to other student groups, high school students experience particularly pronounced levels of AS and sleep problems. In China, high school students are immersed in a highly competitive learning environment and endure substantial AS, which often results in insufficient sleep [49]. Moreover, a study by Kang et al. [50] comparing the sleep duration of Chinese high school and middle school students found that high school students sleep significantly less on both weekdays and weekends. Due to the dual influences of high school students' physiological characteristics (e.g., a tendency for later bedtimes) and social environment (e.g., strict school management and intense competition for higher education), the negative impact of AS on SQ may be further exacerbated. Thus, while studies on other age groups provide valuable references, the unique context and specific mechanisms affecting high school students require more in-depth exploration.

Stress-Coping Theory (SCT) emphasizes that individuals adopt different coping strategies when facing stress to mitigate its negative impact on mental health. According to this theory, moderate PE, as an effective coping mechanism, can help alleviate AS, indirectly improve SQ, and ultimately enhance SWB [51]. Individuals can alleviate AS through the positive physiological and psychological effects of PE. Regular participation in PE fosters the secretion of neurotransmitters like endorphins, helping individuals reduce stress and anxiety, thereby enabling them to cope with academic tasks more calmly [19, 52]. The reduction of AS not only directly benefits mental health but also improves SQ, which in turn further enhances SWB [53]. As AS decreases, individuals' SQ also significantly improves. Further research by Huang et al. [54] found that sustained perception of stress activates the body's stress response, resulting in hormonal changes like elevated cortisol levels. This disruption interferes with sleep regulation and impacts sleep cycles and quality. Sleep aids in individual recovery, and good sleep helps regulate emotions and minimize the prevalence of

negative feelings, thereby further boosting SWB [55]. In summary, PE alleviates AS, which in turn improves SQ, and improved SQ further enhances SWB. This chain mediation effect reveals the multi-level influence of PE on enhancing SWB.

Although previous studies have explored the relationship between PE and SWB among high school students, the mechanism involving AS and SQ as chain mediators has not been thoroughly investigated. Therefore, this study focuses on high school students and, based on the psychophysiological framework from existing literature, aims to uncover how PE influences SWB through pathways involving AS and SQ. This research seeks to provide theoretical support for the development of more effective mental health intervention strategies as illustrated in Fig. 1. The subsequent research hypotheses are presented:

Hypothesis 1 PE significantly and positively influences SWB.

Hypothesis 2 AS acts as an intermediary in the connection between PE and SWB.

Hypothesis 3 SQ functions as an intermediary in the link between PE and SWB.

Hypothesis 4 AS and SQ act as a chain intermediary in the connection between PE and SWB.

Research methods

Sample and data collection procedure

In this study, to minimize selection bias, ensure the representativeness of the sample, and enhance the external validity and generalizability of the findings, a random sampling method was employed for the distribution and collection of questionnaires. In May 2024, participants were randomly selected from First Senior High School of Shangqiu and SHANGQIUSHI Hui MIN ZHONG XUE.

The data were gathered through the Wenjuanxing online survey tool (<https://www.wjx.cn/>). First, the research team coordinated with the teachers of each class, and the teachers introduced the survey's goals and importance were explained to the students in the classroom. The teachers then randomly selected students within each class to participate in the survey, ensuring the randomness and representativeness of the sample. Following this process, teachers shared the questionnaire link in the class group chat, allowing students to voluntarily decide whether to participate. A total of 540 responses were gathered, and after omitting incomplete or insincerely completed questionnaires, 496 valid responses were gathered, resulting in a valid response rate of 91.85%. The participants included 292 males and 204 females. All participants were informed before completing the questionnaire. The criteria for excluding invalid questionnaires are as follows: (1) Questionnaires with more than five items missing responses (a valid questionnaire is defined as one with at least 80% of the items completed; missing responses $\geq 20\%$ are considered invalid); (2) Questionnaires in which $\geq 80\%$ of the items are rated as either "strongly agree" or "strongly disagree," to avoid severe floor or ceiling effects that could compromise the accuracy of data analysis.

Measurement tools

Demographic characteristics

The demographic characteristics include gender (292 males, 204 females), grade level (150 in Grade 10, 181 in Grade 11, 165 in Grade 12), household registration location (423 from rural areas, 73 from urban areas), whether the participant is an only child (114 yes, 382 no), and whether the participant is a left-behind child (53 yes, 443 no) (see Table 1). In addition, we also collected the income levels of their parents as socioeconomic information. There were 34 participants with a parental income of 0–2000 RMB, 42 with 2000–3000 RMB, 81 with 3000–5000 RMB, 221 with 5000–8000 RMB, 99 with

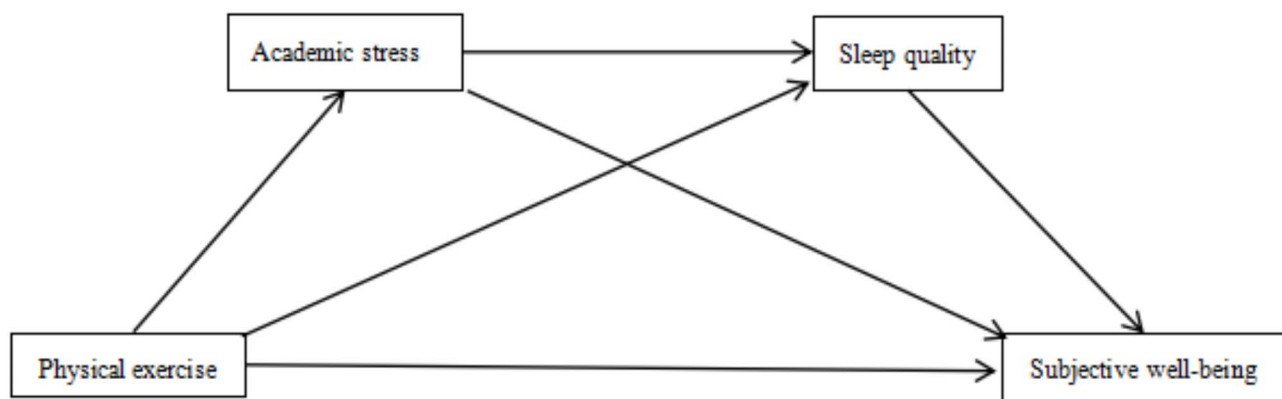


Fig. 1 Research model

Table 1 Descriptive analysis of population characteristics

	Total	grade			Household registration location		Only child		Left-behind children	
		Grade 10	Grade 11	Grade 12	rural	urban	yes	no	yes	no
Gender										
Males	292	92	105	95	245	47	69	223	33	259
Females	204	58	76	70	178	26	45	159	20	184
Total	496	150	181	165	423	73	114	382	53	443

Note: Descriptive statistics for each population characteristic (gender, grade, household registration location, only child, and left-behind children)

8000–15,000 RMB, 16 with 15,000–30,000 RMB, and 3 with an income above 30,000 RMB.

Subjective well-being scale

This study utilized the well-being index scale(WBIS) designed by Campbell [56]. It includes 9 items (For example: I believe life is full of hope) encompassing two dimensions: Overall Affect Index (8 items) and Life Satisfaction (1 item). The scale adopts a 7-point Likert scoring system, spanning from 1 (indicating strong disagreement) to 7 (indicating strong agreement). To ensure consistency with the original scale, this study did not make any modifications to the content or structure of the items. WBIS is calculated by adding the mean score of the Overall Affect Index (weight 1) to the score of the Life Satisfaction dimension (weight 1.1). If item 8 is unanswered, it is treated as missing data and excluded from the overall summation. The score ranges from 2.1 (least happy) to 14.7 (most happy), with higher scores reflect greater SWB. In this research, the scale’s reliability, measured by Cronbach’s alpha, is 0.893.

Sleep quality scale

This study employed the Pittsburgh Sleep Quality Index (PSQI) designed by Buysse et al. [57]. The questionnaire consists of 18 items (For example: In the past month, I have had difficulty falling asleep at night (unable to fall asleep within 30 min)) and includes seven factors: SQ, time taken to fall asleep, length of sleep, sleep effectiveness, disturbances during sleep, use of sedative medications, and functional impairment during the day. Each factor is rated on a scale from 0 to 3. This scale has demonstrated good reliability and validity in high school student populations [58]. To ensure consistency with the original scale, this study did not make any modifications to the content or structure of the items, and the cumulative score of the seven factors represents the overall SQ (PSQI total score). Higher scores reflect worse SQ. In this study, the Cronbach’s alpha for the scale is 0.865.

Physical activity scale

This study used the Physical Activity Rating Scale (PARS-3) designed by Liu et al. [59], which consists of 3 items (For example: How many minutes do you spend on each session of the above-intensity physical activity)

measuring physical activity intensity, duration, and frequency. It employs a 5-point Likert scale, with scores ranging from 1 to 5. To ensure consistency with the original scale, this study did not make any modifications to the content or structure of the items. The total activity score is calculated as: Activity Level = Intensity Score × (Duration Score – 1) × Frequency Score, with a score spanning from 0 to 100. In this research, the scale’s reliability, measured by Cronbach’s alpha, is 0.717.

Academic stress scale

This study utilized the Educational Stress Scale for Adolescents (ESSA) developed by Sun et al. [60]. The scale consists of 16 items (For example: I am very dissatisfied with my academic performance) and covers five factors: academic pressure (4 items), workload (3 items), anxiety about grades (3 items), self-imposed expectations (3 items), and feelings of dissatisfaction (3 items). It employs a 5-point Likert scale, where responses range from 1 (strongly disagree) to 5 (strongly agree). A higher score reflects increased levels of stress. To ensure consistency with the original scale, this study did not make any modifications to the content or structure of the items. In this study, the Cronbach’s alpha for the scale is 0.935.

Statistical methods

Statistical analyses for this study were conducted using SPSS Statistics 26. First, descriptive statistics, correlation analysis, and reliability and validity tests were performed on the scale data to verify the basic characteristics. Subsequently, Model 6 in the PROCESS 4.0 plugin was used to conduct a serial mediation analysis, examining the indirect effects of PE on SWB through AS and SQ. In the mediation analysis, the Bootstrap method (with 5,000 resamples) was employed to test the confidence intervals of the mediation effects of key variables, enhancing the robustness of the analysis. Additionally, before conducting multivariate analysis, normality and common method bias tests were performed to ensure the reliability of the results and the appropriateness of the statistical methods.

Result

To ensure that the data met the assumptions for multivariate analysis and to enhance the accuracy and validity of the results, this study verified normality by examining

kurtosis and skewness. According to Kline [61], an absolute skewness value below 3 and an absolute kurtosis value under 10 are considered acceptable benchmarks. Thus, the primary variables in this research satisfy the requirements for normal distribution (refer to Table 2). The Q-Q plots for normal distribution can be found in Figs. 2, 3 and 4, and 5.

In addition, we used the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity to assess the suitability of the measurement instruments. The KMO value measures sample adequacy, with values greater than 0.5 generally considered appropriate for factor analysis. Bartlett's test of sphericity evaluates whether there is sufficient correlation among variables, with $p < 0.05$ indicating suitability for factor analysis. In this study (Table 2), the KMO values ranged from 0.679 to 0.972, and Bartlett's test of sphericity was significant, confirming the appropriateness for factor analysis.

Common variance bias test

To assess common method bias in the data, the Harman single-factor test was applied. The exploratory factor analysis revealed six factors with eigenvalues exceeding 1, with the first factor accounting for 32.479% of the variance, falling short of the critical threshold of 40% [62]. This suggests that common method bias does not pose an issue in this research.

Correlation matrix of each variable

The findings from the correlation analysis indicate significant relationships between PE, AS, SQ, and SWB. Specifically, PE is significantly negatively correlated with AS, while it is strongly positively associated with SQ and SWB. AS is strongly negatively associated with both SQ and SWB, and SQ is strongly positively associated with SWB (see Table 3).

In addition, this study employed the Variance Inflation Factor (VIF) to test for multicollinearity issues within the model. VIF values for all variables should be below 3.3 [63]. In this study, all variables had VIF values below 3.3 (Table 3), indicating that the model does not suffer from multicollinearity issues.

Additionally, to further control for the influence of grade-level differences on SWB and minimize the interference of individual factors on the research findings, a

one-way ANOVA was conducted to examine potential grade-level (Grade 10, Grade 11, and Grade 12) differences in key research variables, the results showed significant differences in all variables, as shown in Table 4. The results indicated significant differences across grade levels in PE ($F = 4.504, p < 0.05$), AS ($F = 22.797, p < 0.001$), SQ ($F = 24.748, p < 0.001$), and SWB ($F = 18.991, p < 0.001$). These findings highlight that grade-level differences are important factors in understanding PE, AS, SQ, and SWB. Future research could further explore how these differences affect other variables in the model.

Hypothesized model testing

Based on hierarchical regression analysis, the following model was established: PE, AS, and SQ were classified as independent variables, and SWB was classified as the dependent variable, grade level was used as a control variable. This model aimed to examine the main, direct, and indirect effects. Table 5 presents the chain mediation effect results from the hierarchical regression analysis.

The regression coefficient for PE on SWB ($\beta = 0.0579, t = 9.8753, p < 0.001$) indicates that increase in PE is associated with a significant increase in SWB, suggesting a direct positive effect of PE on SWB. PE strongly negatively impacts AS ($\beta = -0.2218, t = -7.7551, p < 0.001$), and SQ strongly positively affects SWB ($\beta = -0.1775, t = -10.9140, p < 0.001$). Additionally, AS significantly negatively impacts SQ ($\beta = 0.2196, t = 16.0823, p < 0.001$) (as shown in Table 5).

This research utilized the bias-corrected percentile Bootstrap approach (with 5,000 Bootstrap samples) and applied Model 6 from Hayes [64] SPSS macro PROCESS 4.2 to perform a chain intermediary effect analysis. This study aims to investigate the mediating roles of AS and SQ in the relationship between PE and SWB, while controlling for grade level.

The results of the Bootstrap chain intermediary analysis are displayed in Table 6; Fig. 2. The overall effect of PE on SWB was 0.0579 (95%CI= [0.0464, 0.0695]), which does not cross zero, suggesting that the overall effect is significant. The overall direct effect of PE on SWB was 0.0201 (95%CI= [0.0136, 0.0266]), confirming the presence of a significant direct effect. The overall indirect effect of PE on SWB was 0.0378 (95%CI= [0.0267, 0.0489]), which also does not cross zero. Specifically, the indirect effect

Table 2 Descriptive statistics of variables

Variables	N	M \pm SD	MIN	MAX	SK	Kur	KMO	Bartlett
PE	496	39.60 \pm 15.933	0	80.00	-0.043	0.005	0.679	< 0.001
AS	496	45.17 \pm 11.043	20.00	76.00	0.095	-0.332	0.972	0.000
SQ	496	9.42 \pm 3.963	0	20.00	0.134	-0.303	0.931	0.000
SWB	496	8.83 \pm 2.315	2.60	14.70	-0.021	-0.377	0.943	0.000

Note: N = sample size; M \pm SD = mean \pm standard deviation; MIN = minimum value; MAX = maximum value; SK = skewness; Kur = kurtosis; KMO = Kaiser-Meyer-Olkin measure of sampling adequacy; Bartlett = Bartlett's test of sphericity. P-values < 0.001 indicate that the variables are suitable for factor analysis

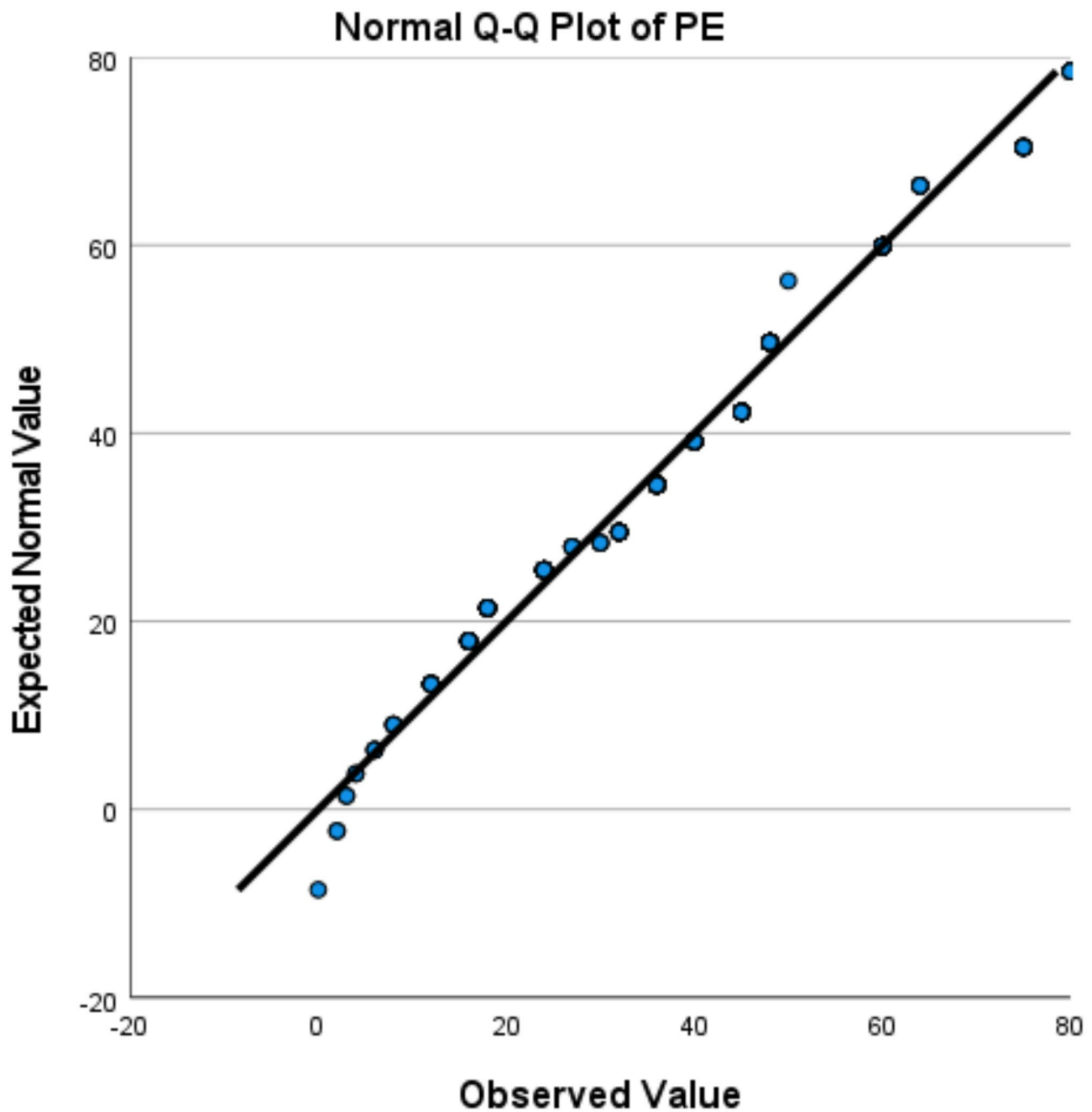


Fig. 2 PE Q-Q plots

of PE on SWB through AS ($\beta = 0.0280$, 95%CI= [0.0191, 0.0369]) is significant, indicating that AS partially mediates the relationship between PE and SWB. This suggests that PE not only directly impacts SWB but also reduces AS, which in turn contributes to improved SWB. Interestingly, the indirect effect of PE on SWB through SQ ($\beta = 0.0012$, 95%CI= [-0.0020, 0.0049]) was not significant, suggesting that the relationship between PE and SWB is not substantially mediated by SQ in this model. Additionally, the chain mediation effect of PE \rightarrow AS \rightarrow

SQ \rightarrow SWB was 0.0086 (95%CI= [0.0058, 0.0121]), suggesting that this model represents a partial chain intermediary effect. Based on the above description, the chain mediation model is illustrated in Fig. 6.

Discussion

This study explored the intermediary roles of AS and SQ in the connection between PE and SWB among Chinese high school students, validating and supporting Hypotheses 1, 2, and 4. The findings reveal that active

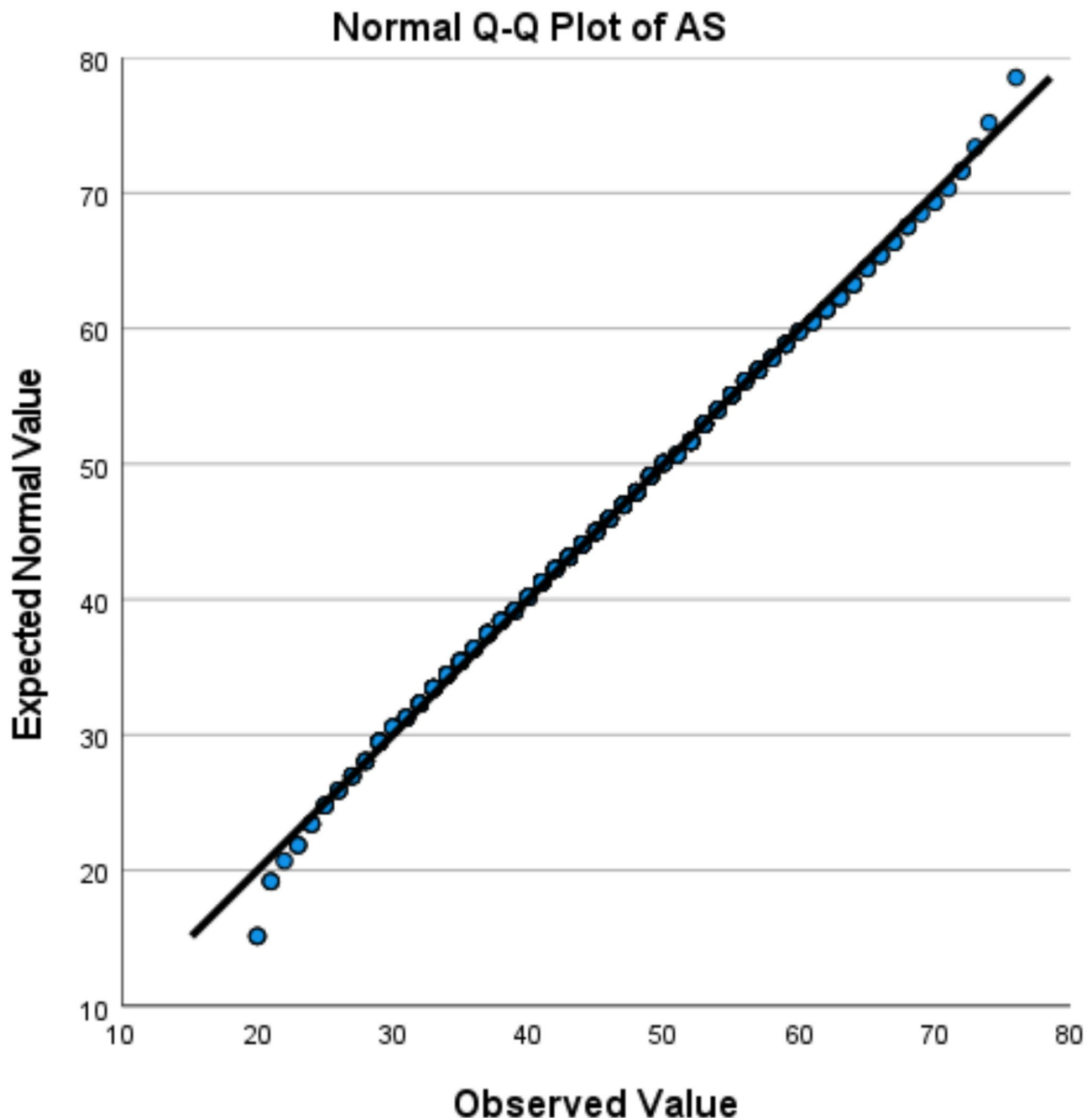


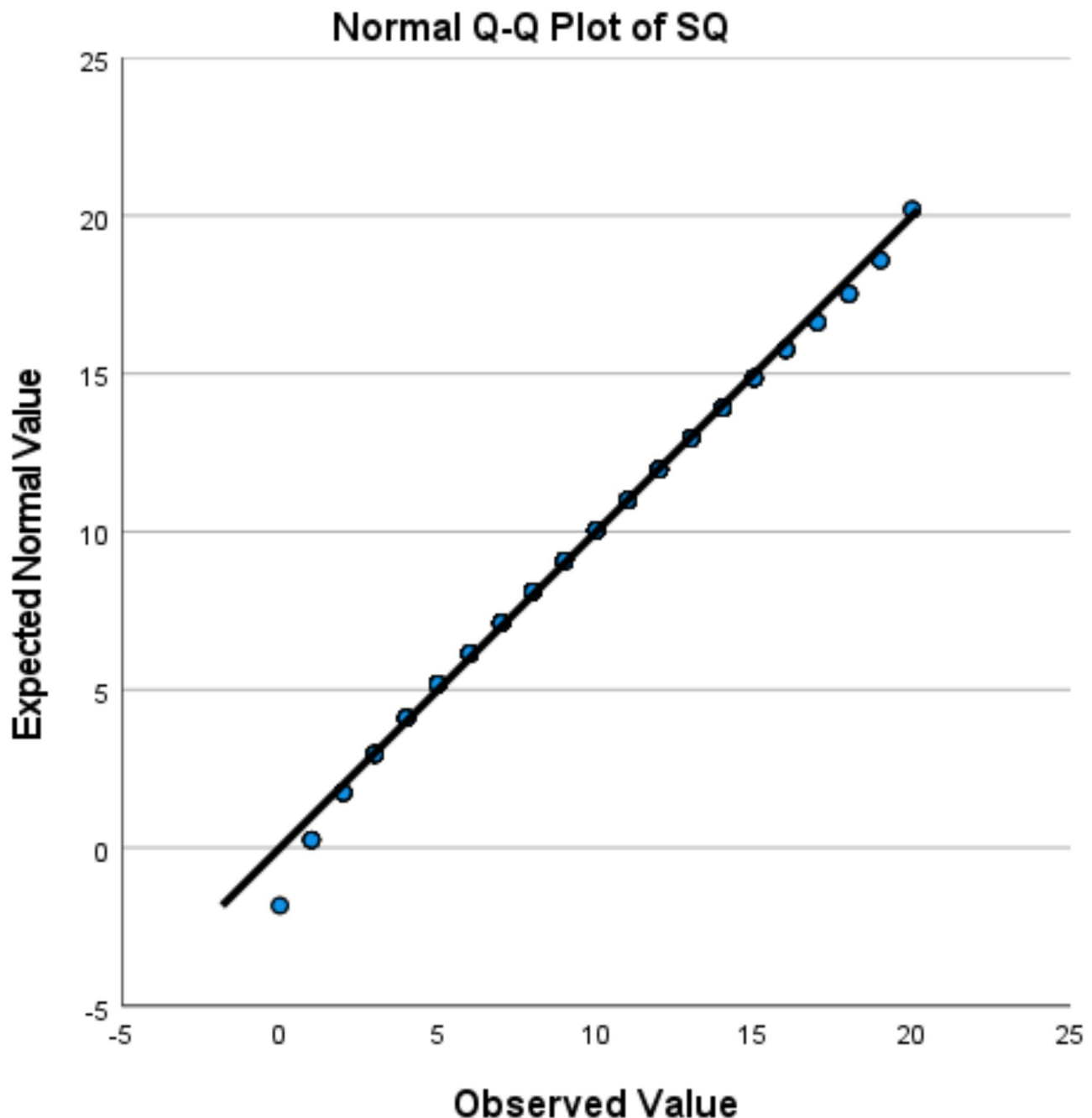
Fig. 3 AS Q-Q plots

involvement in PE can help high school students experience positive emotions, reduce negative emotions, and directly enhance their SWB. Additionally, PE can indirectly influence SWB by alleviating AS and improving SQ. Specifically, PE helps reduce AS, ameliorate SQ, and consequently augment SWB. This chain mediation effect indicates that the impact of PE on high school students' SWB is mediated by the chain effects of AS and SQ, offering empirical support for designing interventions

aimed at Promoting mental wellness among high school students (see Fig. 6).

The direct impact of PE on SWB

PE significantly and positively influences the SWB, congruent with the results of Iwon et al. [19], supporting Hypothesis 1. Iwon et al. [19] found that individuals who regularly exercise exhibit higher levels of well-being compared to beginners and non-exercisers. Additionally, beginners also show increased life satisfaction and

**Fig. 4** SQ Q-Q plots

well-being after engaging in exercise for four weeks. PE helps individuals effectively alleviate stress, reduce anxiety and depression, and other negative emotions [65], leading to a more stable psychological state and more positive emotional experiences, thus positively affecting SWB. In addition, PE can also influence in a round-about way SWB by means of psychological and social mechanisms such as satisfying basic psychological needs, enhancing perceived social support, and elevating exercise self-efficacy [21, 45]. These findings further illustrate

that PE not only benefits individuals' health on a physiological level but also contributes to enhancing well-being on a psychological level.

The mediating effect of AS

AS functions as a bridge between PE and SWB, indicating that AS could be a potential risk factor affecting SWB. This finding aligns with the research of Liang [23], confirming Hypothesis 2, which proposes that AS mediates the association between PE and SWB. Liu et al. [29]

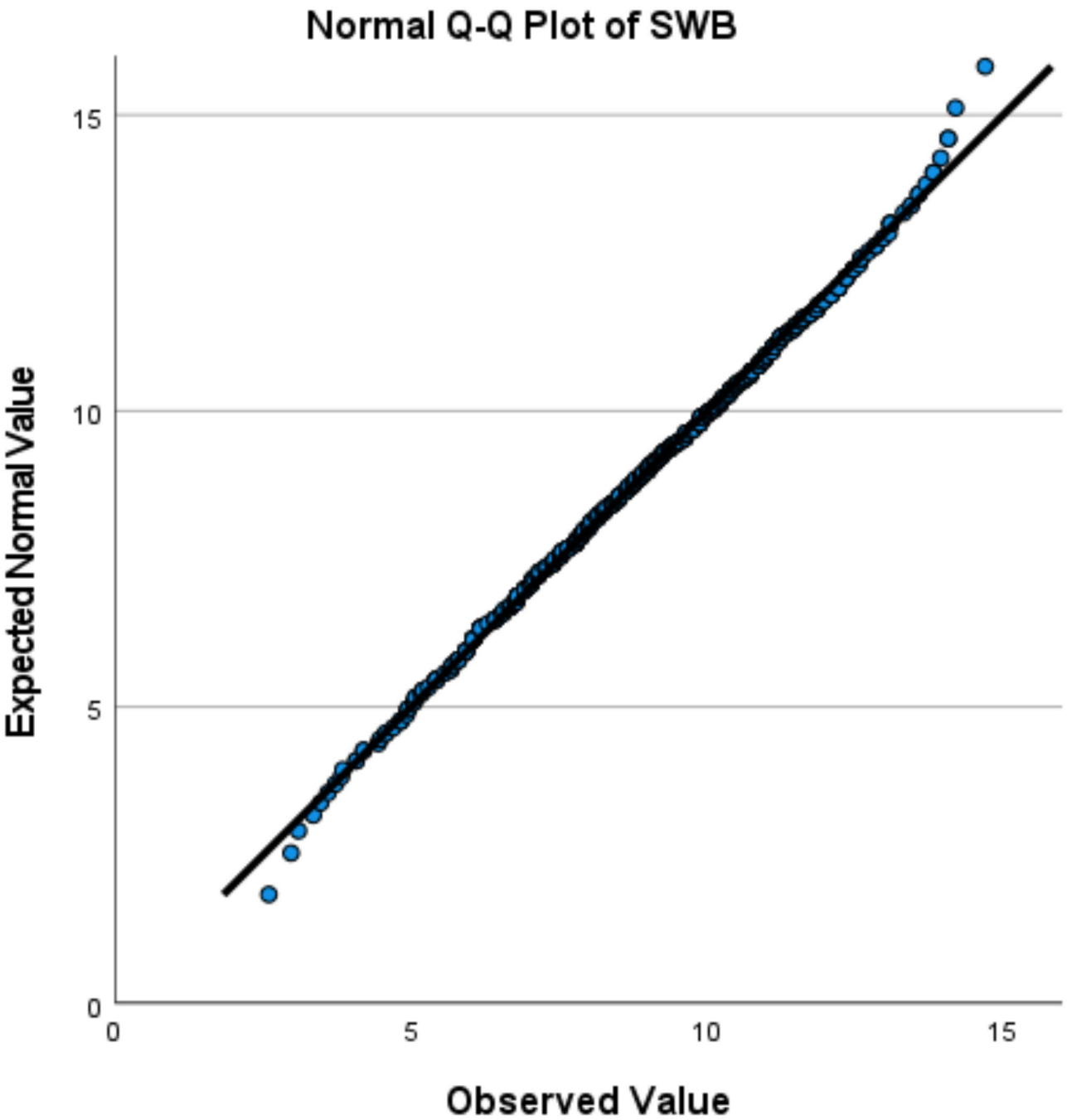


Fig. 5 SWB Q-Q plots

Table 3 Pearson correlation

Variables	PE	AS	SQ	SWB	VIF
PE	1				1.142
AS	-0.351***	1			1.808
SQ	-0.251***	0.639***	1		1.692
SWB	0.423***	-0.839***	-0.718***	1	

Note: VIF=Variance Inflation Factor, used to detect multicollinearity. Pearson correlation coefficients: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

conducted a study on adolescents and found that PE can improve their mental health by alleviating AS, releasing negative emotions, and reducing anxiety levels, thereby significantly enhancing their life satisfaction and well-being. According to the Conservation of Resources theory (COR), individuals expend significant psychological resources, such as self-control, attention, and emotional regulation, when dealing with stress. For high school students under significant AS, resource depletion may

Table 4 Grade differences in SN, CON, AIRE, and BI

	Grade 10(<i>n</i> = 150)		Grade 11(<i>n</i> = 181)		Grade 12(<i>n</i> = 165)		F	<i>p</i>
	M	SD	M	SD	M	SD		
PE	42.44	15.837	39.53	15.702	37.08	15.936	4.504	0.012
AS	42.13	10.769	43.62	10.079	49.64	10.958	22.797	< 0.001
SQ	8.82	3.711	8.39	3.845	11.10	3.786	24.748	< 0.001
SWB	19.29	2.230	9.24	2.202	7.95	2.276	18.991	< 0.001

Note: F and *p* values are based on one-way ANOVA tests for differences across grades (Grade 10, Grade 11, Grade 12). Significant differences are indicated by *p* < 0.001

Table 5 Hierarchical regression analysis of chain mediation effects

Outcome variable	Predictor variable	R	R ²	F	β	SE	t
SWB		0.4591	0.2108	65.8407***			
	PE				0.0579	0.0059	9.8753***
SWB	Grade				-0.5242	0.1172	-4.4712***
		0.8812	0.7766	426.7059***			
SWB	PE				0.0201	0.0033	6.0588***
	AS				-0.1262	0.0061	-20.7411***
	SQ				-0.1775	0.0163	-10.9140***
	Grade				0.0597	0.0647	0.9237
AS	PE	0.4189	0.1755	52.4581***	-0.2218	0.0286	-7.7551***
	Grade				3.1979	0.5717	5.5938***
SQ		0.6425	0.4127	115.2651***			
	PE				-0.0069	0.0092	-0.7482
	AS				0.2196	0.0137	16.0823***
	Grade				0.3150	0.1787	1.7625

Note: Grade = Grade level (10, 11, or 12). F and *p* values indicate the significance of the model fit and predictors

Table 6 Analysis of chain intermediary effects among PE, AS, SQ, and SWB using bootstrap method

Effect	Efficiency value	Boot SE	95% CI lower limit	95% CI upper limit
Aggregate effect	0.0579	0.0059	0.0464	0.0695
Total direct effect	0.0201	0.0033	0.0136	0.0266
Total indirect effect	0.0378	0.0056	0.0267	0.0489
PE→AS→SWB	0.0280	0.0046	0.0191	0.0369
PE→SQ→SWB	0.0012	0.0018	-0.0020	0.0049
PE→AS→SQ→SWB	0.0086	0.0016	0.0058	0.0121

Note: Boot SE = Bootstrap Standard Error, 95% CI = 95% Confidence Interval

lead to reduced coping abilities, resulting in anxiety and depressive symptoms, ultimately diminishing their SWB [66]. PE, by offering a positive coping strategy, not only reduces the excessive depletion of psychological resources but also helps restore these reserves [67]. Consequently, PE indirectly enhances SWB by alleviating AS. AS acts as a mediating factor between PE and SWB, highlighting the important function of PE in enhancing students' SWB.

The mediating role of SQ

In this research, SQ has a strong positive impact on SWB; better SQ correlates with greater amounts of SWB, consistent with the findings of Su and He [55]. However, the

regression path between PE and SQ is not significant, demonstrating that SQ does not intermediary the relationship between PE and SWB, thus invalidating Hypothesis 3. According to Negele et al. [68], PE can effectively ameliorate short-term SQ in adolescents, and maintaining regular PE helps sustain optimal SQ [69]. Yet, this study found no significant impact between the two variables, this may be closely related to the unique lifestyle and contextual factors of high school students, and it is also possible that AS plays a more significant indirect role between the two. It is hypothesized that this may be due to the unique circumstances of high school students, who often need to complete study tasks at night, increasing the likelihood of nighttime eating or consuming caffeinated beverages. These unhealthy habits may negate the favorable impacts of PE on sleep [70]. Additionally, according to the stress-coping theory, PE may primarily enhance SWB through direct emotional improvements, such as the release of endorphins [18]. This physiological mechanism can quickly generate positive emotions, directly boosting well-being without necessarily depending on improved SQ. This may explain why PE can directly enhance SWB but does not exert an indirect effect on SWB through the improvement of SQ. Furthermore, as high school students' sleep patterns are greatly influenced by AS, AS may have a greater moderating effect on SQ, thereby weakening the direct impact of PE

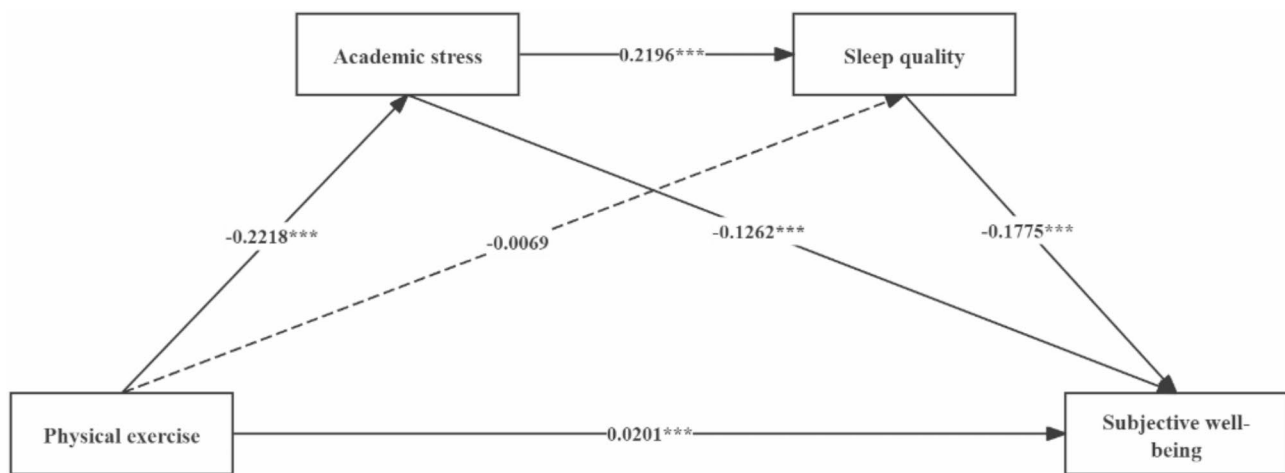


Fig. 6 Mediating model of PE on SWB in high school students

on SQ. The positive effect of PE on SWB is likely achieved primarily through an indirect pathway of alleviating AS, rather than directly improving SQ [46]. In summary, this study did not find a significant impact of PE on SQ, which may be related to the unique lifestyle, unhealthy behavioral habits, and specific contextual pressures of high school students. This finding provides important insights for further understanding the mechanisms through which PE influences SWB in different contexts.

Analysis of the chain mediating role of AS and SQ on SWB

Research indicates that AS plays an important intermediary role in influencing PE on SQ, thereby influencing the association between PE and SWB through a chain intermediary pathway. A strong negative correlation exists between AS and SQ, consistent with the findings of Yuan et al. [53]. As individual AS increases, SQ deteriorates, and vice versa. This suggests that AS, a prevalent source of pressure for high school students, directly affects their SQ, leading to difficulties in falling asleep and insufficient sleep [71]. Furthermore, the study shows that while SQ does not mediate the relationship between PE and SWB, it does serve as a serial mediator between AS and SWB. Deng et al. [48] discovered that elevated levels of AS lead directly to not only poorer SQ but also contribute to emotional disturbances, anxiety, and depression, which subsequently result in sleep problems. AS may arise from students' excessive focus on academic issues or their inability to find effective solutions. Gündoğan [46] posits that such stress disrupts individuals' sleep patterns, making it challenging to maintain healthy sleep. This relationship exhibits distinct characteristics in the context of high school students. Compared to college students, high school students' stress is more concentrated on academic performance, while compared to middle school students, high school students experience an overlap of physiological traits (e.g., a tendency for late-night habits) and social

pressures (e.g., pressures related to higher education entrance). This dual effect may further exacerbate the negative impact of AS on SQ [50]. Overall, it is apparent that AS is an important factor affecting high school students' SQ, with elevated levels of stress making SQ issues more likely.

This study also employed the Bootstrap method to validate the chain intermediary role of AS and SQ in the favorable effect of PE on SWB, confirming Hypothesis 4. This chain intermediary model offers a fresh viewpoint for gaining deeper insights into the connection between PE and SWB. PE can enhance SWB not only through direct pathways but also indirectly by alleviating AS and improving SQ. The conclusions back the stress-buffering theory [72], indicating that PE serves as a positive influencing factor that helps mitigate AS. PE can release endorphins and lower levels of cortisol and other stress hormones, reducing the negative impact of stress on both physical and mental well-being [27]. By alleviating AS, PE can indirectly ameliorate individuals' SQ, thereby enhancing SWB [51, 55]. Engaging in PE not only strengthens the body but also helps reduce AS, ameliorate SQ, and increase individuals' sense of happiness in life. This has a vital part in maintaining students' mental health, enabling them to effectively cope with AS while ensuring both physical and psychological well-being.

Research implications

For high school students, enhancing their SWB and reducing the incidence of mental health issues is a constructive topic of discussion. This study focuses on the impact of PE on SWB, exploring the chain intermediary roles of AS and SQ in this process, which holds significant theoretical and practical implications.

Theoretical Significance: This research offers a new theoretical perspective and empirical evidence regarding the association between PE and SWB. While previous

studies have indicated that favorable impacts of PE on individual SWB, further investigation into the underlying mechanisms is needed. By introducing AS and SQ as mediating variables, this research highlights the fundamental mechanism through which PE enhances SWB by reducing AS and improving SQ, this finding not only enriches the theoretical framework regarding the relationship between PE and mental health but also provides a valuable reference for future research to further explore the connections between exercise and mental health.

The practical significance of this study: For educators and mental health practitioners, it is essential to recognize the significance of PE in augment students' SWB and actively promote the implementation of physical education courses and extracurricular activities to increase student participation. Additionally, teachers need to pay attention to students' AS by flexibly adjusting course structures and homework loads to help students balance their academic and personal lives, thereby promoting mental health. Finally, educators should emphasize the importance of SQ by providing relevant health education to help students develop good routines, ensuring their psychological and physical well-being. For high school students, it is vital to actively participate in various PE activities as an effective means to alleviate stress and enhance well-being. Moreover, high school students should learn to plan their study and rest time effectively to ensure a balance between academic pursuits and overall health. Lastly, they need to prioritize SQ by establishing a regular schedule to improve their attention and learning efficiency, thereby augmenting their SWB. For researchers, future studies should further explore the differential impact of various types of PE on SWB and examine other potential mediating and moderating factors to gain a comprehensive understanding of the mechanisms influencing well-being. Practitioners may also refer to the findings of this study by incorporating PE, AS management, and SQ improvement into intervention programs to provide more personalized psychological support services.

In summary, this study not only deepens our theoretical understanding of how PE affects SWB but also furnishes new perspectives and support for health management, psychological counseling, and educational policies in social practice, contributing significantly to enhancing individual happiness and societal welfare.

Limitations

There are a few constraints in this study. First, it utilized self-reporting methods, which may be influenced by participants' subjective willingness, leading to potential response bias in the reported data. Future research could consider incorporating objective measurement methods, such as sleep monitoring devices and AS assessment

tools, to minimize the influence of subjective bias. Second, the research utilized a cross-sectional design, which cannot establish causal relationships between the variables. Future research could adopt a longitudinal design to gain deeper insights into the long-term effects of PE, AS, and SQ on SWB. Through more objective measurements and repeated data collection, such studies could more clearly reveal lagged effects and causal relationships. Moreover, the study's sample primarily consists of Chinese high school students, which may restrict the generalizability of the findings to students of other ages or cultural backgrounds. The cultural context in which the study was conducted could influence the applicability of the findings to other cultural settings, as the ways in which PE, AS, and SQ are conceptualized and experienced may differ across cultures due to varying societal norms, educational systems, and health practices. To enhance the generalizability of these results, future research should involve diverse populations, such as university students, working adults, or individuals from different cultural contexts. Cross-cultural studies comparing data from different countries or regions could examine whether the relationships between PE, AS, SQ, and SWB hold across cultural boundaries or if cultural differences influence these relationships. This would contribute to a deeper understanding of the universal or context-dependent nature of the effects observed in this study. Additionally, this study did not specifically account for potential demographic imbalances, such as differences between urban and rural students, which could influence the generalizability of the findings. Urban and rural students may have different access to PE facilities, different lifestyle habits, and varying levels of academic or social stress, which could affect their SQ and SWB. Future research should consider balancing demographic characteristics more carefully to better reflect these potential disparities. In addition, no significant relationship was found between PE and SQ, possibly affected by the duration of exercise; future studies could incorporate longer measurement periods for exercise to better control for this variable. At the same time, future studies should explore the effects of different types of exercise on SQ, as various forms of PE (e.g., aerobic exercise, strength training) may have distinct impacts on improving SQ. Finally, this study primarily explored the impact of PE on SWB and emphasized the chain mediating roles of AS and SQ. However, it did not delve deeply into the causal relationship whereby SQ might inversely influence AS. Although this choice was made to focus on the theoretical core of the research, future studies could further validate this inverse causal relationship through longitudinal studies or experimental designs.

Conclusion

This study holds significant importance for research on high school students, as it reveals the direct impact of PE on their SWB. It examines the chain intermediary effects through AS and SQ. The findings indicate that PE has a significant positive impact on SWB, with AS Acting as an intermediary in the connection between PE and SWB; however, SQ does not function as an intermediary. Both AS and SQ act as chain mediators in the influence of PE on SWB. The findings of this study provide empirical support for enhancing high school students' SWB, highlighting the crucial role of PE in mental health interventions. Based on this, educators and policymakers can integrate PE into school practices, alongside measures to reduce AS and improve SQ, thereby effectively enhancing students' well-being. This study offers practical guidance for developing educational policies and implementing targeted interventions to promote high school students' mental health.

Author contributions

Conceptualization: Suh-Jung Kang, Ruirui Cheng; Methodology: Lei Yang, Suh-Jung Kang; Formal analysis and investigation: Suh-Jung Kang; Writing - original draft preparation: Suh-Jung Kang, Ruirui Cheng; Writing - review and editing: Ruirui Cheng; Supervision: Lei Yang. All the authors have read and agreed to the published version of the manuscript.

Funding

Not applicable.

Data availability

The data that support the findings of this study are available on request from the corresponding author.

Declarations

Ethics approval and consent to participate

The researchers confirms that all research was performed in accordance with relevant guidelines/regulations applicable when human participants are involved (e.g., Declaration of Helsinki or similar). This study was approved by the Ethics Committee of Shangqiu Normal University. The participants received oral and written information and provided written informed consent before participating in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

¹College of Physical Education, Shangqiu Normal University, Shangqiu 476000, Henan, China

²College of Culture and Arts, Sangmyung University, Seoul 03016, Republic of Korea

Received: 8 October 2024 / Accepted: 17 February 2025

Published online: 01 March 2025

References

- Diener E. Subjective well-being. *Psychol Bull.* 1984;95:34.
- Zhang M, et al. The association between physical activity and subjective well-being among adolescents in southwest China by parental absence: a moderated mediation model. *BMC Psychiatry.* 2023;23(1). <https://doi.org/10.1186/s12888-023-04982-8>
- Lenneis A, et al. The influence of sleep on subjective well-being: an experience sampling study. *Emotion.* 2024;24(2):451–64. <https://doi.org/10.1037/e00001268>
- Tian J, Yu H, Austin L. The effect of physical activity on anxiety: the mediating role of subjective well-being and the moderating role of gender. *Psychol Res Behav Manage.* 2022;15:3167–78. <https://doi.org/10.2147/prbm.S384707>
- Ericson SM, et al. Does emotion regulation mediate the relationship between self-compassion and subjective well-being? A cross-sectional study of adults living in the United States. *J Health Psychol.* 2024;29(8):863–76. <https://doi.org/10.1177/13591053231209668>
- Fredrickson BL. The role of positive emotions in positive psychology: the broaden-and-build theory of positive emotions. *Am Psychol.* 2001;56. <https://doi.org/10.1037//0003-066x.56.3.218>
- Marquez J, Long E. A global decline in adolescents' subjective well-being: a comparative study exploring patterns of change in the life satisfaction of 15-year-old students in 46 countries. *Child Indic Res.* 2021;14:1251–92.
- Katsantonis I, McLellan R, Marquez J. Development of subjective well-being and its relationship with self-esteem in early adolescence. *Br J Dev Psychol.* 2022;41(2):157–71. <https://doi.org/10.1111/bjdp.12436>
- DiLeo LL, et al. Three-wave longitudinal study of a dual-factor model: mental health status and academic outcomes for high school students in academically accelerated curricula. *School Mental Health.* 2022;14(3):514–30. <https://doi.org/10.1007/s12310-021-09497-9>
- Ayvaci ER, et al. Clinical correlates of anxious depression in youth from the Texas Youth depression and suicide research network (TX-YDSRN). *J Affect Disord.* 2024;362:510–7. <https://doi.org/10.1016/j.jad.2024.07.035>
- Waterman EA, et al. Impact of peer victimization on adolescent suicidality and depressed Mood: moderating role of protective factors. *J Sch Violence;* 2024. <https://doi.org/10.1080/15388220.2024.2309569>
- Kang CY, et al. Prevalence, risk factors and clinical correlates of suicidal ideation in adolescent patients with depression in a large sample of Chinese. *J Affect Disord.* 2021;290:272–8. <https://doi.org/10.1016/j.jad.2021.04.073>
- Organization WH. Global Accelerated Action for the health of adolescents (AA-HAI) - second edition. Switzerland: Geneva; 2023.
- Fu Y. The impact of Gaokao high-stakes testing on student mental health in China: an analysis of stress levels and coping mechanisms among senior high school students. *Res Adv Educ.* 2024;3(5):23–32. <https://doi.org/10.56397/rae.2024.05.03>
- Wang GG et al. Sleep patterns and academic performance during preparation for college entrance exam in Chinese adolescents. *J Sch Health.* 2016;86(4): 298–306.
- Zhang X, Dimitriou D, Halstead EJ. Sleep, anxiety, and academic performance: a study of adolescents from public high schools in China. *Front Psychol.* 2021;12. <https://doi.org/10.3389/fpsyg.2021.678839>
- Liu N, Zhong Q. The impact of sports participation on individuals' subjective well-being: the mediating role of class identity and health. *Humanit Social Sci Commun.* 2023;10(1). <https://doi.org/10.1057/s41599-023-02064-4>
- Li Z, Huang F. Mechanisms of the impact of sports participation on college students' psychological well-being. *School Behav Personality.* 2024;52(5).
- Iwon K, et al. Elevating subjective well-being through physical exercises: an intervention study. *Front Psychol.* 2021;12. <https://doi.org/10.3389/fpsyg.2021.702678>
- Jetzke M, Mutz M. Sport for pleasure, fitness, medals or slenderness? Differential effects of sports activities on Well-Being. *Appl Res Qual Life.* 2020;15(5):1519–34. <https://doi.org/10.1007/s11482-019-09753-w>
- Yao S-J, et al. The relationship between physical exercise and subjective well-being among Chinese junior high school students: a chain mediating model. *Front Psychol.* 2023;13. <https://doi.org/10.3389/fpsyg.2022.1053252>
- Luo Y, Deng Y, Zhang H. The influences of parental emotional warmth on the association between perceived teacher–student relationships and academic stress among middle school students in China. *Child Youth Serv Rev.* 2020;114. <https://doi.org/10.1016/j.childyouth.2020.105014>
- Liang q. The influence of physical exercise on college students' learning stress and mental health. *Revista De Psicologia Del Deporte/Journal Sport Psychol.* 2023;32:11.
- Chen Z, et al. How time pressure matter university faculties' job stress and well-being? The perspective of the job demand theory. *Front Psychol.* 2022;13. <https://doi.org/10.3389/fpsyg.2022.902951>

25. Cosma A, et al. Cross-national time trends in adolescent mental well-being from 2002 to 2018 and the Explanatory Role of Schoolwork pressure. *J Adolesc Health*. 2020;66(6):S50–S58. <https://doi.org/10.1016/j.jadohealth.2020.02.010>
26. Jiang M-m, et al. The influence of academic pressure on adolescents' problem behavior: chain mediating effects of self-control, parent-child conflict, and subjective well-being. *Front Psychol*. 2022;13. <https://doi.org/10.3389/fpsyg.2022.954330>
27. Wu X. Effects of sports training and psychological training on employees' psychological stress. *REVISTA DE PSICOLOGIA DEL DEPORTE*. 2022;31(3):101–10.
28. Ye H, Guo K. Exercise adherence and subjective well-being: a chain mediating effect model. *Social Behav Personality*. 2023;51(10).
29. Liu GF, Liu YL, Li HY. Effects of long-term physical training on depression in adolescents. *REVISTA DE PSICOLOGIA DEL DEPORTE*; 2023;32(2):247–53.
30. Demir A, Barut AI. The relationship between university students' psychological resilience and anxiety levels and comparison in terms of physical activity levels gender and academic achievement. *BALTIC J HEALTH PHYS ACTIVITY*. 2020;12:75–83. <https://doi.org/10.29359/BJHPA.2020.Suppl.1.08>
31. Ding Q, Dong S, Zhang Y. Does parental phubbing aggravates adolescent sleep quality problems? *Front Psychol*. 2023;14. <https://doi.org/10.3389/fpsyg.2023.1094488>
32. Liu J, et al. Childhood sleep: physical, cognitive, and behavioral consequences and implications. *World J Pediatr*. 2022;20(2):122–32. <https://doi.org/10.1007/s12519-022-00647-w>
33. Chehri A, et al. Sleep hygiene and sleep quality in Iranian adolescents during the COVID-19 pandemic. *BMC Psychol*. 2023;11(1). <https://doi.org/10.1186/s40359-023-01165-8>
34. Zhu X, Stress A, et al. Physical activity, sleep, and mental health among Chinese adolescents. *Int J Environ Res Public Health*. 2021;18(14). <https://doi.org/10.3390/ijerph18147257>
35. Wang p and x, Wang. Effect of time management training on anxiety, depression, and sleep quality. *Iranian Journal of Public Health*. 2018;47(12):1822–1831.
36. Hu Y, Wang Y, Sun Y. Diary study: the protective role of self-compassion on stress-related poor sleep quality. *Mindfulness*. 2018;9(6):1931–40.
37. Wang W, et al. Associations between poor sleep quality, anxiety symptoms, and depressive symptoms among Chinese adolescents before and during COVID-19: a longitudinal study. *Front Psychiatry*. 2022;12. <https://doi.org/10.3389/fpsyg.2021.786640>
38. Short MA, et al. The relationship between sleep duration and mood in adolescents: a systematic review and meta-analysis. *Sleep Med Rev*. 2020;52. <http://doi.org/10.1016/j.smrv.2020.101311>
39. da Costa BGG, et al. Movement behaviors and their association with depressive symptoms in Brazilian adolescents: a cross-sectional study. *J SPORT HEALTH Sci*. 2022;11(2):252–9. <https://doi.org/10.1016/j.jshs.2020.08.003>
40. Morbée S, et al. An examination of the reciprocal associations between physical activity and anxiety, depressive symptoms, and sleep quality during the first 9 weeks of the COVID-19 pandemic in Belgium. *Mental Health and Physical Activity*; 2023;24. <https://doi.org/10.1016/j.mhpa.2022.100500>
41. Alnawwar MA, et al. The effect of physical activity on sleep quality and sleep disorder: a systematic review. *Cureus*; 2023. <https://doi.org/10.7759/cureus.43595>
42. Greco G, et al. Effect of physical exercise on sleep quality in college students: mediating role of smartphone use. *PLoS ONE*. 2023;18(11). <https://doi.org/10.1371/journal.pone.0288226>
43. Dubinina E, et al. Physical activity is associated with sleep quality: results of the ESSE-RF epidemiological study. *Front Psychol*. 2021;12. <https://doi.org/10.3389/fpsyg.2021.705212>
44. Tomás O-M-d-P, et al. Influencia De Los hábitos deportivos en El Conocimiento, calidad e higiene del sueño adolescente. *Sportis Sci J School Sport Phys Educ Psychomotricity*. 2024;10(1):71–93. <https://doi.org/10.17979/sportis.2024.10.1.9939>
45. Lin S, et al. Physical exercise and undergraduate students' subjective well-being: mediating roles of basic psychological need satisfaction and sleep quality. *Behav Sci*. 2022;12(9). <https://doi.org/10.3390/bs12090316>
46. Gündoğan S. The relationship between academic stress and sleep quality in adolescents: the mediating role of school burnout and depression. *Educ Sci*. 2023;48(215). <https://doi.org/10.15390/eb.2023.11497>
47. Buri T, et al. Calidad De sueño y su relación con El estrés académico en estudiantes de bachillerato. *Ciencia Latina Revista Científica Multidisciplinar*. 2023;7(1):1245–62. https://doi.org/10.37811/cl_rcm.v7i1.4479
48. Deng J, et al. Effects of adolescent academic stress on sleep quality: mediating effect of negative affect and moderating role of peer relationships. *Curr Psychol*. 2021;42(6):4381–90. <https://doi.org/10.1007/s12144-021-01803-7>
49. Zhang X, et al. Perceived academic stress and depression: the mediation role of mobile phone addiction and sleep quality. *Front Public Health*. 2022;10. <https://doi.org/10.3389/fpubh.2022.760387>
50. Kang V, et al. Sleep deficiency and sleep health problems in Chinese adolescents. *Clin Med Insights: Pediatr*. 2012;6. <https://doi.org/10.4137/CMPed.S8407>
51. Theodoratou M, Argyrides M. Neuropsychological insights into coping strategies: integrating theory and practice in clinical and therapeutic contexts. *Psychiatry Int*. 2024;5(1):53–73. <https://doi.org/10.3390/psychiatryint5010005>
52. Chuan K, Xiong YM. The influence of physical exercise behaviour on college students' mental health. *Revista de Psicología del Deporte*; 2023;32(3):446–56.
53. Yuan M-Z, et al. Research on the impact of regular exercise behavior of college students on academic stress and sleep quality during the COVID-19 pandemic. *Healthcare*. 2022;10(12). <https://doi.org/10.3390/healthcare10122534>
54. Huang Y, et al. Effects of perceived stress on college students' sleep quality: a moderated chain mediation model. *BMC Psychol*. 2024;12(1). <https://doi.org/10.1186/s40359-024-01976-3>
55. Su P, He M. Relationship between sleep quality and subjective well-being: resilience as a mediator and belief in a just world as a moderator. *Front Psychiatry*. 2023;14. <https://doi.org/10.3389/fpsyg.2023.1297256>
56. Campbell A. Subjective measures of well being[J]. *Am Psychol*. 1976;31(2):117.
57. Buysse DJ, et al. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res*. 1989;28:193–213.
58. Jiang L, Yoo Y. Adolescents' short-form video addiction and sleep quality: the mediating role of social anxiety. *BMC Psychol*. 2024;12(1). <https://doi.org/10.1186/s40359-024-01865-9>
59. Liu Z, et al. Relationship between physical activity, parental psychological control, basic psychological needs, anxiety, and mental health in Chinese engineering college students during the COVID-19 pandemic. *Front Psychol*. 2022;13. <https://doi.org/10.3389/fpsyg.2022.802477>
60. Sun J, et al. Educational stress scale for adolescents. *J Psychoeducational Assess*. 2011;29(6):534–46. <https://doi.org/10.1177/0734282910394976>
61. Kline R. Principles and practice of structural equation Modeling[M]. New York: Guilford; 2005.
62. Podsakoff PM, Organ DW. Self-reports in organizational research - problems and prospects. *J Manag*. 1986;12(4):531–44. <https://doi.org/10.1177/014920638601200408>
63. Hair J Jr, et al. A primer on partial least squares structural equation modeling (PLS-SEM). Sage; 2021.
64. Hayes A. Mediation, moderation, and conditional process analysis. Introduction to mediation, moderation, and conditional process analysis: A regression based approach. 2013;1:12–20.
65. Li X, et al. Physical activity and social anxiety symptoms among Chinese college students: a serial mediation model of psychological resilience and sleep problems. *BMC Psychol*. 2024;12(1). <https://doi.org/10.1186/s40359-024-01937-w>
66. Lee Y, et al. The effect of resource loss on depression and peritraumatic distress during the early period of the COVID-19: considering the pandemic-situational and social context. *BMC Public Health*. 2023;23(1). <https://doi.org/10.1186/s12889-023-15628-5>
67. Mahindru A, Patil P, Agrawal V. Role of physical activity on mental health and well-being: a review. *Cureus*; 2023. <https://doi.org/10.7759/cureus.33475>
68. Negele L, et al. Association between objectively assessed physical activity and sleep quality in adolescence. Results from the GINIplus and LISA studies. *Sleep Med*. 2020;72:65–74. <https://doi.org/10.1016/j.sleep.2020.03.007>
69. Edwards MK, Loprinzi PD. Experimentally increasing sedentary behavior results in decreased sleep quality among young adults. *Ment Health Phys Act*. 2017;12:132–40. <https://doi.org/10.1016/j.mhpa.2017.04.002>
70. Calamaro CJ, Mason TBA, Ratcliffe SJ. Adolescents living the 24/7 lifestyle: effects of caffeine and technology on sleep duration and daytime functioning. *Pediatrics*. 2009;123(6):E1005–10. <https://doi.org/10.1542/peds.2008-3641>
71. Time WS, et al. The relationship between academic stress, sleep quality, and psychological wellbeing in Pasifika and New Zealand European students at the University of Otago. *J Racial Ethnic Health Disparities*. 2024. <https://doi.org/10.1007/s40615-024-02043-8>

72. Cohen S, Wills TA. Stress, social support, and the buffering hypothesis. *Psychol Bull.* 1985;98(2):310–57. <https://doi.org/10.1037/0033-2909.98.2.310>

Publisher's note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.