BMC Public Health

RESEARCH

Open Access

The relationship between exercise habits and mental health among university students in China: a cross-sectional study based on instrumental variable analysis

Lixian Zhu[1], Xuan Xiong[2*], Zhongquan Li[3], Shuqiao Meng[4] and Yifei Zhai[2*]

Abstract

Background Exercise habits significantly influence the mental health of university students. However, previous research has often neglected the endogeneity issues in this context, leading to biased estimates and limiting the ability to establish a clear causal relationship. This study aimed to address endogeneity issues and investigate the causal effect of exercise habits on the mental health of university students.

Methods This cross-sectional study was conducted involving 1,120 university students from China. Data on demographic characteristics, exercise habits, and mental health were collected using both online and offline questionnaires. To evaluate the mental health benefits of exercise habits, we employed both the instrumental variable (IV) approach and ordinary least squares (OLS) regression.

Results The OLS estimates revealed a positive association between exercise habits and positive affect ($\beta = 0.179$, $p < .001$), life satisfaction ($\beta = 0.134$, $p < .001$), and self-actualization ($\beta = 0.086$, $p < .001$) among university students. The IV analysis indicated that exercise habits positively influenced positive affect ($\beta = 0.263$, $p < .001$), life satisfaction ($\beta = 0.151$, $p = .006 < .01$), and self-actualization ($\beta = 0.102$, $p = .013 < .05$). A comparison of the estimation results suggests that the OLS approach underestimates the mental health benefits of exercise habits.

Conclusions This study provides preliminary causal evidence that exercise habits contribute to the promotion of mental health in university students. These findings offer valuable insights into potential preventive strategies for addressing mental health issues in this population through exercise interventions.

Keywords Exercise habits, Mental health, University students, Endogeneity issues, Instrumental variable

*Correspondence:
Xuan Xiong
xiongxuan@nju.edu.cn
Yifei Zhai
zyf@nju.edu.cn
[1]Sports Science Institution, Nanjing University, Nanjing, Jiangsu, China
[2]Department of Physical Education, Nanjing University, Nanjing, Jiangsu, China
[3]Department of Social Psychology, Nanjing University, Nanjing, Jiangsu, China
[4]School of Physical Education, Xidian University, Xian, Shanxi, China

Introduction

Mental health is a crucial factor for the comprehensive improvement of individual qualities. However, rapid social changes have increasingly highlighted mental issues among people [1]. As a specific group, university students' minds are still in a developmental phase, making them prone to various psychological issues [2, 3]. For nations, university students are a precious human resource and play a pivotal role in the country's future development [4]. For individuals, university years represent a critical growth period that can significantly influence their future social integration, lifestyle, and career [5]. Therefore, the prevention and treatment of mental health issues among university students hold significant social importance and are a key focus across various sectors.

Exercise, as one of the methods for preventing and treating mental health issues among university students [6], is not only easy to implement but also cost-effective and practical, thereby increasingly becoming a popular health intervention approach. Empirical research indicates that long-term exercise interventions can improve the mental health of various age groups [7–9], special populations [10, 11], and individuals with psychological disorders [12, 13]. However, a significant portion of the research also suggests that long-term exercise does not yield benefits for mental health [14–16]. There are three key factors contributing to the lack of significant findings. First, the relatively short duration of exercise interventions may have undermined the anticipated improvements in mental health outcomes [17, 18]. Second, some participants engaged in the interventions primarily to receive external rewards, lacking intrinsic motivation, which may have diminished the psychological benefits [19]. Third, in some studies, a substantial proportion of participants were absent during the intervention period, resulting in less effective outcomes [20]. From these, it can be inferred that the duration and autonomy of exercise are closely related to the extent of mental health benefits. As Liwei Zhang et al. have pointed out, the inconsistent findings in the research on the relationship between long-term exercise and mental health necessitate a focus on under what conditions the positive psychological effects of exercise manifest [21]. Based on this, the article hypothesizes that characteristics reflecting an individual's consistent and autonomous exercise may be key to promoting mental health.

Exercise habits are automated behavioral patterns formed through long-term repetitive exercise in a stable context [22, 23]. Exercise habits reflect the characteristics of an individual's consistent and autonomous exercise, providing a new perspective for exploring the mental health benefits of exercise. Research commonly suggests that exercise is controlled both habitually and consciously [24, 25]. Gardner et al. [26, 27] point out that exercise habits primarily refer to the control of behavior during the pre-exercise phase, termed as "habitual instigation" [28, 29]. At present, studies indicate that exercise habits are closely related to students' mental health [30–32]. These studies have laid a foundation for understanding the relationship between exercise habits and mental health. However, most existing studies primarily use observational data, which carry the risk of endogeneity issues, potentially leading to biased estimation results.

Endogeneity refers to the issue in regression analysis where the independent variables are correlated with the residual terms, leading to biased estimation results [33]. Specific to the study of the relationship between exercise habits and university students' mental health, endogeneity issues may arise due to the potential presence of omitted variables and reverse causation. The instrumental variable method is widely regarded as an effective approach for addressing endogeneity issues and, to some extent, inferring causal relationships between variables. From the perspective of achieving the power of causal inference, the instrumental variable method is superior to some other methods [33] (difference-in-difference method and propensity score method). Therefore, an increasing number of studies have employed the IV method to explore causal relationships between variables in recent years. These include studies on the relationship between exercise and mental ill-health [34], exercise habits and income [35], as well as exercise and deviant behavior [36].

The instrumental variable can successfully isolate a portion of the variation in the endogenous independent variable that possesses exogenous characteristics. By leveraging this exogenously derived variation, an unbiased estimation of the dependent variable can be achieved (Fig. 1.). In studies employing the instrumental variable (IV) method, identifying effective instruments is a commonly encountered challenge. A valid instrumental variable must simultaneously satisfy three key assumptions: the first-stage assumption, the independence assumption, and the exclusion restriction assumption [37]. The first-stage assumption requires that the instrumental variable be strongly correlated with the independent variable; the independence assumption mandates that the instrumental variable be uncorrelated with the model's residuals; and the exclusion restriction assumption stipulates that the instrumental variable can only affect the dependent variable through its influence on the independent variable.

The effectiveness of instrumental variable design is rooted in the research context. In the context of this study, designing an appropriate instrumental variable requires an understanding of the daily life patterns of university students in China. The daily routines of

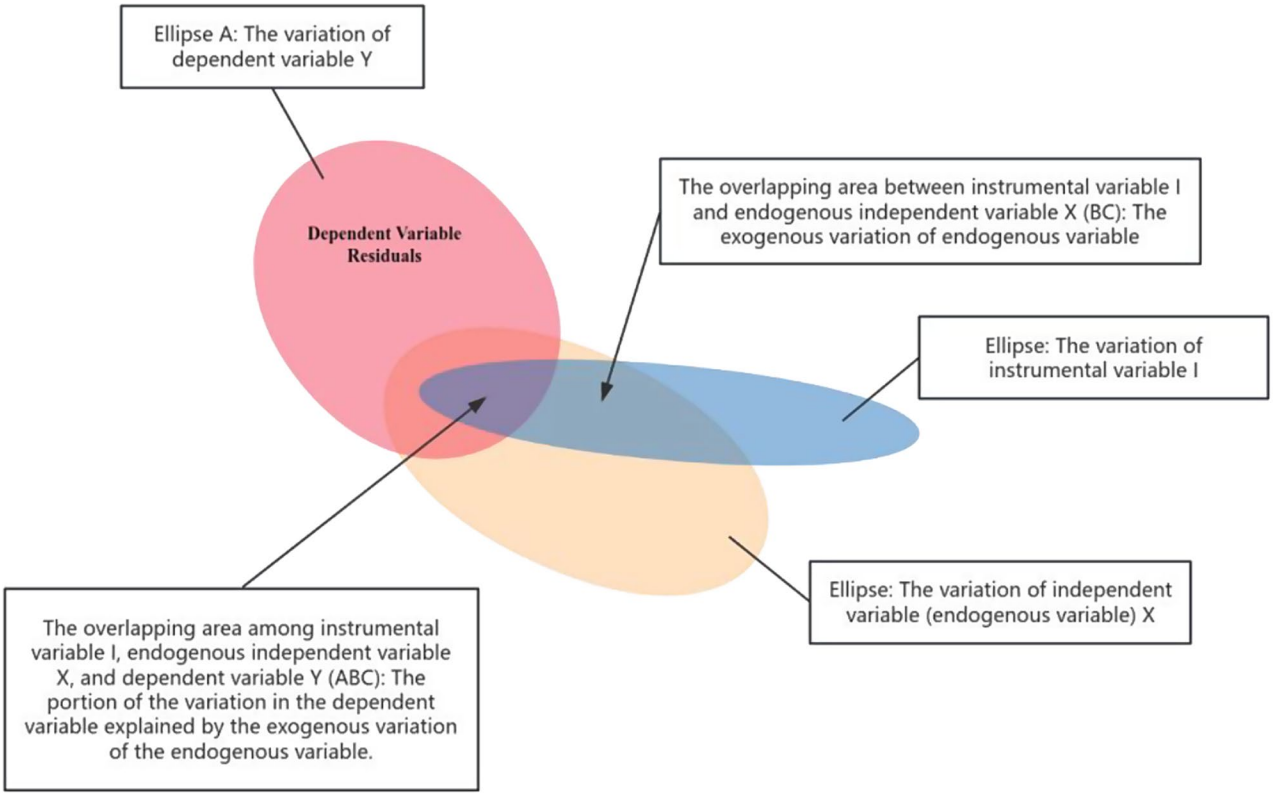

Fig. 1 Diagram of the basic approach to identifying causal relationships using the instrumental variable method. (Adapted from Huang B, Fan W & Zhu Y, 2022, p. 202)

Chinese university students exhibit two main characteristics: First, centralized on-campus accommodation [38], meaning that most students live in dormitories on campus. Second, aside from holidays, students' extracurricular activities (such as exercise) primarily take place on campus [39]. The dormitories can be regarded as students' "home" on campus, serving as the ultimate destination for most on-campus residents. When deciding whether to engage in exercise, students are influenced by the accessibility of sports facilities around their dormitories, that is, the distance between dormitory and sports field can affect students' exercise behavior. Consequently, it can be inferred that the "Distance between Dormitory and Sports Field" is associated with students' exercise habits intensity. Generally, the allocation of student dormitories is influenced by certain demographic factors, making the "Distance between Dormitory and Sports Field" not entirely random. If these factors are controlled for, the allocation of student dormitories becomes random, and thus the distance can also be considered random. In addition, the "Distance between Dormitory and Sports Field" cannot directly affect students' mental health; it can only influence mental health indirectly by shaping students' exercise habits. Based on these, the study posits that the "Distance between Dormitory and Sports Field" has the potential to serve as an instrumental variable.

Based on this, we employ the instrumental variable (IV) method to address endogeneity issues and explore the potential causal relationship between exercise habits and mental health among university students. In the context of Chinese universities, we specifically use the "Distance between Dormitory and Sports Field" as instrumental variable. This study aims to verify previous research on the relationship between exercise habits and the mental health of university students by addressing endogeneity. Additionally, the use of causal identification strategies to infer the causal relationship between exercise habits and mental health provides a insights and foundation for future longitudinal studies.

Methods

Participants

Students from three universities in a certain city were selected as the participants for this study. To maximize sample diversity, we selected a comprehensive university, a science and engineering university, and a teacher training university. Due to the significant differences in exercise behaviors between students from sports universities and those from non-sports universities, which can lead to measurement errors, students from sports universities

were not included as participants in the study. Questionnaires were distributed to collect data on exercise habits, mental health, and demographic information from students across the three universities. A total of 1206 questionnaires were collected, and after excluding 86 invalid questionnaires, 1120 valid questionnaires were retained (Fig. 2).

In the participants, males accounted for 58.48% and females for 41.52%, with an average age of 21.62 years. Among these university students, the Han ethnic group is the majority, accounting for 93.04% of the total; most students major in science and engineering, representing 64.38% of the total; a minority of students are from rural households, specifically, 30.71% of the total; the majority of students come from families with an annual income of over 14,286 dollars, comprising 54.46% of the total. The average strength of exercise habits among the university students in the sample is 50.31, with a standard deviation of 20.08. From the perspective of various mental health indicators among university students, the average score for positive affect in the sample is 33.66, with a standard deviation of 6.93; the average score for life satisfaction is 21.02, with a standard deviation of 6.43; the score for self-actualization is 39.9, with a standard deviation of 4.73 (Table 1).

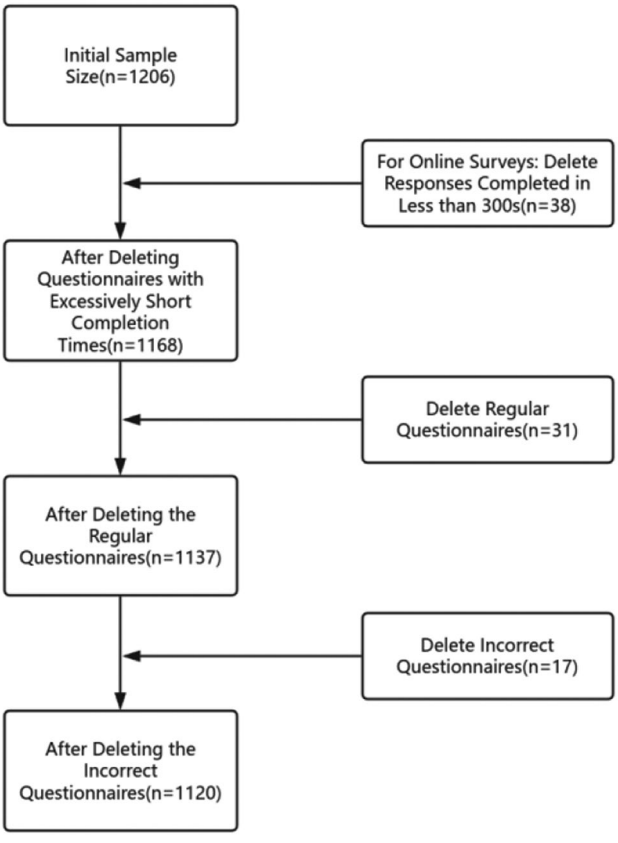

Fig. 2 Questionnaires screening process

To ensure adequate statistical power, we performed a power analysis using G*Power software. The model in this study includes one primary predictor variable (exercise habits) and 12 covariates (such as gender, age, and family income), resulting in a total of 13 predictor variables for the analysis. Parameters were set as follows: a medium effect size (f^2= 0.35), a significance level of α=0.01, and a target power of 0.95. The analysis indicated that a minimum sample size of 112 would be required to detect a medium effect. With 1120 valid questionnaires collected, this study far exceeds the minimum sample size, ensuring robust statistical power.

Measures

Exercise habits

The Self-Report Habit Index (SRHI) was used as the measurement tool for exercise habits. SRHI was developed by Verplanken and Orbell [40]. Since its development in 2003, this scale has been used to measure various habitual behaviors, including exercise habits [41]. The Self-Report Habit Index (SRHI) begins with the lead statement "Behavior X is something." and comprises 12 items (e.g., "I do frequently", "I do automatically", "that's typically 'me' "). The SRHI uses a 7-point Likert scale, where higher scores indicate stronger habit strength. In student populations across multiple countries, SRHI has been shown to have good internal consistency in measuring exercise habits [42–45]. In our study, the Cronbach's alpha coefficient for SRHI was 0.973.

Mental health

According to the World Health Organization (WHO), mental health is a state of well-being, "in which the individual realizes his or her own abilities, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to his or her community" [46]. Therefore, we draw upon the operationalization of mental health by Compton et al. [47], discussing exercise habits from the perspectives of subjective well-being and personal growth. For subjective well-being, based on the discussions by Diener and Qiao [48, 49], "positive affect" and "life satisfaction" are used as indicators to measure subjective well-being. For personal growth, considering that Maslow's theory of self-actualization is the most renowned theory of personal growth, which is highly relevant to personal growth [47]. Hence, self-actualization is used as an indicator to measure personal growth. In practical measurement, the positive affect subscale of the Positive and Negative Affect Schedule (PANAS), the Satisfaction with Life Scale (SWLS), and the Short Index of Self-actualization are used to measure university students' positive affect, life satisfaction, and personal growth, respectively.

Table 1 Summary statistics

Variables	Nature of variables	Description
Independent Variable		
Exercise Habits	Numeric	12–84 points (mean 50.31, standard 20.08)
Dependent Variables		
Positive Affect	Numeric	10–50 points (mean 33.66, standard 6.93)
Life Satisfaction	Numeric	5–35 points (mean 21.02, standard 6.43)
Self-actualization	Numeric	25–60 points (mean 39.90, standard 4.73)
Instrumental Variable		
Distance between Dormitory and Sport Field	Numeric	51.22–1500 m (mean 566.29, standard 372.73)
Covariates		
Gender	Categorical	0 = male (41.52%), 1 = female (58.48%)
Age	Numeric	16–33 years old (mean 21.62, standard 2.95)
Major	Categorical	0 = Arts and Humanities (35.62%), 1 = Science and Engineering (64.38%)
Ethnicity	Categorical	0 = Han ethnicity (93.04%), 1 = Ethnic minorities (6.96%)
Father Education	Categorical	1 = Elementary school and below (6.07%), 2 = Junior high school (19.20%), 3 = High school (18.13%), 4 = Associate degree (18.30%), 5 = Bachelor's degree (30.97%), 6 = Master's degree (5.54%), 7 = Doctorate (1.79%)
Mother Education	Categorical	1 = Elementary school and below (6.07%), 2 = Junior high school (19.20%), 3 = High school (18.13%), 4 = Associate degree (18.30%), 5 = Bachelor's degree (30.97%), 6 = Master's degree (5.54%), 7 = Doctorate (1.79%)
Family Income	Categorical	1 = Below 2,857 dollars (6.70%), 2 = 2,857 to 7,143 dollars (13.39%), 3 = 7,143 to 14,286 dollars (25.45%), 4 = Above 14,286 dollars (54.46%)
Household Registration	Categorical	0 = Rural household registration (30.71%), 1 = Urban household registration (69.29%)
Chronic Disease	Categorical	0 = No(18.12%), 1 = Yes (81.88%)
Mental Disorder	Categorical	0 = No(97.59%), 1 = Yes (2.41%)

The Positive and Negative Affect Schedule (PANAS) was developed by Watson et al. [50]. PANAS begins with the lead statement, "Please read each word and choose the corresponding option based on your actual situation in the past 1–2 weeks," measuring the respondent's degree of agreement with each emotional state. The Positive Affect subscale consists of 10 items (e.g., "Excited," "Inspired") and uses a 5-point Likert scale for scoring, with higher scores indicating higher levels of positive emotions. Huang et al. conducted a study on the applicability of this scale in the Chinese population and demonstrated the suitability of the Chinese version of the Positive and Negative Affect Schedule among Chinese individuals [51]. In our study, the Cronbach's alpha coefficient for this scale was 0.907.

The Satisfaction with Life Scale (SWLS) was developed by Diener et al. [52]. The scale consists of 5 items (e.g., "In most ways my life is close to my ideal"), and uses a 7-point Likert scoring system, with higher scores indicating greater life satisfaction. Xiong et al. tested the reliability and validity of the scale, and the results indicated that the SWLS possesses good reliability and validity when used among the general population [53]. In a study on the relationship between altruistic behavior and subjective well-being among university students, the SWLS was also demonstrated to have good reliability and validity in this population [54]. In our study, the Cronbach's alpha coefficient for SWLS was 0.874.

The Short Index of Self-actualization was developed by Jones et al. [55], consisting of 15 items, including 7 positively scored items and 8 negatively scored items (e.g., "I believe that people are essentially good and can be trusted," "I do not feel responsible to help anybody"). The scale uses a 4-point Likert scoring system, where higher scores indicate higher levels of self-actualization. Yang et al. applied the Short Index of Self-actualization as a measurement tool in a study on the discrepancy between reality and ideals among university students, where the scale demonstrated good reliability in this research [56]. In our study, the Cronbach's alpha coefficient for this scale was 0.691, indicating that the reliability of the scale is acceptable [57].

Instrumental variable

We use the "Distance between Dormitory and Sports Field" as an instrumental variable. As described above, a valid instrumental variable must satisfy the first-stage assumption, the independence assumption, and the exclusion restriction assumption.

First, the first-stage assumption requires that the instrumental variable be strongly correlated with the independent variable (intensity of exercise habits). Studies point out that the accessibility of sports facilities is

associated with individuals' motivation and frequency of engaging in physical activities [58–60]. The distance between dormitory and sports field reflects the accessibility of the sports field; the shorter the distance, the higher the accessibility. Therefore, it is reasonable to believe that the closer the dormitory is to the sports field, the stronger the students' motivation to exercise and the higher their frequency of physical activity, ultimately leading to stronger exercise habits. In fact, the first-stage assumption can also be directly demonstrated by regressing the intensity of exercise habits, as shown in Table 2. The first-stage assumption of the instrumental variable holds (β = -0.010, $p<.001$). In addition, we conducted a weak instrument test. The results show that the first-stage F-statistic is 30.126, which is higher than 10. According to Stock and Yogo [61], an F-statistic greater than 10 allows us to reject the null hypothesis of a weak instrument. The above statistical results indicate that the instrumental variable satisfies the first-stage effect assumption, and the instrumental variable used in this study qualifies as a strong instrument.

Secondly, the independence assumption requires that the instrumental variable be uncorrelated with the model's residuals, a condition that can be satisfied by random variables. Typically, the allocation of dormitories is primarily influenced by gender, grade, major, and school. When these variables are controlled for, the distribution of student dormitories is random, meaning that the accessibility of sports field is random for each student. At this point, "Distance between Dormitory and Sports Field" can be considered a random variable.

Finally, the exclusion restriction assumption stipulates that the instrumental variable can only affect the dependent variable indirectly through its impact on the independent variable. Currently, no studies have demonstrated a direct relationship between the accessibility of sports field and individual's mental health. Given the communal nature of campus life for Chinese students, we believe that the "distance between the dormitory and the sports field" can only affect their mental health through its impact on their exercise behavior.

In fact, besides the first-stage assumption, the independence and exclusion restriction assumptions of the instrumental variable approach cannot be tested directly [37], but the scientific validity and rationality of the choice of instrumental variables can be indirectly demonstrated through previous research. For example, some studies use "the distance between home address and sports facilities" as an instrumental variable to predict individuals' exercise behavior, thereby exploring the mental health benefits of physical activity [62, 63].

Table 2 The first stage effect of the instrumental variable and weak instrument test

	First-stage effect
Distance between Dormitory and Sport Field	-0.010***
Constant	78.895***
Control Variables	Yes
First Stage F-statistic	30.126***
N	1120

Note (1) Significance levels: *$p<.05$, **$p<.01$, ***$p<.001$; (2) The dependent variable in the model is "intensity of exercise habits"

The measurement of "Distance between Dormitory and Sports Field" was conducted using the "Network Analysis" feature in Quantum GIS (QGIS). Specifically, the map data of the designated universities was imported into the software, and the dormitories and sports fields were marked. The "network analysis" function of the software was then used to calculate the shortest path. In a university with multiple sports fields, we assume that the sports field closest to the dormitory is preferred by the students residing in that dormitory (Fig. 3.).

Covariates

Research indicates that gender and age [64], family economics [65, 66], chronic diseases [64], and history of mental illness [67] all simultaneously affect an individual's exercise behavior and mental health. We controlled for these variables to minimize the impact of confounding variables on the estimation results. Additionally, we included several commonly used demographic variables, such as grade, school, ethnicity, major, parental education, and household registration.

Procedure

Before distributing the formal questionnaire, students from three public sports classes were selected to fill out the questionnaire to test its internal consistency and the average time taken to complete it. Through the pretest test, the average completion time for the questionnaire was found to be 300 s (6 min), which was used as the basis for screening online questionnaires. The official questionnaire was distributed in both offline and online formats. The offline questionnaires were administered by researchers during eight public sports classes and one public elective class. Researchers announced the purpose of the questionnaire and the method for completing it on-site, and waited to collect the questionnaires immediately after the students had completed them. The online questionnaires were distributed by department counselors to the department WeChat group via QR codes and links, to be completed by students. Upon completing the questionnaire, students will receive a monetary reward as compensation. To ensure that students complete the questionnaire seriously and with high quality, both the online electronic questionnaire and the offline paper questionnaire include general instructions, section-specific guidance, and an anonymity statement.

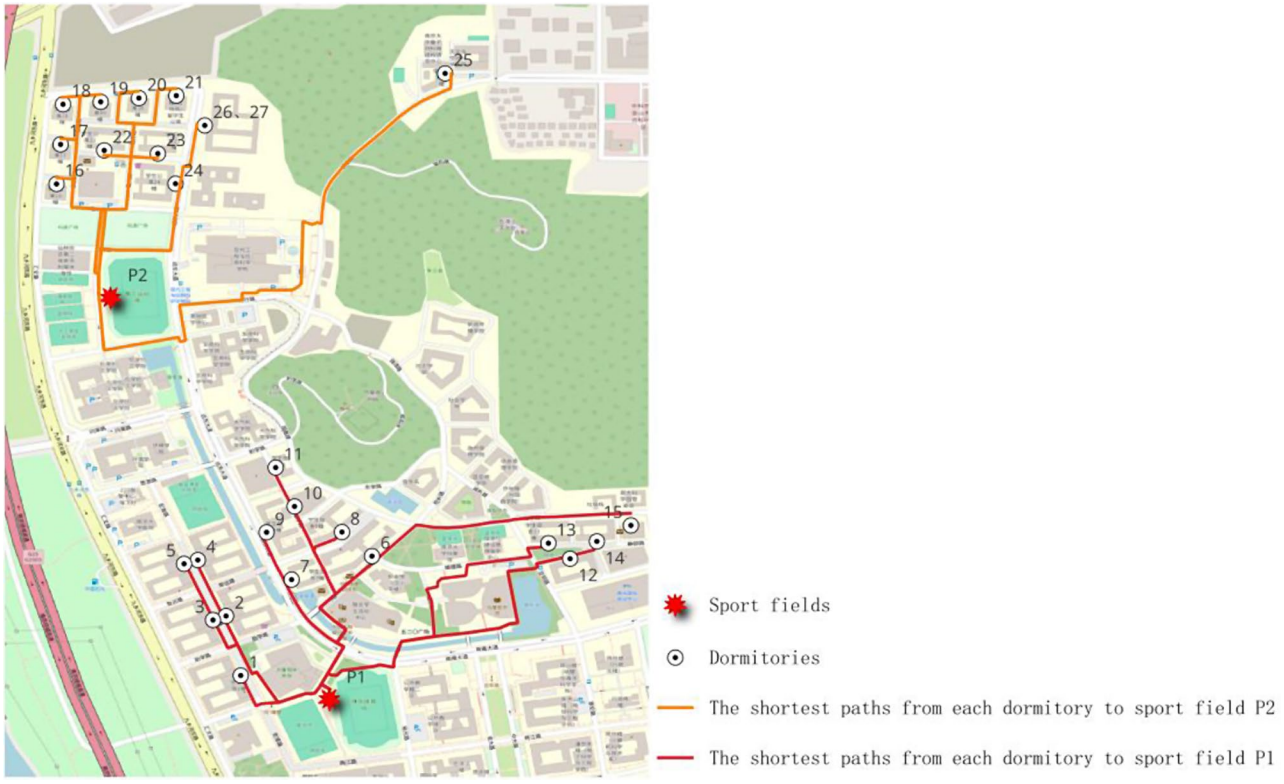

Fig. 3 Schematic diagram of the distances between dormitories and sports field at a certain university

Statistical analysis

The statistical package Stata 15 and R programming language were used for data analyses. Significance level was set at $p \leq .05$. First of all, correlation analysis was used to discuss the quantitative relationship between exercise habits and mental health indicators among university students. Secondly, to more visually demonstrate the quantitative relationship between exercise habits and mental health, scatter plots were drawn for the strength of exercise habits against scores for positive affect, life satisfaction, and self-actualization. Finally, the instrumental variable approach was used to explore the causal relationship between exercise habits and mental health among university students. Practically, this was implemented using the Two Stage Least Squares (2SLS) method for estimation. A first-stage regression model is constructed to identify the impact of the instrumental variable on university students' exercise habits:

$$\begin{aligned} \mathrm{E} = {} & \alpha_1 + \beta_1 \cdot \mathrm{iv\_distance} + \theta_1 \cdot \mathrm{gender} + \theta_2 \cdot \mathrm{age} \\ & + \theta_3 \cdot \mathrm{grade} + \theta_4 \cdot \mathrm{major} + \theta_5 \cdot \mathrm{ethnic} \\ & + \theta_6 \cdot \mathrm{father\_edu} + \theta_7 \cdot \mathrm{mother\_edu} \\ & + \theta_8 \cdot \mathrm{income} + \theta_9 \cdot \mathrm{HR} + \theta_{10} \cdot \mathrm{school} \\ & + \theta_{11} \cdot \mathrm{CD} + \theta_{12} \cdot \mathrm{MD} + \varepsilon_{\mathrm{E}} \end{aligned} \tag{1.1}$$

In Eq. 1.1, "iv_distance" represents the instrumental variable "Distance between Dormitory and Sports Field". In order to improve the accuracy of the instrumental variable method results, we controlled for a series of confounding variables, which from left to right are "Gender", "Age", "Grade", "Major", "Ethnicity", "Father's Education", "Mother's Education", "Family Income", "Household Registration", "School", "Chronic Diseases", and "Mental Disorders". Performing OLS regression on the first-stage model yields the predicted value E' of the endogenous variable, exercise habits. This predicted value, along with the instrumental variable and control variables from the first-stage regression, is used to identify the mental health benefits of exercise habits:

$$\begin{aligned} \mathrm{Y} = {} & \mu_1 + \beta_2^{\mathrm{IV,2SLS}} \cdot \mathrm{E}' + \lambda_1 \cdot \mathrm{gender} + \lambda_2 \cdot \mathrm{age} \\ & + \lambda_3 \cdot \mathrm{grade} + \lambda_4 \cdot \mathrm{speciality} + \lambda_5 \cdot \mathrm{ethnic} \\ & + \lambda_6 \cdot \mathrm{father\_edu} + \lambda_7 \cdot \mathrm{mother\_edu} \\ & + \lambda_8 \cdot \mathrm{income} + \lambda_9 \cdot \mathrm{hukou} + \lambda_{10} \cdot \mathrm{school} \\ & + \lambda_{11} \cdot \mathrm{CD} + \lambda_{12} \cdot \mathrm{MD} + \varepsilon_{\mathrm{Y}} \end{aligned} \tag{1.2}$$

In Eq. 1.2, Y represents three indicators of mental health—positive affect, life satisfaction, and self-actualization. Under the assumption that the instrumental variable satisfies the first-stage effect, independence, and exclusion restriction assumptions, the estimated

Table 3 Correlation between university students' exercise habits and mental health

	Exercise habits	Positive affect	Life satisfaction	Self-actualization
Exercise Habits	1			
Positive Affect	0.512**	1		
Life Satisfaction	0.298**	0.662**	1	
Self-actualization	0.251**	0.615**	0.520**	1

Note Significance levels: *$p<.05$, **$p<.01$ (two-tailed test)

coefficient $\beta_2^{IV,2SLS}$ is the consistent estimate of the mental health benefits of exercise habits.

Results

Correlation between exercise habits and mental health among university students

Table 3 presents the results of the correlation analysis between exercise habits and various indicators of mental health among university students. Specifically, the strength of university students' exercise habits is significantly positively correlated with positive emotions, life satisfaction, and self-actualization.

To illustrate the relationship between the intensity of exercise habits and university students' mental health more clearly, scatter plots were created for exercise habits against the three mental health indicators. Figures 4 and 5, and 6 represent scatter plots of exercise habit strength with positive affect, life satisfaction, and self-actualization among university students, respectively. The blue

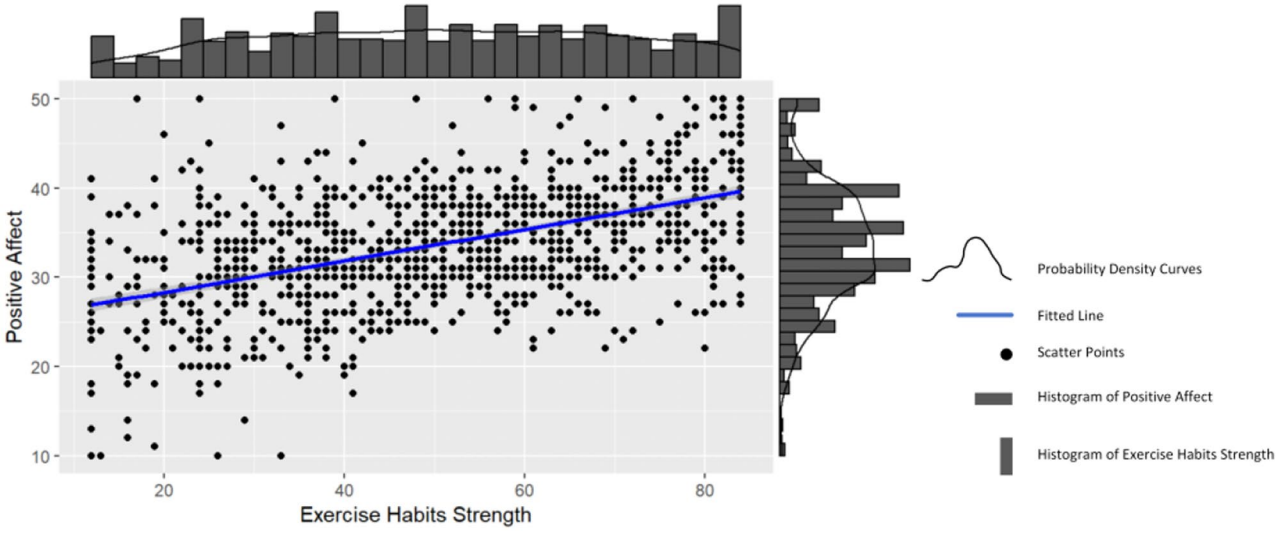

Fig. 4 Scatter plot of exercise habit strength and positive affect among university students

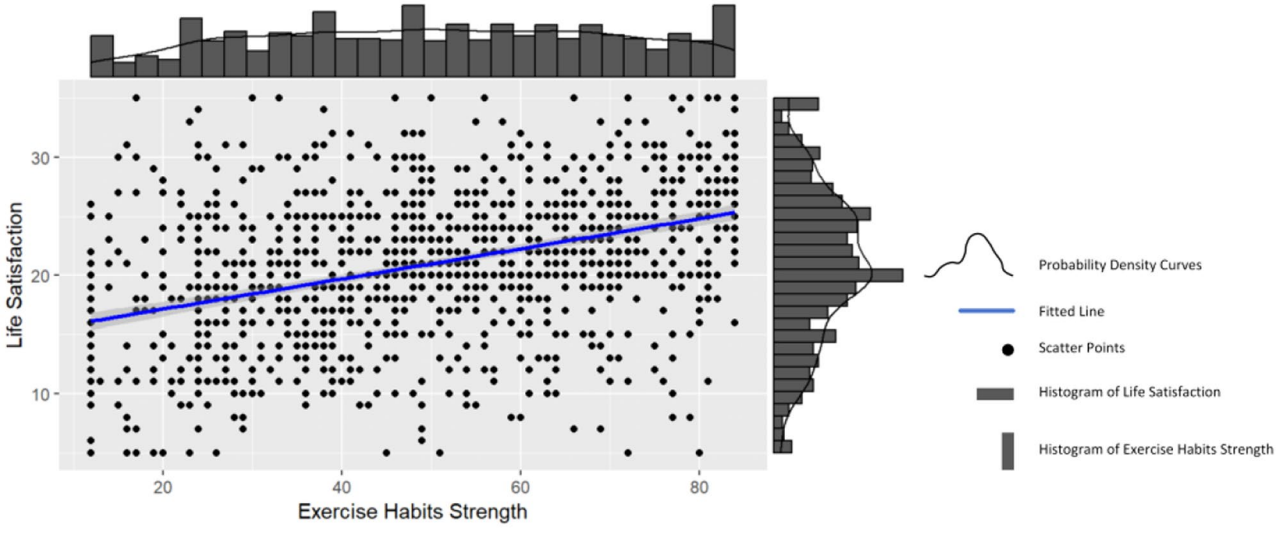

Fig. 5 Scatter plot of exercise habit strength and life satisfaction among university students

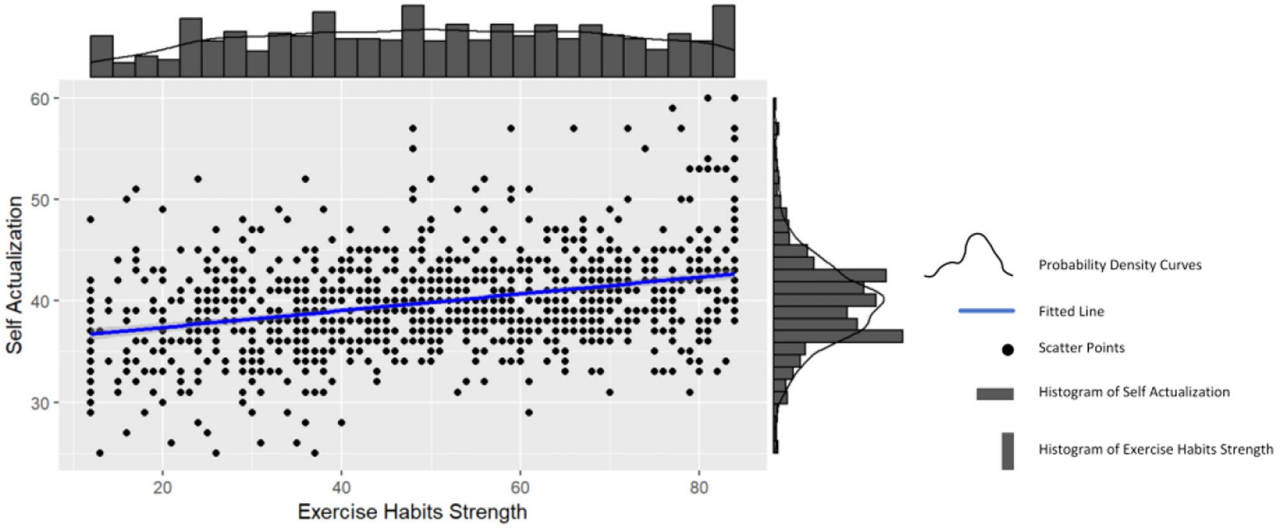

Fig. 6 Scatter plot of exercise habit strength and self actualization among university students

Table 4 Mental health benefits of exercise habits in university students

	OLS model			2SIS model		
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Variables						
Positive Affect	0.179***			0.263***		
	(0.010)			(0.057)		
Life Satisfaction		0.134***			0.151**	
		(0.009)			(0.055)	
Self-actualization			0.086***			0.102*
			(0.007)			(0.041)
Covariates	Yes	Yes	Yes	Yes	Yes	Yes
Constant	17.990***	8.014	30.191***	9.835	6.374	28.650***
R^2	0.292	0.202	0.163	0.242	0.200	0.159
N	1120	1120	1120	1120	1120	1120

Note (1) Significance levels: *$p<.05$, **$p<.01$, ***$p<.001$; (2) Robust standard errors in parentheses

line in the figure represents the fitted line, and the shaded area around it represents the estimation error of the predicted values. In these three scatter plots, the top of each image features histograms and probability density curves of university students' exercise habit strength, while the right side of each image displays histograms and probability density curves for university students' positive affect, life satisfaction, and self actualization, respectively. The scatter plots visually demonstrate a positive relationship between the strength of exercise habits and university students' positive affect, life satisfaction, and self-actualization. However, correlation does not imply causation, but sometimes two variables are correlated because of their causal relationship [68]. Whether the relationship between exercise habits and mental health still holds after controlling for other variables, and the causal relationship between exercise habits and mental health, requires further analysis.

Ordinary least squares estimation and instrumental variable estimation

Table 4 presents the results of OLS and 2SLS regressions of exercise habits on university students' mental health. Models 1, 2, and 3 provide estimates of the mental health benefits of exercise habits using OLS. Model 1 examines the impact of exercise habits on university students' positive affect, Model 2 on their life satisfaction, and Model 3 on their self-actualization. The results show that, after controlling for observable confounding variables, exercise habits positively influence university students' positive affect (β=0.179, $p<.001$), life satisfaction (β=0.134, $p<.001$), and self-actualization (β=0.086, $p<.001$), indicating that the exercise habits strength is a significant predictor of university students' positive emotions, life satisfaction, and self-actualization.

Models 4, 5, and 6 estimate the mental health benefits of exercise habits using the 2SLS. Model 4 presents the 2SLS regression results of exercise habits on university students' positive affect, Model 5 on their life satisfaction,

and Model 6 on their self-actualization. The results indicate that exercise habits positively influence university students' positive affect (β=0.263, $p<.001$), life satisfaction, and self-actualization (β=0.151, $p=.006<.01$; β=0.102, $p=.013<.05$), which concluded that exercise habits can enhance university students' mental health.

The comparison of coefficients between OLS and 2SLS shows that the OLS estimates are lower than those of 2SLS, indicating that OLS underestimates the mental benefits of exercise habits among university students. This highlights the bias in OLS estimates, emphasizing the importance of using the instrumental variable approach for more accurate estimation of the effects of exercise habits.

Robustness test

To illustrate the robustness of the results obtained through the instrumental variable approach, a robustness test was conducted on the 2SLS results from the previous section. First, robustness test was conducted by reducing the sample size. Since extreme values in the mental health measures within the sample may affect the mental health benefits of exercise habits, we employ the practice of removing outliers. The operational procedure is as follows: in the scales for positive affect, life satisfaction, and self-actualization, participants that scored full marks or "1 point" on all items in any one of the scales are considered outliers and are removed accordingly. As shown in the estimates for Model 1 in Table 5, after removing the outliers, the estimated results for the mental health benefits of exercise habits are largely consistent with the 2SLS estimates from the previous section, demonstrating the robustness of the instrumental variable estimation results.

Secondly, robustness tests were conducted by adding instrumental variables. This study employs "Distance between Dormitory and Sports Field" as an instrumental variable, which reflects the travel cost for students to exercise and is closely related to the strength of students' exercise habits. In fact, within the same dormitory building, the travel cost for students to exercise can also vary depending on changes in the dormitory floor. By incorporating the instrumental variable "Dormitory Floor," the travel cost required for students to exercise can be more precisely determined. Therefore, we attempt to incorporate the additional travel costs associated with the floor by using both "Distance between Dormitory and Sports Field" and "Dormitory Floor" as instrumental variables for a 2SLS regression, to test whether there are significant changes in the estimated mental health benefits of exercise habits. In terms of measuring "Dormitory Floor," for dormitory buildings without elevators, "Dormitory Floor" is quantified as the actual floor level; for dormitory buildings with elevators, "Dormitory Floor" is considered as "1st floor"[1]. According to the estimates from Model 2 in Table 5, after incorporating the "Dormitory Floor," the results regarding the benefits of exercise habits on mental health remain unchanged and the estimates are similar, demonstrating the robustness of the instrumental variable estimation results.

Table 5 Robustness test of the mental health benefits of exercise habits among university students

Variables	Model 1	Model 2
Positive Affect	0.239***(0.052)	0.272***(0.053)
N	1085	
Life Satisfaction	0.135**(0.050)	0.172**(0.050)
N	1078	
Self-actualization	0.108**(0.037)	0.144***(0.038)
N	1111	
Instrumental Variables:		
Distance between Dormitory and Sport Field	√	√
Dormitory Floor		√
N		1120

Note (1) Significance levels: *$p<.05$, **$p<.01$, ***$p<.001$; (2) Robust standard errors in parentheses

Discussion

This study addresses endogeneity issues using the instrumental variable approach and suggests preliminary evidence of a potential causal relationship between exercise habits and the mental health of university students. Specifically, our study provides initial evidence suggesting that exercise habits have a positive influence on enhancing positive affect, life satisfaction, and self-actualization. Notably, as the Cronbach's alpha coefficient for the scale used to measure self-actualization in this study was not particularly ideal, the conclusion regarding the relationship between exercise habits and self-actualization among university students should be interpreted with caution. The causal relationship between the two requires further validation in future research. After exploring the relationship between exercise habits and mental health among university students, we conducted robustness tests to assess the stability of the instrumental variable estimates. The robustness tests further confirmed that the estimates of the mental health benefits of exercise habits obtained through the instrumental variable approach are robust.

Some studies have focused on the benefits of exercise habits (or regular exercise) on mental health and have found a positive association between the two [69–72]. By addressing the endogeneity issues arising from omitted variables and reverse causation, we further strengthen

[1] For students living in dormitory buildings with elevators, the travel cost of exercising is approximately equivalent to that of the "1st floor." Therefore, the "Dormitory Floor" for these students is considered as "1st floor.".

the evidence for the beneficial effects of exercise habits on mental health. First, we mitigate the estimation bias caused by omitted variables. For example, the timing of the questionnaire distribution in this study was close to the school's final exam week. Research indicates that students during exam week may experience varying degrees of negative emotions [73], such as stress and anxiety [74], which negatively impact their mental health [75]. Additionally, students during exam weeks face significant challenges in maintaining regular exercise routines [76], which can lead to a decrease in the strength of their exercise habits. If changes in students' exercise habits and mental health during exam weeks are not considered, the estimated results will be underestimated. In fact, due to the limitations of human knowledge, there are many similar confounding variables in reality that have not been considered, and even some considered confounders are difficult to measure, such as individual ability, personality, and specific family factors. By employing the instrumental variable method, we better address the issue of omitted variables and correct the estimation bias. Second, we addressed the estimation bias caused by reverse causation. Research has shown that higher levels of mental health are associated with habitual exercise [77]. Thus, there may be a reverse causation relationship between exercise habits and mental health. Under the conditions where the three assumptions of the instrumental variable are satisfied, the instrumental variable establishes a unique causal pathway from the endogenous independent variable to the dependent variable [37]. This clarifies, to some extent, the causal relationship between exercise habits and the mental health of university students. Previous research, along with the findings of this study, collectively supports the conclusion that a causal relationship between exercise habits and university students' mental health is highly likely to exist, providing a foundation and inspiration for future research.

By comparing the OLS and 2SLS estimation results in this study, it was found that OLS underestimates the mental health benefits of exercise habits. We believe that there are two main reasons why IV estimates are larger than OLS estimates. On the one hand, the bias in the OLS estimation results may be caused by omitted variables. As mentioned above, certain unobservable omitted variables and reverse causation have led to an underestimation of the mental health benefits of exercise habits.

On the other hand, the local average treatment effect (LATE) of the instrumental variable method may also be a reason why the 2SLS estimated coefficients are larger than the OLS. Since the instrumental variable method only uses part of the exogenous variation in the independent variable to perform regression analysis on the dependent variable, some subjects unaffected by the instrumental variable are excluded [37]. This makes the treatment effect obtained through the instrumental variable method a local average treatment effect. In our study, a very likely phenomenon is that students with lower exercise habits strength are more sensitive to "distance". Specifically, these students' exercise behaviors are more likely to be influenced by dormitory assignments, whereas for those students with high exercise habit intensity, the distance of their dormitory from the sports field hardly affects their exercise behaviors. When using "Distance between Dormitory and Sports Field" as an instrumental variable to estimate the effects of exercise habits on university students' mental health, the results reflected by the instrumental variable are not based on the Average Treatment Effect (ATE) of the sample, but rather a weighted average. Since students with weaker exercise habits are more likely to be influenced by the instrumental variable, these students will carry a larger weight in the analysis. According to adaptation theory, as exercise continues, individuals will develop physiological and psychological adaptations to the activity [78]. Based on the adaptation theory, students with weaker exercise habits derive greater marginal benefits from physical activity compared to those with stronger exercise habits. Since the instrumental variable model more closely reflects the mental benefits for students with weaker exercise habits, its estimated values are higher than those of the OLS estimates. The LATE of instrumental variables provides tentative insights into the potential role of promoting student participation in physical activities and foresting exercise habits. First, when building sports facilities, schools should consider placing them near dormitories to improve accessibility, thereby increasing student participation and encouraging the development of exercise habits. Second, when allocating dormitories, schools could prioritize placing specific groups (such as students with weaker physical conditions or those struggling with obesity) on lower floors or closer to sports facilities to enhance their access and encourage more frequent participation in physical activities, ultimately helping them establish exercise habits.

This study provides potential insights on preventing mental health issues among university students through exercise. Our results preliminarily indicate that exercise habits play an important role in promoting the mental health development of university students. This may imply that university administrators may consider placing more emphasis on fostering students' exercise habits. As Ji and Liu both have pointed out, the educational concept of "lifelong physical education" is one of the key focuses of university sports work in the new era [79, 80]. By conducting school sports programs aimed at cultivating exercise habits among university students, rather than merely increasing their frequency and duration of physical activity, it is possible that the physical

fitness of university students may be enhanced, and the occurrence of mental health issues potentially reduced. However, given that the sample diversity still needs further improvement, the results should be interpreted with caution, including the recommendations mentioned in the discussion regarding the construction of sports facilities, dormitory arrangements, and the implementation of school sports programs. It is important to note that the effectiveness of interventions aimed at promoting exercise habits may vary depending on institutional environments, cultural factors, and individual differences.

Our study still has limitations. First, as mentioned above, the sample for this study is drawn from only three universities. This lowers the external validity of the research findings, limiting their generalizability to universities in other regions. Second, while the instrumental variable approach has been helpful in addressing endogeneity issues and investigating the causal relationship between university students' exercise habits and mental health, it is important to acknowledge that, compared to longitudinal studies, cross-sectional data have inherent limitations in fully establishing causality. Third, we only explore the impact of exercise habits on the mental health of university students and lack an investigation into the mechanisms by which exercise habits affect their mental health. This limitation makes it difficult to reveal a deeper relationship between exercise habits and the mental health of university students. To address the identified limitations, subsequent research can be improved in the following three aspects: First, future research can enhance sample diversity to improve the external validity of the findings, thereby making the results more broadly applicable and generalizable; second, to further explore the causal relationship, future research can employ panel data or conduct experimental studies to further explore the causal link between exercise habits and students' mental health; and third, further research can explore the underlying mechanisms through which exercise habits influence university students' mental health, such as the mediating roles of psychological resilience or self-efficacy, to gain a deeper understanding of how and why these effects occur.

Conclusion

Exercise habits, as one of the key factors enabling individuals to engage in sustained autonomous exercise, play an important role in preventing and alleviating mental health issues among university students. By using instrumental variables to address the endogeneity problems that may have existed in previous research, we explore the benefits of exercise habits on mental health. The results suggest that there is likely a causal relationship to a large extent, where exercise habits significantly influence the mental health of university students. This study provides support from the perspective of addressing endogeneity for prior research on the relationship between exercise habits and the mental health of university students. It also offers insights for future longitudinal studies aimed at exploring the causal link between exercise habits and students' mental health, carrying certain significance.

Acknowledgements

We would like to express our sincerest gratitude to all the participants, who has contributed to the study.

Author contributions

LXZ planned the study and redacted the manuscript. LXZ and YFZ made significant contributions to data collection. LXZ, XX and ZQL statistically analyzed the data. YFZ and SQM funded the research. LXZ, YFZ, XX, ZQL and SQM critically revised the important intellectual content of the work. All authors reviewed the manuscript.

Funding

This research was funded by the Jiangsu Province Social Science Foundation Project, with project code: 20TYB006; the Fundamental Research Funds for the Central Universities, with project code: ZYTS24161.

Data availability

Data that has been anonymized is available for research purposes upon request to Lixian Zhu zlxnju@163.com.

Declarations

Ethics approval and consent to participate

This study received approval from the Psychological Ethics Committee of Nanjing University (NJUPSY202408001) and was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Participation was entirely voluntary, and all participants provided informed consent before completing the questionnaire digitally.

Consent for publication

All authors have read and consent to submission.

Competing interests

The authors declare no competing interests.

Received: 21 August 2024 / Accepted: 21 November 2024
Published online: 02 December 2024

References

1. Yu GL. Research on mental health education theories and policies. Beijing: Beijing Normal University Publishing Group; 2020. pp. 5–6.
2. Beauchamp MR, Puterman E, Lubans DR. Physical inactivity and mental health in late adolescence. JAMA Psychiatry. 2018;75(6):543–4. https://doi.org/10.1001/jamapsychiatry.2018.0385.
3. Hiçdurmaz D, Inci F, Karahan S. Predictors of mental health symptoms, automatic thoughts, and self-esteem among university students. Psychol Rep. 2017;120(4):650–69. https://doi.org/10.1177/0033294117707945.
4. Yin HC, Lu M, Wang XL, et al. Study on the impact of sports on the psychological health of university students. China Sport Sci. 2007;5:41–6. https://doi.org/10.16469/j.css.2007.05.006.
5. Tang HY, Chen Q, Wu JH. The relationship between college student's social development level and mental health: the mediating role of alexithymia and the gender difference. Psychol Dev Educ. 2021;37(5):735–42. https://doi.org/10.16187/j.cnki.issn1001-4918.2021.05.15.
6. Mikkelsen K, Stojanovska L, Polenakovic M, et al. Exercise and mental health. Maturitas. 2017;106:48–56. https://doi.org/10.1016/j.maturitas.2017.09.003.
7. Chang YC, Lu MC, Hu IH, et al. Effects of different amounts of exercise on preventing depressive symptoms in community-dwelling older adults: a

prospective cohort study in Taiwan. BMJ Open. 2017;7:e014256. https://doi.org/10.1136/bmjopen-2016-014256.
8. Atlantis E, Chow CM, Kirby A, et al. An effective exercise-based intervention for improving mental health and quality of life measures: a randomized controlled trial. Prev Med. 2004;39(2):424–34. https://doi.org/10.1016/j.ypmed.2004.02.007.
9. Berger BG, Owen DR. Mood alteration with yoga and swimming: aerobic exercise may not be necessary. Percept Mot Skills. 1992;75:1331–43. https://doi.org/10.2466/pms.1992.75.3f.1331.
10. Abd El-Kade SM, Al-Jiffri OH. Exercise alleviates depression related systemic inflammation in chronic obstructive pulmonary disease patients. Afr Health Sci. 2016;16(4):1078–88. https://doi.org/10.4314/ahs.v16i4.25.
11. Imayama I, Alfano CM, Kong A, et al. Dietary weight loss and exercise interventions effects on quality of life in overweight/obese postmenopausal women: a randomized controlled trial. Int J Behav Nutr Phys Activity. 2011;8:118. https://doi.org/10.1186/1479-5868-8-118.
12. Kerling A, Tegtbur U, Gützlaff E, et al. Effects of adjunctive exercise on physiological and psychological parameters in depression: a randomized pilot trial. J Affect Disord. 2015;177:1–6. https://doi.org/10.1016/j.jad.2015.01.006.
13. Song HY, Li ZQ, Yu SH, et al. Sports intervention therapy of college student's mental disorders (depression, anxiety and obsession). J Phys Educ. 2010;17(7):51–5. https://doi.org/10.16237/j.cnki.cn44-1404/g8.2010.07.027.
14. Noggle JJ, Steiner NJ, Minami T, et al. Benefits of yoga for psychosocial well-being in a US high school curriculum: a preliminary randomized controlled trial. J Dev Behav Pediatr. 2012;33(3):193–201. https://doi.org/10.1097/DBP.0b013e31824afdc4.
15. Hubbs A, Doyle EI, Bowden RG, et al. Relationships among self-esteem, stress, and physical activity in college students. Psychol Rep. 2012;110(2):469–74. https://doi.org/10.2466/02.07.09.PR0.110.2.469-474.
16. Ford HT, Puckett JR, Blessing DL, et al. Effects of selected physical activities on health-related fitness and psychological well-being. Psychol Rep. 1989;64(1):203–8. https://doi.org/10.2466/pr0.1989.64.1.203.
17. Khalsa SB, Hickey-Schultz L, Cohen D, et al. Evaluation of the mental health benefits of yoga in a secondary school: a preliminary randomized controlled trial. J Behav Health Serv Res. 2012;39:80–90. https://doi.org/10.1007/s11414-011-9249-8.
18. Eather N, Riley N, Miller A, et al. Efficacy and feasibility of HIIT training for university students: the Uni-HIIT RCT. J Sci Med Sport. 2019;22(5):596–601. https://doi.org/10.1016/j.jsams.2018.11.016.
19. Baghurst T, Kelley BC. An examination of stress in college students over the course of a semester. Health Promot Pract. 2014;15(3):438–47. https://doi.org/10.1177/1524839913510316.
20. Dougherty M, Hearst MO, Syed M, et al. Life events, perceived stress and depressive symptoms in a physical activity intervention with young adult women. Ment Health Phys Act. 2012;5(2):148–54. https://doi.org/10.1016/j.mhpa.2012.05.001.
21. Zhang LW, Mao XZ, Wang J. Handbook of research on sport & exercise psychology. Shanghai: East China Normal University; 2020. pp. 43–4.
22. Kaushal N, Rhodes RE, Spence JC, et al. Increasing physical activity through principles of habit formation in new gym members: a randomized controlled trial. Ann Behav Med. 2017;51(4):578–86. https://doi.org/10.1007/s12160-017-9881-5.
23. Yan JF, Sun H, Zhang J, Liu ZD. Analysis and implications of international experience on the factors, measurement methods and intervention strategies of forming physical activity habits. J Beijing Sport Univ. 2022;45(4):63–77. https://doi.org/10.19582/j.cnki.11-3785/g8.2022.04.006.
24. Rebar AL, Dimmock JA, Jackson B, et al. A systematic review of the effects of non-conscious regulatory processes in physical activity. Health Psychol Rev. 2016;10(4):395–407. https://doi.org/10.1080/17437199.2016.1183505.
25. Hagger MS. Redefining habits and linking habits with other implicit processes. Psychol Sport Exerc. 2020;46:101606. https://doi.org/10.1016/j.psychsport.2019.101606.
26. Gardner B, Phillips LA, Judah G. Habitual instigation and habitual execution: definition, measurement, and effects on behaviour frequency. Br J Health Psychol. 2016;21(3):613–30. https://doi.org/10.1111/bjhp.12189.
27. Phillips LA, Gardner B. Habitual exercise instigation (vs. execution) predicts healthy adults' exercise frequency. Health Psychol. 2016;35(1):69–77. https://doi.org/10.1037/hea0000249.
28. Verplanken B, Melkevik O. Predicting habit: the case of physical exercise. Psychol Sport Exerc. 2008;9(1):15–26. https://doi.org/10.1016/j.psychsport.2007.01.002.
29. Gardner B, Rebar AL, Lally P. 'Habitually deciding' or 'habitually doing'? A response to Hagger (2019). Psychology of Sport and Exercise. 2020; 47: 101539. https://doi.org/10.1016/j.psychsport.2019.05.008
30. Zhang XH, Shen LQ, Li M. The relations between sports activities habit and psychological healthy of middle school students. J Chengdu Sport Univ. 2002;4:47–50. https://doi.org/10.15942/j.jcsu.2002.04.014.
31. He ZK, Qian MY, Yang Y, et al. The impact of exercise attitude and exercise adherence on mental health of college student. China Sport Sci. 2007;6:39–44. https://doi.org/10.16469/j.css.2007.06.008.
32. Yan XJ, Chen ZN, Xia Y, et al. Analysis of influencing factors of depression symptoms among undergraduate students at a medical college in Guangzhou. Med Soc. 2024;37(3):121–6. https://doi.org/10.13723/j.yxysh.2024.03.019.
33. Huang B, Fang C, Wang D. Causal inference in education research: principles and applications of related methods. J East China Normal Univ (Educational Sciences). 2017;35(4):1–14. https://doi.org/10.16382/j.cnki.1000-5560.2017.04.001.
34. Berrie L, Feng Z, Rice D, et al. Does cycle commuting reduce the risk of mental ill-health? An instrumental variable analysis using distance to nearest cycle path. Int J Epidemiol. 2024;53(1):dyad153. https://doi.org/10.1093/ije/dyad153.
35. Cheng ZQ. Can exercise habit bring higher incomes? South China J Econ. 2020;07:121–40. https://doi.org/10.19592/j.cnki.scje.371089.
36. Tang BB, Liu LP. Sports Sci. 2019;40(4):35–45. https://doi.org/10.13598/j.issn1004-4590.2019.04.006. Extracurricular physical activities and deviant behaviors of middle school students: An Instrumental Variable Analysis of Data from CEPS.
37. Huang B, Fan W, Zhu Y. Causal inference: applications in education and other social science. Beijing: Educational Science Publishing House; 2022. pp. 214–68.
38. Li XP. An empirical research on college students' satisfaction with their residential environment on campus. Fudan Educ Forum. 2017;15(5):76–82. https://doi.org/10.13397/j.cnki.fef.2017.05.013.
39. Sun YM, Shan JW. Practical significance and implementation strategy of college students' sports life under the background of healthy China. Sport Sci Technol. 2023;44(3):114–5. https://doi.org/10.14038/j.cnki.tykj.2023.03.045.
40. Verplanken B, Orbell S. Reflections on past behavior: a self-report index of habit strength. J Appl Soc Psychol. 2003;33(6):1313–30. https://doi.org/10.1111/j.1559-1816.2003.tb01951.x.
41. Gardner B, de Bruijn GJ, Lally P. A systematic review and meta-analysis of applications of the self-report habit index to nutrition and physical activity behaviours. Ann Behav Med. 2011;42(2):174–87. https://doi.org/10.1007/s12160-011-9282-0.
42. Chatzisarantis NLD, Hagger MS. Mindfulness and the intention-behavior relationship within the theory of planned behavior. Pers Soc Psychol Bull. 2007;33(5):663–76. https://doi.org/10.1177/0146167206297401.
43. Jurg ME, Kremers SPJ, Candel MJJM, et al. A controlled trial of a school-based environmental intervention to improve physical activity in Dutch children: JUMP-in, kids in motion. Health Promot Int. 2006;21(4):320–30. https://doi.org/10.1093/heapro/dal032.
44. Rhodes R, de Bruijn GJ, Matheson DH. Habit in the physical activity domain: integration with intention temporal stability and action control. J Sport Exerc Psychol. 2010;32(1):84–98. https://doi.org/10.1123/jsep.32.1.84.
45. Chu XY, Xiao HY. Teenager physical exercise habit formation influencing factor model establishment and analysis. J Phys Educ. 2020;27(3):116–23. https://doi.org/10.16237/j.cnki.cn44-1404/g8.2020.03.018.
46. World Health Organization. Promoting mental health: concepts, emerging evidence, practice: a report of the World Health Organization, Department of Mental Health and Substance Abuse in collaboration with the Victorian Health Promotion Foundation and the University of Melbourne. World Health Organ. 2005. https://iris.who.int/handle/10665/43286.
47. Compton WC, Smith ML, Cornish KA, et al. Factor structure of mental health measures. J Personal Soc Psychol. 1996;71(2):406–13. https://doi.org/10.1037/0022-3514.71.2.406.
48. Diener E, Oishi S, Lucas RE. National accounts of subjective well-being. Am Psychol. 2015;70(3):234–42. https://doi.org/10.1037/a0038899.
49. Qiao YC, Fan YZ. Interrogation and response: eight basic problems in the study of the relationship between physical activity and happiness. J Shanghai Univ Sport. 2020;44(7):1–15. https://doi.org/10.16099/j.sus.2020.07.001.
50. Watson D, Clark LA, Tellegen A. Development and validation of brief measures of positive and negative affect: the PANAS scales. J Personal Soc Psychol. 1988;54(6):1063–70. https://doi.org/10.1037/0022-3514.54.6.1063.

51. Huang L, Yang TZ, Ji ZM. Applicability of the positive and negative affect scale in Chinese. Chin Mental Health J. 2003;17(1):54–6. https://doi.org/10.3321/j.issn:1000-6729.2003.01.018.
52. Diener E, Emmons RA, Larsen RJ, et al. The satisfaction with life scale. J Pers Assess. 1985;49(1):71–5. https://doi.org/10.1207/s15327752jpa4901_13.
53. Xiong CQ, Xu YL. Reliability and validity of the satisfaction with life scale for Chinese demos. China J Health Psychol. 2009;17(8):948–9. https://doi.org/10.13342/j.cnki.cjhp.2009.08.026.
54. Zhu F, Liang JH, Ma YK. The Effect of realistic altruistic behavior and network altruistic behavior on subjective well-being of college students: multiple mediation effects. J Psychol Sci. 2022;45(3):628–34. https://doi.org/10.16719/j.cnki.1671-6981.20220316.
55. Jones A, Crandall R. Validation of a short index of self-actualization. Pers Soc Psychol Bull. 1986;12(1):63–73. https://doi.org/10.1177/0146167286121007.
56. Yang RH, Chen ZY. The relationship between actual-ideal discrepancy and self-efficacy, self-actualization, self-identity and mental symptoms. Chin J Clin Psychol. 2010;18(4):507–8. https://doi.org/10.16128/j.cnki.1005-3611.2010.04.004.
57. Wu ML. Questionnaire statistical analysis in practice–SPSS operation and application. Chongqing: Chongqing University; 2010. pp. 248–9.
58. Lee SA, Ju YJ, Lee JE, et al. The relationship between sports facility accessibility and physical activity among Korean adults. BMC Public Health. 2016;16:893. https://doi.org/10.1186/s12889-016-3574-z.
59. Macdonald L. Associations between spatial access to physical activity facilities and frequency of physical activity; how do home and workplace neighbourhoods in West Central Scotland compare? Int J Health Geogr. 2019;18:2. https://doi.org/10.1186/s12942-019-0166-z.
60. Gidlow C, Cerin E, Sugiyama T, et al. Objectively measured access to recreational destinations and leisure-time physical activity: associations and demographic moderators in a six-country study. Health Place. 2019;59:102196. https://doi.org/10.1016/j.healthplace.2019.102196.
61. Stock JH, Yogo M. Testing for weak instruments in linear IV regression. Natl Bureau Economic Res. 2002;284:1–61. https://doi.org/10.3386/t0284.
62. Ruseski JE, Humphreys BR, Hallman K, et al. Sport participation and subjective well-being: instrumental variable results from German survey data. J Phys Activity Health. 2014;11(2):396–403. https://doi.org/10.1123/jpah.2012-0001.
63. Huang AL. Exploring the effect of health return of physical exercising by using multi-model identification technology–An. J Phys Educ. 2017;24(2):73–9. https://doi.org/10.16237/j.cnki.cn44-1404/g8.2017.02.011. analysis based on the data of Chinese General Social Survey 2012.
64. Puterman E, Weiss J, Beauchamp MR, et al. Physical activity and negative affective reactivity in daily life. Health Psychol. 2017;36(12):1186–94. https://doi.org/10.1037/hea0000532.
65. Wang YT, Fan XF, Zhang L, et al. Influence of family income on college students' mental health: the role of self-concept and collective self-esteem. Psychol Res. 2022;15(1):70–7. https://doi.org/10.19988/j.cnki.issn.2095-1159.2022.01.009.
66. Griffiths K, Moore R, Brunton J. Sport and physical activity habits, behaviours and barriers to participation in university students: an exploration by socio-economic group. Sport Educ Soc. 2022;27(3):332–46. https://doi.org/10.1080/13573322.2020.1837766.
67. Ströhle A. Physical activity, exercise, depression and anxiety disorders. J Neural Transm. 2009;116:777–84. https://doi.org/10.1007/s00702-008-0092-x.
68. Hayes AF, Rockwood NJ. Conditional process analysis: concepts, computation, and advances in the modeling of the contingencies of mechanisms. Am Behav Sci. 2020;64(1):19–54. https://doi.org/10.1177/0002764219859633.
69. Jansson A, Bjärsholm D, Krugly S, et al. Mental health and exercise habits among police students in Sweden: a three-year retrospective study. Police J. 2024;97(3):401–16. https://doi.org/10.1177/0032258X231181327.
70. Herbert C, Meixner F, Wiebking C, et al. Regular physical activity, short-term exercise, mental health, and well-being among university students: the results of an online and a laboratory study. Front Psychol. 2020;11:509. https://doi.org/10.3389/fpsyg.2020.00509.
71. Levante A, Quarta S, Massaro M, 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. https://doi.org/10.1016/j.heliyon.2024.e26626.
72. Han HJ, Duan QT. Study on the relationship between sports participation and subjective well-being of undergraduates. J Guangzhou Sport Univ. 2012;32(6):97–100. https://doi.org/10.13830/j.cnki.cn44-1129/g8.2012.06.024.
73. Ju W, Zhang Y. Effect of psychological group counseling on college students' test anxiety. China J Health Psychol. 2021;29(2):297–300. https://doi.org/10.13342/j.cnki.cjhp.2021.02.029.
74. Kumari R, Sharma M, Fatima A, et al. Evaluated stress and anxiety in college students before and after midterm exam. Medico-Legal Update. 2021;21(2):1025–9. https://doi.org/10.37506/mlu.v21i2.2818.
75. Hu X, Fan ZM, Hu XY, et al. The impact of maladaptive perfectionism on text anxiety for college students: a moderated mediating model. Psychol Explor. 2023;43(1):54–60.
76. Jung ME, Brawley LR. Concurrent self-regulatory efficacy as a mediator of the goal: Exercise behaviour relationship. J Health Psychol. 2013;18(5):601–11. https://doi.org/10.1177/1359105313479238.
77. Pasco JA, Jacka FN, Williams LJ, et al. Don't worry, be active: positive affect and habitual physical activity. Australian New Z J Psychiatry. 2011;45(12):1047–52. https://doi.org/10.3109/00048674.2011.621063.
78. Chen XP. Evolution of the biological basis model in sports training-from supercompensation to Adaptation Theory. China Sport Sci. 2017;37(1):3–13. https://doi.org/10.16469/j.css.201701001.
79. Ji L, Ma DH. Review and prospect of school physical education development in China in the past forty years of reform and opening-up. J Sports Res. 2018;1(5):1–11. https://doi.org/10.15877/j.cnki.nsic.2018.05.001.
80. Liu B, Tai F, Han Y, et al. Research on the background, basis and path of revising the regulations on School Physical Education in the New Era. China Sport Sci. 2022;42(6):11–8. https://doi.org/10.16469/j.css.202206002.

Publisher's note