The impact of Baduanjin as a form of exercise snack on the physical and mental health of sedentary college students

El impacto del Baduanjin como snack deportivo en la salud física y mental de universitarios sedentarios

Authors

Xiaobin Wang [1]
Witid Mitranun[1]

[1] Srinakharinwirot University, Ongkharak, Nakhon Nayok, Thailand

Corresponding author:
Witid Mitranun
mitranunwitid@hotmail.com

Received: 29-04-26
Accepted: 30-05-26

How to cite in APA

Wang, X., & Mitranun, W. (2026). The impact of Baduanjin as a form of exercise snack on the physical and mental health of sedentary college students. *Retos, 82,* 979-992. https://doi.org/10.47197/retos.v82.119586

Abstract

Background: Exercise snacks are a time-efficient strategy to mitigate the adverse effects of sedentary behavior. However, evidence regarding the use of Baduanjin as exercise snacks remains limited.
Objective: This study aimed to evaluate the long-term effects of a Baduanjin-based exercise snacks intervention on body composition, physical fitness, and mental health in college students, and to examine differences across body mass index (BMI) subgroups of normal-weight and overweight.
Methods: Sixty sedentary college students were stratified and randomly assigned to either an experimental or control group: experimental-normal BMI (EG-NB, n = 15), experimental-overweight/obese (EG-OB, n = 15), control-normal BMI (SCG-NB, n = 15), and control-overweight/obese (SCG-OB, n = 15). The experimental groups participated in a 12-week Baduanjin exercise snack intervention consisting of three daily sessions (8 min/session), five days per week, whereas the control groups maintained their usual lifestyle and physical activity levels. A mixed-design ANOVA examined group × time interactions.
Results: After the 12-week intervention, significant time × group interactions were observed for body weight, BMI, muscle mass, vertical jump performance, and self-esteem (all $p < 0.05$). The EG-OB group showed significant reductions in body weight and BMI compared with baseline ($p < 0.05$). Vertical jump performance significantly declined in both control groups, whereas no significant reductions were observed in the experimental groups. In addition, Rosenberg Self-Esteem Scale scores significantly increased in both experimental groups (both $p < 0.05$).
Conclusion: Baduanjin-based exercise snacks may improve body weight, BMI, and self-esteem while maintaining lower-body explosive performance, particularly in overweight individuals.

Keywords

Baduanjin; body composition; exercise snacks; physical fitness; mental health; college students.

Resumen

Antecedentes: Los *exercise snacks* son una estrategia eficiente en términos de tiempo para reducir los efectos adversos del comportamiento sedentario. Sin embargo, la evidencia sobre el uso del Baduanjin como *exercise snacks* sigue siendo limitada.
Objetivo: Este estudio tuvo como objetivo evaluar los efectos a largo plazo de una intervención basada en *exercise snacks* con Baduanjin sobre la composición corporal, la aptitud física y la salud mental en estudiantes universitarios, así como examinar las diferencias entre subgrupos según el índice de masa corporal (IMC), clasificados como normopeso y sobrepeso.
Métodos: Sesenta estudiantes universitarios sedentarios fueron estratificados y asignados aleatoriamente a un grupo experimental o control: experimental-normopeso (EG-NB, n = 15), experimental-sobrepeso/obesidad (EG-OB, n = 15), control-normopeso (SCG-NB, n = 15) y control-sobrepeso/obesidad (SCG-OB, n = 15). Los grupos experimentales participaron en una intervención de *exercise snacks* con Baduanjin durante 12 semanas, que consistió en tres sesiones diarias (8 min/sesión), cinco días por semana, mientras que los grupos control mantuvieron su estilo de vida habitual y niveles de actividad física. Se realizó un ANOVA mixto para examinar las interacciones grupo × tiempo.
Resultados: Después de la intervención de 12 semanas, se observaron interacciones significativas grupo × tiempo para el peso corporal, IMC, masa muscular, rendimiento en salto vertical y autoestima (todos $p < 0,05$). El grupo EG-OB mostró reducciones significativas en el peso corporal y el IMC en comparación con los valores iniciales ($p < 0,05$). El rendimiento en salto vertical disminuyó significativamente en ambos grupos control, mientras que no se observaron reducciones significativas en los grupos experimentales. Además, las puntuaciones de la Escala de Autoestima de Rosenberg aumentaron significativamente en ambos grupos experimentales (ambos $p < 0,05$).
Conclusión: Los *exercise snacks* basados en Baduanjin pueden mejorar el peso corporal, el IMC y la autoestima, al tiempo que ayudan a mantener el rendimiento explosivo de la fuerza del tren inferior, especialmente en individuos con sobrepeso.

Palabras clave

Baduanjin; composición corporal; píldoras de ejercicio físico; aptitud física; salud mental; estudiantes universitarios.

Introduction

Physical inactivity and excessive sedentary behavior have emerged as critical public health concerns among university students worldwide. Sedentary behavior refers to waking activities performed in a sitting or reclining posture with an energy expenditure of ≤1.5 METs (Owen et al., 2010). With the rapid proliferation of digital technologies, university students are increasingly exposed to prolonged screen time, resulting in daily sedentary durations frequently exceeding 6–8 hours (Barkley & Lepp, 2016). Accumulating epidemiological evidence indicates that sedentary behavior is independently associated with increased risks of all-cause mortality, cardiovascular disease, and metabolic disorders, even after accounting for moderate-to-vigorous physical activity (Rezende et al., 2014).

From a physiological perspective, prolonged sedentary exposure disrupts metabolic homeostasis through reduced lipoprotein lipase activity, impaired glucose uptake, and endothelial dysfunction (Hamilton et al., 2007; Owen et al., 2010). These alterations contribute to adverse cardiometabolic profiles, including insulin resistance and central adiposity (Healy et al., 2008). Psychologically, insufficient physical activity has been consistently linked to elevated risks of depression, impaired sleep quality, and dysregulated neurobiological processes such as reduced brain-derived neurotrophic factor expression (Huang et al., 2014; Kredlow et al., 2015; Schuch et al., 2018). Collectively, these findings highlight the urgent need for feasible and sustainable interventions targeting both physical and mental health outcomes in this population.

Traditional exercise interventions, including moderate-intensity continuous training and high-intensity interval training, are effective but often limited by low adherence due to time constraints and physical demands (Keating et al., 2017). In this context, exercise snacks—defined as brief, intermittent bouts of physical activity distributed throughout the day—have emerged as a time-efficient strategy to interrupt sedentary behavior and induce favorable metabolic adaptations (Gibala & Little, 2020; Islam et al., 2022). Evidence suggests that such activity fragmentation can improve postprandial glycemic control and cardiovascular function, with effects comparable to conventional exercise paradigms (Dunstan et al., 2012; Jenkins et al., 2019). However, most existing protocols rely on relatively vigorous activities, limiting their applicability among sedentary and overweight individuals.

Baduanjin, a traditional Chinese mind–body exercise characterized by low intensity, rhythmic movement, and breath regulation, may represent a promising alternative. Previous studies have demonstrated its efficacy in improving cardiometabolic health, body composition, and psychological well-being through mechanisms involving autonomic regulation and metabolic optimization (Gao et al., 2024; Wen et al., 2024; Zou et al., 2018). Despite these benefits, the integration of Baduanjin within the exercise snack framework remains largely unexplored, particularly with respect to differential responses across weight status and the synergistic effects on physical and mental health.

College students represent an important target population for physical activity interventions due to the high prevalence of sedentary behavior and growing mental health concerns. A recent systematic review and meta-analysis demonstrated that physical activity consistently reduces symptoms of depression, anxiety, and stress in college students despite variations in exercise protocols (Ruiz et al., 2024). Therefore, practical and time-efficient strategies to increase daily physical activity are needed. In this context, incorporating Baduanjin into an exercise snack format may provide a feasible approach to reduce sedentary behavior while promoting both physical and mental health among Chinese college students.

Therefore, this study aimed to develop a Baduanjin-based exercise snack intervention model and systematically evaluate its effects on physical fitness, body composition, and mental health among university students. Using a 12-week randomized controlled design, this study further examined potential heterogeneity in intervention responses across different weight categories, with the goal of providing an accessible and sustainable strategy for health promotion in sedentary populations.

Method

Research Design

This study adopted a randomized controlled experimental design. The research subjects were college students from a university in China. A total of 60 students aged between 18 and 20 years old were included, among whom 30 were male and 30 were female. The participants were stratified based on body mass index (BMI) and were divided into the normal BMI group (18.5 - 24.9 kilograms per square meter) and the overweight to obese group (≥ 25.0 kilograms per square meter). In each BMI group, the subjects were randomly assigned to the normal BMI group (n = 30) and the overweight group (n = 30) according to the computer-generated random number table. The randomization and blinding procedures during the process ensured the balance of gender ratios in each group.

The study lasted for 12 weeks and aimed to explore the long-term intervention effect of Baduanjin as an exercise snack. The experimental group adopted a decentralized intervention mode, conducting three sessions of Baduanjin practice each day (at 12:00, 18:00, and 22:00), each session lasting approximately 8 minutes; the control group maintained their original lifestyle and did not receive additional exercise intervention. Before and after the intervention, measurements were taken of the participants' body composition, physical fitness, and indicators related to mental health. Repeated measures analysis of variance was used for statistical analysis to compare the differences within and between groups over time, with a significance level set at $p < 0.05$.

Participants

This study recruited volunteers through an offline recruitment method at a university in China. Initially, 70 college students aged between 18 and 20 (half male and half female) were included. Based on their body mass index (BMI), they were divided into the normal BMI group (18.5 - 24.9 kilograms per square meter) and the overweight to obese group (≥ 25.0 kilograms per square meter), and were randomly assigned to the experimental group and the control group within each BMI category according to gender. The sample size was determined based on previous relevant studies and combined with the expected dropout rate. In the end, a total of 60 participants completed the study and were included in the analysis. All participants were full-time college students (covering liberal arts, science, and engineering), and the baseline survey showed that their average daily sedentary time was ≥ 6 hours.

This study adopted a stratified random grouping design. Based on the body mass index (BMI), the research subjects were divided into the normal BMI group (18.5 - 24.9 kilograms per square meter) and the overweight to obese group (≥ 25.0 kilograms per square meter). Then, within each BMI stratum, these groups were randomly divided into the experimental group and the control group, with 30 subjects in each group.

Experimental group: normal BMI group *(*EG-NB*)* (n = 15) and overweight to obese group *(*EG-OB*)* (n = 15), participated in the 12-week Baduanjin exercise snack intervention.

Control group: normal BMI group *(*SCG-NB*)* (n = 15) and overweight to obese group *(*SCG-OB*)* (n = 15), without Baduanjin intervention, maintaining the original lifestyle and daily physical activity level.

To control confounding factors, the stratified randomization method was used during the grouping process to ensure a good balance in age, gender, and baseline physical activity levels among all groups.

Experimental Procedures

Before the formal intervention experiment, all the participants in the experimental group received Baduanjin adaptive training for 1 week (one session per day, 60 minutes each). The training was uniformly guided by professional coaches and combined with self-practice through instructional videos to ensure the correctness of the movements.

During the formal intervention phase, the experimental group received a 12-week intervention based on Baduanjin exercise snacks. They practiced three times a day (at 12:00, 18:00, and 22:00), each session lasting approximately 8 minutes, for 5 days a week.

Participants performed the standardized Baduanjin (Eight-Section Brocade) exercise consisting of a preparatory posture followed by eight sequential forms. The session began with standing in a relaxed posture with feet shoulder-width apart and natural breathing. The subsequent forms included: (1) raising both hands upward to stretch the trunk; (2) simulating drawing a bow in a horse-riding stance; (3) alternately raising and pressing the hands upward and downward to extend the body; (4) turning the head backward while extending the arms to stretch the neck and shoulders; (5) gently shaking the head and swinging the trunk with the waist as the axis; (6) bending forward to hold the feet while maintaining controlled breathing; (7) performing alternating forward punches in a horse-riding stance; and (8) repeatedly lifting and lowering the heels with light ground contact. All movements were performed slowly, smoothly, and continuously, with coordinated breathing, controlled posture, and a relaxed natural rhythm throughout the exercise session.

To adapt the traditional Baduanjin practice to the exercise snack intervention model, the total exercise duration was reduced from the conventional ~12 minutes to approximately 8 minutes by moderately increasing the movement tempo, while preserving the original movement sequence and breathing pattern. This modification maintained the integrity of the traditional practice while improving the practicality, feasibility, and participant adherence of the intervention. The intervention sessions were supervised by trained monitors. Participants recorded their exercise sessions through an online platform and uploaded practice videos for compliance monitoring and assessment. Participants in the control group were instructed to maintain their usual lifestyle habits throughout the study period and did not engage in any additional structured exercise interventions.

This research is divided into three stages: the baseline test, the intervention period, and the final test.

During the baseline testing phase (Week 0), all participants were evaluated for body composition, physical fitness, and mental health. Body composition was assessed using a body composition analyzer (TEZEWA-T6100, China), which measured body weight, body mass index (BMI), body fat percentage, waist-to-hip ratio, and muscle mass. Physical fitness was evaluated using standardized testing equipment (ORIENT, China). Vital capacity was measured using a spirometer (WT2500), grip strength using a digital handgrip dynamometer (WT2530), flexibility using the sit-and-reach test (WT2515), balance using the single-leg standing test with eyes closed (WT2535), and lower-limb explosive power using a vertical jump tester (WT2520). Two trials were performed for each physical fitness test, and the best score was recorded. All physical fitness assessments were conducted using standardized protocols with established validity and reliability. Mental health was assessed using the University Personality Inventory (UPI), the Pittsburgh Sleep Quality Index (PSQI), and the Rosenberg Self-Esteem Scale (RSES), all of which are standardized instruments with established validity and reliability.

During the intervention period (weeks 1-12), the experimental group carried out the Baduanjin as an exercise snack intervention according to the established plan, while the control group maintained their original lifestyle and did not receive any additional exercise intervention.

During the final testing phase (Week 12), the same measurement methods and indicators as the baseline were used to re-evaluate the subjects' body composition, physical fitness, and mental health levels.

Data Analysis

Statistical analyses were conducted using SPSS version 26.0. Normality and homogeneity of variance were assessed for all continuous variables. Data with a normal distribution were expressed as mean ± standard deviation (Mean ± SD).

A 12-week intervention study, a mixed-design repeated-measures ANOVA was conducted with group (intervention vs. control) and BMI category as between-subject factors, and time (pre-intervention and post-intervention) as the within-subject factor. The primary focus was on the group × time interaction effect to evaluate the intervention efficacy.

When significant main or interaction effects were detected, Bonferroni-adjusted post hoc comparisons were performed. All statistical tests were two-tailed, with the level of significance set at $p < 0.05$. Effect sizes were reported using partial eta squared (partial η^2).

Gender, age, and height were not included as covariates in the statistical models. This was based on the study design, in which sex distribution was balanced through stratified randomization, the age range of participants was relatively narrow (18–20 years), and height was indirectly accounted for in the BMI calculation; therefore, their potential confounding effects were considered minimal.

Missing data were handled using the intention-to-treat (ITT) principle, with multiple imputation applied when appropriate.

Ethical Considerations

This study has been approved by the Ethics Review Committee of Jiuquan Vocational University (Approval Number: JQZY-2025BS-0716). All participants signed written informed consent forms before the start of the study, and were fully informed of the study purpose, research procedures, and potential risks. During the research process, the relevant principles of the Declaration of Helsinki were strictly followed to ensure the voluntariness and safety of the participants' participation. All data were anonymized and used solely for scientific research analysis to protect the privacy and information security of the participants.

Results

Body Composition

Baseline body composition characteristics are shown in Table 1. No significant baseline differences were observed between groups, except for waist-to-hip ratio in the NB subgroup ($p = 0.035$).

Table 1. Baseline characteristics of participants' body composition data

	NB		P-value	OB		P-value
	SCB-NB	EG-NB		SCG-OB	EG-OB	
Body weight (kg)	64.71±9.90	64.50±8.21	0.458	87.39±16.85	88.21±18.52	0.591
Body Mass Index (kg/m2)	22.74±1.59	22.80±1.62	0.754	27.54±1.94	29.17±3.80	0.083
Body fat percentage (%)	25.39±5.02	26.34±7.18	0.765	29.96±6.36	32.49±6.58	0.123
Waist-hip Ratio	0.79±0.06	0.83±0.02	0.035	0.90±0.06	0.93±0.06	0.151
Muscle mass (kg)	42.96±11.16	44.96±8.64	0.432	55.42±14.39	55.44±14.90	0.785

The data are Mean±SD.

After the 12-week intervention, body fat percentage and waist-to-hip ratio showed significant group effects ($p < 0.05$), but no significant time or interaction effects. Muscle mass demonstrated a significant time × group interaction ($F = 4.024$, $p < 0.05$, $\eta^2 = 0.188$). For body weight, significant group ($F = 10.687$, $p < 0.001$, $\eta^2 = 0.381$) and time × group interaction effects were observed ($F = 11.843$, $p < 0.001$, $\eta^2 = 0.406$). Only the EG-OB group showed a significant reduction in body weight after training (−4.48 kg, $p < 0.05$), whereas no significant changes were found in the other groups (Table 2, Table 3, Figure 1). Similarly, BMI showed significant group ($F = 20.926$, $p < 0.001$, $\eta^2 = 0.547$) and interaction effects ($F = 11.727$, $p < 0.001$, $\eta^2 = 0.404$). BMI significantly decreased only in the EG-OB group (−1.17 kg/m^2, $p < 0.05$) (Table 4, Table 5, Figure 2)

Table 2. Comparison of body weight (kg) data before and after training: EG-NB, EG-OB, SCG-NB, SCG-OB

Groups	n	Baseline	12 weeks later	△ Changes
EG-NB	14	64.50±8.21	65.86±8.63	+ 1.36
EG-OB	14	88.21±18.52	84.73±18.47	-4.48
SCG-NB	14	64.71±9.90	66.08±11.12	+ 1.37
SCG-OB	14	87.39±16.85	86.78±17.22	-0.61

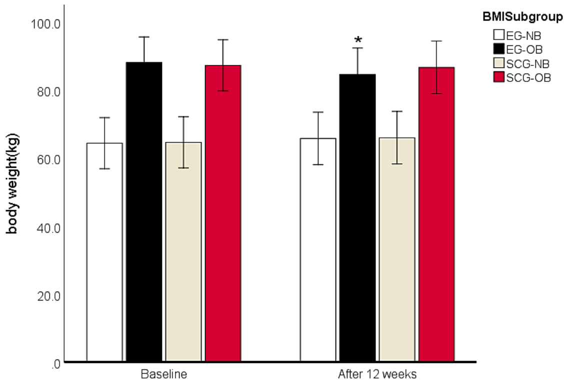
The data are Mean±SD. △ represents the difference from baseline after training.

Table 3. Results of Analysis of Variance for body weight

Effects	df	F	p	Eta^2
Time	1,52	0.997	0.323	0.019
Group	3,52	10.687	< 0.001***	0.381
Time×group	3,52	11.843	< 0.001***	0.406

Note: The time main effect was not significant (p>0.05), the group main effect was extremely significant (p<0.001), and the interaction effect was extremely significant (p<0.001).

Figure 1. Weight changes in different BMI subgroups before intervention and after 12 weeks



Note: *p < 0.05.EG-NB indicates normal BMI in the experimental group; EG-OB indicates overweight BMI in the experimental group; SCG-NB represents normal BMI in the control group; SCG-OB indicates overweight BMI in the control group.

Table 4. Comparison of BMI (kg/m2) data before and after training: EG-NB, EG-OB, SCG-NB, SCG-OB

Groups	n	Baseline	12 weeks later	△ Changes
EG-NB	14	22.80±1.62	23.30±1.60	+0.5
EG-OB	14	29.17±3.80	28.00±3.83	-1.17
SCG-NB	14	22.74±1.59	23.22±1.62	+0.48
SCG-OB	14	27.54±1.94	27.30±1.95	-0.24

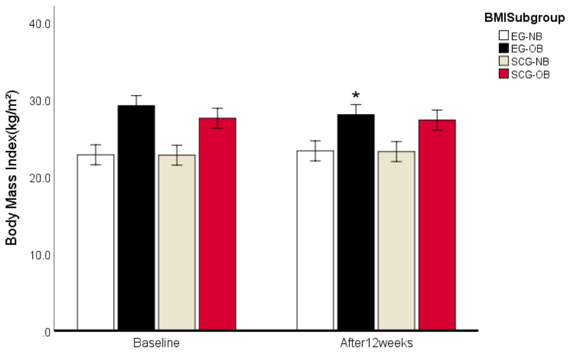
The data is Mean±SD. △ represents the difference from baseline after training.

Table 5. Results of Analysis of Variance for BMI

Effects	df	F	p	Eta^2
Time	1,52	0.896	0.348	0.017
Group	3,52	20.926	< 0.001***	0.547
Time×group	3,52	11.727	< 0.001***	0.404

Note: The time main effect was not significant (p>0.05), the group main effect was extremely significant (P<0.001), and the interaction effect was extremely significant (p<0.001).

Figure 2. BMI changes in different BMI subgroups before intervention and after 12 weeks



Note: *p < 0.05.EG-NB indicates normal BMI in the experimental group; EG-OB indicates overweight BMI in the experimental group; SCG-NB represents normal BMI in the control group; SCG-OB indicates overweight BMI in the control group.

Physical Fitness

Baseline physical fitness characteristics are presented in Table 6, with no significant differences between groups.

Table 6. Baseline characteristics of participants' physical fitness data

	NB		p-value	OB		p-value
	SCB-NB	EG-NB		SCG-OB	EG-OB	
Vital capacity (ml)	2903.79±738.33	3019.93±679.79	0.679	3649.21±936.01	3550.14±921.72	0.854
Grip strength (kg)	36.44±9.79	32.22±9.43	0.256	41.52±8.07	36.87±10.51	0.201
Seated body flexion (cm)	10.88±4.11	9.32±13.25	0.747	9.60±5.58	13.59±5.30	0.064
Single Leg Stance Test (second)	14.57±5.89	16.13±12.54	0.676	10.92±6.99	16.82±11.67	0.117
Vertical jump test (cm)	28.79±4.37	29.71±4.68	0.592	32.00±4.32	30.36±7.73	0.196

The data are Mean±SD.

No significant intervention effects were found for vital capacity, grip strength, or single-leg standing performance (all $p > 0.05$). Sit-and-reach performance demonstrated a significant interaction effect ($F = 3.510$, $p = 0.022$, $\eta^2 = 0.168$), although no within-group changes reached significance. Post-intervention, EG-OB showed significantly greater flexibility than SCG-OB ($p = 0.050$) (Table 7, Table 8, Figure 3).

Table 7. Comparison of Seated body flexion data before and after training: EG-NB, EG-OB, SCG-NB, SCG-OB

Groups	n	Baseline	After12weeks	△ Changes
EG-NB	14	9.32±13.25	11.13±9.60	+1.81
EG-OB	14	13.59±5.30	13.67±4.77	+0.08
SCG-NB	14	10.88±4.11	8.21±5.34	-2.67
SCG-OB	14	9.60±5.58	9.61±5.09	+0.01

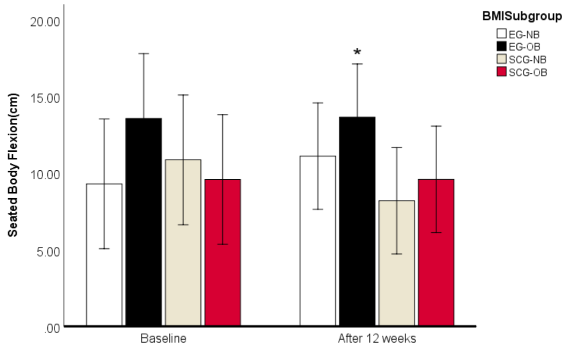
The data are Mean±SD. △ indicates the difference from baseline after 12 weeks.

Table 8. Results of Analysis of Variance for seated body flexion

Effects	df	F	p	Eta^2
Time	1,52	0.152	0.698	0.003
Group	3,52	1.074	0.368	0.058
Time×group	3,52	3.510	0.022 *	0.168

Note: The time main effect and group main effect were not significant (p>0.05), while the interaction effect was significant (p<0.05).

Figure 3. Changes of Seated body flexion in different BMI subgroups at baseline and after 12 weeks



Note: *P < 0.05. EG-NB indicates normal BMI in the experimental group; EG-OB indicates overweight BMI in the experimental group; SCG-NB represents normal BMI in the control group; SCG-OB indicates overweight BMI in the control group.

For vertical jump performance, significant time ($F = 17.344$, $p < 0.001$, $\eta^2 = 0.250$) and interaction effects were observed ($F = 4.812$, $p = 0.005$, $\eta^2 = 0.217$). Vertical jump performance significantly decreased in both control groups (SCG-NB: −3.90 cm; SCG-OB: −3.39 cm, $p < 0.05$), whereas no significant decline was observed in the experimental groups (Table 9, Table 10, Figure 4).

Table 9. Comparison of vertical jump test data before and after Training: EG-NB, EG-OB, SCG-NB, SCG-OB

Groups	n	Baseline	12 weeks later	△ Changes
EG-NB	14	29.71±4.68	29.64±3.92	-0.07
EG-OB	14	30.36±7.73	30.07±7.42	-0.29
SCG-NB	14	28.79±4.37	25.07±8.19	-3.9
SCG-OB	14	32.00±4.32	28.07±5.05	-3.39

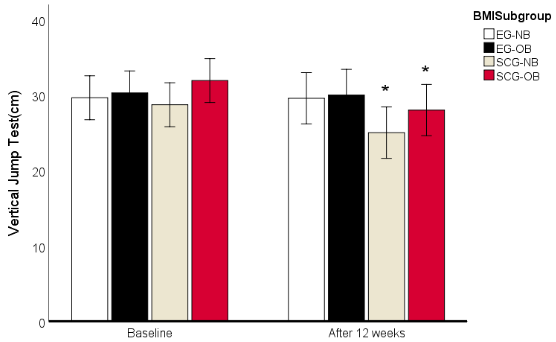
The data are Mean±SD. △ represents the difference from baseline after training.

Table 10. Results of Analysis of Variance for the vertical jump test

Effects	df	F	p	Eta^2
time	1,52	17.344	0.001 * * *	0.250
group	3,52	1.036	0.384	0.056
Time×group	3,52	4.812	0.005 * *	0.217

Note: Both the time main effect and the interaction effect were extremely significant (p<0.01), while the group main effect was not significant (p>0.05).

Figure 4. Changes in vertical jump tests in different BMI subgroups before intervention and 12 weeks after intervention



Note: EG-NB indicates normal BMI in the experimental group; EG-OB indicates overweight BMI in the experimental group; SCG-NB represents normal BMI in the control group; SCG-OB indicates overweight BMI in the control group.

Psychological Outcomes

Baseline psychological characteristics are shown in Table 11, with no significant differences between groups.

Table 11. Baseline characteristics of participants' mental health data

	NB		p- value	OB		p- value
	SCB-NB	EG-NB		SCG-OB	EG-OB	
Pittsburgh Sleep Quality Index	6.00±2.48	5.00±2.83	0.660	6.43±3.20	5.29±3.12	0.168
Rosenberg Self-Esteem Scale	26.07±2.27	25.57±2.74	0.603	25.14±3.06	26.50±1.79	0.291
University Personality Inventory	14.07±11.36	13.64±12.09	0.565	13.86±11.87	11,57±8.15	0.564

The data are Mean±SD.

No significant effects were found for PSQI or UPI scores (all $p > 0.05$). However, self-esteem scores demonstrated significant time ($F = 6.845$, $p = 0.012$, $\eta^2 = 0.116$), group ($F = 3.802$, $p = 0.015$, $\eta^2 = 0.180$), and interaction effects ($F = 4.588$, $p = 0.006$, $\eta^2 = 0.209$).

Post hoc analyses showed significant increases in Rosenberg Self-Esteem Scale scores in both experimental groups (EG-NB: +3.07; EG-OB: +3.14, both $p < 0.05$), while no significant changes were observed in control groups. At post-intervention, self-esteem scores were significantly higher in EG-NB and EG-OB compared with their respective control groups (both $p < 0.01$) (Table 12, Table 13, Figure 5).

Table 12. Comparison of Rosenberg Scale data before and after training: EG-NB, EG-OB, SCG-NB, SCG-OB

Groups	n	Baseline	12 weeks later	△ Changes
EG-NB	14	25.57±2.738	28.64±3.249	+3.07
EG-OB	14	26.50±1.79	29.64±5.96	+3.14
SCG-NB	14	26.07±2.269	25.43±2.472	-0.64
SCG-OB	14	25.14±3.06	24.71±2.70	-0.43

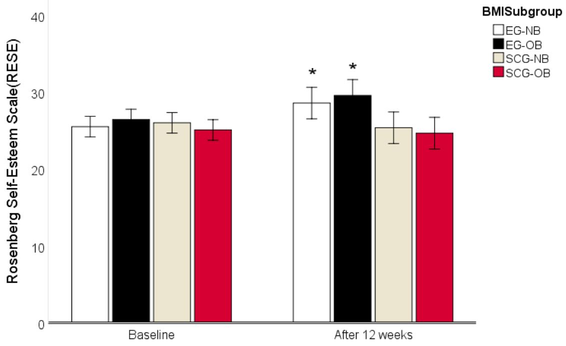
The data are Mean±SD. △ represents the difference from baseline after training.

Table 13. Results of Analysis of Variance for Rosenberg Scale

Effect	df	F	p	Eta^2
time	1,52	6.845	0.012 *	0.116
group	3,52	3.802	0.015 *	0.180
Time×group	3,52	4.588	0.006 * *	0.209

Note: The time main effect and group main effect were both significant (p<0.05), and the interaction effect was extremely significant (p<0.05)

Figure 5. Changes in the Rosenberg Scale before and 12 weeks after the intervention in different BMI subgroups



Note: EG-NB indicates normal BMI in the experimental group; EG-OB indicates overweight BMI in the experimental group; SCG-NB represents normal BMI in the control group; SCG-OB indicates overweight BMI in the control group.

Discussion

This study is among the first to incorporate the traditional Chinese mind–body exercise Baduanjin into an exercise snack intervention framework and systematically examine its long-term effects over 12 weeks in sedentary college students. Overall, the findings suggest that brief, repeated bouts of Baduanjin practice may confer beneficial effects on selected health outcomes, particularly in overweight individuals. Specifically, the intervention was associated with significant reductions in body weight and BMI, maintenance of lower-body explosive performance, and improvements in self-esteem. These findings highlight the potential of Baduanjin-based exercise snacks as a feasible and accessible strategy for mitigating some of the adverse consequences of sedentary behavior in young adults.

Long-term interventions and changes in body composition

Regarding body composition, the effects of the Baduanjin intervention appeared to demonstrate a clear baseline-dependent pattern. Specifically, significant reductions in body weight and BMI were observed only in the overweight experimental group (EG-OB), whereas no significant changes were found in participants with normal BMI. In the EG-OB group, body weight decreased from 88.21 ± 18.50 kg to 84.73 ± 18.47 kg (−4.48 kg), while BMI decreased from 29.17 ± 3.80 to 28.00 ± 3.83 (−1.17 kg/m^2). In contrast, the remaining groups showed no significant changes. These findings are consistent with previous evidence suggesting that exercise interventions tend to produce greater weight-related adaptations in overweight individuals compared with those of normal weight (Gao et al., 2024).

From a mechanistic perspective, although Baduanjin is generally classified as a low-intensity exercise modality with relatively limited energy expenditure per session (Gao et al., 2024), its repeated daily implementation may generate meaningful cumulative energy expenditure over time (Wen et al., 2024). The present findings further support the notion that frequent interruptions of sedentary behavior through short bouts of low-intensity activity may gradually translate into measurable reductions in body weight and BMI during long-term interventions.

In contrast, no significant changes were observed in body fat percentage or waist-to-hip ratio following the intervention. One possible explanation is that exercise-only interventions, particularly those performed at low-to-moderate intensity without dietary modification, may have limited effects on adiposity-related outcomes. Previous studies have reported that significant reductions in body fat percentage are more consistently observed when exercise interventions are combined with dietary control or involve greater training intensity and volume over prolonged periods (Huang et al., 2025; Khodadadi et al., 2023; Wen et al., 2024). Therefore, the relatively modest training stimulus of Baduanjin-based exercise snacks may have been insufficient to induce detectable changes in fat percentage within the 12-week intervention period.

Additionally, muscle mass remained relatively stable across all groups, suggesting that low-intensity, repetitive movement patterns may contribute to the maintenance of skeletal muscle through sustained neuromuscular activation rather than promoting substantial hypertrophic adaptations. This observation is consistent with previous findings indicating that low-intensity exercise may help preserve muscle mass despite limited anabolic stimulation (Yang et al., 2025).

Taken together, the present findings suggest that the effects of Baduanjin on body composition may primarily reflect a selective adaptation process driven by cumulative energy expenditure, with more pronounced benefits observed in overweight individuals.

Mechanism of changes in physical fitness

The present findings indicate that Baduanjin elicits a selective effect on physical fitness, characterized primarily by functional maintenance rather than performance enhancement. The vertical jump performance (which is an indicator of lower limb explosive power and neuromuscular activation ability) remained stable in the intervention group. The research data showed that compared with the baseline level, EG-NB decreased from 29.71 ± 4.68 to 29.64 ± 3.92 (a decrease of 0.07), and EG-OB decreased from 30.36 ± 7.73 to 30.07 ± 7.42 (a decrease of 0.29), with the decrease not being significant. However, in the control group, SCG-NB decreased from 28.79 ± 4.37 to 25.07 ± 8.19 (a decrease of 3.90), and SCG-OB decreased from 32.00 ± 4.32 to 28.07 ± 5.05 (a decrease of 3.39), showing a significant decrease. This indicates that Baduanjin may be able to alleviate functional decline associated with activities. From a physiological perspective, this effect is plausibly attributable to repeated low-intensity neuromuscular activation, which, despite being insufficient to induce hypertrophy or maximal strength gains, may help preserve motor unit recruitment and neuromuscular efficiency (Xie et al., 2024; Yang et al., 2025). Conversely, reduced physical activity and prolonged sedentary exposure have been associated with impaired muscle function and neuromuscular performance (Owen et al., 2010; Pinto et al., 2023).

There was no significant change in grip strength and vital capacity indicators, which was related to the principle of exercise-specific and insufficient mechanical and metabolic loads (Garber et al., 2011). The observed flexibility findings may be explained by the controlled, multi-joint, and rhythmically coordinated movements inherent to Baduanjin. Although no significant within-group changes were observed, the overweight experimental group demonstrated greater post-intervention flexibility than the overweight control group, suggesting that regular Baduanjin practice may help maintain flexibility in sedentary individuals. These movement characteristics are thought to enhance flexibility, proprioception, and motor coordination, consistent with previous evidence from mind–body exercise modalities (Zou et al., 2018). Collectively, these findings suggest that Baduanjin primarily contributes to maintaining neuromuscular function and mitigating decline, rather than improving maximal physical capacity.

Mental health effects

The research found that the practice of Baduanjin significantly enhanced the self-esteem of college students. The research data showed that, compared with the baseline, after 12 weeks of intervention, the self-esteem score of EG-NB increased from 25.57 ± 2.74 to 28.64 ± 3.25 (an increase of 3.07), and that of EG-OB increased from 26.50 ± 1.79 to 29.64 ± 5.96 (an increase of 3.14). The self-esteem level of the intervention group significantly increased, while that of the control group decreased. These results are consistent with the theory of self-efficacy, which states that individuals improve their self-evaluation by completing controlled physical activity tasks (Li et al., 2015).

Regarding mechanisms of action, physical activity improves psychological well-being, particularly mood and self-perception, through enhanced interoceptive awareness and positive shifts in body image (Rippe et al., 1998; Zhang & Min, 2022). Similarly, Baduanjin exerts psych regulatory effects via its integrated emphasis on mindful breathing, precise movement coordination, and intentional postural control. Components that collectively attenuate physiological arousal and reduce perceived psychological stress (Cheng, 2015).

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI). Baseline scores revealed that the majority of participants reported no clinically significant insomnia symptoms or sleep disturbances; consequently, no statistically significant change in global PSQI score was observed following the intervention. Although a robust body of evidence demonstrates that both acute and chronic physical activity (including mind-body modalities) can improve sleep quality, these benefits are most consistently documented in individuals with preexisting sleep impairments (Kline et al., 2021; Korkutata et al., 2025). Meta-analytic evidence further indicates that physical activity interventions yield modest yet reliable improvements in objective and subjective sleep parameters predominantly among adults exhibiting baseline sleep deficits, effects that generalize across age and sex (Kline et al., 2021).

In summary, this study indicates that Baduanjin's primary psychological benefits arise from embodied self-regulation, mediated through heightened somatic awareness, refined sensorimotor integration, and strengthened self-efficacy, rather than generalized stress reduction or sleep modulation. The intervention demonstrated a selective, significant enhancement in self-esteem, underscoring its efficacy as a body-centered approach to psychological resilience.

Theoretical and practical Implications of the exercise snack model

Building upon the existing theoretical framework of exercise snacks, the present study expands its applicability to low-intensity mind–body exercise modalities. Specifically, the findings demonstrate that Baduanjin, when performed in a short-duration, high-frequency format (≤10 min/session, three times daily), can elicit measurable physiological and psychological benefits without increasing the overall weekly exercise burden. This finding extends the traditional exercise snack paradigm, which has primarily emphasized high-intensity intermittent activities, and highlights the potential of culturally adaptable, low-intensity interventions.

From a theoretical perspective, the results suggest that the health effects of exercise may depend not only on exercise intensity, but also on the temporal distribution and behavioral organization of physical activity throughout the day. Previous research has largely focused on moderate-to-vigorous continuous or intermittent exercise interventions (Islam et al., 2022; Jones et al., 2024; Weston et al., 2025). In contrast, the present findings indicate that distributing low-intensity mind–body exercise into multiple short bouts across the day may also produce positive physiological and psychological adaptations. Accordingly, the study supports the concept that increasing the frequency of movement and interrupting prolonged sedentary behavior may represent a practical strategy for health promotion (Chen et al., 2025; Francois et al., 2014; Jenkins et al., 2019; Wang et al., 2025).

In addition, embedding exercise into everyday contexts, such as work breaks or post-meal periods, may reduce the psychological burden associated with exercise initiation and improve long-term adherence by enhancing compatibility with existing lifestyle patterns. This context-embedded activity model may help explain the sustainability and practicality of exercise snack interventions in real-world settings.

From a practical perspective, the intervention used in this study demonstrated strong feasibility and translational potential. Its primary advantages include minimal equipment requirements, flexible implementation within fragmented time periods, and moderate intensity suitable for a wide range of populations, including sedentary individuals and those with lower physical fitness. Therefore, Baduanjin-based exercise snacks may represent a scalable and accessible public health strategy for settings such as universities, workplaces, and community health programs.

Limitations of Research

Although this study systematically explored the health-promoting effects of Baduanjin in the exercise snacks model at the long-term intervention level, there are still several limitations.

1. The sample size is relatively small, and the research subjects are mainly concentrated in the student population, which limits the generalizability of the research conclusion to people of different ages and health conditions.

2. The intervention period is 12 weeks, which can reflect the mid-term effect, but it is not sufficient to reveal the long-term adaptation characteristics of low-intensity exercise in the "exercise snack" model, especially the cumulative effects on indicators such as body fat distribution and cardiopulmonary function, which still need further observation. Moreover, this study did not strictly control potential confounding factors such as diet and daily physical activities, which may have certain impacts on changes in body composition.

3. At the mechanism level, this study mainly makes inferences based on behavioral and physiological indicators, lacking objective physiological data such as heart rate variability (HRV), endocrine or metabolic indicators, and there is still room for further deepening the explanation of the "neural regulation - behavioral accumulation" mechanism.

4. The operation of the "exercise snack" model in this study mainly reflects the frequency and duration aspects and has not further refined the influence of different time structures (such as interval duration, single dose) on the intervention effect.

Conclusions

Based on the findings of this study, Baduanjin, as a low-intensity mind–body exercise, appears to provide gradual and multidimensional health benefits when implemented within an exercise snack framework. Its repeated integration into daily life may contribute to cumulative improvements in physical function and psychological well-being, with more pronounced effects observed among participants with overweight BMI. Rather than serving as a performance-enhancing intervention, Baduanjin-based exercise snacks may be more suitable for maintaining functional capacity and promoting self-esteem in sedentary young adults. These findings extend the emerging evidence on exercise snacks by demonstrating that a traditional mind–body exercise can be effectively incorporated into a time-efficient health promotion strategy. Given its simplicity and accessibility, this approach may be applied in university and community settings to encourage regular physical activity among sedentary populations. Future research should examine the long-term sustainability of these effects, optimize exercise snack prescriptions, and evaluate their effectiveness across more diverse populations.

Acknowledgements

The author would like to express his gratitude to all the colleagues who have provided assistance and support for this research, as well as to the contributions made by them. We also wish to thank all the participants who voluntarily participated in this research for their contributions. Additionally, we are grateful to the School of Physical Education and Health of Jiuquan Vocational University for providing the relevant equipment and assistance.

Financing

This research did not receive any funding from any public or private institutions.

Author Affiliations

Xiaobin Wang[1], Witid Mitranun[1]

[1] Department of Sports Science, Faculty of Physical Education, Sports, and Health, Srinakharinwirot University, Ongkharak, Nakhon Nayok 26120, Thailand.

References

Barkley, J. E., & Lepp, A. (2016). Mobile phone use among college students is a sedentary leisure behavior which may interfere with exercise. *Computers in Human Behavior, 56*, 29-33. https://doi.org/10.1016/j.chb.2015.11.001

Chen, J., Lu, Y., Zhao, H., Liu, H., & Yao, J. (2025). The effectiveness of exercise snacks as a time-efficient treatment for improving cardiometabolic health in adults: a systematic review and meta-analysis. *Frontiers in Cardiovascular Medicine, 12*. https://doi.org/10.3389/fcvm.2025.1643153

Cheng, F. K. (2015). Effects of Baduanjin on mental health: A comprehensive review. *Journal of Bodywork and Movement Therapies, 19*(1), 138–149. https://doi.org/10.1016/j.jbmt.2014.11.001

Dunstan, D. W., Kingwell, B. A., Larsen, R., Healy, G. N., Cerin, E., Hamilton, M. T., Shaw, J. E., Bertovic, D. A., Zimmet, P. Z., Salmon, J., & Owen, N. (2012). Breaking Up Prolonged Sitting Reduces Postprandial Glucose and Insulin Responses. *Diabetes Care, 35*(5), 976–983. https://doi.org/10.2337/dc11-1931

Francois, M. E., Baldi, J. C., Manning, P. J., Lucas, S. J. E., Hawley, J. A., Williams, M. J. A., & Cotter, J. D. (2014). 'Exercise snacks' before meals: a novel strategy to improve glycaemic control in individuals with insulin resistance. *Diabetologia, 57*(7), 1437–1445. https://doi.org/10.1007/s00125-014-3244-6

Gao, H., Li, X., Wei, H., Shao, X., Tan, Z., Lv, S., Pan, L., Yu, T., Ye, Q., Zhang, H., & Zhu, X. (2024). Efficacy of Baduanjin for obesity and overweight: a systematic review and meta-analysis. *Frontiers in Endocrinology, 15*. https://doi.org/10.3389/fendo.2024.1338094

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I.-M., Nieman, D. C., & Swain, D. P. (2011). Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults. *Medicine & Science in Sports & Exercise, 43*(7), 1334–1359. https://doi.org/10.1249/mss.0b013e318213fefb

Gibala, M. J., & Little, J. P. (2020). Physiological basis of brief vigorous exercise to improve health. *The Journal of Physiology, 598*(1), 61–69. Portico. https://doi.org/10.1113/jp276849

Hamilton, M. T., Hamilton, D. G., & Zderic, T. W. (2007). Role of Low Energy Expenditure and Sitting in Obesity, Metabolic Syndrome, Type 2 Diabetes, and Cardiovascular Disease. *Diabetes, 56*(11), 2655–2667. https://doi.org/10.2337/db07-0882

Healy, G. N., Wijndaele, K., Dunstan, D. W., Shaw, J. E., Salmon, J., Zimmet, P. Z., & Owen, N. (2008). Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes care, 31*(2), 369-371. https://doi.org/10.2337/dc07-1795

Huang, T., Feng, H., Xie, Z., Wang, Y., Wang, Q., & Wang, Z. (2025). Effects of exercise on body fat percentage and cardiorespiratory fitness in sedentary adults: a systematic review and network meta-analysis. *Frontiers in Public Health, 13*. https://doi.org/10.3389/fpubh.2025.1624562

Huang, T., Larsen, K. T., Ried-Larsen, M., Møller, N. C., & Andersen, L. B. (2014). The effects of physical activity and exercise on brain-derived neurotrophic factor in healthy humans: A review. *Scandinavian Journal of Medicine & Science in Sports, 24*(1), 1–10. https://doi.org/10.1111/sms.12069

Islam, H., Gibala, M. J., & Little, J. P. (2022). Exercise Snacks: A Novel Strategy to Improve Cardiometabolic Health. *Exercise and Sport Sciences Reviews, 50*(1), 31–37. https://doi.org/10.1249/jes.0000000000000275

Jenkins, E. M., Nairn, L. N., Skelly, L. E., Little, J. P., & Gibala, M. J. (2019). Do stair climbing exercise "snacks" improve cardiorespiratory fitness? *Applied Physiology, Nutrition, and Metabolism, 44*(6), 681–684. https://doi.org/10.1139/apnm-2018-0675

Jones, M. D., Clifford, B. K., Stamatakis, E., & Gibbs, M. T. (2024). Exercise Snacks and Other Forms of Intermittent Physical Activity for Improving Health in Adults and Older Adults: A Scoping Review of Epidemiological, Experimental and Qualitative Studies. *Sports Medicine, 54*(4), 813–835. https://doi.org/10.1007/s40279-023-01983-1

Keating, S. E., Johnson, N. A., Mielke, G. I., & Coombes, J. S. (2017). A systematic review and meta-analysis of interval training versus moderate-intensity continuous training on body adiposity. *Obesity Reviews, 18*(8), 943–964. Portico. https://doi.org/10.1111/obr.12536

Khodadadi, F., Bagheri, R., Negaresh, R., Moradi, S., Nordvall, M., Camera, D. M., Wong, A., & Suzuki, K. (2023). The Effect of High-Intensity Interval Training Type on Body Fat Percentage, Fat and Fat-Free Mass: A Systematic Review and Meta-Analysis of Randomized Clinical Trials. *Journal of Clinical Medicine, 12*(6), 2291. https://doi.org/10.3390/jcm12062291

Kline, C. E., Hillman, C. H., Bloodgood Sheppard, B., Tennant, B., Conroy, D. E., Macko, R. F., Marquez, D. X., Petruzzello, S. J., Powell, K. E., & Erickson, K. I. (2021). Physical activity and sleep: An updated umbrella review of the 2018 Physical Activity Guidelines Advisory Committee report. *Sleep Medicine Reviews, 58*, 101489. https://doi.org/10.1016/j.smrv.2021.101489
Korkutata, A., Korkutata, M., & Lazarus, M. (2025). The impact of exercise on sleep and sleep disorders. *Npj Biological Timing and Sleep, 2*(1). https://doi.org/10.1038/s44323-024-00018-w
Kredlow, M. A., Capozzoli, M. C., Hearon, B. A., Calkins, A. W., & Otto, M. W. (2015). The effects of physical activity on sleep: a meta-analytic review. *Journal of Behavioral Medicine, 38*(3), 427–449. https://doi.org/10.1007/s10865-015-9617-6
Li, M., Fang, Q., Li, J., Zheng, X., Tao, J., Yan, X., Lin, Q., Lan, X., Chen, B., Zheng, G., & Chen, L. (2015). The Effect of Chinese Traditional Exercise-Baduanjin on Physical and Psychological Well-Being of College Students: A Randomized Controlled Trial. *Plos One, 10*(7), e0130544. https://doi.org/10.1371/journal.pone.0130544
Owen, N., Healy, G. N., Matthews, C. E., & Dunstan, D. W. (2010). Too much sitting: the population health science of sedentary behavior. *Exercise and sport sciences reviews*, *38*(3), 105–113. https://doi.org/10.1097/JES.0b013e3181e373a2
Pinto, A. J., Bergouignan, A., Dempsey, P. C., Roschel, H., Owen, N., Gualano, B., & Dunstan, D. W. (2023). Physiology of sedentary behavior. *Physiological reviews, 103*(4), 2561-2622. https://doi.org/10.1152/physrev.00022.2022
Rezende, L. F. M. d., Rodrigues Lopes, M., Rey-López, J. P., Matsudo, V. K. R., & Luiz, O. d. C. (2014). Sedentary Behavior and Health Outcomes: An Overview of Systematic Reviews. *PLoS ONE, 9*(8), e105620. https://doi.org/10.1371/journal.pone.0105620
Rippe, J. M., Price, J. M., Hess, S. A., Kline, G., DeMers, K. A., Damitz, S., Kreidieh, I., & Freedson, P. (1998). Improved Psychological Well-Being, Quality of Life, and Health Practices in Moderately Overweight Women Participating in a 12-Week Structured Weight Loss Program. *Obesity Research, 6*(3), 208–218. Portico. https://doi.org/10.1002/j.1550-8528.1998.tb00339.x
Ruiz, F. A. A., Amaya, J. A. C., Restrepo, D. F. A., & Cano, J. A. R. (2024). Efectos de la actividad física en estudiantes universitarios con trastornos de salud mental: una revisión sistemática con metaanálisis. *Retos, 59*, 982–1002. https://doi.org/10.47197/retos.v59.108367
Schuch, F. B., Vancampfort, D., Firth, J., Rosenbaum, S., Ward, P. B., Silva, E. S., Hallgren, M., Ponce De Leon, A., Dunn, A. L., Deslandes, A. C., Fleck, M. P., Carvalho, A. F., & Stubbs, B. (2018). Physical Activity and Incident Depression: A Meta-Analysis of Prospective Cohort Studies. A*merican Journal of Psychiatry, 175*(7), 631–648. https://doi.org/10.1176/appi.ajp.2018.17111194
Wang, T., Laher, I., & Li, S. (2025). Exercise snacks and physical fitness in sedentary populations. *Sports Medicine and Health Science, 7*(1), 1–7. https://doi.org/10.1016/j.smhs.2024.02.006
Wen, N., Zhao, F., Sun, S., Xiong, J., & Zheng, G. (2024). The effect of Baduanjin on body mass and body composition of college students: A randomized controlled trial. *Medicine, 103*(44), e40393. https://doi.org/10.1097/md.0000000000040393
Weston, K. L., Little, J. P., Weston, M., McCreary, S., Kitchin, V., Gill, A., Niven, A., McNarry, M. A., & Mackintosh, K. A. (2025). Application of Exercise Snacks across Youth, Adult and Clinical Populations: A Scoping Review. *Sports Medicine - Open, 11*(1). https://doi.org/10.1186/s40798-025-00829-6
Xie, Y., Zhang, Q., Xin, D., & Wang, Y. (2024). Effects of a 12-week Baduanjin regimen on biomechanical properties of axial muscle fascia in ankylosing spondylitis. *Medicine, 103*(52), e40522. https://doi.org/10.1097/md.0000000000040522
Yang, S., Chen, S., Zhang, Y., Zhou, Z., Li, D., & Zeng, P. (2025). Effects of Tai Chi and Baduanjin on muscle mass, muscle function, and activities of daily living in individuals with sarcopenia: a systematic review and meta-analysis. *Frontiers in Public Health, 13*. https://doi.org/10.3389/fpubh.2025.1636857
Zhang, Z., & Min, H. J. (2022). Effects of Different Physical Exercises on Physical and Mental Health of Female College Students. *Journal of Healthcare Engineering, 2022*, 1–5. https://doi.org/10.1155/2022/7812005
Zou, L., Pan, Z., Yeung, A., Talwar, S., Wang, C., Liu, Y., Shu, Y., Chen, X., & Thomas, G. A. (2018). A Review Study on the Beneficial Effects of Baduanjin. *The Journal of Alternative and Complementary Medicine, 24*(4), 324–335. https://doi.org/10.1089/acm.2017.0241

Authors and translators' details:

Xiaobin Wang	wangxiaobin868@gmail.com	Author
Witid Mitranun	mitranunwitid@hotmail.com	Author