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ORIGINAL ARTICLE

Effects of resistance exercise training and stretching on chronic insomnia

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Objective: The aim of this study was to assess the effects of resistance exercise and stretching on sleep, mood, and quality of life in chronic insomnia patients.
Methods: Three 4-month treatments included: resistance exercise (n=10), stretching (n=10), and control (n=8). Sleep was evaluated with polysomnography, actigraphy, and questionnaires. Mood and quality of life were assessed with the Profile of Mood States (POMS) and the Medical Outcomes Study Short-Form 36-Item Health Survey (SF-36), respectively.
Results: There were no significant treatment differences between resistance exercise and stretching. However, compared with the control treatment, resistance exercise and stretching led to significantly greater improvements in Insomnia Severity Index scores (-10.5±2.3, -8.1±2.0 vs. 2.3±1.8, respectively), and actigraphic measures of sleep latency (-7.1±4.6, -5.2±1.9 vs. 2.2±2.1 min), wake after sleep onset (-9.3±2.8, -7.1±3.0 vs. 3.6±4.2 min), and sleep efficiency (4.4±1.8, 5.0±0.8 vs. -2.3±2%). Pittsburgh Sleep Quality Index (PSQI) global scores (-5.3±0.8, -3.9±1.5 vs. -0.1±0.8) and sleep duration (1.2±0.3, 1.6±0.6 vs. -0.1±0.2 h) also improved following both experimental treatments compared with control. PSQI-Sleep efficiency increased after resistance exercise compared with control (19.5±3.9 vs. 2.1±4.3%). No significant differences were observed in polysomnography or quality of life measures. Tension-anxiety was lower in the stretching group than the control group.
Conclusion: Moderate-intensity resistance exercise and stretching led to similar improvements in objective and subjective sleep in patients with chronic insomnia.
Clinical trial registration: NCT01571115

Keywords: Sleep; physical activity; mood; flexibility; strength exercise

Introduction

Insomnia is a prevalent complaint, affecting about 15% of the general population across the world.[1] Insomnia is characterized by difficulty falling or staying asleep, waking up too early, or experiencing sleep dissatisfaction for at least 3 months.[2,3] Insomnia affects daytime functioning and causes deficits in attention, concentration, and memory, as well as fatigue and negative mood, decreasing the quality of life of patients. Common treatments for chronic insomnia are based on pharmacotherapy, which is associated with mortality,[4] adverse side effects, tolerance and dependence, withdrawal effects,[5] and high costs.[6] Thus, non-pharmacologic therapies have been increasingly studied,[7,8] and their clinical use has been encouraged.

In the last 10 years, studies have investigated the effects of exercise on patients with sleep disorders, such as sleep apnea[9,10] and chronic insomnia.[11-15] Aerobic exercise has been reported to have a number of effects on chronic insomnia, including improvement in sleep quality, sleep efficiency (SE), and sleep duration, as well as decreases in sleep onset latency (SOL) and wake after sleep onset (WASO).[11,14]

However, to our knowledge, there is no evidence regarding the chronic effects of resistance exercise on chronic insomnia.[16] However, studies investigating the effects of resistance exercise training on the sleep of older adults with major depression,[17,18] women with fibromyalgia,[19] generalized anxiety disorder,[20] and heart failure[21] have reported significant improvements in subjective sleep quality,[17,18] SE,[20] and sleep latency.[17] However, to our knowledge, no study has examined the effects of resistance exercise on polysomnographic measures.[16]

Stretching has also been associated with sleep improvements. Some controlled trials have reported that stretching and flexibility activities, such as tai chi[22,23] and yoga,[24]

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have led to improvements in self-reported sleep quality in older adults. However, the effects of stretching on chronic insomnia also are not well established, although some studies have described positive effects in postmenopausal woman and older adults.[25,26]

The purpose of this study was to assess the effects of resistance exercise and stretching on insomnia severity, objective and subjective sleep, mood, and quality of life in patients with chronic insomnia. We hypothesized that resistance exercise would lead to greater improvements in sleep than stretching, but that both treatments would more effectively reduce insomnia complaints and improve objective sleep, mood states, and quality of life than a control treatment.

Methods

Screening

Ethical approval for all experimental measures was granted by the university's human research ethics committee and conformed to Declaration of Helsinki principles (clinical trials registration: NCT01571115).

The participants were recruited through newspaper, magazine, and radio advertisements. Interested prospective participants contacted the researchers and were initially screened in a phone interview. The initial inclusion criteria were: a) 30 to 55 years old; b) insomnia complaints $\geqslant$ 6 months; c) at least one daytime insomnia-related complaint. The initial exclusion criteria were: a) use of psychoactive drugs; b) history of psychiatric diseases; c) a shift work schedule; d) regular exercise in the last 6 months.

Prospective participants who passed the phone screening were invited to the Sleep Clinic for further orientation. During the visit, the prospective participants signed a written informed consent form approved by the ethics committee. A medical screening determined clinical diagnosis of insomnia (based on modified DSM-IV criteria, including minimum symptom duration of 6 months and minimum frequency of at least 3 times a week), electrocardiogram abnormalities, a history of cardiac disease contraindicating exercise, and the coexistence of major depression. Baseline polysomnography (PSG) excluded participants with an apnea-hypopnea index $>$ 15 or a periodic leg movement index $>$ 15.

The available patients were randomly allocated into resistance exercise or stretching, using the RANDBET WEEN function (1:1 basis) in Microsoft Excel®. Patients unavailable for the intervention program were assigned (non-randomly) to the non-intervention control treatment.

Treatments

Resistance exercise training

The resistance exercise sessions were scheduled three times a week for four months (48 total sessions), focusing on the upper and lower limbs, abdominals, and paravertebral areas. Each session included four exercises for the upper limbs: biceps, triceps, back, and pectorals; four exercises for the lower limbs: flexors, extensors, abductors, and adductors; one trunk flexion exercise for the abdominal area; and one trunk extension exercise for the paravertebral area (spinal stabilizers). Initially, an intensity corresponding to 50% one-repetition maximum (1RM) was used, which was then increased to 60% 1RM after the 2nd month. Each exercise was performed in three series of 12 repetitions with 30-s intervals between series and 1-min intervals between the different types of exercise. Each full training session lasted approximately 50 min. Before and after the exercise sessions, the participants stretched for 5 min and warmed up/cooled down on an ergometric bicycle (Life Cycle 9100) for 5 min. All exercise sessions were performed at the same time of the day, 5 to 6 p.m.

Stretching

Stretching followed the Tworoger et al. protocol,[25] which consisted of 48 stretching sessions, including 60 min of low-intensity stretching, three times a week, from 5 to 6 p.m., for 4 months. The session began with a 5-min walk around the room, followed by 45 min of stretching exercises involving the upper and lower limbs, with 8-10 types for each body region.

Design and procedures

The design included two evaluations: baseline (pre-intervention) and after the 4-month intervention (not during the intervention) or after the control treatment. All evaluations were conducted according design in all three experimental groups (Figure 1).

Measures

Insomnia severity

The Insomnia Severity Index (ISI) was used to assess insomnia-related complaints. It is a short and easy self-applied scale with seven items scored from 0 to 4, with a total score varying from 0 to 28. The total score is interpreted as follows: absence of insomnia (0-7); sub-threshold insomnia (8-14); moderate insomnia (15-21); and severe insomnia (22-28).[27]

Subjective sleep quality

The Pittsburgh Sleep Quality Index (PSQI) was used to assess sleep quality over the previous 4 weeks in the pre- and post-intervention. SOL, sleep duration, and SE (ratio between sleep duration and total time in bed x 100) were obtained. A global score $>$ 5 indicates poor sleep quality.[28]

Objective home sleep

The participants were instructed to use the Octagonal Sleep Watch 2.01® (Ambulatory Monitoring, Inc., Ardsley, USA) device on their non-dominant wrist[29] for 15 consecutive days, including weekdays and weekends, while maintaining their typical routine. They were also instructed to record their bedtime and wake-up time by pressing the event button. During the recording period, the participants

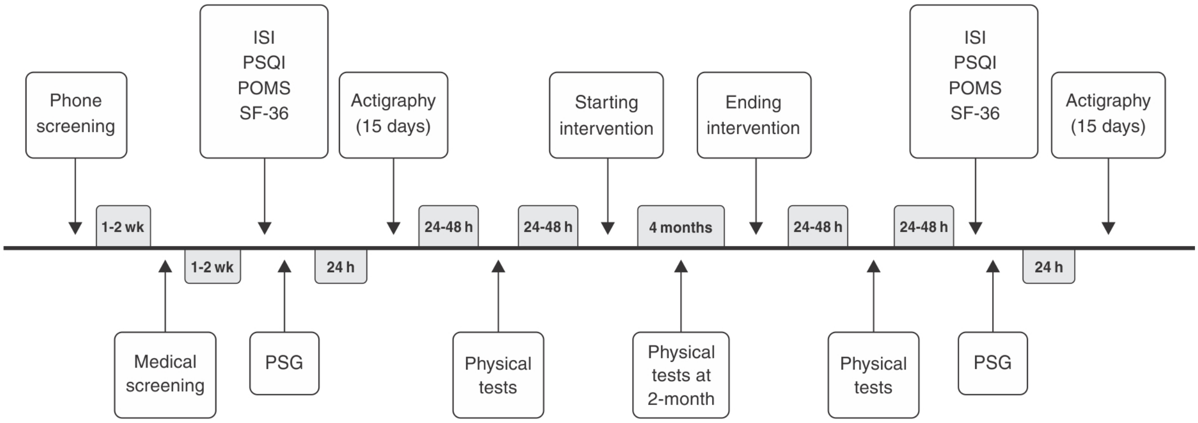

Figure 1 Study design timeline.ISI = insomnia severity index; POMS = Profile of Mood States; PSG = polysomnography; PSQI = Pittsburgh Sleep Quality Index; REM = rapid eye movements; SE = sleep efficiency; SF-36: Short Form 36-Item Health Survey; SOL = sleep onset latency; TST = total sleep time; WASO = wake after sleep onset.

were requested to keep a sleep and activity diary for later comparison with the actigraphy data. The data were acquired in Zero-Crossing Mode using 1-min epochs.[29,30] A computer analysis was performed using the algorithm suggested by Cole et al.,[30] which is available in Action W2 version 2.5.

Polysomnography (PSG)

PSG was performed with an EMBLA S7000 device in different 30-s windows classified as awake, sleep stages N1, N2, and N3 (non-rapid eye movement – NREM), and rapid eye movement (REM) sleep, according to Iber et al.[31] Four electroencephalogram (EEG) leads (C3-A2, C4-A1, Fz-A1, and O1-A1), two electrooculography (EOG) channels (C3), two electromyography (EMG) channels (submental and legs), and one electrocardiography (ECG) lead (modified D2) were recorded. The recording began at the patient's habitual bedtime and finished at 7 a.m. The analyzed sleep variables were: total sleep time (TST), SE (the ratio between TST and total recording time x 100), SOL, REM latency (LREM), WASO, arousals, apnea hypopnea index, periodic leg movement, and percentage of each sleep stage. Analysis of the events during PSG was carried out by two investigators, who used international criteria and were blind to volunteer grouping.

Mood and quality of life

The Profile of Mood States (POMS) questionnaire was used to evaluate mood states. It consists of 65 items in six domains: tension-anxiety, depression, anger-hostility, vigor-activity, fatigue, and confusion-bewilderment. The total mood disturbance score is derived by subtracting the vigor-activity score from the sum of the scores on the other subscales.[32]

Medical Outcomes Study Short-Form 36-Item Health Survey (SF-36) questionnaire was used to assess participant quality of life. It includes eight components: physical function, physical role, body pain, general health, vitality, social functioning, emotional role, and mental health. All scores ranged from 0 to 100, with a higher score indicating better quality of life.[33]

Physical tests

Maximum strength

A 1RM strength test was used to assess maximum strength in the exercise group. The participants were instructed to warm up on an ergometric bicycle for 5 min; the warm-up routine also included specific movements with fitness equipment that were assessed in the test. Four one-repetition attempts were then performed to establish the 1RM load, which was only validated when the movements were correctly performed. The recovery periods between attempts lasted from 3 to 5 min. The following Technogym muscle workout equipment was used: adductor for the thigh adductors; abductor for the thigh abductors; leg extension for the quadriceps; leg curl for the hamstrings; abdominal crunch for the abdominal region; lower back for the paravertebral muscles; chest press for the pectoral area; vertical traction for the shoulders; arm curl for the biceps; and arm extension for the triceps.

Stretching

Flexibility was assessed with the Wells & Dillon sit-and-reach test,[34] which measures, in inches, posterior chain flexibility. The patients were asked to sit, legs outstretched, facing a wooden box with the soles of their bare feet flat against the side of the box and their knees kept locked flat against the floor. At the beginning of the test, one palm was placed on top of the other, facing down, at the edge of the top surface of the box, which was fitted with a measuring line. At the evaluator's command, the hands were slid forward, flexing the trunk to achieve the greatest possible distance. Three attempts were made, and the best result was used for analysis.

Data analysis

STATISTICA version 7.0 was used for all analyses. One-way analysis of variance (ANOVA) was used to verify differences in baseline measures. The primary outcome variable (ISI score) was evaluated by analysis of covariance (ANCOVA) of value changes (post- minus pre-intervention values) with control for baseline, followed by Duncan's post hoc test.

Changes in secondary outcomes (sleep and mood) were evaluated in an identical fashion to ISI scores. Pearson correlations were used to verify associations between changes in sleep and mood. Changes in maximal strength and flexibility were also assessed using repeated measures ANOVA following the resistance exercise and stretching interventions, respectively. The data are presented as mean ± standard error; statistical significance was set at $p < 0.05$.

Results

A total of 253 individuals responded to the study's advertisement by telephone or e-mail and expressed interest in participating. Of this total, 192 did not meet the inclusion criteria. During the initial assessment stage, 30 of the remaining individuals were excluded in the medical screening. Thus 20 patients began the intervention programs and nine remained in the control group. One control group participant subsequently abandoned the study due to family problems. Thus, the final control group consisted of eight individuals (n=8), the stretching group of 10 (n=10), and the resistance group of 10 (n=10). All insomnia patients successfully completed the 48 exercise sessions. When a session was missed, it was rescheduled on any other weekday in the same week. Thus, all patients completed the 48-session protocol.

There were no significant baseline differences between treatments. The general characteristics of the participants are described in Table 1. Significant differences were observed in ISI between groups ($F_{2,24} = 7.27$; $p = 0.003$). Duncan post-hoc analysis showed significant differences between the control group and both the resistance exercise and stretching groups (Table 2). Global PSQI scores also differed between groups ($F_{2,24} = 6.08$; $p=0.007$),

Table 1 General participant characteristics

	Control (n=8)	Stretching (n=10)	Resistance (n=10)
Age (years)	40.3±2.7	45.5±2.5	44.5±2.2
Weight (kg)	76.8±5.5	68.2±4.8	70.6±3.2
Height (cm)	166.5±4.1	162.5±2.4	163.6±2.5
BMI (kg/m^2)	27.9±2.0	25.9±1.7	26.7±1.6
Insomnia duration (years)	8.4±3.1	6.5±2.7	5.4±1.4

Data presented as mean ± standard error.
BMI = body mass index.
One-way analysis of variance (ANOVA), $p > 0.05$.

Table 2 Sleep evaluated by polysomnography, actigraphy, and questionnaires

	Control (n=8)		Stretching (n=10)		Resistance (n=10)	
	Baseline	Change (Δ)	Baseline	Change (Δ)	Baseline	Change (Δ)
ISI (0-28)	16.8±2.6	2.3±1.8	18.7±1.2	-8.1±2.0*	21.3±1.0	-10.5±2.3*
Wrist actigraphy						
TST (min)	395.4±14.8	-21.4±18.7	392.4±13.1	23.5±19.3	363.5±17.9	31.6±9.9
SOL (min)	16.2±3.0	2.2±2.1	17.0±2.1	-5.2±1.9*	19.6±5.1	-7.1±4.6*
WASO (min)	34.8±5.0	3.6±4.2	30.1±4.0	-7.1±3.0*	34.9±6.3	-9.3±2.8*
SE (%)	86.3±2.2	-2.3±2.0	89.1±0.8	5.0±0.8*	86.8±1.7	4.4±1.8*
Polysomnography						
SOL (min)	32.2±12.1	-4.3±10.1	22.9±7.0	4.6±9.1	28.4±6.6	-6.4±6.5
REM latency (min)	86.1±19.5	24.5±21.7	133.9±23.2	-41.0±23.1	85.5±11.9	21.5±24.0
TST (min)	301.3±31.0	26.9±19.5	333.5±23.3	39.2±20.3	317.2±18.6	-12.7±20.8
SE (%)	74.1±6.5	1.4±4.5	78.8±4.3	4.5±4.3	78.4±5.1	-1.9±4.5
WASO (min)	72.4±24.1	-1.0±17.2	65.3±14.2	-14.5±14.4	62.3±20.8	-5.5±9.7
Stage 1 sleep (%)	16.0±5.1	-3.2±1.3	8.5±1.7	1.0±2.0	10.9±2.4	0.4±1.6
Stage 2 sleep (%)	42.7±2.4	6.1±3.0	48.9±2.5	0.2±2.4	45.5±1.7	0.7±4.5
Stage 3 sleep (%)	24.3±3.4	-3.7±2.1	23.5±3.2	-2.5±2.1	24.2±2.7	-1.9±3.5
REM sleep (%)	17.0±3.3	0.6±2.0	19.1±2.0	1.3±2.4	19.4±2.7	0.9±1.4
PSQI						
Global score (0-21)	12.8±0.9	-0.1±0.8	12.0±0.7	-3.9±1.5*	12.7±0.4	-5.3±0.8*
Sleep latency (min)	78.1±20.7	-15.6±18.4	67.3±23.4	-37.9±25.3	75.0±15.9	-47.5±15.0
SE (%)	59.8±7.7	2.1±4.3	64.9±6.0	13.3±6.3	69.8±3.7	19.5±3.9*
Sleep duration (h)	4.3±0.5	-0.1±0.2	4.3±0.3	1.6±0.6*	4.6±0.3	1.2±0.3*

Data presented as baseline and mean change ± standard error.
ISI = insomnia severity index; PSQI = Pittsburgh Sleep Quality Index; REM = rapid eye movements; SE = sleep efficiency; SOL = sleep onset latency; TST = total sleep time; WASO = wake after sleep onset.
* Analysis of covariance (ANCOVA): $p < 0.05$ statistically significant compared with control.

as well as SE ($F_{2,24}$ = 4.21; p = 0.03) and sleep duration ($F_{2,24}$ = 4.81; p = 0.02), assessed using PSQI. Post-hoc analysis showed significant differences between the control group and both the resistance and stretching groups for global PSQI score and sleep duration. Compared with the control group, PSQI-sleep efficiency improved only after resistance exercise (Table 2). No significant differences in ISI or PSQI were found between resistance exercises and stretching.

There were significant differences in actigraphy data between groups for sleep latency ($F_{2,24}$ = 4.16; p = 0.03), SE ($F_{2,24}$ = 5.46; p = 0.01) and WASO ($F_{2,24}$ = 5.94; p = 0.008). Post-hoc analysis showed significant differences between the control group and both the resistance exercise and stretching group for all above-described sleep variables (Table 2). However, there were no significant post-intervention differences between the resistance exercise and stretching groups for actigraphic sleep. No significant differences were observed between groups for polysomnographic sleep measures.

Significant improvements were observed between groups in tension-anxiety as assessed with the POMS scale ($F_{2,24}$ = 4.41; p = 0.02). Post-hoc analysis showed significant differences between the control and stretching groups (Table 3), but not between the resistance exercise and stretching groups. No significant correlations were observed between changes in tension-anxiety and sleep improvements. No significant quality of life differences were observed between groups (Table 3). Table 4 summarizes the significant differences in maximum strength and flexibility between baseline, 2-month and post-intervention measures.

Table 3 Clinical symptoms of mood and quality of life

	Control (n=8)		Stretching (n=10)		Resistance (n=10)	
	Baseline	Change (Δ)	Baseline	Change (Δ)	Baseline	Change (Δ)
POMS (score)						
Tension-anxiety	11.6±3.2	0.9±2.4	14.8±2.1	-6.8±1.3*	8.0±2.5	-1.8±1.6
Depression	10.3±4.2	-1.2±1.4	15.9±4.7	-5.9±2.7	8.8±3.1	-3.5±2.8
Anger-hostility	10.8±3.8	3.4±6.1	13.5±3.5	-5.2±1.8	11.2±4.1	-1.5±1.5
Vigor-activity	16.5±1.3	0.8±1.0	12.7±2.1	3.9±2.2	19.3±2.2	0.4±3.3
Fatigue	9.9±2.6	-0.4±1.5	13.7±2.4	-4.8±1.4	11.7±2.2	-4.9±2.2
Confusion bewilderment	3.4±1.4	-1.4±1.0	6.8±2.1	-3.6±1.5	3.6±1.4	-1.8±1.1
SF-36 (0-100)						
Physical functioning	79.8±8.2	-1.9±1.9	69.5±8.7	8.5±5.6	92.5±3.0	2.5±1.7
Role-physical	62.5±14.2	9.4±17.6	47.5±13.1	23.8±12.7	52.5±9.5	15.0±9.3
Body pain	70.0±11.7	-0.1±9.4	57.2±8.4	8.0±7.8	58.9±7.6	13.4±11.1
General health perception	63.1±9.3	13.4±6.4	56.9±6.6	11.9±5.4	77.8±4.8	0.8±6.1
Vitality	52.5±6.9	3.7±4.3	33.5±7.6	25.5±8.9	45.0±7.6	23.0±8.2
Social functioning	67.2±11.1	5.9±5.7	52.5±9.1	29.0±9.5	67.5±10.1	17.5±11.2
Role-emotional	66.7±12.6	16.7±8.9	30.0±13.6	26.7±20.4	36.7±10.5	33.3±15.7
Mental health	64.0±7.0	-2.5±4.9	47.6±7.9	21.2±8.2	57.4±8.1	20.2±7.3

Data presented as baseline and mean change ± standard error.
POMS = Profile of Mood States; SF-36 = Short Form 36-Item Health Survey.
* Analysis of covariance (ANCOVA): $p < 0.05$ statistically significant compared with control.

Table 4 Physical tests: 1RM and sit and reach flexibility test results

	Baseline	2 months	Post with
1RM exercises (lb)		Resistance exercise (n=10)	
Leg extension	116.5±2.5	123.7±2.3	143.5±2.7*†
Leg curl	89.5±2.1	103.3±2.2	122.3±2.0*†‡
Abductor	119.0±2.7	128.2±2.7	144.8±2.4*†‡
Abductor	103.5±2.7	116.7±2.4	137.3±2.6*†‡
Vertical Traction	98.0±2.3	110.1±2.2	122.8±2.6*†
Chest press	71.0±1.9	77.0±2.0	89.5±2.2*†‡
Arm Curl	26.0±1.0	39.8±1.7	50.8±1.7*†‡
Arm extension	76.5±1.8	89.0±2.4	102.5±2.3*†‡
Lower back	85.0±2.6	102.3±2.5	119.2±2.5*†‡
Abdominal crunch	57.5±1.9	69.5±2.4	83.8±2.9*†‡
		Stretching (n=10)	
Sit and reach test (cm)	22.2±26.4	27.3±19.7	31.1±15.2*†‡

Data presented as mean ± standard error in pounds.
1RM = one-repetition maximum test.
Repeated measures analysis of variance (ANOVA) – Duncan post-hoc test, $p < 0.05$.
* Baseline vs. post-treatment.
† 2-month vs. 4-month; ‡ baseline vs. 2-month.

Discussion

The results did not support our first hypothesis that resistance exercise would lead to greater improvements in sleep than stretching. However, in agreement with our second hypothesis, both resistance exercise and stretching decreased insomnia severity (ISI). Moreover, both the resistance exercise and the stretching interventions improved sleep quality (PSQI) and actigraphic measures of home sleep (SOL, WASO, and SE) compared to the control group, but no significant differences between treatments were observed for polysomnographic variables. Stretching also reduced tension-anxiety, but no other significant treatment differences were observed for mood or quality of life.

Previous studies have described the positive effects of moderate-intensity aerobic exercise on objective and subjective sleep in patients with chronic insomnia.[11,13,14] The positive effects of resistance exercise training on chronic insomnia had not been previously described in the literature. However, resistance exercise has been shown to cause significant improvements in subjective sleep quality in older adults with depression.[17,18]

A number of mechanisms have been proposed to explain improved sleep following acute and chronic exercise, including anxiolytic /antidepressant effects[35,36] and circadian phase-shifting effects.[37] In the present study, no significant mood differences were observed between the resistance exercise and control groups.

Sleep improvement after stretching has also been observed in previous studies on postmenopausal women[25] and older adults[26] using a similar protocol. These improvements could be indicative of the tension-reducing effects of stretching, which could work in a similar way to progressive muscle relaxation, an established non-pharmacologic treatment for chronic insomnia.[7,8] In the present study, a significant reduction in tension-anxiety was also observed between the stretching and control groups. Similarly, Li et al.[38] found a significant reduction in anxiety after progressive muscle relaxation in pulmonary arterial hypertension patients. Nevertheless, no significant correlation was observed between sleep improvement and anxiety reduction in the present study. Our expectation that resistance exercise would lead to greater sleep improvements than stretching was based on the more extensive literature indicating sleep improvements following resistance exercise.[17-19]

To our knowledge, this is the first study to have investigated the chronic effects of resistance exercise on insomnia and the first study to have evaluated sleep after resistance exercise using actigraphy and PSG.[16] The mechanisms by which resistance exercise might improve sleep are unclear.[16] The lack of significant difference is consistent with the results of Tworogger et al.,[25] who compared moderate-intensity aerobic exercise and stretching in post-menopausal women.

In the present study, the lack of significant improvements in PSG measurements of objective sleep could be attributable to the fact that PSG was assessed on only one night, whereas actigraphy was assessed over 15 nights. Actigraphy has been a reliable method for evaluating sleep patterns in patients with insomnia.[39,40] These results are consistent with previous research in which no significant differences in PSG were observed after yoga and stretching in postmenopausal women.[24]

One limitation of the present study was that participants were randomly assigned to the resistance or stretching groups, but not to the control group. It should be pointed out that our university's institutional review board does not allow patients to be assigned to a non-treatment control that is not expected to provide any benefit. However, control participants may be assessed in the manner employed in this study if they refuse to enter an experimental protocol. There were no significant differences between the control group and the other participants in baseline measures (see Table 1). Nevertheless, there could have been differences between individuals who were willing and able to participate in the experimental study and those who were not. These differences could have favored greater improvements in the experimental participants, although the control group could not be considered non-volunteers, since they did devote considerable time to the study assessments. However, numerous other potential biases associated with non-randomization and fewer participant-researcher interactions in the control group could have resulted in greater improvements in the experimental treatments, including expectancy, demand, and Hawthorne effects.

The small sample size was also a limitation. However, there was adequate power to detect differences between the control and experimental treatments. Moreover, post-hoc analysis indicated that 80% power to detect significant differences ($p < 0.05$) in improvement in ISI between resistance exercise and stretching would have required 109 participants.

In conclusion, the results suggest no significant differences between 4-month resistance exercise vs. stretching for improving insomnia severity and objective and subjective sleep in patients with chronic insomnia. However, both the resistance exercise and stretching treatments led to significantly greater effects than in the control group.

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Disclosure

The authors report no conflicts of interest.

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