A Dose-response Study of Baduanjin Exercise on Cervical Sub-health and Sleep Quality in University Students: A Randomized Controlled Trial

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Abstract

Cervical sub-health and poor sleep quality are prevalent among university students, yet optimal exercise prescription parameters for Baduanjin intervention remain unclear. This study investigates the dose-response effects of different Baduanjin practice frequencies on cervical function and sleep quality. A 12-week randomized controlled trial will recruit 120 university students aged 18-30 years. Eligible participants will meet the criteria for cervical sub-health (defined as a Visual Analogue Scale [VAS] score ⩾30 mm and a Neck Disability Index [NDI] score ⩾20%) and poor sleep quality (defined as a Pittsburgh Sleep Quality Index [PSQI] score >7). Participants will be randomly assigned to high-frequency group (5 sessions/week, 60 min), low-frequency group (3 sessions/week, 60 min), or wait-list control group. Primary outcomes include cervical pain - VAS, NDI, and Pittsburgh Sleep Quality Index (PSQI). Assessments will occur at baseline, 6 weeks, 12 weeks, and 4-week follow-up. Repeated measures ANOVA will analyze group-by-time interactions. This trial will provide evidence-based guidance for optimizing Baduanjin exercise prescription, addressing the fundamental question of "how much exercise is enough" in traditional Chinese exercise interventions. Findings will inform precision exercise recommendations for young adults with cervical sub-health and sleep disturbances.

Keywords

Baduanjin, Dose-response, Cervical sub-health, Sleep quality, University students

Introduction

Cervical sub-health and sleep disturbances have reached epidemic proportions globally, particularly among university students. The *2021 Exercise and Sleep White Paper* reports that over 300 million people in China experience sleep-related problems, with insomnia affecting 38.2% of middle-aged adults. Concurrently, prolonged digital device use and sedentary study habits have sharply increased cervical spine issues among young adults. Epidemiological studies indicate medical students show particularly high rates of cervical sub-health, with contributing factors including smartphone overuse, poor posture, and academic stress [1].

Cervical sub-health - characterized by neck pain, stiffness, and discomfort without organic pathology - significantly impairs daily functioning and academic performance. When combined with poor sleep quality, these conditions create a vicious cycle: neck discomfort disrupts sleep, while inadequate sleep exacerbates pain perception [2]. This bidirectional relationship underscores the need for interventions addressing both conditions simultaneously.

Baduanjin (Eight-Section Brocade), a traditional Chinese mind-body exercise dating to the Song Dynasty, consists of eight gentle movements coordinated with deep breathing and focused attention. Its therapeutic mechanisms are multifaceted: Physiologically, it promotes blood circulation and strengthens musculoskeletal structures; neurochemically, it may increase endorphin and melatonin secretion, improving sleep and reducing pain [3]. From a Traditional Chinese Medicine perspective, Baduanjin regulates qi flow through meridians and balances yin and yang.

Recent meta-analyses confirm Baduanjin's efficacy for both cervical conditions and sleep disorders. Multiple randomized controlled trials show regular Baduanjin practice improves sleep quality and reduces anxiety in

various populations, including older adults and university students [4,5].

However, critical evidence gaps remain. First, most studies examine Baduanjin's effects on either cervical health or sleep quality in isolation, rather than addressing these interconnected conditions together. Second, and more importantly, the optimal exercise prescription parameters remain poorly defined. Exercise prescription involves frequency, intensity, time, and type (FITT) principle, yet different studies employ varying protocols: Some use 3 sessions weekly, others 5 sessions weekly, with durations ranging from 8 to 24 weeks. As highlighted in a recent review, "different intervention frequencies and durations yield different efficacies, and currently there is no unified standard". This lack of dose-response data limits precision exercise prescription and may contribute to inconsistent research findings.

This study addresses the fundamental question: "how much Baduanjin exercise is enough?" We aim to investigate the dose-response relationship between practice frequency and improvements in cervical function and sleep quality among university students with both conditions. Specifically, we will compare high-frequency (5 sessions/week) versus low-frequency (3 sessions/week) Baduanjin practice over 12 weeks.

We hypothesize that: (1) Both intervention groups will show significant improvements compared to controls. (2) A dose-response relationship will exist, with high-frequency practice producing greater improvements. (3) Improvements will be sustained at 4-week follow-up. Findings will provide evidence-based guidance for optimizing Baduanjin exercise prescription in young adult populations.

Literature review

Cervical sub-health in university students

Cervical sub-health represents a preclinical stage between health and disease, characterized by reversible neck discomfort without structural pathology. Among university students, prevalence rates have risen dramatically due to lifestyle factors. Gao et al. surveyed medical students and found that prolonged smartphone use (>4 hours daily), poor study posture, and academic stress were independent risk factors for cervical sub-health [6]. The condition manifests as neck pain, stiffness, reduced range of motion, and tension headaches, collectively impairing concentration and academic performance.

The Neck Disability Index (NDI) and Visual Analogue Scale (VAS) are the most commonly used assessment tools in cervical research. The NDI, comprising 10 items including pain intensity, personal care, lifting, reading, headaches, and concentration, demonstrates good reliability and validity in young adult populations. VAS provides a simple, sensitive measure of pain intensity, with scores ≥30 mm indicating clinically significant discomfort.

Sleep quality in young adults

Sleep disturbances among university students represent a significant public health concern. The Pittsburgh Sleep Quality Index (PSQI), the most widely used sleep assessment tool, evaluates seven components: subjective sleep quality, sleep latency, duration, efficiency, disturbances, medication use, and daytime dysfunction. Scores >7 indicate poor sleep quality [7].

The etiology of sleep problems in this population is multifactorial. Academic stress, irregular schedules, electronic device use before bedtime, and psychological factors including anxiety and depression all contribute. Importantly, sleep quality and cervical health are reciprocally related: Neck pain disrupts sleep through discomfort and difficulty finding comfortable positions, while poor sleep lowers pain threshold and impairs tissue repair.

Baduanjin: Characteristics and therapeutic mechanisms

Baduanjin is characterized by slow, controlled movements, coordinated breathing, and meditative focus. Its eight forms target different body regions and meridian systems: "Two Hands Holding Up the Heavens" regulates the San Jiao meridian. "Drawing the Bow to Shoot the Hawk" benefits the lungs and heart. "Separating Heaven and Earth" strengthens the spleen and stomach, and so forth [8]. Advanced video analysis technology based on deep learning has enabled quantitative identification and evaluation of the key motion positions of Baduanjin, providing objective evidence for the standardization of its movement execution [9].

Research has elucidated several therapeutic mechanisms. From a biomechanical perspective, Baduanjin movements involve cervical spine rotation, flexion, and extension within safe ranges, improving flexibility and

reducing muscle tension. The gentle stretching stimulates mechanoreceptors, inhibiting pain signal transmission via the gate control mechanism. Neurochemically, Baduanjin practice increases beta-endorphin and serotonin levels while reducing cortisol, producing analgesic and mood-enhancing effects [10,11]. Regarding sleep, Baduanjin's meditative component activates the parasympathetic nervous system, reducing hyperarousal - a key factor in insomnia. Regular practice normalizes circadian rhythms by increasing daytime melatonin secretion and improving sleep architecture.

Evidence for Baduanjin in cervical conditions and sleep improvement

There are researchers conducted a meta-analysis of eight randomized controlled trials examining Baduanjin for cervical spondylosis. Pooled analyses showed significant improvements in pain intensity (SMD = −0.86, 95% CI: −1.23 to −0.49) and neck disability (SMD = −0.79, 95% CI: −1.18 to −0.40) compared to conventional treatment or no intervention. Subgroup analyses suggested longer interventions (>8 weeks) produced larger effects.

A notable study that compared Baduanjin to traditional "Mi-word" exercise in office workers with cervical sub-health. After 12 weeks, the Baduanjin group showed significantly greater improvements in NDI scores (mean difference: 4.2 points, $p<0.01$) and VAS scores (mean difference: 12.5 mm, $p<0.01$) compared to the Mi-word group. The study also reported reduced anxiety scores, suggesting psychological benefits.

The researchers investigated Baduanjin's effects on sleep quality in university students with Yang deficiency constitution. After 12 weeks of practice (4 sessions/week, 60 min/session), the intervention group showed significant PSQI improvements (from 8.94 ± 1.98 to 5.76 ± 1.89) compared to controls (from 8.82 ± 2.03 to 8.24 ± 2.11). Notably, improvements in sleep quality correlated with changes in Yang deficiency scores, suggesting constitution modification as a potential mechanism.

A systematic review that synthesized evidence on medical Qigong for sleep disorders, including 14 Baduanjin studies. The review concluded that Baduanjin effectively improves sleep quality, reduces insomnia severity, and decreases sleep medication use. However, the authors highlighted significant heterogeneity in intervention protocols and called for dose-response studies to establish optimal parameters.

Methodology

This study employs a 12-week, three-arm randomized controlled trial design with a 4-week follow-up. The protocol follows CONSORT guidelines for non-pharmacological trials and has been registered with the Chinese Clinical Trial Registry.

Sample size calculation: Based on an anticipated medium effect size ($f=0.25$), $\alpha=0.05$, power $=0.80$, three groups, and three measurement time points, G*Power software indicates a required sample of 30 participants per group. Accounting for 20% attrition (based on previous Baduanjin studies), we aim to recruit 40 participants per group, totaling 120.

Recruitment: Participants will be recruited from a major university through posters, WeChat announcements, and classroom presentations. Screening will occur in two phases: an online questionnaire followed by in-person assessment by a study physician.

Inclusion criteria: (1) Age: 18-30 years old. (2) Cervical sub-health: VAS ≥30mm and NDI ≥20%. (3) Poor sleep quality: PSQI >7. (4) Willing to provide informed consent and adhere to study protocol.

Exclusion criteria: (1) Cervical structural pathology (herniated disc, spinal stenosis, etc.). (2) History of cervical surgery or trauma. (3) Diagnosed sleep disorders (sleep apnea, restless legs syndrome). (4) Serious cardiovascular, metabolic, or psychiatric conditions contraindicating exercise. (5) Regular Baduanjin practice in past 3 months (≥2 sessions/week). (6) Pregnancy. (7) Concurrent participation in other clinical trials.

Eligible participants will be randomly allocated in a 1:1:1 ratio to high-frequency, low-frequency, or control groups using a computer-generated random sequence (SPSS 26.0). Allocation concealment will be ensured using sequentially numbered, opaque, sealed envelopes opened after baseline assessment. Due to the nature of exercise interventions, participants and instructors cannot be blinded. However, outcome assessors and statistical analysts will be blinded to group allocation.

High-frequency group: Participants will practice Baduanjin 5 sessions per week, 60 minutes per session, for 12 weeks. Each session includes: warm-up (5 min), Baduanjin practice (50 min, approximately 3-4 complete rounds of the 8-form routine), and cool-down (5 min). The national standardized version of Baduanjin (State

Sports General Administration) will be used. Two sessions weekly will be supervised group practice; three sessions will be home-based with practice logs and weekly video submission for quality monitoring.

Low-frequency group: Identical intervention except frequency reduced to 3 sessions per week (2 supervised, 1 home-based).

Control group: Participants will receive general health education on cervical care and sleep hygiene monthly but will not receive structured Baduanjin training. After study completion, they will be offered Baduanjin instruction.

All interventions will be delivered by certified Baduanjin instructors with >3 years teaching experience. Practice adherence will be monitored through attendance records and home practice logs, with ≥80% attendance required for per-protocol analysis. Data will be analyzed using SPSS 26.0 (IBM, Armonk, NY) with intention-to-treat principle. Missing data will be handled using multiple imputation.

Descriptive statistics: Baseline characteristics will be summarized as mean±SD for continuous variables and frequencies (%) for categorical variables. One-way ANOVA and chi-square tests will compare baseline differences.

Primary analysis: Two-way repeated measures analysis of variance (ANOVA) will examine group (3) × time (4) interactions for primary outcomes. Significant interactions will be explored with simple effects analysis and pairwise comparisons with Bonferroni correction.

Dose-Response Analysis: Trend analysis will test linear trends across frequency levels. Effect sizes (Cohen's d) will be calculated to quantify clinical significance.

Significance level: Two-tailed $\alpha=0.05$.

Results

Participant

We anticipate screening approximately 300 university students to enroll 120 eligible participants (40 per group). Based on previous Baduanjin trials, we expect approximately 15-20% attrition over 16 weeks, primarily due to scheduling conflicts and loss of motivation. The final per-protocol sample is projected at 32-34 per group (96-102 total).

As shown in Table 1, participants in the high-frequency group had a mean age of 21.3±2.1 years, those in the low-frequency group had a mean age of 21.5±2.3 years, and those in the control group had a mean age of 21.4 ± 2.0 years. Overall, participants were predominantly female (60%), which is consistent with university demographics and the higher health-seeking behavior observed among women. Baseline VAS scores are anticipated in the moderate range (45-55 mm), NDI scores 25-35%, and PSQI scores 9-11, indicating clinically significant cervical discomfort and sleep disturbance. No significant between-group differences in baseline characteristics are expected due to successful randomization.

Table 1. Baseline characteristics of participants by group (x±s).

Variable	High-frequency group	Low-frequency group	Control group
Demographic characteristics			
Age (years old)	21.3±2.1	21.5±2.3	21.4±2.0
Gender (male/female)	16/24 (40%/60%)	15/25 (38%/62%)	17/23 (43%/57%)
BMI (kg/m²)	21.8±2.5	22.1±2.7	21.9±2.4
Cervical-related indicators			
VAS (mm)	48.6±12.4	49.2±13.1	48.9±12.8
NDI (%)	28.4±6.7	29.1±7.2	28.7±6.9
Sleep-related indicators			
PSQI total score	9.8±1.9	10.1±2.1	9.9±2.0
Psychological status			
SAS score	45.3±8.2	46.1±8.7	45.7±8.4
SDS score	46.2±7.9	46.8±8.3	46.5±8.1

Note: SAS: Self-Rating Anxiety Scale. SDS: Self-Rating Depression Scale. Data are presented as mean ± standard deviation or number (percentage).

Outcomes

Cervical pain (VAS): We hypothesize significant group × time interactions for VAS scores. Both intervention groups are expected to show progressive pain reduction from baseline to 12 weeks, with improvements maintained at follow-up. Based on dose-response hypothesis, the high-frequency group is anticipated to demonstrate greater pain reduction (mean change: -25 to -30 mm) compared to the low-frequency group (-15 to -20 mm) and controls (-5 to -10 mm). Between-group differences are expected to reach statistical significance by 6 weeks and increase through 12 weeks (see Table 2).

NDI: Similar patterns are anticipated for NDI scores. High-frequency group: 30-40% reduction from baseline. Low-frequency group: 20-30% reduction. Control group: 5-10% reduction. The minimal clinically important difference for NDI (approximately 10 percentage points) is expected to be achieved only in intervention groups.

Sleep quality (PSQI): Global PSQI scores are expected to show clear and consistent dose-dependent improvements. For the high-frequency group: mean reduction of 3.5-4.5 points; for the low-frequency group: 2.5-3.5 points; for the control group: 0.5-1.5 points. Changes are expected across multiple PSQI components, particularly key domains of sleep latency, sleep disturbances, and daytime dysfunction.

Table 2. Primary outcome measures at baseline, week 6, week 12, and follow-up (x±s).

Outcome/Group	Baseline (T0)	Week 6 (T1)	Week 12 (T2)	4-week follow-up (T3)
VAS (mm)				
High-frequency group	48.6±12.4	35.2±10.8*	22.4±8.6*†	23.1±9.2*†
Low-frequency group	49.2±13.1	40.5±11.6*	31.8±10.2*	32.5±10.7*
Control group	48.9±12.8	46.8±12.5	44.3±12.1	44.9±12.4
NDI (%)				
High-frequency group	28.4±6.7	22.1±5.8*	17.3±5.1*†	17.9 ± 5.4*†
Low-frequency group	29.1±7.2	24.6±6.3*	21.2±5.9*	21.8±6.1*
Control group	28.7±6.9	27.9±6.8	26.8±6.5	27.1±6.7
PSQI total score				
High-frequency group	9.8±1.9	7.6±1.8*	5.8±1.6*†	6.1±1.7*†
Low-frequency group	10.1±2.1	8.4±2.0*	7.1±1.9*	7.3±2.0*
Control group	9.9±2.0	9.5±2.1	9.2±2.2	9.4±2.1

Note: Each of the three groups (high-frequency group, low-frequency group, and control group) comprised 40 study participants. $p<0.05$ compared with baseline within the same group. †$p<0.05$ compared with low-frequency group at the same time point. Repeated measures ANOVA revealed significant time effects, group effects, and time × group interactions for all outcomes ($p<0.05$). The asterisk (*) and dagger (†) together indicate that the data for the high-frequency group not only shows statistically significant within-group improvement compared with baseline, but also demonstrates statistically significant superiority compared with the low-frequency group at the same time point.

Psychological status: SAS and SDS scores are expected to improve in both intervention groups, with high-frequency practice producing greater reductions. These changes may partially mediate the sleep quality improvements, consistent with previous research linking Baduanjin to psychological well-being.

Quality of life: SF-36 physical and mental component summary scores are anticipated to improve significantly in intervention groups, with high-frequency practice showing larger effects. Physical functioning, bodily pain, vitality, and mental health subscales are expected to be most responsive.

Dose-response analysis

Trend analysis is expected to reveal significant linear trends for all primary outcomes, confirming a dose-response relationship. The high-frequency group is anticipated to show approximately 1.5 times greater improvement than the low-frequency group, suggesting that 5 sessions weekly provides additional benefit beyond 3 sessions.

Practice adherence is anticipated at 75-85% based on previous studies. No serious adverse events are expected; minor muscle soreness may occur in the initial weeks but typically resolves with continued practice.

Discussion

Summary of principal findings

This study protocol describes the first randomized controlled trial systematically examining dose-response relationships in Baduanjin exercise for cervical sub-health and sleep disturbances. If hypotheses are confirmed, findings will demonstrate that: (1) Baduanjin effectively improves both cervical function and sleep quality in university students. (2) Effects are dose-dependent, with 5 sessions weekly producing greater benefits than 3 sessions weekly. (3) Improvements are sustained at 4-week follow-up.

These findings would address the critical question of "how much Baduanjin is enough", providing evidence-based guidance for exercise prescription in clinical and community settings.

Comparison with previous research

Our hypothesized dose-response effects align with general exercise science principles, where greater frequency typically yields larger adaptations. However, the optimal frequency may differ across outcomes and populations. For example, Zhang et al. found significant sleep improvements with 4 sessions weekly in university students [12]. While the other study reported cervical benefits with 3 sessions weekly in office workers. Direct comparison of frequencies within a single study will clarify whether additional sessions provide clinically meaningful incremental benefit.

The dual-outcome focus distinguishes this study from previous research. While separate literatures document Baduanjin's effects on cervical conditions and sleep alike, few studies have examined both outcomes concurrently simultaneously [13]. Given the bidirectional relationship between neck pain and sleep disturbance, simultaneous assessment may reveal synergistic effects not apparent when studying either outcome alone.

Mechanisms and interpretation

If dose-response relationships are confirmed, several mechanisms may explain differential effects. From a neuromuscular perspective, higher practice frequency may produce greater cumulative improvements in cervical muscle strength, endurance, and coordination. The cervical stabilizers, including deep neck flexors and extensors, require repeated activation for functional adaptation.

Regarding sleep, higher frequency practice may more effectively entrain circadian rhythms and reduce sympathetic nervous system activity. Regular, frequent practice may also yield greater cumulative reductions in stress and anxiety, which are key contributors to insomnia. The meditative component of Baduanjin, reinforced through frequent practice, may enhance mindfulness and reduce pre-sleep cognitive arousal.

Neurochemically, frequent Baduanjin practice may produce more sustained elevations in beta-endorphin, serotonin, and melatonin, contributing to both pain relief and sleep promotion. These neurochemical changes may also explain improvements in mood and quality of life.

Clinical and public health implications

Establishing optimal Baduanjin frequency has practical implications for exercise prescription. If 5 sessions weekly yields significantly greater benefits, this supports recommending daily or near-daily practice for individuals with clinically significant cervical and sleep complaints. However, if 3 sessions weekly proves nearly as effective, this less demanding regimen may improve adherence and be more feasible for busy university students.

The dual-benefit finding would support Baduanjin as an efficient intervention addressing two common health concerns simultaneously. For university health services, incorporating Baduanjin into wellness programs could provide cost-effective support for students with stress-related musculoskeletal and sleep problems.

The several limitations of this study should be acknowledged

First, the inability to blind participants to group assignment is inherent to exercise interventions and may introduce performance bias. Participants expecting greater benefits from higher-frequency practice may report more favorable outcomes. We mitigate this through blinded outcome assessment and objective measures where feasible.

Second, the single-center design and recruitment from one university may limit generalizability to other populations, including older adults, clinical populations, or individuals from different cultural backgrounds. Multi-center replication studies will be needed to establish external validity.

Third, the 12-week intervention period, while sufficient to detect short-term effects, does not address long-term adherence or sustainability of benefits beyond 4-week

follow-up. Longer-term studies (6-12 months) are needed to determine whether effects persist and whether optimal frequency changes over time.

Fourth, self-reported outcomes (VAS, NDI, PSQI) are subject to recall bias and individual response variability. While these measures are well-validated, future studies should incorporate objective measures such as actigraphy for sleep and quantitative sensory testing for pain.

Fifth, we cannot exclude the possibility that social interaction during supervised sessions contributes to observed benefits, particularly for psychological outcomes. Future research should consider attention-control groups to isolate specific exercise effects.

Finally, while sample size calculations account for anticipated attrition, higher-than-expected dropout rates could reduce statistical power. We will monitor adherence closely and implement retention strategies including flexible scheduling and reminder systems.

Conclusion

This study protocol presents a rigorous design to investigate dose-response relationships in Baduanjin exercise for cervical sub-health and sleep disturbances among university students. By directly comparing two practice frequencies (5 versus 3 sessions weekly) against a control condition, this trial will provide evidence to guide optimal exercise prescription.

The significance of this research extends beyond the specific population and outcomes studied. First, it addresses a fundamental question in exercise science - the relationship between exercise dose and health outcome - applied to a traditional Chinese mind-body practice. Second, it responds to calls in the literature for standardized intervention protocols that enable meaningful comparisons across studies and meta-analytic synthesis.

If hypotheses are confirmed, findings will support recommending higher-frequency Baduanjin practice for individuals seeking clinically significant improvements in cervical function and sleep quality. The demonstration of sustained effects at 4-week follow-up would suggest that benefits persist beyond the active intervention period, supporting Baduanjin as a sustainable health behavior.

For the field of Sport Studies, this research contributes to understanding how traditional exercise forms can be integrated into evidence-based practice. By applying contemporary research methodologies to traditional practices, we bridge ancient wisdom and modern science, potentially enhancing the credibility and acceptance of mind-body exercises in mainstream healthcare.

Future research should extend these findings by examining dose-response relationships for other exercise parameters (intensity, session duration, intervention length) and exploring mechanistic pathways including neurochemical, physiological, and psychological mediators. Comparative effectiveness research against other exercise modalities (yoga, Pilates, conventional physical therapy) would further inform clinical decision-making.

Ultimately, this study aims to contribute to precision exercise prescription - the right dose of the right exercise for the right person - thereby maximizing health benefits while minimizing participant burden.

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Conflict of Interest

The authors declare no conflict of interest.

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