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The effects of Baduanjin exercise on the psychological condition and heart rate variability of sports-disadvantaged college students: A randomised trial

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Abstract

Objective To investigate the effects of a 16-week Baduanjin exercise programme on the psychological status and heart rate variability (HRV) of college students in a sports-disadvantaged group, offering a theoretical basis for the potential of Baduanjin exercise to improve mental health.

Trial Design This prospective study enrolled 93 college students from Wuyi University, exempt from the National Standards for Students' Physical Health due to illness or disability. The participants were divided into a control group ($n=47$) and an experimental group ($n=46$). Over 16 weeks, the experimental group engaged in the Baduanjin exercise, whereas the control group did not participate in regular physical training.

Methods We assessed the Symptom Checklist-90-Revised (SCL-90-R, the primary outcome) scores and HRV (time domain and frequency domain indices, the secondary outcomes) of all participants both before and after the 16-week programme.

Results (1) Post-16 weeks of Baduanjin exercise, a statistically significant difference was observed in the SCL-90-R scores between the control and experimental groups ($P<0.01$, $P<0.05$). Notably, the scores for interpersonal sensitivity, depression, anxiety, psychoticism, and other factors (predominantly relating to sleep and diet) were significantly lower in the experimental group (t = 4.234, 2.616, 3.450, 2.226, 3.980, $P<0.01$, $P<0.05$). (2) Following the exercise regimen, the experimental group showed a substantial decrease in heart rate, low-frequency (LF) power, and the LF/high-frequency ratio (LF/HF ratio), and a significant increase in HF compared with the control group (t = 2.358, 4.528, − 2.595, $P<0.05$ $P<0.01$).

Conclusion Sixteen weeks of Baduanjin exercise may substantially enhance HRV, potentially aiding in balancing sympathetic–vagal nerve activity and thus contributing to the regulation of mental health.

Keywords Baduanjin, Sports-disadvantaged students, Mental health, Heart rate variability

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Introduction

The term 'sports-disadvantaged group' is specifically used by colleges and universities to refer to students with chronic diseases, physical disabilities or dysfunctions, or those recovering from illness or surgery. These students are unable to participate in regular physical exercise and high-intensity sports like their peers, making them a vulnerable and disadvantaged demographic within college and university physical education [1]. Research has shown a notable increase in psychological disorders among these physically vulnerable college students [2]. Additionally, physical diseases and disabilities often cause increased psychological strain for students in the sports-disadvantaged group, leading to feelings of inferiority, anxiety, depression, and interpersonal communication disorders, which directly affect their mental health [3]. Thus, finding effective methods to enhance the mental health and physical and mental development of these students has become an urgent concern.

Baduanjin, a traditional Chinese physical and mental exercise programme, consists of eight movements, each performed on both the left and right sides of the body. The programme incorporates deep rhythmic breathing, meditation, and musculoskeletal stretching and relaxation, integrating physical and mental practices that can alleviate stress, anxiety, and depression [4]. Chen Huawei et al. [5] demonstrated that 16 weeks of Baduanjin exercise could improve the physical shape and function of sick and disabled college students, positively impacting their mental health. However, the exact mechanisms by which Baduanjin achieves these benefits remain unclear. Canadian research indicated that Baduanjin training effectively improved the physical condition of patients with Parkinson's disease and reduced their incidence of falls, suggesting its beneficial impact on motor function recovery [6]. Additionally, the Qigong Baduanjin exercise has shown advantages over usual activities in improving female college students' body shape (weight and body mass index), cardiovascular and respiratory lung function, flexibility, balance ability, muscle endurance, and mental health [5].

Heart rate variability (HRV) refers to the degree of variation between normal sinus beats and is an important indicator of autonomic nerve function, including the balance between the sympathetic and parasympathetic nervous systems. Research has shown that changes in HRV are closely related to mood and can be utilised to assess an individual's emotional state [7]. Studies have reported that enhanced parasympathetic activity in HRV positively influences emotional regulation and mental health [8]. Through examining HRV characteristics in anxious states, it was concluded that HRV serves as an effective measure of mental health in college students [9]. Previous research indicates that psychiatric disorders, such as depression and anxiety, can lead to increased systemic sympathetic and decreased parasympathetic activity. This imbalance may result in neuro-cardiac impairment and cerebrovascular disease due to alterations in the autonomic nervous system [10]. Furthermore, increased sympathetic activation and/or parasympathetic inhibition under psychosocial stress conditions have been linked to panic attacks and depression [11]. However, it remains unclear whether Baduanjin exercise can enhance the mental health of college students in sports-disadvantaged groups by modulating sympathetic–vagal balance. Therefore, this study aims to explore the influence of Baduanjin exercise on psychological status and HRV, providing a theoretical foundation for improving the mental health of college students in sports-disadvantaged groups.

Participants and methods

Participants

This randomised, prospective study enrolled 93 college students from Wuyi University. These students were exempted from the National Standards for Students' Physical Health due to illness or disability during the 2019–2020 academic year between March and June 2022. The group included 49 men and 44 women.

The sample size, calculated based on a normal distribution, was performed with a power of 0.80 and a 2-tailed alpha level set to 0.05. The minimum number of participants required was estimated to be 40 per group [12].

Subsequently, adhering to the principle of gender equality, the 93 college students were randomly divided into two groups using computer-generated sequential and random numbering. All students were compliant and cooperated actively in completing the experiment. Before the exercise intervention, all students filled out an informed consent form, and the study was approved by the university's ethics committee (Ethics No. 20220048).

Participants who smoked or were taking medications known to affect heart rate or mood were excluded from the study.

Research methods

Study design

The experimental group underwent the Baduanjin intervention for 16 weeks, three times a week (Monday, Wednesday, and Friday), for 60 min each session. This included 5 min of preparatory activities and 5 min of relaxation activities. The exercise sessions were conducted in the playground or gymnasium. The instructor responsible for Baduanjin had over 1 year of teaching experience and had practised Baduanjin for more than 2 years. Before commencing the formal exercise sessions, professional teachers trained the sports-disadvantaged college students in the experimental group in Baduanjin technical movements until all members could practise

them skilfully. Background music with commands was played during practice, and the students alternated between practice sets according to these commands. The control group did not undergo any interventions and maintained their original living habits.

Before and after the 16-week intervention, participants were invited to complete an HRV test under the guidance of a professional physical fitness tester. The HRV of each student was tested three times before and after the intervention, and the average value was recorded. The self-assessment scale of psychological symptoms in the Symptom Checklist-90-Revised (SCL-90-R) was used to evaluate the mental health level of the two groups before and after the intervention.

The self-assessment scale of psychological symptoms – symptom Checklist-90

The SCL-90, developed by American scholar L. R. Derogatis in 1975, possesses high validity and reliability. It is extensively employed in outpatient screening for mental disorders and diseases [13]. The scale comprises 90 items across nine subscales, including 10 factors: somatisation, obsessive-compulsive, interpersonal sensitivity, depression, anxiety, hostility, terror, paranoia, psychosis, sleep, and diet. The scale employs a 5-grade rating system: 1 (none), 2 (mild), 3 (moderate), 4, and 5 (severe), with Cronbach's alpha coefficient ranging from 0.78 to 0.96 [14].In our study, the Cronbach's alpha coefficient for the SCL-90 was 0.91, indicating high internal consistency.

Before the test, the participants were briefed about the purpose and significance of the SCL-90. The form was filled in following unified guidance to ensure the authenticity and reliability of the results. Anonymous numbering was used, and participants were given 10–15 min to complete the questionnaire. A higher total score indicates more severe mental health issues.

Measurement of heart rate variability

Before and after the experiment, the participants were equipped with a Polar Team Pro heart rate (HR) monitor (10 Hz, Polar Electro, Kempele, Finland). Basic information, such as height, weight, and date of birth, was entered into the computer. The participants then rested in a quiet laboratory, lying on their backs with their eyes closed for 5 min (they were reminded not to sleep). Subsequently, their HR was recorded for 10 min.

To control for the influence of breathing on HRV, participants were instructed to maintain a steady breathing rate of 12–15 breaths per minute during the recording period. A visual pacing stimulus was provided to guide breathing rhythm.

Following this, the HRV time domain (HR in beats per minute) and frequency domain indices were calculated using Kubios HRV software. The frequency domain indices included low-frequency (LF) power (0.04–0.15 Hz), indicating sympathetic nerve regulation of HR; high-frequency (HF) power (0.15–0.40 Hz), indicating parasympathetic nerve regulation of HR; and the low-frequency/high-frequency ratio (LF/HF ratio), indicating the balance between sympathetic and vagus nerve activities.

Statistical processing

All experimental data are presented as the mean ± standard deviation. Statistical analysis was conducted using SPSS 19.0 software. A paired t-test was utilised to compare differences between the control and experimental groups before and after the Baduanjin intervention. An independent sample t-test was employed to analyse differences in psychological indices and HRV parameters between the control and experimental groups both before and after the intervention. Repeated measures ANOVA was used to assess group x time interactions, demonstrating the longitudinal effects of the intervention compared to control. A P-value of <0.05 was considered to indicate statistical significance.

Results

Baseline comparisons

At baseline, there were no significant differences between the experimental and control groups in terms of SCL-90 scores or HRV measures (all $P>0.05$), indicating that both groups started from comparable levels before the intervention.

Demographic information

The experimental group comprised 24 male students with an average age of 19.21 ± 0.17 years, average height of 1.73 ± 0.03 m, and average weight of 70.31 ± 2.97 kg, as well as 22 female students with an average age of 19.76 ± 0.26 years, average height of 1.59 ± 0.03 m, and average weight of 60.13 ± 2.63 kg. The control group included 25 male students with an average age of 19.18 ± 0.32 years, average height of 1.72 ± 0.03 m, and average weight of 69.46 ± 3.49 kg, alongside 22 female students with an average age of 18.96 ± 0.11 years, average height of 1.60 ± 0.02 m, and average weight of 60.82 ± 1.53 kg. There were no significant differences in sex composition ratio, age, height, and weight between the two groups ($P>0.05$) (Table 1).

The effect of Baduanjin exercise on the mental health of sports-disadvantaged college students

The results revealed that after 16 weeks of Baduanjin exercise, the SCL-90 scores of the experimental group differed significantly from those of the control group ($P<0.05$). Before the Baduanjin intervention, there were no significant differences in the SCL-90 scores between

Table 1 Demographic information

Items	control group	experimental group	*P* value
Gender			0.876
male	25	24	0.846
female	22	22	0.976
Age			0.558
male	19.18 ± 0.32	19.21 ± 0.17	0.754
female	18.96 ± 0.11	19.76 ± 0.26	0.547
Height			0.754
male	1.72 ± 0.03	1.73 ± 0.03	0.645
female	1.60 ± 0.02	1.59 ± 0.03	0.768
Weight			0.331
male	69.46 ± 3.49	70.31 ± 2.97	0.543
female	60.82 ± 1.53	60.13 ± 2.63	0.241
Physical disabilities			0.389
male	1	0	0.456
female	2	1	0.246
Alcohol and smoking habits			0.289
male	2	1	0.563
female	4	3	0.289
Medication usage			0.429
male	3	2	0.478
female	5	3	0.289

Table 2 Mental health results of college students in physically disadvantaged groups before and after the Baduan Jin intervention()

	group	*n*	Before the exercise (pre)	After-exercise (post)	t	*P* (pre vs. post)
somatization	Control group	47	1.43 ± 0.93	1.45 ± 0.88	-0.275	0.785
	Experimental group	46	1.41 ± 0.98	1.24 ± 0.87$^{\#}$	2.429	0.019
Forced symptoms	Control group	47	2.02 ± 1.11	2.04 ± 1.06	-0.275	0.785
	Experimental group	46	2.04 ± 1.03	1.75 ± 0.98$^{\#\#}$	3.472	0.001
interpersonal sensitivity	Control group	47	2.29 ± 0.93	2.32 ± 1.02	-0.374	0.710
	Experimental group	46	2.31 ± 1.01	1.52 ± 0.89$^{\#\#**}$	10.893	0.000
depression	Control group	47	2.23 ± 0.87	2.25 ± 1.18	-0.158	0.875
	Experimental group	46	2.22 ± 1.05	1.72 ± 0.75$^{\#\#*}$	4.693	0.000
anxiety	Control group	47	2.02 ± 0.85	2.04 ± 0.91	-0.151	0.881
	Experimental group	46	1.98 ± 0.77	1.46 ± 0.72$^{\#\#}$	4.899	0.000
hostile	Control group	47	1.98 ± 0.97	1.94 ± 1.03	0.321	0.749
	Experimental group	46	1.91 ± 0.91	1.59 ± 0.78$^{\#}$	2.185	0.034
terrifying	Control group	47	1.60 ± 0.97	1.64 ± 1.11	-0.306	0.761
	Experimental group	46	1.61 ± 1.06	1.33 ± 0.79	2.227	0.031
bigoted	Control group	47	1.79 ± 0.69	1.81 ± 0.90	-0.256	0.799
	Experimental group	46	1.80 ± 1.04	1.67 ± 1.12	0.829	0.411
psychosis	Control group	47	2.11 ± 0.79	2.15 ± 0.98	-0.269	0.789
	Experimental group	46	2.07 ± 0.85	1.69 ± 0.98$^{\#}$	2.514	0.016
other factors	Control group	47	2.36 ± 0.97	2.40 ± 1.09	-0.405	0.688
	Experimental group	46	2.39 ± 0.98	1.61 ± 0.80$^{\#\#}$	6.750	0.000

$^{\#\#}P<0.01$, $^{\#}P<0.05$, for the pre-and post-experiment comparison; $^{**}P<0.01$, $^{*}P<0.05$, and the control group was compared with the experimental group

the two groups (all $P>0.05$). Following the intervention, the scores for somatization, forced symptoms, interpersonal sensitivity, depression, anxiety, hostile, psychosis, and other factors (mainly relating to sleep and diet) were significantly lower than before the Baduanjin intervention (all $P<0.05$). In addition, the scores for interpersonal relation and depressed factors were significantly lower compared with the control group (all $P<0.05$) (Table 2).

Repeated measures ANOVA revealed significant group x time interactions for interpersonal sensitivity ($F=15.32$, $P<0.001$), depression ($F=10.47$, $P<0.01$), anxiety ($F=12.89$, $P<0.001$), psychosis ($F=8.76$, $P<0.01$), and other factors ($F=14.23$, $P<0.001$), indicating that the

Baduanjin intervention had a significant effect on these mental health indicators over time compared to the control group.

The effect of Baduanjin exercise on the heart rate variability of sports-disadvantage college students

The results indicated that after 16 weeks of Baduanjin exercise, there were significant decreases in the time domain and frequency domain of HRV, HR, LF, and LF/HF ratio, and a significant increase in HF in the experimental group ($P<0.01$). Conversely, there were no significant differences in the time domain and frequency domain of HRV, HR, LF, and LF/HF ratio in the control group (all $P>0.05$). Before the Baduanjin intervention, there were no significant differences in the HRV time domain and frequency domain indices between the two groups of sports-disadvantaged college students ($P>0.05$). After the Baduanjin intervention, the LF and the LF/HF ratio of the experimental group were significantly lower than those in the control group (5.494 and 7.938, respectively; all $P<0.05$), and the HF was significantly higher compared with in the control group (t = -6.620, $P<0.01$). There was no statistical difference in HR between the two groups (t=13.384, $P<0.01$) (Table 3).

Repeated measures ANOVA showed significant group x time interactions for LF (F=18.76, $P<0.001$), HF (F=20.45, $P<0.001$), and LF/HF ratio (F=22.13, $P<0.001$), further confirming the longitudinal effects of the Baduanjin intervention on HRV parameters.

Discussion

Previous studies [15] have shown that 8 weeks of 24-step simplified Taijiquan exercise can promote the development of college students' mental toughness and school adaptation, particularly in terms of emotional control, goal focus, interpersonal relationships, and family support in college students' mental toughness. Additionally, the exercise aids in learning adaptation, peer relationship adaptation, physical and mental adaptation, and school-life adaptation. The Taijiquan exercise also sharpens college students' minds, stimulates their potential, and maintains a positive and optimistic emotional attitude to deal with setbacks in school and life. Moreover, it better enhances the ability of campus adaptation. The styles of Taijiquan and Baduanjin are markedly different, each possessing unique characteristics. Both styles have demonstrated effectiveness in intervening in chronic diseases, especially in the case of type 2 diabetes mellitus [16].

The effect of Baduanjin intervention on the mental health of sports-disadvantaged college students

Baduanjin is a traditional physical and mental exercise method characterised by slow, coordinated, and coherent movements. It involves deep rhythmic breathing combined with meditation, aiming to stretch and relax the musculoskeletal system of the whole body and calm the mind, thereby positively impacting mental health [14]. A meta-analysis has shown that Baduanjin exercise, a component of Health Qigong, considerably improves the mental health of various participants, including college students, middle-aged individuals, and older adults. It reduces negative emotions such as anxiety, depression, fear, hostility, obsessive-compulsiveness, and stress, and enhances somatisation, self-esteem, self-image, and interpersonal sensitivity [17].

The present study found that 16 weeks of Baduanjin exercise notably improved the sports-disadvantaged students' body shape, physiological functions (including a reduction in blood pressure and HR), and mental health [18, 19]. There was also a notable improvement in the SCL-90 scores of the experimental group after the 16-week Baduanjin exercise intervention. Compared with the control group, factors such as interpersonal sensitivity, depression, anxiety, psychotic symptoms, and aspects primarily involving sleep and diet in the experimental group showed substantial improvement. This demonstrates that Baduanjin exercise can enhance students' communication abilities and emotional states, fostering self-regulation and promoting psychological optimism. Thus, this study concludes that Baduanjin exercise can have a positive effect on the mental health of college

Table 3 HRV results of college students in physically disadvantaged groups before and after the Ba Duan Jin intervention ()

HRV	group	Before the experiment pre	After the experiment post	t price pre vs. post	*P* price pre vs. post
HR(beat/min)	Control group	73.98 ± 3.95	73.68 ± 4.14	1.924	0.061
	Experimental group	74.06 ± 4.27	72.43 ± 4.15$^{\#\#}$	13.384	0.000
HF(ms^2)	Control group	560.45 ± 78.79	550.19 ± 80.21	1.692	0.097
	Experimental group	567.11 ± 84.08	596.15 ± 90.39$^{\#\#*}$	-6.620	0.000
LF(ms^2)	Control group	742.40 ± 118.52	750.81 ± 111.86	-1.497	0.141
	Experimental group	733.15 ± 92.37	699.33 ± 98.12$^{\#\#*}$	5.494	0.000
LF/HF	Control group	1.34 ± 0.21	1.37 ± 0.19	-1.964	0.056
	Experimental group	1.31 ± 0.22	1.19 ± 0.20$^{\#\#**}$	7.938	0.000

$^{\#\#}P<0.01$, pre-and post-experiment comparison, * * $P<0.01$, * $P<0.05$, and the control group was compared with the experimental group

students from sports-disadvantaged backgrounds, a finding consistent with Zhang Cheng's research [20].

Furthermore, Yang Lin [21] and other studies have categorised Health Qigong Baduanjin as a low-to-medium intensity aerobic exercise that benefits the mental health and mood of college students. Liang Qianrong [22] observed that the improvement in physical and mental health indicators among Baduanjin exercise participants positively correlated with the frequency and duration of exercise. Consequently, any subsequent study should extend the period of Baduanjin practice to ascertain the duration of its benefits on the mental health of college students from sports-disadvantaged groups.

The effect of Baduanjin intervention on heart rate variability among sports-disadvantaged college students

Heart rate variability is an accurate, non-invasive index for evaluating the autonomic nervous system. It objectively measures emotional health and adaptability to stress, serving as an important indicator of mental health (including stress, depression, and anxiety), general cardiovascular health, and as a major predictor of mortality [23]. Heart rate variability plays a crucial role in emotional regulation and mental health and is considered an indicator of a person's self-regulation, interpersonal communication abilities, and psychological flexibility [24, 25]. Paniccia et al. [26] demonstrated that the HRV decreased in both healthy individuals and untreated patients with major depression, suggesting that severe depression could lead to a decrease in HRV. This evidence indicates that individuals without a history of cardiovascular disease may experience cardiovascular function impairment due to other causes.

Long-term engagement in physical exercise has been shown to increase HRV, balance autonomic nervous system activity, and promote relaxation and stress relief. It increases happiness and enhances emotional regulation and mental health by augmenting parasympathetic nerve regulation and/or reducing sympathetic nerve activity [27]. Research by Telles et al. revealed a strong synchronistic relationship between respiratory rhythm and the normalised high-frequency power (nHF) component of HRV [28]. A meta-analysis suggests that practitioners of Tai Chi and yoga can achieve a meditative state by adjusting their breathing patterns, thus enhancing vagus nerve activity, which may explain the increase in nHF [29].

Health Qigong Baduanjin is an exercise demanding precise breathing control. It involves deep and slow abdominal breathing, characterised by even, gentle, deep, and prolonged breaths, and includes a breath-holding phase of 1–2 s at the end of each movement. Scholars have found that 8–16 weeks of Health Qigong (including yoga), practised 2–4 times per week for 90 min, can considerably alter the HRV of college students, middle-aged people, and older adults. Increasing the weekly training duration correlates with a more substantial change in the normalised low-frequency power/nHF (nLF/nHF) ratio [30].

The present study showed that after 16 weeks of Baduanjin exercise, there were notable decreases in the time domain and frequency domain of HRV, HR, LF, and LF/HF ratio in the experimental group, whereas the HF increased considerably compared with the control group. The long-term practice of Baduanjin could, therefore, reduce sympathetic nerve activity and increase vagus nerve impulses, thus positively impacting autonomic nervous system balance. Increased parasympathetic nerve activity releases acetylcholine, which can slow the HR down upon binding with its receptors and counteract sympathetic nerve excitation caused by psychological stress. Consequently, Baduanjin exercise could be used to improve the mental health of students from sports-disadvantaged groups, as it may balance sympathetic and vagus nerve impulses and reduce HR, thus enhancing students' mood and mental health. Moreover, the long-term practice of Baduanjin exercise could provide a viable option for functional exercise and mental health improvement for college students from sports-disadvantaged groups.

Limitations

Although the authors found that training using Baduanjin was beneficial for sports-disadvantaged college students, this study has several limitations. First, the participants were drawn from different colleges within the same district, which, even with strict inclusion and exclusion criteria, might have led to sampling bias and limited the generalisability of the conclusions. Second, in addition to Baduanjin exercise training in the experimental group, some participants received conventional medications or rehabilitation treatments that might have influenced the results but were not controlled in this study. Third, the relatively small sample size and the absence of statistical calculations for further subgroup analyses based on sex or other factors might have constrained the study's depth. The effect of the Baduanjin exercise on the motor function of sports-disadvantaged college students needs verification through larger sample-sized randomised controlled trials.

Conclusion

A 16-week programme of Baduanjin exercise appears to considerably harmonise sympathetic–vagal nerve activity, thereby improving the mood of students from sports-disadvantaged groups and regulating their mental health. This study furnishes empirical data supporting the broader promotion of the Baduanjin exercise on university campuses. Such an initiative would enable a

greater number of sports-disadvantaged college students to engage in Baduanjin exercise, potentially enhancing both their physical and mental well-being.

The effect of the Baduanjin exercise on the motor function of sports-disadvantaged college students needs verification through larger sample-sized randomised controlled trials with longer intervention periods. Future research should also explore the potential mechanisms underlying the observed benefits and investigate whether these effects are maintained over time after the cessation of the intervention.

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Author contributions
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Data availability
All data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of Wuyi University (No.20220048), and informed consent was obtained from all participants.

Consent for publication
N/A.

Competing interests
The authors declare no competing interests.

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