Evaluating the Impact of Aerobic Exercise on Psychological Resilience in College Students: A Multi-Sensor Approach

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Abstract

In order to further analyze the promoting effect of aerobic exercise on the psychological resilience and overall mental health of college students and provide an important scientific basis for higher education to improve students' psychological quality through exercise intervention, this study explores the impact of aerobic exercise on college students' psychological resilience. Over 16 weeks, students engaged in structured aerobic activities, resulting in notable improvements in resilience. The study used advanced methods, including multiple sensors and Bayesian algorithms, to accurately measure exercise intensity. Traditional methods focused mainly on physiological indicators, but this study addressed the gap by also evaluating the psychological effects of exercise. Using Kumpfer's resilience theory, the researchers employed multi-sensor signal fusion to assess exercise load, demonstrating that aerobic exercise intensity could significantly enhance resilience. Despite some limitations like a small sample size and reliance on self-reports, the study highlighted the importance of integrating aerobic exercise into education for stress management and mental health. Future research should involve larger samples, explore diverse activities, and use advanced technologies.

Keywords: Students' psychological resilience; Aerobic exercise; Load intensity assessment; Bayesian algorithm; Mediating effect.

Abstracto

Este estudio examinó cómo el ejercicio aeróbico afecta la resiliencia psicológica de los estudiantes universitarios. Durante 16 semanas, los estudiantes participaron en actividades aeróbicas estructuradas, lo que resultó en mejoras notables en la resiliencia. El estudio utilizó métodos avanzados, incluidos múltiples sensores y algoritmos bayesianos, para medir con precisión la intensidad del ejercicio. Los métodos tradicionales se centraban principalmente en indicadores fisiológicos, pero este estudio abordó la brecha evaluando también los efectos psicológicos del ejercicio. Utilizando la teoría de la resiliencia de Kumpfer, los investigadores emplearon la fusión de señales multisensor para evaluar la carga de ejercicio, demostrando que la intensidad del ejercicio aeróbico podría mejorar significativamente la resiliencia. A pesar de algunas limitaciones, como un tamaño de muestra pequeño y la dependencia de los autoinformes, el estudio destacó la importancia de integrar el ejercicio aeróbico en la educación para el manejo del estrés y la salud mental. Las investigaciones futuras deberían incluir muestras más grandes, explorar diversas actividades y utilizar tecnologías avanzadas.

Palabras clave: Resiliencia psicológica de los estudiantes; Ejercicio aeróbico; Evaluación de la intensidad de la carga; algoritmo bayesiano; Efecto mediador.

Introduction

In the context of globalization, the lack of physical activity has become an increasingly serious health challenge. It is not only a major risk factor leading to chronic diseases such as cardiovascular disease, diabetes, and osteoporosis, but also has a profound impact on individual mental health. According to the World Health Organization report, health problems caused by lack of exercise have become one of the leading causes of death worldwide, which urgently requires us to explore and promote positive lifestyles to promote universal health. Specifically, aerobic exercise has attracted significant attention due to its ability to significantly improve cardiovascular function, enhance immunity, and promote mental health. In recent years, scientific research has gradually revealed the close relationship between exercise and mental health. Aerobic exercise has a positive impact on brain structure and function by promoting the release of brain-derived neurotrophic factors, enhancing neural plasticity, and reducing inflammatory responses, thereby helping to prevent and treat various psychological disorders, including depression (Gubareva et al., 2024; Leuchter et al., 2022; Ochmann et al., 2021; Zhang et al., 2022b). In addition, exercise can significantly enhance an

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individual's psychological resilience, that is, the ability to quickly recover and adapt to adversity, stress, or trauma, which is of great significance for improving quality of life and promoting social integration.

However, although the potential benefits of aerobic exercise on psychological resilience have been preliminarily validated, existing research has mostly focused on monitoring physiological indicators, with little in-depth exploration of the specific mechanisms of psychological changes during exercise and their intrinsic relationship with psychological resilience. In addition, research on specific populations such as college students is still insufficient. As the backbone of society in the future, college students are facing multiple pressures such as schoolwork, employment, and interpersonal relationships. Especially under the influence of COVID-19, their mental health problems are more prominent. Therefore, conducting research on the relationship between aerobic exercise and psychological resilience for college students not only helps to reveal the specific mechanisms by which exercise promotes mental health but also provides a scientific basis and practical guidance for mental health education in universities.

In the above context, this study aims to fill the gap in research on the impact of aerobic exercise on the psychological resilience of college students. By integrating multi-sensor technology and the Bayesian algorithm, it accurately tracks the physiological (such as heart rate and blood pressure) and psychological (such as emotions and stress perception) changes of college students during aerobic exercise. Combined with Kumpfer's psychological resilience theory, it deeply explores the changes in psychological resilience and physiological psychological mechanisms under different exercise intensities. This not only provides a scientific basis for the application of exercise prescriptions in the field of mental health but also provides practical guidance for universities to design scientific exercise intervention programs and promote students' comprehensive development. The research approach of this article is as follows:

(1) Research background and purpose: To explore the impact of aerobic exercise on the psychological resilience of college students, with the aim of promoting their mental health.

(2) Theoretical model of psychological resilience: Applying Kumpfer's theory of psychological resilience, analyzing the construction and improvement mechanism of psychological resilience.

(3) Assessment of aerobic exercise load intensity: Multi-sensor and Bayesian algorithms are used to accurately evaluate aerobic exercise load, ensuring the scientific nature of exercise intensity.

(4) The mediating role of physical exercise and psychological resilience: exploring the mechanism by which physical exercise enhances psychological resilience through physiological and psychological mediation.

(5) Experimental design and implementation: Design and implement aerobic exercise intervention experiments for college students and collect physiological and psychological data.

(6) Results and Discussion: Analyze the data, verify the effect of aerobic exercise on improving psychological resilience, and discuss the underlying mechanisms.

(7) Conclusion and outlook: Summarize the research findings, point out the limitations of the study, and look forward to future research directions.

Literature Review

Ochmann et al. (2021) explored the link between physical activity, resilience, and aerobic capacity. 70 healthy, inactive adults (18 - 45) were split into groups. The intervention group had supervised running. Aerobic capacity and resilience were measured. 43 met the criteria, and 31 were completed. Gubareva et al. (2024) studied sports' impact on students' (17.8±1.2) exam-stress adaptation. 160 students were divided into non-sports and sports-active groups. Physiological and psychophysiological parameters were assessed. Sports-active students had better indicators. Zhang et al. (2022b) explored PA and negative emotional states in 1117 Chinese college students. Regression analysis showed PA, exercise intensity - tolerance, and resilience were negatively correlated with negative states. Leuchter et al. (2022) explored the exercise intensity-stress relationship among U.S. medical students. Two surveys at UCLA. Only 27% achieved HEPA levels. Higher HEPA intensity is linked to lower stress. Du, Zhang and Chang (2022) investigated physical activity intensities' impact on high school students' mental health. 786 students participated. Physical activities improve mental health and resilience. Tai chi was effective. Fan et al. (2021) studied acute aerobic exercise at different intensities on inhibitory control in 30 college students with smartphone addiction. Moderate-intensity exercise improved response inhibition.

Zhang, Ren and Zou (2022a) explored how physical exercise impacts life satisfaction in 1,012 college students. Exercise commitment and adherence had different mediating effects. Yuan et al. (2022) investigated persistent physical exercise's impact on primary school students' well-being in Nanchang. There were gender and grade-level differences. Exercise was positively correlated with positive emotions. Shen and Yang (2022) explored advanced techniques in nonlinear system identification for sports training. A "load-fitness state" model was established. A controller improved tracking accuracy. Yang et al. (2024) investigated the sRPE - TRIMP correlation in cross-country skiing. 10 athletes' 273 training sessions were analyzed. Correlation differed by intensity and duration. Lea et al. (2021) evaluated RPE's validity in isometric exercise for 29 male participants. RPE is valid for monitoring intensity and physiological exertion.

Wearable Technology (WT) has been used in multiple fields. Definitions emphasize their features. WT is transforming sports. Monitoring physiological functions is popular. It helps in rehabilitation and sports training. De Fazio et al. (2023) reviewed wearable sensors for sports and rehabilitation. The review provided an overview and identified the best technologies. Seçkin, Ateş and Seçkin (2023) reviewed WT's role in sports performance. The review analyzed wearables' use and highlighted potential advancements. Zhou (2022) proposed a new track and field training measurement method using wearable nano-equipment. It improved efficiency. Santos et al. (2021) evaluated soccer players' training load in SSGs. 24 players from different age groups participated. Age-related differences were noted. Wearable technology is crucial.

Theoretical Model of Psychological Resilience

Kumpfer's Resilience Framework (KRF) was initially developed to understand resilience and its predictors among at-risk youth. Since then, the framework has been expanded and applied to various populations facing different stressors. KRF is proposed based on ecosystem theory. It provides a framework for in-depth understanding and evaluation of individual resilience, as shown in Figure 1 (Zhang et al., 2023).

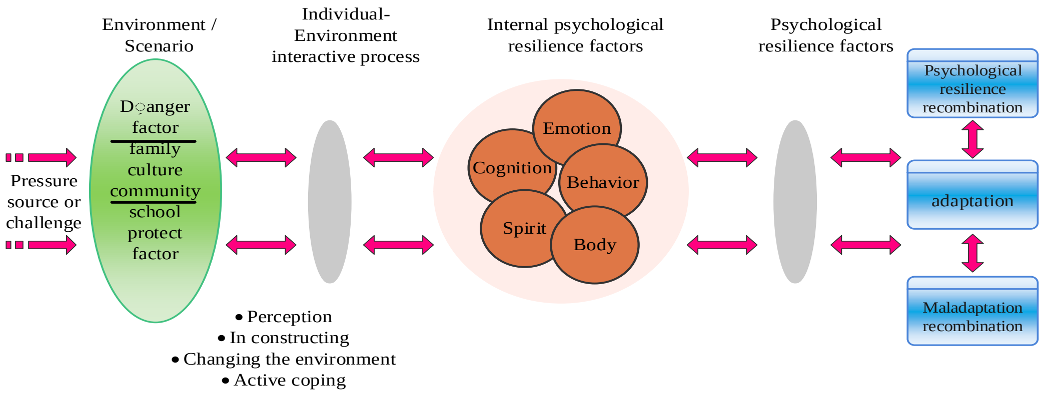


Figure 1: Kumpfer's Theoretical Model of Resilience.

The model primarily includes the following three core modules: Environmental Characteristics, Individual Characteristics, and Dynamic Mechanism and Positive Development Outcomes. The environmental characteristics module focuses on the external environment of individuals, encompassing various protective and risk factors. Protective factors may include family support, educational resources, and social networks, which help individuals maintain a positive attitude and behavior when facing challenges. Conversely, risk factors such as poverty, family conflict, and social exclusion may increase the risk of psychological distress.

The individual characteristics section emphasizes the internal attributes and abilities of individuals, such as self-esteem, self-efficacy, and problem-solving skills. These internal factors play a crucial role in how individuals handle pressure and challenges, influencing their adaptation and coping strategies.

The dynamic mechanism and positive development outcomes module, also known as elastic restructuring, describes how individuals achieve positive psychological development through interaction and self-adjustment with their environment. It highlights the dynamic adaptation process individuals undergo in response to stress and adversity, including cognitive restructuring, emotion regulation, and behavioral coping strategies (Pangallo, 2014).

As can be seen from the framework, in the first part, Kumpfer believes that when individuals face stressors or challenges, their external situations or environmental factors (such as family situation, cultural context, community environment, school environment, and peer interactions) include both risk and protective factors. These two types of factors interact to promote the balance of negative influences. Generally, when the number of risk factors is small and their intensity is low, and the number of protective factors is large with high intensity, the protective factors will counteract the risk factors, thereby reducing their adverse effects and inhibiting the generation of negative emotions in individuals. However, when there are many high-intensity risk factors, there may be insufficient protection, resulting in individual harm (Tansey et al., 2017).

The second part involves the interaction between the individual and the environment. The internal action mechanism of an individual has a protective effect. As depicted in the figure, an individual's internal action mechanism intentionally or unintentionally selects, reconstructs, and changes the environment, actively responding to it. When the internal and external environments interact, a subsequent recovery process occurs. This interaction process modifies the risk factors and avoids relevant negative factors, aiding individuals in better adapting to survival. The third part concerns the generation of psychological resilience, which results from the interaction between the internal and external environments. Kumpfer proposed the factors of psychological resilience from five aspects: cognition, positive emotion regulation, spirit, positive self-image, and behavior (Desgorces et al., 2023). The last part of the framework discusses the outcomes of psychological resilience adjustment. The first outcome is that various external pressures and challenging events impact individuals. After experiencing these pressures and challenges, individuals' sense of self-worth improves, enhancing their psychological resilience. This improvement promotes a more proactive approach to dealing with negative events and increases self-control, meaning that individuals become more resilient after facing stress and challenges. The second outcome is active adaptation, where individuals can restore their original balance after encountering stimulating events. Instead of avoiding the situation or engaging in avoidance behaviors, they actively respond, which serves as a form of self-protection. The third outcome is the opposite of the first. After experiencing a stimulating event, an individual's resilience may not improve or may even worsen, returning directly to the initial level. This indicates that the individual cannot adapt well, and their functioning decreases to a lower level (Guo et al., 2022).

Assessment of Aerobic Exercise Load Intensity

Appropriate aerobic exercise load intensity is crucial for enhancing students' psychological resilience. Psychological resilience refers to the ability to recover quickly and move forward when facing pressure, frustration, or adversity. Through aerobic physical exercise, students can better adjust their emotions, stay calm, and improve their problem-solving abilities in the face of challenges. Assessing aerobic exercise load intensity ensures that exercise difficulty is moderate, avoiding poor results from being too easy or frustration from being too difficult. Effective identification and positioning of intensity signals are achieved through multiple sensors distributed across various parts of the body. To shorten signal transmission time, reduce the volume of information transmission, and improve data identification accuracy, multi-sensor signal fusion is utilized (Friedman et al., 2022; Liu, Menhas, & Saqib, 2024; Wang et al., 2024). Given the large amount and complexity of intensity data, the sampling frequency is high, leading to significant overall consumption. Therefore, this paper compresses the collected intensity signals in descending high-dimensional order, extracting and classifying the signals with higher amplitude and greater chaos, as shown in Figure 2 below.

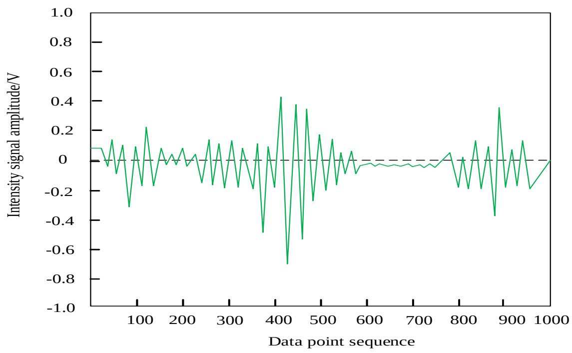


Figure 2: Schematic Diagram of High Frequency Intensity Signal.

After that, it will carry out unified hierarchical fusion with other sensors. This can not only ensure the accuracy of data acquisition but also reduce the classification error in the process and improve the efficiency of the overall strength signal fusion. The specific fusion scheme is shown in Figure 3.

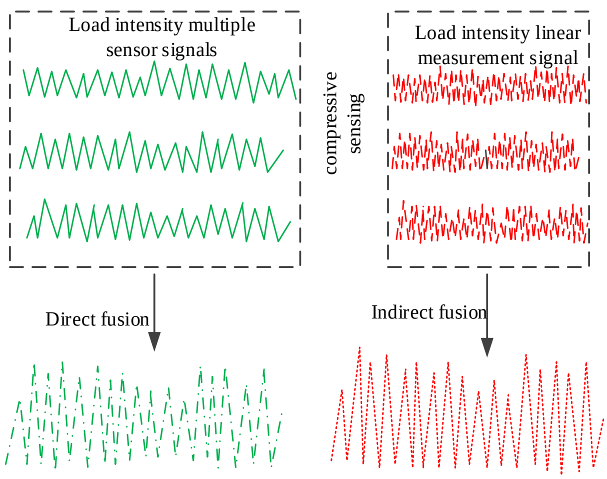


Figure 3: Aerobic Exercise Load Intensity Information Fusion Scheme.

Bayesian algorithm is used for intensity numerical fusion, which can efficiently use the collected sample data to ensure the stability and accuracy of aerobic exercise load intensity signal. First, suppose that N_n strength signal sensor is arranged in each part of the human body, and the average variance between sensors is σ_i^2, $i = 1,2,\cdots,N_n$. The measured value of the intensity signal between nodes is $X_i(1,2,\cdots,N_n)$ and the value conforms to the Gaussian distribution (Holland et al., 2020; Zhu et al., 2015). Let $x_i(1,2,\cdots,N_n)$ be the strength measurement value on the N_n sensor node, and X be the fusion value of the measurement value. Using Bayesian algorithm, we can get:

$$p(x|x_1,x_2,\cdots,x_N) = \frac{p_1(x,x_1,x_2,\cdots,x_N)}{p_2(x_1,x_2,\cdots,x_N)} \quad (1)$$

In the formula, p indicates that it follows the parameter and conforms to the $N_n(x_0,\sigma_0^2)$ distribution, σ^2 indicates the normal fitting value, p_1 indicates that it follows the parameter and conforms to the $N_n(x_1,\sigma_1^2)$ distribution, and so on, and p_i conforms to the $N_n(x_i,\sigma_i^2)$ distribution. Let a constant value a and $a = 1/p(x|x_1,x_2,\cdots,x_N)$ be independent of the obedience parameter. Based on this condition, the obedience parameter p can be expressed as:

$$p(x|x_1,x_2,\cdots,x_N) = a \cdot \exp\left\{-\frac{1}{2}\sum_{i=1}^{N_n}\left(\frac{x_i - x}{\sigma_i}\right)^2 - \frac{1}{2}\left(\frac{x_i - x_0}{\sigma_0}\right)^2\right\} \quad (2)$$

Therefore, the calculated value of $a = p(x|x_1,x_2,\cdots,x_N)$ conforms to the normal sequence distribution. Assuming that the fusion parameter x conforms to the $N_n(\tilde{x},\tilde{\sigma}^2)$ distribution, the following expression can be obtained:

$$p(x|x_1,x_2,\cdots,x_N) = \frac{1}{\sqrt{2\pi\sigma}}\exp\left\{-\frac{1}{2}\left(\frac{x-\tilde{x}^2}{\sigma}\right)\right\} \quad (3)$$

By comparing the fusion parameter relationship in formula (2) and formula (3), we can get:

$$\tilde{x} = \left(\sum_{i=1}^{s}\frac{x_i}{\sigma_i^2} + \frac{x_0}{\sigma_0^2}\right)\left(\sum_{i=1}^{s}\frac{1}{\sigma_i^2} + \frac{1}{\sigma_0^2}\right)^{-1} \quad (4)$$

Where S is the optimal fusion coefficient, and the fusion formula of aerobic exercise load intensity based on this optimal state is:

$$\tilde{x} = \int_0 x\frac{1}{\sqrt{2\pi\sigma}}\exp\left\{-\frac{1}{2}\left(\frac{x-\tilde{x}^2}{\tilde{\sigma}}\right)\right\}dx = \left(\sum_{i=1}^{s}\frac{x_i}{\sigma_i^2} + \frac{x_0}{\sigma_0^2}\right)\left(\sum_{i=1}^{s}\frac{1}{\sigma_i^2} + \frac{1}{\sigma_0^2}\right)^{-1} \quad (5)$$

According to the Bayesian data fusion process described above, all aerobic exercise load intensity information collected by human body sensors can be fitted and classified. This approach not only reduces the computational load of subsequent monitoring and analysis but also improves overall efficiency and accuracy, ensuring the data's referential integrity and authenticity.

The sensor's original data is decomposed and reconstructed to eliminate noise, minimize the impact of abnormal factors, and reduce calculation errors. First, the original aerobic exercise load intensity data set ζ is established, and the wavelet transform equation is used for calculation.

$$\begin{cases}\zeta_{2n}(t) = \sqrt{2}\sum_{k\in Z} h_{0k}\zeta_n(2t-k)\\ \zeta_{2n+1}(t) = \sqrt{2}\sum_{k\in Z} h_{1k}\zeta_n(2t-k)\end{cases} \quad (6)$$

In the formula, t represents the time parameter, ζ represents the scale function, h_{0k} and h_{1k} represent the wavelet transform function. According to the defined sequence $\{\zeta_{2n}(t)\}(n \in Z)$ of the function (Z represents the sequence set of positive integers), the recurrence formula of the wavelet packet transform coefficient can be determined as follows:

$$\begin{cases}d_k^{i+1,2n} = \sum_l h_{0(2l-k)}d_l^{i-n}\\ d_k^{j+1,2n+1} = \sum_l h_{1(2l-k)}d_l^{j-n}\end{cases} \quad (7)$$

where d is the wavelet packet transform coefficient and k is a constant value. According to the principle of data reconstruction, the following relationship can be obtained:

$$d_k^{j+n} = \sum_k g_{0(l-2k)}d_k^{j+1,2n} + \sum_k g_{1(l-2k)}d_k^{j+1,2n+1} \quad (8)$$

where g_0 and g_1 represent the low-frequency and high-frequency data filters corresponding to the scaling function and the wavelet transform function, respectively. After eliminating the abnormal data, it is necessary to denoise all the aerobic exercise intensity information in the monitoring set. This allows monitoring signals to be allocated to the corresponding nodes in sequence after wavelet packet decomposition, improving the continuity of signal distribution and reducing the interleaving phenomenon.

Through this process, the final aerobic exercise load intensity monitoring signal is obtained. Using occupancy rate, consumption, and tolerance, a specific aerobic exercise load state evaluation is conducted to determine whether the monitoring signal indicates a state of high intensity or high load. The relationship between the monitoring state $L_{(t)}$of the sensor, the evaluation parameter state $V_{(t)}$of aerobic exercise load intensity, and the sensitivity value$D_{(t)}$ at any time is expressed as follows:

$$D_{(t)} = \frac{fV_{(t)}}{\tilde{x}L_{(t)}} \quad (9)$$

Where f is the reference value. With the increase in sensitivity value $D_{(t)}$, parameter f is more sensitive to the change of its state. Based on this change rule, it is necessary to select the parameters with high sensitivity and small-time delay for constant analysis when evaluating the strength state.

H_1 represents the monitoring probability of exceeding the aerobic exercise load intensity standard, H_0 represents the monitoring probability of normal aerobic exercise load intensity, Y_i represents the load parameter threshold, C_i represents the real-time detection of the i intensity data, and U_t represents the decision state. When $L(C_i) > Y_i$, it indicates that the monitoring intensity has exceeded the load value. When $L(C_i) < Y_i$, it indicates that the monitoring intensity does not exceed the load value and belongs to the normal state.

In order to more intuitively reflect the reliability of monitoring intensity data, the deviation value of the target state $L(C_i)$ is quantified by a single parameter decision, and the reliability of the monitoring intensity data is defined according to the quantization level. Therefore, when $L(C_i) > Y_i$, in order to intuitively reflect the extent to which the monitoring data exceeds the parameter Y_i, it is necessary to effectively quantify the value in the interval $[Y_i, \infty]$. Let there be a value A_1 in the set, and the value belongs to the interval $A_1 \in [Y_i, \infty]$, so that $L(C_i) > A_1(H_0 \approx 0)$ can be used. When $L(C_i) < Y_1$, let there be a value B_1 in the set, and the value belongs to the interval $[-\infty, Y_i]$, let $L(C_i) < Y_i(H_1 \approx 0)$. Only in this way can we fully improve the reliability of monitoring data, ensure the accuracy of judgment, and reduce the calculation error.

If the reliability value of the single parameter A_1 is expressed by N different levels of evaluation thresholds, when $L(C_i) \geq Y_i$, there are:

$$Y_{i,j}^{-1} = Y_i + D_{(t)} j \frac{A_i - Y_i}{N}, j = 0,1,2,\cdots, N-1 \quad (10)$$

When the value of the evaluation parameter is $Y_{i,j}^{1} = \infty$, the credibility of the decision state $U_t = 1$ can be expressed as:

$$Y_i = j, Y_{i,j}^{1} \leq L(C_i) \leq Y_{i,j+1}^{1} \quad (11)$$

When $L(C_i) < Y_i$, make $Y_{i,j}^{0} = Y_i - j\frac{Y_i - B_{1i}}{N}$. When $Y_{i,j}^{0} = -\infty$, the reliability of judging state $U_t = 0$ can be expressed as:

$$Y_i = j, Y_{i,j+1}^{0} \leq L(C_i) \leq Y_{i,j}^{0} \quad (12)$$

In most cases, the aerobic exercise load intensity monitoring algorithm is composed of multiple evaluation parameters, and the judgment intensity information based on each parameter is:

$$u_t = \begin{cases} H_i \\ O_i \\ U_i \end{cases} \quad (13)$$

where H_i represents the decision state, O_i represents the classification level of credibility, U_i represents the state vector of the fusion center, and $U_i = (U_1, U_2, \cdots, U_n)$ achieves the final strength numerical decision through definition and calculation.

The mediating effect of physical exercise and psychological resilience

Research Background and Purpose

The aim of this study is to explore in depth the impact mechanism of physical exercise, especially aerobic exercise, on the psychological resilience of college students, and to verify the mediating role of self-efficacy in this relationship. By constructing theoretical models, evaluating aerobic exercise load intensity, and collecting and analyzing relevant data, this study aims to provide empirical support and practical guidance for mental health education in universities.

Research Methods and Types

Research Method: This study adopts quantitative research methods, combined with questionnaire surveys, physiological monitoring, and statistical analysis techniques, to comprehensively examine the relationship between physical exercise, self-efficacy, and psychological resilience. Specifically, subjective data such as psychological resilience and self-efficacy of participants will be collected through the design of standardized questionnaires, while objective data such as load intensity during aerobic exercise will be monitored using multi-sensor technology.

Research type: This study belongs to cross-sectional research, which involves collecting and analyzing data from a selected sample at a single time point. Although cross-sectional studies cannot directly infer causal relationships, they can reveal the correlation between variables and provide a basis for subsequent longitudinal studies or experimental interventions.

Data Collection Techniques

Questionnaire survey: This study used validated psychological resilience scales and self-efficacy scales to distribute questionnaires to college students online or offline. The questionnaire covers personal basic information, physical exercise habits, psychological resilience level, and self-efficacy. To ensure data quality, the questionnaire was pre-tested and revised to improve its reliability and validity.

Physiological monitoring: Real-time monitoring of participants' load intensity during aerobic exercise using multi-sensor technology such as heart rate monitors, accelerometers, etc. Sensors are distributed in different parts of the body to comprehensively capture physiological changes during movement. Transmit data to a computer for subsequent analysis through wireless transmission technology.

Data quality control: A series of measures are taken during the data collection process to ensure data quality. Including but not limited to providing necessary guidance and instructions to questionnaire respondents to ensure they have a full understanding of the questionnaire content; Regularly calibrating and maintaining physiological monitoring equipment to ensure the accuracy and reliability of data; Preliminary screening and cleaning of collected data to eliminate outliers and missing values.

Mediation Effect Test

The scales and tests used in this study have undergone rigorous reliability and validity testing. The Psychological Resilience Scale and Self Efficacy Scale are both mature scales widely used domestically and internationally and have been appropriately revised and supplemented according to the research objectives. Physiological monitoring equipment has also been calibrated and certified by professional institutions to ensure the accuracy and reliability of data. Multiple statistical methods and software (such as SPSS, AMOS, etc.) were used in the data analysis process to ensure the accuracy and reliability of the analysis results. The specific inspection process is as follows:

Physical exercise can promote individual self-efficacy and significantly improve psychological resilience. Based on the theoretical model of psychological resilience and the conclusions from aerobic exercise load intensity assessments, the mediating effect was analyzed. The concept of self-efficacy as a mediator between physical exercise and psychological resilience is crucial. It explains how physical exercise enhances individual self-efficacy, which in turn boosts psychological resilience. In other words, physical exercise indirectly fosters psychological resilience by improving self-efficacy. This mediating effect offers a new perspective on the relationship between physical exercise and psychological resilience and provides a theoretical foundation for developing effective intervention measures. Accordingly, this paper proposes a hypothetical model, as illustrated in Figure. 4:

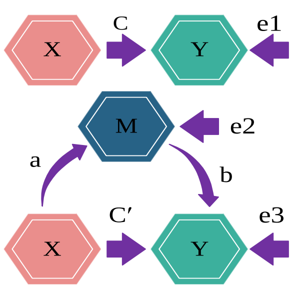


Figure 4: Schematic Diagram of the Basic Principle of the Intermediate Variable.

In Figure. 4, the basic principle of intermediary variables shows that the intermediary effect refers to the process in which independent variables affect dependent variables through intermediary variables. This process can be verified by a regression equation and a mediation effect test. For the theme of aerobic exercise load intensity assessment to improve students' psychological resilience, the independent variable X is the aerobic exercise load intensity assessment method, the intermediary variable M is individual self-efficacy, and the dependent variable Y is the psychological resilience level.

The mediation effect refers to the influence relationship ($X \rightarrow Y$) between independent variable X and dependent variable Y, which is indirectly generated by through one or more variables (M). These intermediary variables are called mediation variables, and the indirect impact of the independent variable on the dependent variable through these mediation variables is called the mediation effect. The figure illustrates the regression equation and its basic principle for investigating whether there is an intermediary variable M between the independent variable X and the dependent variable Y.

$$Y = cX + e1 \quad (14)$$

$$M = aX + e2 \quad (15)$$

$$Y = c'X + bM + e3 \quad (16)$$

Where a is the influence coefficient of the independent variable X on the intermediary variable M, b is the influence coefficient of the intermediary variable M on the dependent variable Y, and c' is the direct influence coefficient of X on Y after controlling for the intermediary variable. By combining the concept of the mediating effect, we can explore the relationship between paths a, b, and c through statistical analysis, and verify the mediating effect of self-efficacy between physical exercise and psychological resilience.

If the results show that both path a and path $b$are significant, and path c is also significant, it can be confirmed that self-efficacy has a mediating effect between aerobic exercise load intensity assessment and psychological resilience. In general, this mediating effect analysis can reveal the complex relationship between physical exercise, self-efficacy, and psychological resilience, providing a theoretical basis for formulating effective intervention measures and promoting the improvement and development of students' psychological resilience.

If the significance test of the mediation effect coefficient b is greater than the set significance level (0.65) after the above steps, it indicates that the mediation effect is significant.

By centralizing all variables, the mediation path inspection process adopts the mediation inspection step, as shown in Figure. 5:

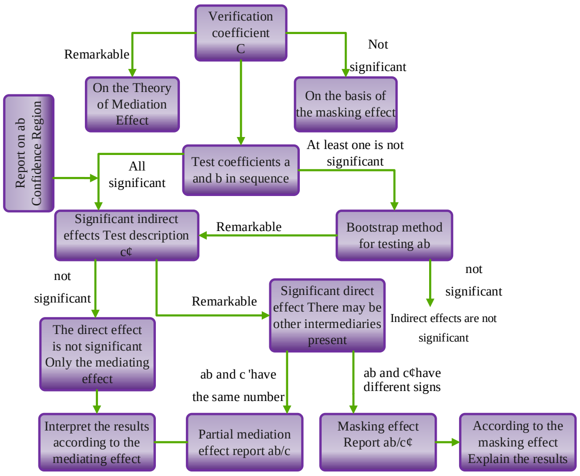


Figure5: Inspection Flow Chart.

The mediation effect test is conducted according to the process in Fig. 5 to determine whether the mediation effect is significant. This test verifies whether the mediating variable plays a statistically significant role between the independent variable and the dependent variable. If the mediating effect is statistically significant, it indicates that there is a mediating relationship between aerobic exercise load intensity and students' psychological resilience through self-efficacy. This demonstrates that the intensity of aerobic exercise can increase the level of students' psychological resilience.

Conversely, if the mediating effect is not statistically significant, it shows that the intensity of aerobic exercise does not affect students' psychological resilience. Based on this analysis, research on assessing aerobic exercise load intensity to improve students' psychological resilience is realized.

Experimental Analyses

To investigate the effect of different aerobic exercise intensities on the psychological resilience of college students, 50 healthy students from a university were selected as experimental subjects, with an average age of 19.23 years (± 1.23 years). Designed a structured aerobic exercise plan for 16 weeks (one semester), conducted three times a week for 30 minutes each time. The specific exercise plan, experimental conditions, experimental indicators, results, etc. are shown below.

Experimental Subjects and Settings

This study investigates the impact of aerobic exercise intensity on the psychological resilience of college students. A class of students from a college, with a total of 50 participants, was selected for testing. The average age of the students is 19.23 ± 1.23 years old. Experimental details are shown in Table 1.

Table 1

Experimental Details

Parameter	Description
Number of Students	50
Average Age	19.23 ± 1.23 years
Duration of Exercise Session	30 minutes
Frequency of Sessions	Three times a week
Total Duration of Experiment	16 weeks (one semester)

To evaluate the influence of aerobic physical exercise on students' psychological resilience, a structured exercise program was implemented. The exercise regimen consisted of 30-minute aerobic exercise sessions conducted three times a week over a period of 16 weeks, spanning one semester. Details of the exercise program and the experimental setup are provided in Table 2.

Table 2

Teaching Plan of Aerobic Physical Exercise Course.

Serial Number	Aerobic exercise course	
	Content	Exercise time
1	Warming up	10 min
2	Alternate fast walking and jogging	25 min
3	Dynamic stretching	15 min
4	Intermittent sprint	10 min
5	Relax stretch	15 min

Experimental Control

Based on the support of 15 literature reviews and best practices, the following control measures are designed:

(1) Health and baseline assessment: Ensure that all participants are physically healthy and suitable to participate in the study and collect baseline data to assess their initial level of psychological resilience.

(2) Teaching and training management: Strictly control the progress, frequency, and content of sports courses, avoid interference from other sports activities, and ensure the accuracy of experimental results.

(3) Strength evaluation and monitoring:

Intensity assessment: Evaluate the intensity levels of two types of aerobic exercise before the experiment and re-evaluate after 18 weeks to verify the training effect.

Load intensity monitoring: Multi-sensor technology is used to monitor exercise load intensity, with sensors installed in different parts of the participant's body to obtain comprehensive measurement values through signal fusion. The data collection adopts a centralized node for unified collection, ensuring accuracy and timeliness.

Experimental Index

Verify the RMSE (root mean square error) value of load intensity monitoring under the three methods, and the calculation formula is:

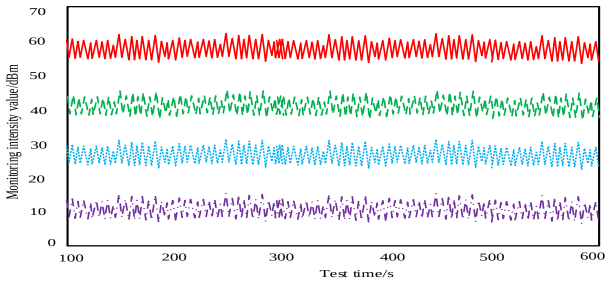
$$RMSE = \frac{\sum_{i=0}^{M} \|u_i - u_j\|}{M} \tag{17}$$

Where M is the number of signal sources, u_i is the root position of the i transmission signal, and u_j is the position of the j transmission signal.

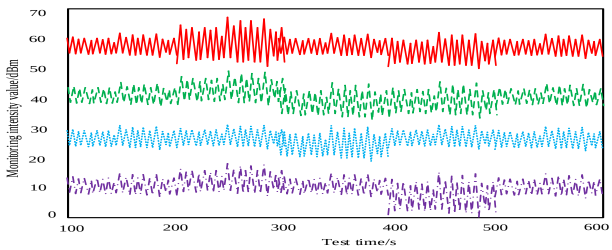
Results and Discussion

Stability of the Monitoring Curve

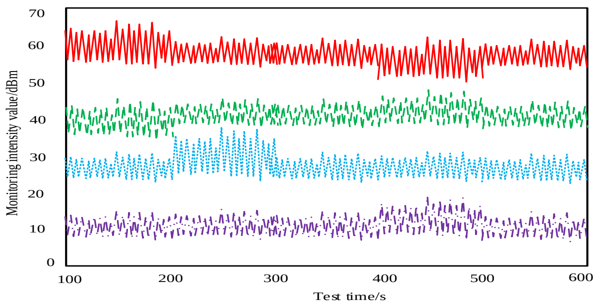
As illustrated in Fig. 6, the monitoring curve obtained using the method proposed in this paper demonstrates strong stability when compared with other methods. The data variability within the monitoring time range is minimal, indicating that the algorithm's fault tolerance is robust. This allows for the accurate determination of strength values that exceed the established standards based on actual conditions. Consequently, the method effectively reduces the error rate in evaluation calculations by providing precise and reliable data analysis.



(a) Method in this paper



(b) Reference (Shen & Yang, 2022) method



(c) Reference (Lea et al., 2021) method

Figure 6: Assessment of Aerobic Exercise Load Intensity.

As shown in Fig. 6, the monitoring method used in this study exhibited stronger stability compared to other methods such as the reference (Shen & Yang, 2022) and reference (Lea et al., 2021) methods. The monitoring curve maintained low data variability throughout the entire time range, which directly reflects the high error tolerance and robustness of the algorithm. This stability ensures that even in dynamically changing environments, strength values exceeding established standards can be accurately determined, thereby improving the accuracy and reliability of data analysis. Therefore, the method used in this study not only provides technical support for the accurate assessment of aerobic exercise load intensity but also lays a solid foundation for subsequent psychological resilience assessment.

Comparative Analysis of Monitoring Errors

To further validate the effectiveness of the proposed method, a comparative analysis of monitoring errors was conducted using two reference methods: the method from reference (Shen & Yang, 2022) and the method from the reference (Lea et al., 2021). The Root Mean Square Error (RMSE) values for each method were calculated, and the experimental results are presented in Fig. 7.

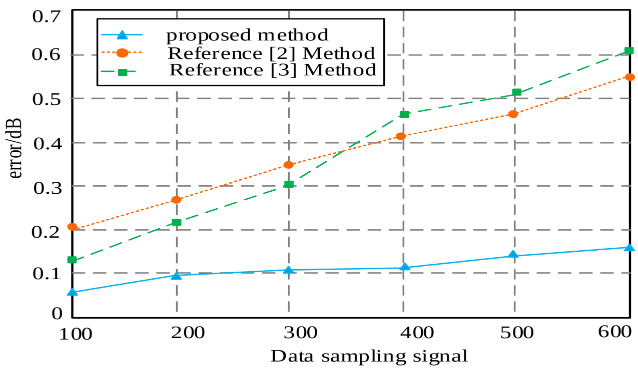


Figure. 7: Monitoring root means square error curve of three methods.

As shown in Figure. 7, the root mean square error (RMSE) value of this research method is significantly lower than the other two methods, demonstrating its superior accuracy and reliability. Specifically, the highest RMSE value of this research method is only 0.16, far lower than the maximum value of 0.57 of the reference methods. This result not only validates the superiority of our research method in practical applications but also further emphasizes its important role in reducing monitoring errors and improving evaluation accuracy.

Significance Level Test

Following the aerobic exercise load intensity evaluation, an assessment was conducted to measure the students' psychological resilience. This evaluation was crucial to determine the impact of the aerobic exercise regimen on the students' mental toughness. Figure. 8 illustrates the assessment results of the students' psychological resilience after participating in the 18-week aerobic exercise program.

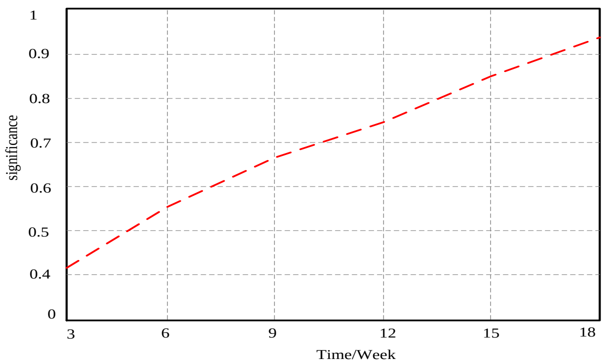


Figure. 8: Assessment of students' psychological resilience.

As shown in Fig. 8, after 18 weeks of an aerobic exercise program, students' psychological resilience levels significantly improved, and this result is highly significant. This discovery suggests that regular aerobic exercise can effectively improve individuals' psychological resilience and help them better cope with stress and challenges. The results of this study further confirm the positive role of aerobic exercise in promoting mental health and enhancing the psychological resilience of college students.

Discussion

This study validated the superiority of the proposed method in evaluating aerobic exercise load intensity by comparing the stability and error of different monitoring methods. The stability of the monitoring curve (Fig. 6) and the comparative analysis of RMSE values (Fig. 7) jointly demonstrate the accuracy and reliability of this method. This technological innovation not only provides new perspectives and tools for sports science research but also provides strong support for load monitoring in actual sports training.

Meanwhile, this study also found that aerobic exercise has a significant positive impact on the psychological resilience of college students (Fig. 8). This result is consistent with the conclusion that exercise can promote the release of neurotransmitters, improve emotional states, and thus enhance psychological resilience. This study further confirms this viewpoint through empirical data and emphasizes the importance of regular aerobic exercise in mental health education for college students.

In addition, the methodological contribution of this study lies in the adoption of multi-sensor signal fusion technology and Bayesian algorithms. The application of these advanced technologies not only improves the accuracy and real-time performance of monitoring but also provides richer information for subsequent data analysis. This interdisciplinary research method provides useful references and inspirations for future related research.

In summary, this study validated the effectiveness of the proposed method in evaluating aerobic exercise load intensity and promoting psychological resilience through rigorous experimental design and scientific analysis methods. The research results not only enrich the relevant theories of sports science and psychology but also provide strong support for practical applications. Future research can further explore the effects of different types, intensities, and durations of exercise on psychological resilience, as well as the mechanisms underlying individual differences.

Conclusion

This study delves into the key role of aerobic exercise in promoting psychological resilience among college students. Through a systematic aerobic exercise program lasting over 16 weeks, significant improvements were observed in students' resilience, stress management, and overall mental health. This discovery not only enriches the existing literature on the relationship between exercise and mental health but also provides new perspectives and empirical support for how to effectively integrate exercise elements into higher education programs. This study clearly demonstrates the positive impact of aerobic exercise on psychological resilience, which is consistent with previous research on the argument that exercise promotes mental health. However, this study further refined this relationship through specific experimental design and quantitative data, emphasizing the important role of aerobic exercise in a specific group of college students, and providing concrete and feasible suggestions for educators and policymakers. The combination of multi-sensor and Bayesian algorithms used in this study provides technical support for accurate measurement of exercise load. The innovation of this methodology not only improves the accuracy of monitoring but also establishes a solid physiological foundation for subsequent psychological resilience assessment. This study emphasizes the correlation between evaluating exercise load intensity and cultivating self-efficacy, pointing out that scientific exercise plans can enhance students' confidence and ability to cope with challenges. This discovery is consistent with Bandura's self-efficacy theory, providing a new theoretical basis for how to improve students' psychological quality through exercise intervention in educational practice.

It is recommended that universities include aerobic exercise as a compulsory or elective course in their curriculum when developing teaching plans, ensuring that every student receives sufficient exercise time to promote their psychological resilience development. Policymakers should encourage and support schools to build comprehensive sports facilities, provide diverse sports programs and professional guidance services, and create a good sports environment for students. Considering the differences in physical fitness and interests among different students, it is recommended to develop personalized exercise plans to meet their needs and improve their participation and effectiveness in sports.

Although this study has achieved significant results, there are still some limitations, such as a relatively small sample size, limited study duration, and some data relying on self-report. These limitations may have a certain impact on the universality and accuracy of the results. In order to comprehensively evaluate the impact of aerobic exercise on psychological resilience, future research should expand the sample size, extend the study time, and use multiple data sources for cross-validation. In addition, the findings of this study emphasize the importance of continuous monitoring and evaluation. Future research can further explore the long-term effects of exercise interventions and the differences in the impact of different types, intensities, and frequencies of exercise on psychological resilience. At the same time, by combining wearable technology and biomarker monitoring, the physiological and psychological mechanisms between exercise and psychological resilience can be more deeply revealed, providing a scientific basis for developing more effective intervention strategies.

Biography

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