

RESEARCH

Open Access



The effect of physical activity and life events on mental health of college students: the mediating role of psychological vulnerability

Zhifeng Wang¹, Fengyun Wang¹, Baolei Ma¹, Haihong Xue¹, Botao Liu² and Dongmei Wang^{3*}

Abstract

Background Life events are important risk factors for negative psychology such as depression and anxiety. However, individuals who experienced the same life events might not necessarily develop mental health problems. Some inherent psychological qualities among individuals may determine their mental health status under life events. Physical activity is beneficial to physical and mental health. What is the combined effect of physical activity and life events on individual depression and anxiety, and whether it can alleviate the psychological risk induced by life events, at present, there is no relevant research report.

Objective To systematically analyze the combined effect of physical activity and life events on mental health of college students and the related mediating mechanism.

Methods Guided by a series of hypotheses, the study conducted a cross-sectional survey on the physical activity level, life event experience, psychological vulnerability, depression and anxiety of 3552 Chinese college students. On the basis of hierarchical comparison, correlation analysis, logistics regression analysis and structural equation model method were further used to explore the effect of physical activity and life events on mental health and the relationship between variables, and to test the research hypotheses in sequence.

Results Physical activity was negatively but life events were positively correlated with anxiety and depression; Psychological vulnerability played a partial mediating role between physical activity and life events and mental health, accounting for 22.17% and 23.42% of the total effect, respectively; Physical activity and life events had an interaction effect on mental health, and psychological vulnerability played a completely mediating role, accounting for 91.86% of the total effect; Physical activity could significantly reverse the negative effect of life events on mental health.

Conclusions Life events are important risk factors for poor mental health such as depression and anxiety. However, physical activity can effectively reverse the adverse effects of life events on mental health, and it is related to the mediating role of psychological vulnerability.

Keywords Physical activity, Life events, Anxiety, Depression, Psychological vulnerability, Mediating role

*Correspondence:

Dongmei Wang
wangdm72@126.com

¹Department of Physical Education, Xi'an Polytechnic University, Shanxi 710048, China

²School of Mathematical Sciences, Xinjiang Normal University, Urumqi 830017, China

³College of Sports Medicine and Rehabilitation, Shandong First Medical University & Shandong Academy of Medical Sciences, Tai'an 271000, Shandong, China



© 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/>.

Introduction

Life events are the sum of various stimuli that people face in their life, work, study and social support systems. Although not as strong as major emergencies, they are frequent and long-lasting. Long-term exposure to chronic stress stimuli such as life events can easily lead to various mental health problems such as anxiety [1, 2], depression [3], post-traumatic stress disorder [4] and suicide [5]. Studies have even found that life events are strongly associated with senile dementia [6] and self-harm and aggressive behavior in adolescents [7]. It can be seen that life events are closely related to mental health. Long-term exposure to chronic stress stimuli such as life events will have a negative effect on individual mental health.

Although life events are closely associated with mental health, not all individuals who experienced life events will have psychological disorders. Even after experiencing the same life events, some individuals develop severe psychological disorders, while others remain healthy. This result suggests that some psychological qualities among individuals may play an important role in regulating the relationship between life events and mental health, and psychological vulnerability may be one of the important quality factors. Psychological vulnerability is an individual's psychological ability to bear stressful events [8] or the possibility of psychological imbalance and the tendency not to recover easily [9]. In recent years, the relationship between psychological vulnerability and individual mental health has attracted attention. Nobre et al. [10] conducted a cross-sectional study on 260 adolescents and found that psychological vulnerability was an important predictor of individual coping behavioral deficits and was positively correlated with poor mental health. Sampaio et al. [11] confirmed this result by conducting a cross-sectional survey of 115 municipal workers. Nogueira et al. [12] also reported that psychological vulnerability was a negative predictor of mental health. Dadandi et al. [13] also found that psychological vulnerability positively predicted fear and distress during COVID-19 after conducting a cross-sectional survey of 783 Turkish adults. Bruehlman-Senecal et al. conducted a 4-week randomized controlled study on 221 college students and found that psychological vulnerability was closely related to loneliness and depression [14]. Hirsch et al. [15] also reported that individuals with high psychological vulnerability were prone to negative psychological outcomes while individuals with low psychological vulnerability were prone to positive psychological outcomes after experiencing life events. The stress-vulnerability model also showed that [16], individuals were genetically or biologically vulnerable to psychosis and could tolerate a certain amount of stressful stimuli. However, once the tolerable threshold was exceeded, mental health risk

arose. Individuals with high psychological vulnerability could cause mental health problems by mild stimulation of life events, but individuals with low psychological vulnerability could cause mental disorders only by high-intensity stress stimulation. A recent study also showed that psychological vulnerability could not only positively predict depression, but also act as a mediating variable between cognitive integration and depression [17]. It can be seen that psychological vulnerability is closely associated with mental health.

Then, what is the relationship between life events and psychological vulnerability, and whether the effect of life events on individual psychology is related to psychological vulnerability? Scholars have also studied this issue. Thoits et al. [18] first confirmed the difference of psychological vulnerability among individuals. Woman, the elderly, as well as unmarried, less educated and low-income groups, were vulnerable to life events because life events reduced psychological capital and increased psychological vulnerability of this group. Neurophysiological studies [19] also confirmed that childhood poverty could reduce the coupling between the amygdala and the ventromedial prefrontal cortex (vmPFC) in the resting state, thereby increasing individual psychological vulnerability. This result was also confirmed by Swartz et al. [20]. The Stress-Sensitization Model [21] also showed that early traumatic life events could increase individual psychological vulnerability and stress sensitivity, resulting in later weaker life events could cause severe psychological problems. Meyers et al. [22] further confirmed in a large-scale cross-sectional survey involving 18,713 samples that individuals who had experienced traumatic life events in childhood had a higher sense of stress and were more sensitive to the psychological pressure brought by "9.11" terrorist attacks, suggesting that life events could positively affect psychological vulnerability. Uğur et al. conducted a cross-sectional survey on 389 college students and found that fear of negative evaluation was positively correlated with individual psychological vulnerability [23]. Swanepoel et al. [9] reported that, psychological vulnerability could also act as a mediating variable, mediating the relationship between adverse life events and multiple sclerosis symptoms. It can be seen that life events have a certain effect on psychological vulnerability, and the effect of life events on individual psychology may be realized by influencing psychological vulnerability.

Physical activity is easy to carry out, has a low degree of "stigma" and has a positive effect on human physiology and psychology [24]. It was confirmed that physical activity could reduce a variety of psychological symptoms such as anxiety, depression and PTSD induced by adverse life events [25–27]. It was also reported that physical activity played an important role in maintaining

individual mental health after emergencies such as earthquakes [28], the Fukushima nuclear accident [29], covid-19 [30], floods, hurricanes [31], terrorist attacks [32] and wars [33]. In addition to the above-mentioned studies on adults and adolescents, many other studies have confirmed that physical activity can reduce PTSD, depression and psychological distress induced by life events among college students [34, 35]. According to the distraction hypothesis, individuals who pay too much attention to experienced life events are prone to psychological problems such as unrealistic fantasies, stress, anxiety and depression [36]. Engaging in physical activity can distract people's attention from adverse life events, thus leading to the effect of relaxing mental stress and fighting anxiety and depression. Self-efficacy theory also shows that a person's self-efficacy is positively correlated with the ability to control potentially threatening stimuli. Individuals with high self-efficacy have less anxiety and depression when facing life events. Physical activity can improve self-efficacy, enhance the ability to adapt to internal and external pressure, and then play a role in anti-anxiety and anti-depression [37]. It can be seen that physical activity is closely related to individual mental health under the background of life events, and high-level physical activity can reduce negative psychological levels such as anxiety and depression.

In addition to the relationship between physical activity and mental health, the relationship between physical activity and psychological vulnerability has also attracted much attention. Hu & Li [38] reported that physical activity level was negatively correlated with psychological vulnerability score of the elderly, and improving physical activity level was helpful to reduce the psychological vulnerability of the elderly. Carmona-Torres et al. [39] also reported that low levels of physical activity were positively associated with psychological vulnerability, anxiety and depression (women) and substance abuse. Rodríguez-Romo et al. [40] also found that moderate to high levels of physical activity could reduce the psychological vulnerability of college students. Levenstein et al. [41], Hemmeter & Ngamsri [42] and Debbia et al. [43] also confirmed that a sedentary lifestyle was an important risk factor for increased psychological vulnerability, and regular physical activity could prevent this increased susceptibility. Psychological resilience is a good psychological quality corresponding to psychological vulnerability. Nowacka-Chmielewska et al. [44] proposed in a review paper that a sedentary lifestyle was associated with psychological vulnerability, while an active lifestyle was associated with psychological resilience. Belcher et al. [45] further found that physical activity, exercise and aerobic fitness could all improve psychological resilience by enhancing the top-down control function of the central nervous system, and buffer the adverse effects of

psychological vulnerability on psychology. It can be seen that physical activity may be negatively correlated with psychological vulnerability, and high-level physical activity can help reduce psychological vulnerability.

In summary, life events and physical activity are closely associated with psychological vulnerability and mental health. However, it is difficult to reflect the real human life scene when discussing the relationship between the above four elements in a separate state. Because in real life, some individuals engage in certain physical activity while experiencing sustained low-intensity life events, then what is the combined effect of physical activity and life events on individual psychology? No systematic studies have been seen so far. Therefore, the interaction term of physical activity and life events was taken as an independent variable, and was integrated into the research framework together with physical activity, life events, psychological vulnerability and mental health to systematically examine the interrelationship between the above factors. Based on the research conclusions of the above literature and the research objectives of this topic, the following hypotheses and research framework are proposed (Fig. 1).

Hypothesis 1 Life events negatively affect mental health.

Hypothesis 2 Psychological vulnerability negatively affects mental health.

Hypothesis 3 Life events positively affect psychological vulnerability.

Hypothesis 4 Life events affect mental health through psychological vulnerability.

Hypothesis 5 Physical activity positively affects mental health.

Hypothesis 6 Physical activity negatively affects psychological vulnerability.

Hypothesis 7 Physical activity affects mental health through psychological vulnerability.

Hypothesis 8 Physical activity and life events can have an interactive effect on psychological vulnerability. For individuals with higher levels of physical activity, the positive effect of life events on psychological vulnerability is relatively weak.

Hypothesis 9 Physical activity and life events can have an interactive effect on mental health, and this interaction effect may be mediated by psychological vulnerability. For individuals with higher levels of physical activity, the neg-

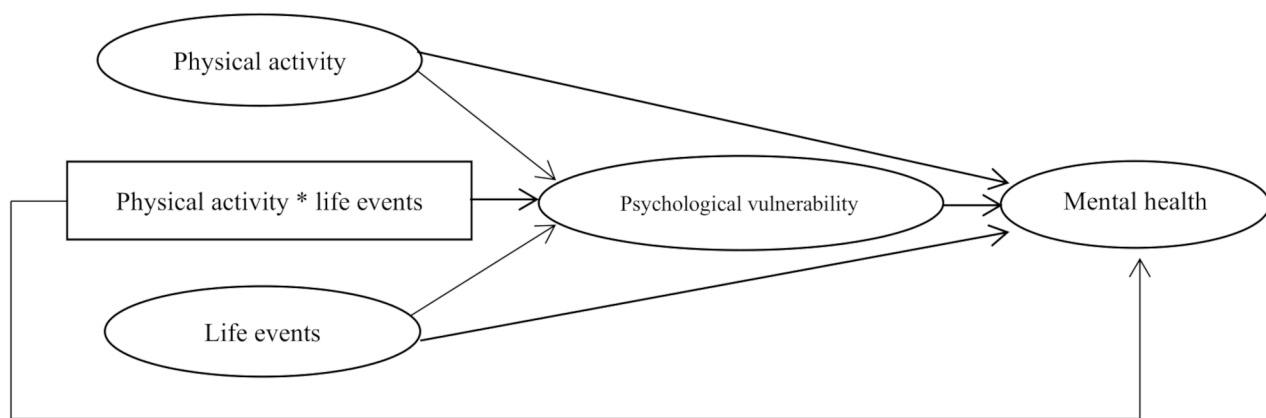


Fig. 1 Research framework

ative effect of life events on mental health was relatively weak.

Methods

Subjects

A cluster random sampling was conducted on 7 college students from Shaanxi, Henan, Hunan and other provinces by using mobile questionnaire star. 3881 questionnaires were obtained. 3552 valid questionnaires were collected, with an effective rate of 91.53%. The age range was 19–23 years old (19.37 ± 3.18), including 1819 males (51.22%) and 1733 females (48.78%). Based on the power analysis program in G*power 3.1 software, when α was set to 0.05, this sample size could provide a statistical power of over 0.90 for an effect size of $f = 0.25$.

Physical activity rating scale-3 (PARS-3)

The scale was designed by Hashimoto [46] and translated and revised by Liang and Liu [47]. It was used to assess the daily physical activity of college students from three dimensions: physical activity intensity, duration and frequency. Each dimension was divided into 5 grades, with 1 to 5 points respectively. Physical activity amount = physical activity intensity score \times (physical activity duration score–1) \times physical activity frequency score. The highest score of the scale was 100, and the lowest was 0. The higher the score, the greater the physical activity amount. The scale has been widely used to assess physical activity of young people in Chinese culture [48, 49], and its test-retest reliability was 0.82 in the study of Liang and Liu [47]. The Cronbach's α coefficient of PARS-3 in this study was 0.69.

Mental vulnerability questionnaire (MVQ)

The scale was compiled by Eplov et al. [50], it consisted of 22 items, which were divided into three dimensions: psychosomatic symptoms, psychiatric symptoms and interpersonal problems. 5-point Likert scale was adopted,

1 = never, 2 = rarely, 3 = sometimes, 4 = frequently, 5 = always. The lowest score was 22 and the highest score was 110. The higher the score, the greater the psychological vulnerability [51]. The total Cronbach's α of the scale was 0.920. The Cronbach's α of psychosomatic symptoms, psychiatric symptoms and interpersonal problems were 0.942, 0.944 and 0.871, respectively.

Adolescent self-rating life events checklist (ASLEC)

ASLEC reported in the literature was used to assess the extent to which adolescents affected by life events [52]. The scale consisted of 27 items grouped into six dimensions of negative life events: interpersonal relationship, academic pressure, being punished, personal loss, health and adaptability and others. Each item was scored on a 5-point Likert scale. Participants were asked to indicate whether these life events had occurred in the past twelve months. If the answer was “no”, the score was 0. If the answer was “yes”, it was required to assess the effect of life events from 1 (not at all) to 5 (very significant). The total score of the scale ranged from 0 to 135, and the higher the score, the more severe the effect of life events. The Cronbach's α coefficient of this scale was 0.90.

Symptom checklist 90 (SCL-90)

SCL-90 was used to assess the mental health status of college students. The scale was compiled by Derogatis [53], including 90 items, divided into 10 dimensions: depression, anxiety, somatization, obsessive-compulsive symptoms, interpersonal sensitivity, hostility, terror, paranoia, psychosis, and other dimensions that assess appetite and sleep disorders. A 5-point Likert scale was used to score, 1 = none, 2 = very light, 3 = medium, 4 = slightly severe, 5 = severe. The Cronbach's α coefficient of this scale was 0.96. Studies showed that the general mental health problems of Chinese college students were mainly reflected in anxiety and depression [54, 55], so anxiety and depression were mainly selected as mental health indicators

Table 1 Stratified comparison of mental health by gender and age ($n = 3552$)

Variable		n	Anxiety			Depression		
			M	SD	F/t	M	SD	F/t
Gender	male	1819	17.38	8.24	15.689**	20.89	10.15	19.578**
	female	1733	28.77	10.45		31.92	13.57	
Age	19-20yr	1226	23.35	7.37	1.697	28.39	9.87	1.357
	20-22yr	1380	20.57	9.68		24.91	9.46	
	22-23yr	946	25.88	8.07		29.67	10.49	

Note: *: $p < 0.05$; **: $p < 0.01$. Same as below

Table 2 Correlation analysis between variables ($n = 3552$)

	M	SD	1	2	3	4	5	6	7
1 Gender	-	-							
2 Age	19.37	3.18	-0.03						
3 PARS-3	39.96	20.26	0.41**	0.06					
4 MVQ	43.36	15.68	-0.24**	0.08	-0.23**				
5 ASLEC	59.69	23.36	-0.15*	0.10	-0.15*	0.13*			
6 Anxiety	23.69	11.35	-0.32**	-0.09	-0.45*	0.37**	0.58**		
7 Depression	27.39	13.69	-0.28**	-0.05	-0.36**	0.29**	0.48**	0.90**	

in this study. The anxiety dimension contained 10 items with scores ranging from 10 to 50 points. The depression dimension contained 13 items with scores ranging from 13 to 65.

Quality control

First of all, the purpose, use and response requirements of the survey were explained in the questionnaire guidance. If the participants agree to participate in this survey, they must answer carefully to ensure the integrity and reliability of the questionnaire. Secondly, the duration and response of each questionnaire provided by the questionnaire star were screened. Questionnaires that took less than 5 min to answer or had a large number of missing or similar options were considered invalid and were eliminated. Finally, 329 invalid questionnaires were eliminated. Thirdly, in the data analysis stage, program control and Harman Univariate Test were used to control the common method bias. The results showed that the explained variance of the first common factor was 23.68%, which was less than the critical value of 40%, indicating that the common method bias in the data was not significant. At the same time, the Kolmogorov-Smirnov test showed that the data were normally distributed ($p = 0.18$).

It was also reported that gender [39] and age [25, 29] were two important demographic variables affecting individual psychology and psychological vulnerability, so gender and age were controlled as control variables in this study.

Statistical processing

SPSS 23.0 software was used for statistical analysis. Continuous variables were expressed as mean and standard

deviation. Pearson correlation analysis was used for correlation analysis. For the mediating effect analysis, the regression coefficient was tested step by step according to the mediating effect test procedure proposed by Baron & Kenny [56]. AMOS20.0 program was used to construct a structural equation modeling to further explore the relationship between physical activity, life events, psychological vulnerability, and the interaction terms between physical activity and life events and mental health (anxiety and depression). According to the criteria reported by Ni et al. [4], the fitting state of the model was judged: the closer χ^2/df was to 1, the better. The closer the RMSEA and SRMR were to 0, the better. The closer the indicators such as GFI, AGFI, NFI, TLI, CFI and IFI were to 1, the better the model fits; if these indicators were greater than 0.90, the better the model fits. Bilateral $p < 0.05$ was considered statistically significant.

Results

Stratified comparison of mental health status

Levels of anxiety and depression were compared by gender and age, respectively. The results showed that (Table 1), anxiety ($p < 0.01$) and depression ($p < 0.01$) were significantly higher in women than in men. However, there were no significant significances in anxiety and depression levels among the three age groups.

Correlation analysis

The results of the correlation analysis showed that (Table 2), gender was positively correlated with physical activity ($p < 0.01$), and negatively correlated with psychological vulnerability ($p < 0.01$) and life events ($p < 0.05$) significantly. Gender was also negatively correlated with anxiety ($p < 0.01$) and depression ($p < 0.01$). Physical

activity was negatively correlated with psychological vulnerability, life events, anxiety and depression ($p < 0.01$ or $p < 0.05$). Psychological vulnerability was positively correlated with life events, anxiety and depression ($p < 0.01$ or $p < 0.05$). Life events were positively correlated with anxiety and depression (all $p < 0.01$). There was a significant positive correlation between anxiety and depression ($p < 0.01$). However, there was no significant correlation between age and each variable.

Regression analysis

Because there was a significant correlation between anxiety and depression (Table 2), and because they were both the two main manifestations of mental health problems in college students, anxiety and depression were integrated into a single variable (mental health) for analysis in this study. Firstly, the four variables of psychological vulnerability, life events, physical activity and mental health status were centralized, that is, the sample mean was subtracted. Thereafter, stepwise regression analysis was performed for the above four variables. Table 3 showed the results of regression analysis. Models 1, 3 and 5 examined the effects of physical activity and life events on mental health and the mediating effect of psychological vulnerability. The interaction term between physical activity and life events was added into models 2, 4 and 6, to examine the effects of physical activity, life events, the interaction term between physical activity and life events on mental health, as well as the mediating effect of psychological vulnerability.

Model 1 showed that, after controlling for gender and age, physical activity had a significant negative predictive effect on psychological vulnerability ($p < 0.01$), while life events had no significant effect on psychological vulnerability ($p > 0.05$).

Model 3 showed that physical activity had a significant negative predictive effect on mental health (anxiety and depression) ($p < 0.01$), and life events had a significant positive predictive effect on mental health (anxiety and depression) ($p < 0.01$).

Model 5 showed that, when psychological vulnerability entered model 3, it had a significant positive effect on mental health (anxiety and depression) ($p < 0.01$), and physical activity still had a negative effect on mental health (anxiety and depression) ($p < 0.01$), but the regression coefficient decreased. According to the stepwise test of mediating effect, if the direct effect of the independent variable on the dependent variable was still significant, then the mediating variable played a partial mediating role between the independent variable and the dependent variable. Therefore, psychological vulnerability had a partial mediating effect between physical activity and mental health (anxiety and depression).

Table 3 Regression analysis between variables ($n = 3552$)

Variable	Mental health (anxiety and depression)					
	MVQ			Model 16		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	β	t	t	β	t	t
Gender	-0.216	7.687**	7.112**	-0.191	4.741**	3.798**
Age	0.075	1.061	1.026	0.081	1.129	1.111
PARS-3	-0.356	9.967**	8.464**	-0.408	12.298**	11.698**
ASLEC	0.089	1.264	1.420	0.597	21.214**	17.916**
PARS-3*ASLEC			1.946*		-0.134	2.045*
MVQ					0.221	7.845**
R	0.513			0.575	0.456	0.754
adjR ²	0.287			0.316	0.312	0.423
F	66.647**			47.847**	65.241**	88.364**

Note: *, $p < 0.05$; **, $p < 0.01$

Model 5 also showed that, when psychological vulnerability entered model 3, life events still had a positive effect on mental health (anxiety and depression) ($p < 0.01$). Because life events had no significant effect on psychological vulnerability in the sequential tests ($p > 0.05$), Sobel test was required to determine the mediating relationship between life events, psychological vulnerability and mental health (anxiety and depression) according to the test procedure proposed by Baron & Kenny [56]. The test statistics $= \hat{a}\hat{b} / \sqrt{\hat{a}^2 s_b^2 + \hat{b}^2 s_a^2}$, in which $\hat{a} = 0.089$, $S_a = 0.022$, $\hat{b} = 0.458$, $S_b = 0.024$, $z = 3.885$, $p < 0.01$. The results suggested that psychological vulnerability had a mediating effect between life events and mental health (anxiety and depression).

Model 2 showed that, after the interaction term between physical activity and life events entered model 1, it had a negative predictive effect on psychological vulnerability ($p < 0.05$). A simple slope test was further conducted for the interaction effect. One standard deviation above the mean value of physical activity measurement was defined as “high level of physical activity group”, and one standard deviation below the mean value was defined as “low level of physical activity group”, and the interaction effect diagram was drawn (Fig. 2). The simple slope test showed that, when the level of physical activity was low, psychological vulnerability increased rapidly with the increase of life events ($p < 0.05$). When the level of physical activity was high, psychological vulnerability showed a slow decreasing trend with the increase of life

events ($p > 0.05$). The results suggested that high level of physical activity could reverse the adverse effects of life events on psychological vulnerability.

Model 4 showed that the interaction term between physical activity and life events had a negative effect on mental health (anxiety and depression) ($p < 0.05$). A simple slope test was further conducted on the interaction effect. One standard deviation above the mean value of physical activity measurement was defined as “high level of physical activity group”, and one standard deviation below the mean value was defined as “low level of physical activity group”, and the interaction effect diagram was drawn (Fig. 3). The simple slope test showed that, when the level of physical activity was low, the mental health (anxiety and depression) score increased significantly with the increase of life events ($p < 0.05$). When the level of physical activity was high, the mental health (anxiety and depression) score showed a significant decrease trend with the increase of life events ($p < 0.05$). The results suggested that high level of physical activity reversed effectively the effect of life events on mental health (anxiety and depression).

Model 6 showed that, after psychological vulnerability entered model 4, it had a significant positive effect on mental health (anxiety and depression) score ($p < 0.05$), but the interaction term between physical activity and life events had no significant effect on mental health (anxiety and depression) ($p > 0.05$). The results suggested that psychological vulnerability completely mediated the effect of

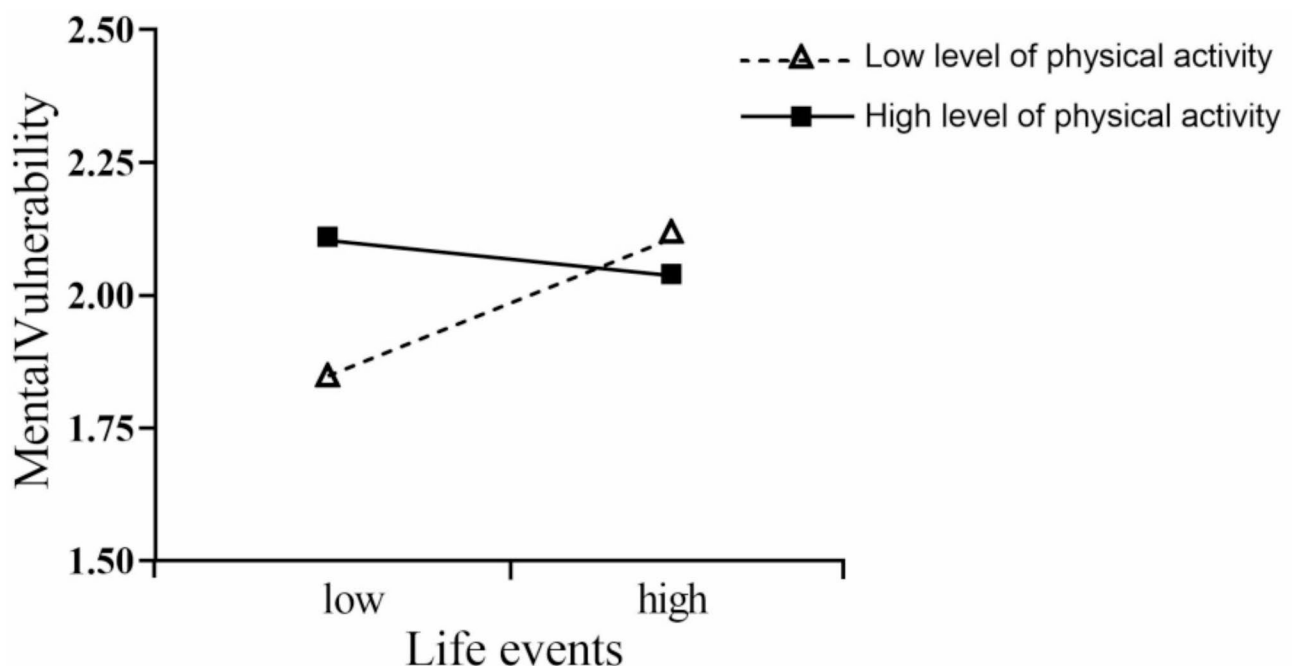


Fig. 2 The moderating effect of physical activity on the relationship between life events and psychological vulnerability

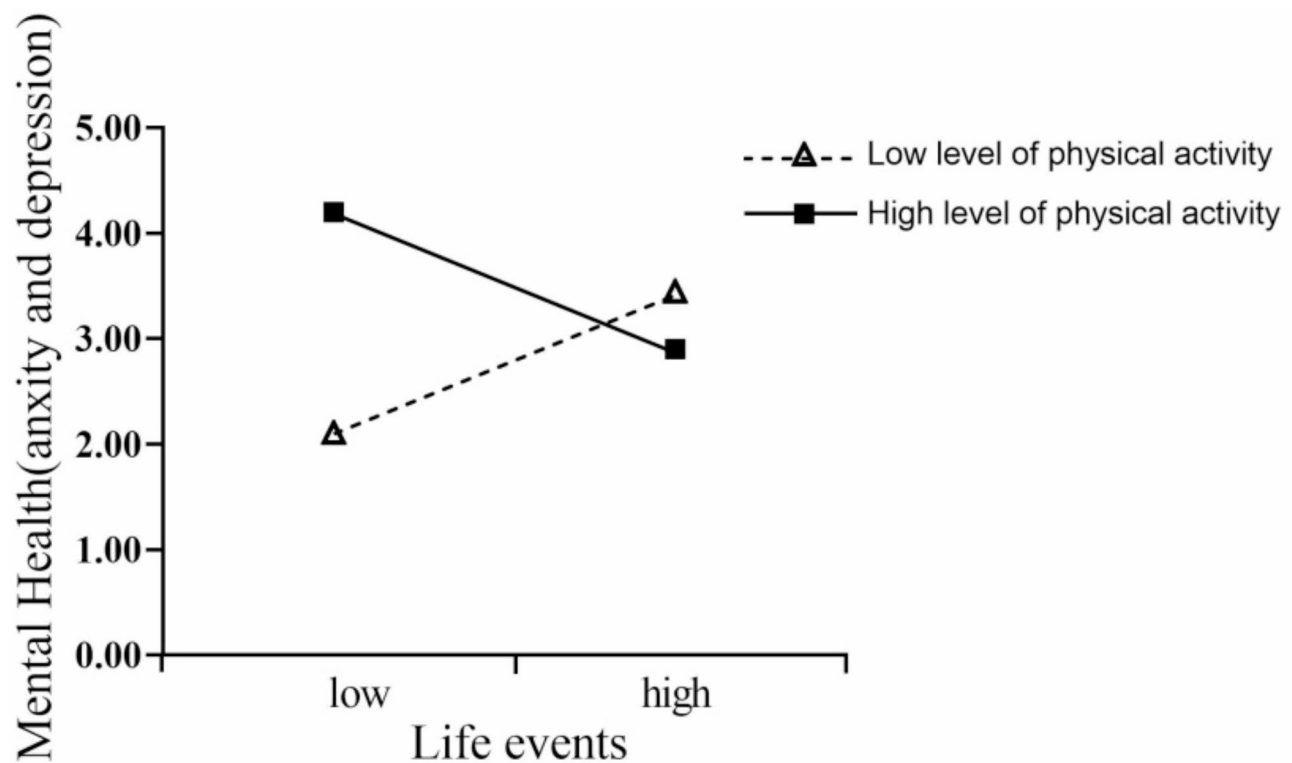


Fig. 3 The moderating effect of physical activity on the relationship between life events and mental health

interaction term between physical activity and life events on mental health (anxiety and depression).

SEM

Structural equation modeling (SEM) was further used to explore the effects of physical activity and life events on college students' mental health (anxiety and depression), as well as the mediating effect of psychological vulnerability. Physical activity included three latent variables: exercise intensity, duration and frequency. Psychological vulnerability included three latent variables: psychosomatic symptoms, psychiatric symptoms and interpersonal problems. Life events included six latent variables: academic pressure, being punished, interpersonal relationship, personal loss, health and adaptability and others. Mental health included two latent variables: anxiety and depression. At the same time, the interaction term of physical activity and life events was included in the model as an independent latent variable. The initial model analysis showed that, the direct path between the interaction term of physical activity and life events and mental health was not significant ($p > 0.05$), therefore, this path did not enter the final model (Fig. 4). The overall model fitting index of the modified final model was $\chi^2/df = 1.347$, RMSEA = 0.072, SRMR = 0.034, GFI = 0.951, AGFI = 0.961, NFI = 0.977, TLI = 0.961, CFI = 0.954, IFI = 0.976, the results showed that the model fit well. Through model analysis, it was found that, after

controlling the two demographic variables, gender and age, the conceptual model and hypotheses mentioned in the introduction were basically confirmed. As shown in the final model, physical activity negatively predicted anxiety and depression, and also negatively predicted psychological vulnerability. However, life events positively predicted anxiety and depression, as well as psychological vulnerability. The interaction term between physical activity and life events negatively predicted psychological vulnerability. The results of psychological vulnerability as the mediating variable showed that, physical activity and life events affected mental health (anxiety and depression) not only through direct effects but also through the mediating effect of psychological vulnerability, which accounted for 22.17% and 23.42% of the total effect, respectively. However, the effect of the interaction term between physical activity and life events on mental health (anxiety and depression) was mainly realized through the mediating effect of psychological vulnerability, which accounted for 91.86% of the total effect. That is, psychological vulnerability played a completely mediating role between the interaction term of physical activity and life events. The direct and indirect effects with 95%CI intervals of all regulatory pathways were presented in Table 4.

PARS-3: physical activity; ASLEC: life events; ID: interpersonal difficulties; AP: academic pressure; BP: being punished; PL: personal loss; HA: health and adaptability;

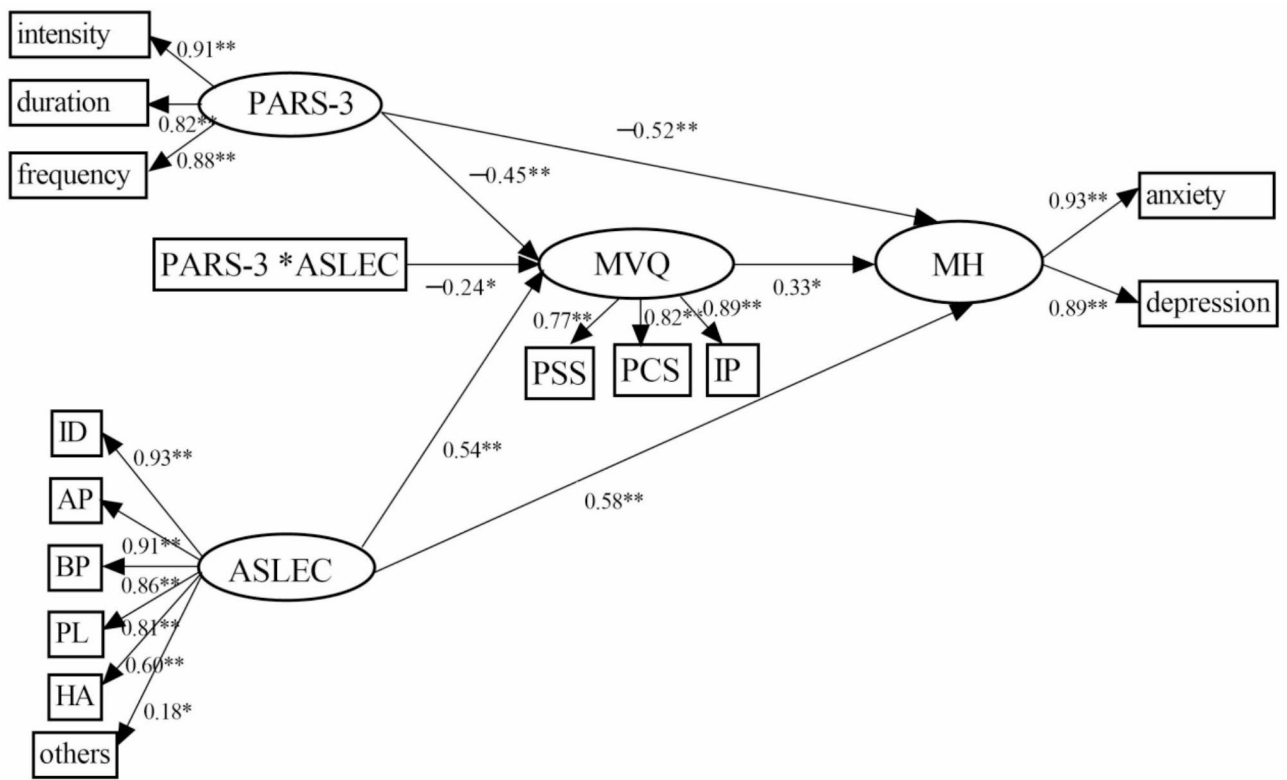


Fig. 4 Interrelationship and change pathway coefficient of variables in the structural equation model

Table 4 The pathway coefficient of the final model

Independent variable	Mediating variable	Dependent variable	Indirect pathway			Direct pathway			mediating/total effect
			β	SE	95%CI	β	SE	95%CI	
ASLEC	MVQ	MH (anxiety and depression)	0.178	0.032	[0.091,0.217]	0.582	0.017	[0.496,0.711]	23.42%
PARS-3			-0.149	0.014	[-0.191,-0.093]	-0.523	0.034	[-0.596,-0.459]	22.17%
PARS-3*ASLEC			-0.079	0.011	[-0.084,-0.051]	-0.007	0.002	[-0.014,0.009]	91.86%

MVQ: psychological vulnerability; PSS: psychosomatic symptoms; PCS: psychiatric symptoms; IP: interpersonal problems; MH: mental health. * $p < 0.05$, ** $p < 0.01$.

Discussion

Anxiety and depression are two types of mental health problems in college students, and there is a close relationship between them [54, 55]. In this study, anxiety and depression were used as a comprehensive variable to assess the mental health status of college students, and a cross-sectional survey was conducted to assess physical activity level, psychological vulnerability, mental health status (anxiety and depression) and life events experiences of 3552 college students. On the basis of stratified comparison and correlation analysis, regression analysis was further used to explore the effects of physical activity, life events and psychological vulnerability on mental

health, and structural equation model was finally used to explore the relationship between the above variables.

Relationship between life events, psychological vulnerability and mental health (anxiety and depression)

This study first found that life events positively affect anxiety and depression in mental health. The more adverse life events college students experienced, the higher their anxiety and depression, and the worse their overall mental health. The results first supported hypothesis 1. Studies found that experiencing adverse life events could increase individual anxiety [57, 58]. Multiple studies also reported that life events were risk factors for depression [59, 60]. Ni et al. [4] also reported a dose-effect relationship between the number of traumatic events and psychological consequences. Physiological studies confirmed that the mechanism by which life events increased individual anxiety and depression might be related to the

dysfunction of the hypothalamic-pituitary-adrenal (HPA) axis [61]. As a chronic stressor, life events could lead to overactivation of HPA [62] and abnormal increase of cortisol secretion [63], and then change the function of the emotional regulation circuit in the central nervous system [64], reducing the emotional regulation function and increasing negative psychology in the face of life events. In addition, life events might also reduce the secretion of neurotransmitters such as 5-HT, NE and DA in the central nervous system [65], thus reducing the positive emotional experience of individuals. This result was also confirmed in the study of Swartz et al. [20]. Studies in cognitive psychology also confirmed that life events might also positively affect depression through the chain mediation of attribution-self-esteem [66]. Łosiak et al. [67] also reported that rumination and cognitive bias played an important modulatory role between life events and depressive symptoms. In addition, life events could also reduce mental health through psychological mechanism such as increasing psychological resource depletion [68], reducing psychological resilience and understanding social support [69], and increasing stress sensitivity [20].

It was also found in this study that life events positively affected psychological vulnerability. That is, experiencing more life events, especially adverse life events early in life would increase individual psychological vulnerability. The results supported hypothesis 3. Neurophysiological studies confirmed that childhood poverty could reduce the coupling between the amygdala and the ventromedial prefrontal cortex (vmPFC) in the resting state, thereby increasing individual psychological vulnerability [19], which was also confirmed by Swartz et al. [20]. Thoits et al. [18] also reported that life events could reduce the psychological capital and increase psychological vulnerability of women, the elderly and low-income groups. The stress-sensitization model also showed that early traumatic life events could increase individual psychological vulnerability and stress sensitivity, resulting in severe psychological problems when experiencing weaker stressful life events later [21]. The results suggested that psychological vulnerability was closely related to mental health. Korten et al. [70] conducted a 10-year follow-up study on 1312 elderly people (aged 65–85) and found that adverse life experiences in childhood could increase their physical and psychological vulnerability, which could lead to increased depression and decreased cognitive function in adulthood. The results of Nobre et al. [10], Nogueira et al. [12], Dadandi et al. [13] and Sampaio et al. [11] also showed that psychological vulnerability was negatively correlated with individual mental health status, and positively correlated with negative psychology such as anxiety and depression. Oruebner et al. [71] further reported that psychological vulnerability was an important regulating

factor for the mental health status of residents in disaster areas after hurricane. Recently, Lv et al. [17] reported that psychological vulnerability could not only positively predict depression, but also act as a mediating variable between cognitive fusion and depression. It was also reported that, as a psychological vulnerability factor, experience avoidance played a mediating role between chronic pain and anxiety [72]. Through regression analysis and structural equation model analysis, it was found that psychological vulnerability was not only positively correlated with anxiety and depression in mental health, but also played a mediating role between life events and mental health (anxiety and depression), with the mediating effect size of 23.42%. Therefore, hypotheses 2 and 4 were also supported.

The relationship between physical activity, psychological vulnerability and mental health (anxiety and depression)

Physical activity had a promoting effect on mental health, and was a good way to reduce individual anxiety, depression and mental stress. This study also confirmed that physical activity was negatively correlated with anxiety and depression in mental health, that is, the higher the level of physical activity, the lower the level of anxiety and depression, and the higher the level of mental health. The results first supported hypothesis 5. A large number of studies have reported the mechanism of physical activity reducing anxiety, depression and other negative psychology. Physiological studies showed that physical activity could improve mental health by reducing HPA activity [24], improving cerebral blood flow [73] and neuroendocrine function (increasing DA and endorphin secretion) [25], and reducing inflammatory response [36]. In addition, physical activity could also improve mental health by improving self-efficacy [37, 74], self-esteem and interpersonal relationships [75, 76], psychological resilience [45] and emotion regulation strategies [77], or distract individuals from adverse life events [36] and other cognitive psychological aspects.

This study also found that physical activity was negatively correlated with psychological vulnerability. That is, the higher the physical activity level, the lower the psychological vulnerability, and the stronger the psychological adaptability under the chronic stress stimulation of life events. This finding supported hypothesis 6. The reason might be that physical activity itself was a kind of stress stimulation, and the human body would have temporary physiological reactions such as hypoxia, dyspnea, rapid heartbeat, muscle soreness and temperature rise during high-level physical activity. In order to overcome the adverse physiological reactions in exercise, individuals need to mobilize psychological capital, improve cognitive control function, and enhance perseverance and other psychological behaviors to persist in exercise.

Therefore, people who often engaged in high-level physical activity would gradually adapt to this stress stimulus, thus improving the ability to resist stress and frustration, and reducing psychological vulnerability. As psychological vulnerability was often analyzed as a mediating variable, this study found through structural equation model analysis that, psychological vulnerability played a mediating role in the relationship between physical activity and mental health (anxiety and depression), with the mediating effect size of 22.17%. The result also suggested that the reduction of individual anxiety and depression after regular physical activity was partly due to the fact that physical activity reduced individual psychological vulnerability. Low level of psychological vulnerability enabled individuals to have a higher ability to resist stress or frustration, and then maintain a stable psychological state in the face of stress stimulation of various life events. The result also directly supported hypothesis 7.

Effect of interaction between physical activity and life events on psychological vulnerability and mental health (anxiety and depression)

One of the biggest highlights of this study is the inclusion of the interaction term between physical activity and life events into regression analysis and structural equation model analysis, which has more practical significance, because college students not only experience life events, but also engage in certain physical activity in their daily life. So, what is the effect of experiencing life events and engaging in physical activity on individuals? No reports have been seen yet. The results of this study showed that the interaction term of physical activity and life events was negatively correlated with psychological vulnerability. The findings partially supported hypothesis 8. The results of this study are consistent with those reported by Rodríguez-Romo et al. [40], Nowacka-Chmielewska et al. [44] and Belcher et al., [45], which also found that physical activity could improve mental resilience, reduce mental vulnerability and buffer the adverse effects of life events on mental health by enhancing the top-down control function of the central nervous system. Further simple slope tests showed that, when the level of physical activity was low, individual psychological vulnerability increased rapidly with the increase of life events. In contrast, when the level of physical activity was high, individual psychological vulnerability showed a slow decreasing trend with the increase of life events. Physical activity reversed the adverse effect of life events on psychological vulnerability. This result can be explained by the theory of post-traumatic growth (PTG) [78], which held that major traumatic events, stressful stimuli or stressful events would have adverse effects on individual psychology, while also producing positive outcomes, such as improving individual psychological resilience or psychological

immunity, so that individuals could effectively cope with similar adverse experiences in the late period. We speculate that individuals who regularly engage in physical activity, especially high-intensity physical activity, have obtained good psychological quality similar to PTG due to long-term exercise load stimulation, which in turn makes them show more and more courageous psychological quality when experiencing life events, and their psychological vulnerability does not increase, but decreases. This result fully supports hypothesis 8.

This study also found that the interaction term of physical activity and life events negatively affected anxiety and depression in mental health, that is, individuals who regularly engaged in high levels of physical activity could maintain lower levels of anxiety and depression even after experiencing life events. The simple slope test further showed that high levels of physical activity could significantly reverse the tendency of anxiety and depression levels to rise with life events. This result partially supported hypothesis 9. After path analysis using structural equation model, it was found that the direct pathway between the interaction terms of physical activity and life events and mental health (anxiety and depression) was not significant, but the indirect pathway mediated by psychological vulnerability was significant. The results suggested that the interaction between physical activity and life events had a promoting effect on mental health mediated by psychological vulnerability. This finding can be explained by the theoretical model of the relationship between psychological quality and mental health [79], which holds that some inherent psychological qualities determine individual psychological state under life events. Even after experiencing the same life events, different individuals will have completely different psychological states due to their different psychological qualities. Psychological vulnerability can be regarded as a kind of psychological quality, and physical activity can improve this individual psychological quality and reduce psychological sensitivity to adverse life events [75]. It can be considered that regular participation in physical activity can reduce individual psychological vulnerability and improve psychological resilience. The good psychological quality will be transformed into the cause of PTG when individuals experience the stress stimulation of life events, leading to the improvement of mental health.

Limitations of the study

Through the survey data of large sample size and the comprehensive application of various analysis methods, this study comprehensively revealed the relationship between physical activity, life events, psychological vulnerability and mental health, and finally confirmed that physical activity can effectively reverse the adverse effects of life events on mental health. However, there are some

limitations in this study. Firstly, this is a cross-sectional study, and no causal inference can be made about the relationship between some variables. For example, it is not possible to determine in this study whether low levels of physical activity are causes or consequences of individual anxiety and depression. Secondly, although this study found that physical activity could reverse the adverse effects of life events on individual mental health, it was impossible to distinguish whether the effect was caused by physical activity before or after life events. Thirdly, the factors affecting mental health of college students are very complex, including natural and social environment, genetic background and personal living habits. However, only gender and age were controlled in this study, which might lead to a certain limitations in the study results. Even so, the results of this study can still provide enlightenment for mental health management and intervention system construction of college students.

Conclusion

On the basis of regression analysis, the structural equation model was further used in this study to explore the relationship between physical activity, life events, psychological vulnerability and mental health (anxiety and depression). Physical activity and life events had significantly opposite main effects on mental health (anxiety and depression). Psychological vulnerability partially mediated the effects of physical activity and life events on mental health. Physical activity and life events could have an interaction effect on psychological vulnerability and mental health, and this interaction effect could reverse the adverse effects of life events. Compare with those of individuals with lower levels of physical activity, the psychological vulnerability and mental health of individuals with higher levels of physical activity tended to decrease as the stimulation intensity of life events increased. The results of this study not only rich the relevant theories of physical activity promoting mental health, but also provide ideas for coping with the adverse effects of life events on individual mental health. Living in a rapidly developing and fiercely competitive society, people may not be able to avoid the negative effects of life events on their psychology, but they can effectively deal with such adverse effects by changing their lifestyle, such as increasing physical activity.

Overall, this study has yielded some results with theoretical value and practical significance. However, there are still problems in this field that need to be further explored. In the future, it is possible to explore the threshold of chronic stress stimuli such as various life events that individuals can tolerate, which is conducive to timely psychological warning or intervention. In addition, it is necessary to explore the dose effect of physical activity in reversing negative psychology such as anxiety

and depression caused by life events for individuals with different psychological vulnerabilities, so as to better exert the intervention effect of physical activity. Thirdly, in the future, longitudinal tracking studies can also be used to reveal the causal relationship between low-level physical activity and negative psychology such as anxiety and depression. Finally, in addition to the two variables of gender and age, it is necessary to include more demographic variables, such as personal lifestyle habits, smoking, BMI, family history of mental illness and so on, which will make the results of this study more scientific.

Abbreviations

ASLEC	Adolescent Self-Rating Life Events Checklist
HPA	Hypothalamic-pituitary-adrenal
MVQ	Mental Vulnerability Questionnaire
PARS-3	Physical Activity Rating Scale-3
PTG	Post-traumatic growth
SCL-90	Symptom Checklist 90
SEM	Structural equation modeling
vmPFC	Ventromedial prefrontal cortex

Acknowledgements

Thanks to all the participants and interviewees.

Author contributions

Zhifeng Wang: Conceptualization, Writing– original draft, Funding acquisition. Fengyun Wang: Investigation. Baolei Ma: Resources. Haihong Xue and Botao Liu: data analysis. Dongmei Wang: Conceptualization, Writing– review & editing.

Funding

This study was supported by grants from the Social Science Foundation of Shanxi Province [grant number: 2024Q006] and National Education Science Plan 2021 Key Project of the Ministry of Education (Project title: “Study of exercise intervention on adolescent psychological crisis under the background of major emergencies”) [grant number: DLA210372].

Data availability

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study and its experimental programs were approved by the Ethics Committee of Xi'an Polytechnic University, issued ID # 2022TY0029. All methods were carried out in accordance with the Declaration of Helsinki and approved by the aforementioned ethics committee. Written informed consent was obtained from all participants.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 16 June 2024 / Accepted: 24 February 2025

Published online: 12 March 2025

References

1. Filiatreau LM, Ebasone PV, Dzudie A, Ajeh R, Pence BW, Wainberg M, et al. Prevalence of stressful life events and associations with symptoms of depression, anxiety, and post-traumatic stress disorder among people entering care for HIV in Cameroon. *J Affect Disord.* 2022;308:421–31.

2. Li Y, Chu J, Wen F, Yu L, Yan J, Wang F, et al. Life events and parent style for mental health in children: a cross-sectional study. *Pediatr Res*. 2023;93(5):1432–8.
3. Qouta S, Punamäki RL, Montgomery E, El Sarraj E. Predictors of psychological distress and positive resources among Palestinian adolescents: trauma, child, and mothering characteristics. *Child Abuse Negl*. 2007;31(7):699–717.
4. Ni T, Zhang Y, Xue S, Xu W, Tang W. PTSD and depressive symptoms in Chinese adolescents exposed to multiple stressors from natural disasters, stressful life events, and maltreatment: a dose-response effect. *Front Psychol*. 2022;13:1050260.
5. Chen T, Roberts K. Negative life events and suicide in the national violent death reporting system. *Arch Suicide Res*. 2021;25(2):238–52.
6. Charles E, Bouby-Serieys V, Thomas P, Clément JP. Relation entre événements de Vie, traumatismes et démence; étude ouverte portant Sur 565 patients déments [Links between life events, traumatism and dementia; an open study including 565 patients with dementia]. *Encephale*. 2006;32(5 Pt 1):746–52.
7. Infurna MR, Reichl C, Parzer P, Schimmenti A, Bifulco A, Kaess M. Associations between depression and specific childhood experiences of abuse and neglect: a meta-analysis. *J Affect Disord*. 2016;190:47–55.
8. Satici SA, Uysal R. Psychological vulnerability and subjective happiness: the mediating role of hopelessness. *Stress Health*. 2017;33(2):111–8.
9. Swanepoel F, van Staden W, Fletcher L. Psychological resilience and vulnerability as mediators between adverse life events and fatigue, motor dysfunction, and paresthesia in multiple sclerosis. *Psychosom Med*. 2020;82(2):138–46.
10. Nobre J, Luis H, Oliveira AP, Monteiro F, Cordeiro R, Sequeira C, et al. Psychological vulnerability indices and the adolescent's good mental health factors: a correlational study in a sample of Portuguese adolescents. *Child (Basel)*. 2022;9(12):1961.
11. Sampaio F, Coelho J, Gonçalves P, Sequeira C. Protective and vulnerability factors of municipal workers' mental health: a cross-sectional study. *Int J Environ Res Public Health*. 2022;19(21):14256.
12. Nogueira MJ, Seabra P, Alves P, Teixeira D, Carvalho JC, Sequeira C. Predictors of positive mental health in higher education students. A cross-sectional predictive study. *Perspect Psychiatr Care*. 2022;58(4):2942–9.
13. Dadandi I. The fear of COVID-19 mediates the relationships between psychological vulnerability, social support and psychological distress. *Psychiatr Danub*. 2022;34(4):766–72.
14. Bruehlman-Senecal E, Hook CJ, Pfeifer JH, FitzGerald C, Davis B, Delucchi KL, et al. Smartphone app to address loneliness among college students: pilot randomized controlled trial. *JMIR Ment Health*. 2020;7(10):e21496.
15. Hirsch CR, Clark DM, Mathews A. Imagery and interpretations in social phobia: support for the combined cognitive biases hypothesis [published correction appears in *Behav Ther*. 2007;38(2):207]. *Behav Ther*. 2006;37(3):223–36.
16. Zubin J, Spring B. Vulnerability—a new view of schizophrenia. *J Abnorm Psychol*. 1977;86(2):103–26.
17. Lv J, Qiu Q, Ye B, Yang Q. The effects of cognitive fusion on depression in primary school principals during the COVID-19 pandemic: the mediating role of psychological vulnerability and the moderating role of self-esteem. *Psychol Res Behav Manag*. 2023;16:1727–39.
18. Thoits PA. Life stress, social support, and psychological vulnerability: epidemiological considerations. *J Community Psychol*. 1982;10(4):341–62.
19. Hanson JL, Albert WD, Skinner AT, Shen SH, Dodge KA, Lansford JE. Resting state coupling between the amygdala and ventromedial prefrontal cortex is related to household income in childhood and indexes future psychological vulnerability to stress. *Dev Psychopathol*. 2019;31(3):1053–66.
20. Swartz JR, Knodt AR, Radtke SR, Hariri AR. Post-secondary maternal education buffers against neural risk for psychological vulnerability to future life stress. *Neuropsychologia*. 2018;109:134–9.
21. Monroe SM, Harkness KL. Life stress, the kindling hypothesis, and the recurrence of depression: considerations from a life stress perspective. *Psychol Rev*. 2005;112(2):417–45.
22. Meyers JL, Lowe SR, Eaton NR, Krueger R, Grant BF, Hasin D. Childhood maltreatment, 9/11 exposure, and latent dimensions of psychopathology: A test of stress sensitization. *J Psychiatr Res*. 2015;68:337–45.
23. Uğur E, Kaya Ç, Tanhan A. Psychological inflexibility mediates the relationship between fear of negative evaluation and psychological vulnerability. *Curr Psychol*. 2021;40(9):4265–77.
24. Wang Z, Jiang B, Wang X, Li Z, Wang D, Xue H, et al. Relationship between physical activity and individual mental health after traumatic events: a systematic review. *Eur J Psychotraumatol*. 2023;14(2):2205667.
25. Chen Z, Lan W, Yang G, Li Y, Ji X, Chen L, et al. Exercise intervention in treatment of neuropsychological diseases: a review. *Front Psychol*. 2020;11:569206.
26. Herbert C. Enhancing mental health, well-being and active lifestyles of university students by means of physical activity and exercise research programs. *Front Public Health*. 2022;10:849093.
27. Schuch FB, Vancampfort D. Physical activity, exercise, and mental disorders: it is time to move on. *Trends Psychiatry Psychother*. 2021;43(3):177–84.
28. Kuroda Y, Iwasa H, Orui M, Moriyama N, Suemoto CK, Yashiro C, et al. Risk factor for incident functional disability and the effect of a preventive exercise program: a 4-year prospective cohort study of older survivors from the great East Japan earthquake and nuclear disaster. *Int J Environ Res Public Health*. 2018;15(7):1430.
29. Oe M, Maeda M, Ohira T, Itagaki S, Harigane M, Suzuki Y, et al. Trajectories of emotional symptoms and peer relationship problems in children after nuclear disaster: evidence from the Fukushima health management survey. *Int J Environ Res Public Health*. 2018;15(1):82.
30. Zhang X, Zhu W, Kang S, Qiu L, Lu Z, Sun Y. Association between physical activity and mood states of children and adolescents in social isolation during the COVID-19 epidemic. *Int J Environ Res Public Health*. 2020;17(20):7666.
31. Brumby S, Chandrasekara A, McCoombe S, Kremer P, Lewandowski P. Farming fit? Dispelling the Australian agrarian myth. *BMC Res Notes*. 2011;4:89.
32. Smith E, Walker T, Burkle FM. Lessons in post-disaster self-care from 9/11 paramedics and emergency medical technicians. *Prehosp Disaster Med*. 2019;34(3):335–9.
33. Hall KS, Morey MC, Beckham JC, Bosworth HB, Sloane R, Pieper CF, et al. Warrior wellness: a randomized controlled pilot trial of the effects of exercise on physical function and clinical health risk factors in older military veterans with PTSD. *J Gerontol Biol Sci Med Sci*. 2020;75(11):2130–8.
34. Levante A, Quarta S, Massaro M, Calabriso N, Carluccio MA, Damiano F, et al. Physical activity habits prevent psychological distress in female academic students: the multiple mediating role of physical and psychosocial parameters. *Heliyon*. 2024;10(4):e26626.
35. Wang Z, Wang F, Jiang B, Xue H, Zhao M, Wang D. Combined effects of physical activity and life events on depression and PTSD in Chinese students aged 16–24 years. *Front Public Health*. 2024;12:1449391.
36. Crush EA, Frith E, Loprinzi PD. Experimental effects of acute exercise duration and exercise recovery on mood state. *J Affect Disord*. 2018;229:282–7.
37. Jönsson T, Ekvall Hansson E, Thorstensson CA, Eek F, Bergman P, Dahlberg LE. The effect of education and supervised exercise on physical activity, pain, quality of life and self-efficacy - an intervention study with a reference group. *BMC Musculoskelet Disord*. 2018;19(1):198.
38. Hu L, Li S. Correlation between physical activity level and psychological frailty in older patients. *Jilin Med*. 2022;43(11):3033–4.
39. Carmona-Torres JM, Cobo-Cuenca AI, Pozuelo-Carrascosa DP, Latorre-Román PÁ, Párraga-Montilla JA, Laredo-Aguilera JA. Physical activity, mental health and consumption of medications in pre-elderly people: the national health survey 2017. *Int J Environ Res Public Health*. 2021;18(3):1100.
40. Rodríguez-Romo G, Acebes-Sánchez J, García-Merino S, Garrido-Muñoz M, Blanco-García C, Díez-Vega I. Physical activity and mental health in undergraduate students. *Int J Environ Res Public Health*. 2022;20(1):195.
41. Levenstein S, Jacobsen RK, Rosenstock S, Jørgensen T. Mental vulnerability, *Helicobacter pylori*, and incidence of hospital-diagnosed peptic ulcer over 28 years in a population-based cohort. *Scand J Gastroenterol*. 2017;52(9):954–61.
42. Hemmeter UM, Ngamsri T. Körperliche aktivität und Psychische gesundheit: Fokus alter [Physical activity and mental health in the elderly]. *Praxis (Bern 1994)*. 2022;110(4):193–8.
43. Debbia F, Rodríguez-Muñoz PM, Carmona-Torres JM, Hidalgo-Lopezosa P, Cobo-Cuenca AI, López-Soto PJ, et al. Association between physical activity, food consumption and depressive symptoms among young adults in Spain: findings of a national survey. *Issues Ment Health Nurs*. 2020;41(1):59–65.
44. Nowacka-Chmielewska M, Grabowska K, Grabowski M, Meybohm P, Burek M, Małeck A. Running from stress: neurobiological mechanisms of exercise-induced stress resilience. *Int J Mol Sci*. 2022;23(21):13348.
45. Belcher BR, Zink J, Azad A, Campbell CE, Chakravarti SP, Herting MM. The roles of physical activity, exercise, and fitness in promoting resilience during adolescence: effects on mental well-being and brain development. *Biol Psychiatry Cogn Neurosci Neuroimaging*. 2021;6(2):225–37.
46. Hashimoto K. Stress. Exercise and quality of life. Beijing: Asian Games Scientific Congress; 1990.
47. Liang D, Liu S. Stress level of college students and its relationship with physical exercise. *Chin Ment Health J*. 1994;8(1):5–6. [Google Scholar].

48. Hao M, Yang J, Xu S, Yan W, Yu H, Wang Q. The relationship between body dissatisfaction, lifestyle, and nutritional status among university students in Southern China. *BMC Psychiatry*. 2023;23(1):705.
49. Zhou J, Huo Y. Chinese youths' physical activity and flourishing during COVID-19: the mediating role of meaning in life and self-efficacy. *Front Psychol*. 2022;13:867599.
50. Eplov LF, Jørgensen T, Birket-Smith M, Segel S, Johansen C, Mortensen EL. Mental vulnerability as a predictor of early mortality. *Epidemiology*. 2005;16(2):226–32.
51. Jørgensen TSH, Wiium-Andersen MK, Jørgensen MB, Osler M. The impact of mental vulnerability on the relationship between cardiovascular disease and depression. *Eur Psychiatry*. 2020;63(1):e16.
52. Shao C, Wang X, Ma Q, Zhao Y, Yun X. Analysis of risk factors of non-suicidal self-harm behavior in adolescents with depression. *Ann Palliat Med*. 2021;10(9):9607–13.
53. Derogatis LR. The symptom checklist–90–R (scl–90–R). *Clinical Psychometrics Research*. 1975.
54. Jiang Y, Zhang L, Mao Z. Physical exercise and mental health: the effect of emotion regulation self-efficacy and emotion regulation strategy. *Stud Psychol Behav*. 2018;16(4):570–6.
55. Wang Z, Jiang B, Wang X, Niu Y, Xue H. Cross-sectional investigation and correlation analysis of psychology of college students returning to campus after COVID-19 lockdown lift. *Front Psychiatry*. 2022;13:915042.
56. Baron RM, Kenny DA. The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *J Pers Soc Psychol*. 1986;51(6):1173–82.
57. Miloyan B, Joseph Bienvenu O, Brilot B, Eaton WW. Adverse life events and the onset of anxiety disorders. *Psychiatry Res*. 2018;259:488–92.
58. Sârbu EA, Iovu MB, Lazăr F. Negative life events and internalizing problems among Romanian youth. *Clin Child Psychol Psychiatry*. 2022;27(2):399–411.
59. Chiappelli J, Kvarita M, Bruce H, Chen S, Kochunov P, Hong LE. Stressful life events and openness to experience: relevance to depression. *J Affect Disord*. 2021;295:711–6.
60. Paykel ES. Life events and affective disorders. *Acta Psychiatr Scand Suppl*. 2003;108(418):61–6.
61. Faravelli C, Lo Sauro C, Lelli L, Pietrini F, Lazzeretti L, Godini L, et al. The role of life events and HPA axis in anxiety disorders: a review. *Curr Pharm Des*. 2012;18(35):5663–74.
62. Bhatnagar S, Vining C, Iyer V, Kinni V. Changes in hypothalamic-pituitary-adrenal function, body temperature, body weight and food intake with repeated social stress exposure in rats. *J Neuroendocrinol*. 2006;18(1):13–24.
63. de Kloet CS, Vermetten E, Geuze E, Kavelaars A, Heijnen CJ, Westenberg HG. Assessment of HPA-axis function in posttraumatic stress disorder: pharmacological and non-pharmacological challenge tests, a review. *J Psychiatr Res*. 2006;40(6):550–67.
64. Price JL, Drevets WC. Neurocircuitry of mood disorders. *Neuropsychopharmacology*. 2010;35(1):192–216.
65. Peng Y, Su Y, Jiang Y. Effect of the warming and tonifying kidney–Yang recipe on monoamine neurotransmitters and pathological morphology of hippocampus tissue in depression model rats. *Technol Health Care*. 2020;28(S1):237–44.
66. Rueger SY, George R. Indirect effects of attributional style for positive events on depressive symptoms through self-esteem during early adolescence. *J Youth Adolesc*. 2017;46(4):701–8.
67. Łosiak W, Blaut A, Kłosowska J, Łosiak-Pilch J. Stressful life events, cognitive biases, and symptoms of depression in young adults. *Front Psychol*. 2019;10:2165.
68. Liu M, Li X, He Z. Self-control mediates, and mobile phone dependence moderates, the relationship between psychological capital and attitudes toward physical exercise among Chinese university students. *Front Psychol*. 2022;13:888175.
69. Ozdemir C, Akbas Gunes N. The effect of diet and regular exercise on psychological resilience in obese or overweight women. *Int J Clin Pract*. 2021;75(8):e14320.
70. Korten NC, Penninx BW, Pot AM, Deeg DJ, Comijs HC. Adverse childhood and recent negative life events: contrasting associations with cognitive decline in older persons. *J Geriatr Psychiatry Neurol*. 2014;27(2):128–38.
71. Gruebner O, Lowe SR, Sampson L, Galea S. The geography of post-disaster mental health: spatial patterning of psychological vulnerability and resilience factors in new York City after hurricane sandy. *Int J Health Geogr*. 2015;14:16.
72. Pak R, Mahmoud Alilou M, Bakhshipour Roudsari A, Yousefpour F. Experiential avoidance as a factor in generalized psychological vulnerability: in the relationship between chronic pain and pain anxiety with pain disability. *Pain Manag Nurs*. 2024;25(3):e256–64.
73. Nilsson MI, Tarnopolsky MA. Mitochondria and aging—the role of exercise as a countermeasure. *Biology (Basel)*. 2019;8(2):40.
74. Wang K, Li Y, Zhang T, Luo J. The relationship among college students' physical exercise, self-efficacy, emotional intelligence, and subjective well-being. *Int J Environ Res Public Health*. 2022;19(18):11596.
75. Awick EA, Phillips SM, Lloyd GR, McAuley E. Physical activity, self-efficacy and self-esteem in breast cancer survivors: a panel model. *Psychooncology*. 2017;26(10):1625–31.
76. Boss M, Kleinert J. Motivational contagion during exercise and the role of interpersonal relationships: an experimental study. *Psych J*. 2021;10(1):128–40.
77. Muñoz-Martínez AM, Naismith I. Social connectedness, emotional regulation, and health behaviors as correlates of distress during lockdown for COVID-19: A diary study. *Appl Psychol Health Well Being*. 2023;15(2):536–60.
78. Hu J, Huang Y, Liu J, Zheng Z, Xu X, Zhou Y, et al. COVID-19 related stress and mental health outcomes 1 year after the peak of the pandemic outbreak in China: the mediating effect of resilience and social support. *Front Psychiatry*. 2022;13:828379.
79. Dai Q, Smith GD. Resilience to depression: implication for psychological vaccination. *Front Psychiatry*. 2023;14:1071859.

Publisher's note

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