Tai Chi and Self-Rated Quality of Sleep and Daytime Sleepiness in Older Adults: A Randomized Controlled Trial

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OBJECTIVES: To determine the effectiveness of tai chi on self-rated sleep quality and daytime sleepiness in older adults reporting moderate sleep complaints.

DESIGN: Randomized, controlled trial with allocation to tai chi or exercise control.

SETTING: General community.

PARTICIPANTS: One hundred eighteen women and men aged 60 to 92.

INTERVENTION: Participants were randomized into tai chi or low-impact exercise and participated in a 60-minute session, three times per week, for 24 consecutive weeks.

MEASUREMENTS: Primary outcome measures were the seven subscales of the Pittsburgh Sleep Quality Index (PSQI), PSQI global score, and Epworth Sleepiness Scale (ESS). Secondary outcome measures were physical performance (single leg stand, timed chair rise, 50-foot speed walk) and 12-item short form (SF-12) physical and mental summary scores.

RESULTS: Tai chi participants reported significant improvements in five of the PSQI subscale scores (sleep quality, sleep-onset latency, sleep duration, sleep efficiency, sleep disturbances) ($P < .01$), PSQI global score ($P = .001$), and ESS scores ($P = .002$) in comparison with the low-impact exercise participants. Tai chi participants reported sleep-onset latency of about 18 minutes less per night (95% confidence interval (CI) = –28.64 to –7.12) and sleep duration of about 48 minutes more per night (95% CI = 14.71–82.41) than low-impact exercise participants. Tai chi participants also showed better scores in secondary outcome measures than low-impact exercise participants. Both groups reported improvements in SF-12 mental summary scores.

CONCLUSION: Older adults with moderate sleep complaints can improve self-rated sleep quality through a 6-month, low- to moderate-intensity tai chi program. Tai chi appears to be effective as a nonpharmacological approach to sleep enhancement for sleep-disturbed elderly individuals. **J Am Geriatr Soc 52:892–900, 2004.**

Key words: exercise; tai chi; quality of sleep; daytime sleepiness

Sleep disorders, such as insomnia, and excessive daytime sleepiness, are major health problems in elderly populations.[1] Self-reported sleep complaints are common,[2] and it is estimated that up to 50% of elderly persons complain about their sleep.[3] In a National Institute on Aging funded study of more than 9,000 persons aged 65 and older, more than one-half of the sample reported at least one chronic sleep complaint.[4] Typical symptoms of sleep problems in the elderly include difficulty falling asleep and maintaining sleep, early morning awakening, and excessive daytime sleepiness. The consequences of chronic sleep problems can include significant health implications. Studies have shown that poor sleep quality or daytime sleepiness in older adults is associated with impaired health status, low levels of physical activity, limitations in activities of daily living, poor physical functioning, depressive symptoms, and increased incidence of cardiovascular disease morbidity and mortality.[5–12]

Many researchers and health organizations have recommended daily exercise as a nonpharmacological sleep-promoting treatment.[1,2,13–15] Regular exercise, such as brisk walking, may help to improve sleep quality and shorten the time it takes to fall asleep in older persons. A community-based, randomized, controlled study of the effect of exercise on sleep quality in older adults with mild to moderate sleep complaints[16] showed that, in comparison with a no-exercise group, older adults participating in moderate-intensity exercise reported significant improvements in self-rated sleep quality. Exercise reduced sleep-onset latency by about 15 minutes and increased sleep duration by approximately 45 minutes per night. By considering an alternative exercise activity, the current

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study investigated the effect of tai chi on improving sleep quality and reducing daytime sleepiness in older adults.

Tai chi, a traditional Chinese health-promoting exercise, is considered a suitable alternative or supplementary form of daily physical exercise for the elderly[17–20] because it is a low- to moderate-intensity, self-paced whole-body activity that incorporates a meditational component accompanying the rhythmical movements. Practicing tai chi has been shown to produce physiological benefits, including reductions in blood pressure,[21–23] improved cardiovascular fitness,[24] and muscle strength,[25–27] and functional benefits, including improved balance,[28] gait speed,[29] and self-rated physical function.[30] Because of the unique balance-improving properties of tai chi, reductions in falls and risk of falling have been documented.[22] It has also been shown to enhance mental health, including reductions in anxiety and depression,[31–33] enhancement in physical self-efficacy and domain-specific esteem,[34,35] and increases in positive affect and well-being.[33,36] Therefore, promoting tai chi among the elderly has the potential to maintain routine physical functioning and improve psychological conditions.

Elderly individuals often experience psychological disturbances such as anxiety and depression, which frequently underlie sleep problems.[2] Because tai chi has been shown to be effective in reducing anxiety[31,32] and depression,[33] the potential utility of tai chi in treating sleep disorders and improving quality of life in older adults is worthy of exploration from a health-promotion perspective. To this end, in a randomized trial, the effects of a tai chi program on self-rated sleep quality, daytime sleepiness, and quality-of-life indicators in adults aged 60 and older were compared with those of a low-impact exercise program.

METHODS

Study Design

The study was a randomized, controlled trial designed to compare the effects of a 24-week tai chi program with low-impact exercise (specifically, stretching/controlled breathing) on quality of sleep and daytime sleepiness in older adults who had reported moderate sleep complaints. Secondary outcomes were measures of physical performance (single leg stand, timed chair rise, 50-foot speed walk) and quality of life (12-item short form (SF-12) physical and mental summary scores). Recruitment occurred through community-wide promotion, including advertisements in local newspapers, churches, senior centers, and senior residences, and referrals. To reduce the potential of participant expectancies on outcomes, the advertisements for recruitment focused more generally on exercise and health outcomes in older adults, rather than sleep quality per se.[16] Data were collected at baseline, 3 months, and 6 months, between March 2002 and June 2003, in a staggered recruitment procedure. The Oregon Research Institute institutional review board approved the research protocol.

Study Participants

Participants were community-dwelling older adults recruited in the Eugene-Springfield area, Oregon. For the purpose of the study, a variety of eligibility criteria were used to enroll participants. With a few exceptions, the inclusion criteria used by another study[16] were closely followed, including (a) aged 60 and older; (b) being inactive, as defined by the absence of involvement in any structured or regular exercise activities during the previous 3 months; (c) being healthy to the extent that participation in exercise testing and an exercise program would not exacerbate any existing disease conditions; (d) physician approval for participation; (e) willingness to be randomly assigned to intervention condition and participate on a weekly basis for the 24-week intervention; (f) free of a clinically diagnosed or clinically significant sleep disorder (e.g., sleep apnea) or a medical or psychiatric condition (e.g., chronic pain, clinical depression) responsible for sleep complaints; (g) use of prescription sleep medication no more than once a week for duration of the study; (h) no use of other psychotropic medication; (i) not a current recipient of sleep disorder treatment; (j) no indication of significant cognitive impairment as indicated by a cutoff score of 3 on the Pfeiffer Mental Status Questionnaire;[37] (k) consumption of no more than seven alcoholic beverages per week or use of alcohol close to bedtime or smoking more than 10 cigarettes per day; and (l) moderate sleep complaints, defined as ratings of 3 or higher on two of three sleep items drawn from the Sleep Questionnaire and Assessment of Wakefulness[38] or a rating of 4 or higher on any one of three sleep items that assessed the problem of falling asleep at night, waking up during the night, and waking and getting up in the morning.

Randomization

Upon receipt of informed consent and completion of the baseline assessments, participants were randomized to experimental groups with an allocation ratio of 1:1 according to computer-generated random numbers. No stratification or blocking factors were used. Assignments were concealed from participants until baseline assessments were completed. The person who generated the randomization schedule was not involved in screening or testing.

Interventions

Participants in the tai chi condition attended a 1-hour exercise session, three times per week, for 24 weeks. The tai chi taught was based on a simplified Yang style, 8-Form Easy Tai Chi,[20] which emphasized multidirectional weight-shifting, awareness of body alignment, and multisegmental (arms, legs, trunk) movement coordination. Regulated breathing was also emphasized as part of the exercise and integrated into the tai chi movement routine. Sessions included 5 to 10 minutes of warm-up, tai chi practice, and 5 to 10 minutes of cool-down. Instruction covered learning new forms and reviewing forms learned in previous sessions. Each practice session included musical accompaniment.

The low-impact exercise comparison group also met for 1 hour, three times per week, for 24 weeks. This program predominantly consisted of seated exercises accompanied by controlled breathing, stretching, and relaxation. The rationale for designing this condition was to provide participants with a structured, low-intensity exercise program that would contain comparable social interaction and enjoyment components but with considerably less meditational components and less physical demands than the tai chi program. Each session began with 10 minutes of warm-up (walking and arm, neck, and leg circles), followed by seated light stretches for upper and lower-body muscle groups along with deep abdominal breathing. Ten minutes of cool-down concluded the session. Music accompanied all class activities.

The majority of the exercise training sessions (82%) took place in the morning (at approximately 10:00 a.m.). To accommodate instructors and participant schedules, some classes (18%) were held in the early afternoon (at approximately 2:30 p.m.). Class sizes ranged from six to 15 people (mean = 10). Intervention classes were conducted in local churches and senior (retirement) residential housing complexes. Five instructors (two for tai chi, three for low-impact exercise) taught the classes. These individual instructors were well qualified in exercise instruction and had a considerable history of teaching in the local community (mean = 10 years for tai chi; mean = 8 years for low-impact exercise).

Measurement and Procedures

The primary outcome measures with respect to efficacy of exercise were self-rated sleep quality and daytime sleepiness. Two measures were used: Pittsburgh Sleep Quality Index (PSQI)[39] and Epworth Sleepiness Scale (ESS).[40] The PSQI includes seven indices: subjective quality, latency (time needed to fall asleep), duration (number of hours of actual sleep per night), efficiency (total sleep time divided by time in bed, converted to a score of 0–3), sleep disturbances (e.g., waking up in the middle of the night), use of sleeping medication, and daytime dysfunction (e.g., having difficulty staying awake during the day). Each of the component scores ranged from 0 to 3. The PSQI total score ranges from 0 to 21 points, with higher scores indicating poorer sleep quality. An additional PSQI score was calculated for percentage of sleep efficiency (number of hours slept divided by the number of hours spent in bed $\times$ 100).[16] The ESS is an eight-item measure that quantifies an individual's sleepiness by his or her tendency to fall asleep in daily situations. Participants were asked to rate on a scale of 0 to 3 how likely they would be to doze off or fall asleep in eight situations, based on their usual daily routine in recent times. Higher scores signify increased daytime sleepiness. The ESS has been well validated and has shown good reliability and internal consistency.[40]

Secondary outcome measures were physical performance (single-leg stand, timed-chair rise, 50-foot speed walk) and quality-of-life indicators operationalized using SF-12.[41] Single-leg stand tests measure right and left leg standing for a maximum of 60 seconds. For each leg, three trials were allowed, with scores averaged across the final two trials. The chair-rise test measures the time required to complete five full stands as quickly as possible from a sitting position,[42] and the 50-foot walk measures the time taken to walk 50 feet.[43] The SF-12 contains 12 self-report items, reflecting what respondents are able to do functionally, how they feel, and how they evaluate their health status. Two component scores, referred to as the mental and physical health summary scores, were calculated according to published scoring algorithms.[41] Each subscale was transformed into a scale from 0 to 100, with higher scores indicating better mental and physical health.

Two other measures used at baseline to assess participants' characteristics were the Center for Epidemiologic Studies Depression scale[44] and the Physical Activity for the Elderly Scale,[45] which assesses levels of physical activity in the areas of leisure, household, and occupational activity during the previous 7 days.

Two research assistants conducted all study outcome assessments. These assessors were trained extensively in accordance with standardized test protocols for each measure. The assessors were not involved in randomization or delivering the intervention, nor were they apprised of the study hypotheses or given information related to prior outcome measures.

Statistical Analysis

All of the primary and secondary analyses were conducted on an intention-to-treat basis, so that all participants were included according to original treatment assignment and analyzed regardless of adherence to treatment or dropout status. Incomplete data resulting from premature intervention dropouts were handled through the last observation carried forward method.[46] Baseline demographic descriptors and primary and secondary outcome measures were compared across groups, using analysis of variance (ANOVA) for continuous variables and the chi-square (or Fisher exact) test for categorical variables. The predefined primary statistical analysis was repeated measures ANOVA, which was performed to compare pre- and postintervention changes in the repeated outcome measures (a within-subjects factor) between the two exercise conditions (a between-group factor). Analyses were conducted with and without important adjustments for baseline covariates (e.g., sex, living condition, health status) using ANOVA or analysis of covariance models. When demographic covariates (age, sex, education, living condition, health status) were included in the models, the results were not changed. Therefore, results from these models are not reported. Pre- and postintervention change scores on the primary and secondary outcome variables and their 95% confidence intervals were computed to determine the intervention effects. Two-sided P-values of less than .05 were considered to indicate statistical significance. No subgroup or supplemental analyses were performed per the a priori analysis plan. All statistical analyses were performed using SPSS (SPSS Inc., Chicago, IL).

Effect sizes from another study[16] were considered in the power calculations. For example, a sample size of 45 participants in each group was estimated to provide more than 80% power to detect between-group mean differences of 2 $\pm$ 3.0 points for the PSQI global sleep quality index, 10 $\pm$ 15 minutes for the sleep latency index, and 45 $\pm$ 1.5 minutes for the sleep duration index at the end of 24-week intervention.

RESULTS

An initial pool of 317 individuals responded to the study promotion. Sixty-three percent of these were not assessed

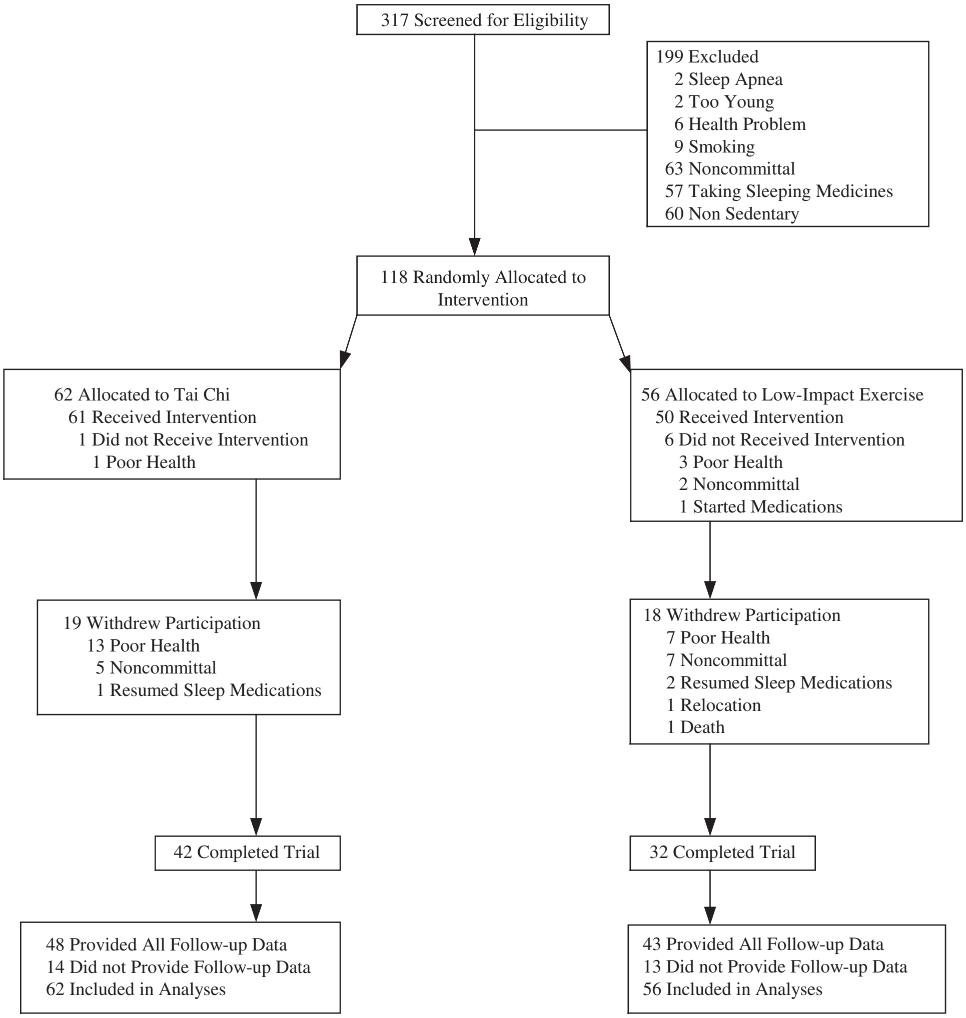

Figure 1. A summary of study randomization, participant flow, and retention through the course of the trial.

because they did not meet the screening criteria (n = 130), reported poor health (n = 6), or were unable to commit to the length of the study (n = 63). One hundred eighteen individuals (37%) met the criteria and were assessed and randomized: 62 to tai chi and 56 to low-impact exercise. Seven randomized individuals (one in tai chi, six in low-impact exercise) did not attend any intervention session (one started taking medications, two could not commit to the study duration, four could not attend because of deteriorating health conditions). Twenty-seven participants (14 in tai chi, 13 in low-impact exercise) were lost during the study follow-up, but there were no significant differences between these participants in the demographic or health descriptors at baseline. A summary of randomization, participant flow, and retention through the course of the trial is shown in Figure 1.

Baseline Participant Characteristics

The baseline demographic characteristics and health indicators of the participants in the two exercise programs are summarized in Table 1. Analyses assessing the comparability of the two experimental groups indicated that they were well matched with regard to baseline demographic, health, depression, and physical activity descriptors. Comparisons of primary and secondary outcome measures at preintervention are presented in Table 2, showing no between-group differences on any outcome measures at baseline. Additionally, there were no statistical differences in primary outcomes (i.e., PSQI and ESS scores) or demographic variables (e.g., sex, living situations) assessed at baseline between those who completed the study (n = 74) and those who did not (n = 44). The mean baseline global index score on the PSQI of 13.34 for this sample placed the participants in the moderate range for sleep complaints.[39]

Attrition, Compliance, and Adverse Events

Thirty-seven participants (33%) withdrew (19 in tai chi; 18 in low-impact exercise), excluding no-shows, during the intervention period. Most dropouts occurred within the first 3 months of the study (66%). Reasons for dropout were medical (health) problems unrelated to study participation (n = 20), personal reasons related to the study (time commitment, inconvenience, etc.) (n = 12), resumed sleep medications (n = 3), death unrelated to study participation (n = 1), and relocation (n = 1). There was no statistical difference between the tai chi and low-impact exercise dropouts in baseline descriptors or primary outcome measures.

A measure of compliance with the intervention protocol was attendance at the group sessions. Based on

Table 1. Baseline Characteristics of Study Participants by Randomized Group

Characteristic	Tai Chi (n = 62)	Low-Impact Exercise (n = 56)	*P*-value*
Female, n (%)	52 (84)	44 (79)	.33
Age, mean ± SD	75.30 ± 7.8	75.45 ± 7.8	.87
White, n (%)	58 (94)	54 (96)	.35
≥High school education, n (%)	60 (97)	53 (95)	.34
Household income <$35,000, n (%)	42 (68)	44 (78)	.23
Living alone, n (%)	42 (68)	30 (54)	.19
Body mass index, kg/m^2, mean ± SD	28.01 ± 5.0	28.18 ± 6.4	.87
Resting pulse, beats/min, mean ± SD	70 ± 13.1	68 ± 12.1	.33
Systolic blood pressure, mm Hg, mean ± SD	133.76 ± 11.5	134.07 ± 11.51	.88
Diastolic blood pressure, mm Hg, mean ± SD	76.22 ± 8.6	76.07 ± 10.4	.93
Habitual physical activity, mean ± SD†	97.57 ± 68.9	102.86 ± 56.3	.65
Health status, mean ± SD‡	3.18 ± 0.9	3.16 ± 0.8	.92
Depression, mean ± SD§	6.34 ± 4.2	7.05 ± 4.4	.37
Common medical conditions, n, mean ± SD‖	2.27 ± 1.5	2.46 ± 1.5	.49
Taking over-the-counter sleep-related medication in previous week, n (%)	15 (24)	11 (20)	.55
Taking sleep-related prescriptions in previous week, n (%)	1 (2)	3 (5)	.26
Visits to health care provider(s) in previous 3 months, n (%)	2 (3)	4 (7)	.33
Treated by an alternative or complementary medicine health care provider in previous 3 months, n (%)	0 (0)	3 (4)	.22

* *P*-values are for comparison between tai chi and low-impact exercise groups.
† Measured using the Physical Activity Scale for the Elderly.[45]
‡ Measured on a 5-point Likert scale ranging from 1 = poor to 5 = excellent; higher scores indicating better health.
§ Measured using a short version of the Center for Epidemiologic Studies Depression scale.[44]
‖ Measured out of nine possible common medical conditions (e.g., diabetes, hypertension, depression).
SD = standard deviation.

instructor rolls of class attendance, class compliance rates across the 24-week period (72 sessions) were calculated for all participants who completed the trial (n = 74) (Figure 1). Median compliance was 60 sessions for both groups, ranging from 33 to 71 sessions for tai chi participants and from 34 to 71 sessions for the controls. Ninety-three percent of tai chi participants and 81% of the low-impact exercise participants attended 50 or more sessions ($P = .13$).

Table 2. Comparison of Pre-Intervention Scores on Primary and Secondary Outcome Measures by Randomized Group

Outcome Measure	Tai Chi (n = 62)	Low-Impact Exercise (n = 56)	F (1,89)	*P*-value
	Mean ± Standard Deviation			
Primary				
Pittsburgh Sleep Quality Index				
Subjective sleep quality	1.39 ± 0.84	1.38 ± 0.92	0.006	.94
Sleep latency, min	39.65 ± 28.45	38.48 ± 31.38	0.05	.83
Sleep duration, hr	6.58 ± 1.27	6.51 ± 1.41	0.07	.78
Habitual sleep efficiency	1.11 ± 1.22	1.18 ± 1.31	0.08	.78
Sleep disturbances	1.37 ± 0.66	1.36 ± 0.61	0.01	.91
Daytime dysfunction	1.09 ± 0.69	1.14 ± 0.72	0.12	.72
Use of sleep medication	0.48 ± 0.92	0.48 ± 0.83	0.001	.99
Global score (range 0–21)	13.32 ± 2.32	13.35 ± 2.66	0.005	.95
Epworth Sleepiness Scale (range 1–24)	9.02 ± 4.06	8.96 ± 3.59	0.005	.94
Secondary				
Right leg-stand (seconds)	7.47 ± 8.84	8.62 ± 12.57	0.33	.56
Left leg-stand (seconds)	7.12 ± 6.97	8.01 ± 10.68	0.29	.59
Chair rise (seconds)	12.49 ± 3.60	12.42 ± 3.53	0.01	.92
50-foot walk (seconds)	15.04 ± 5.76	14.59 ± 4.61	0.22	.64
SF-12 Physical Summary Score (range 1–100)	50.28 ± 24.68	52.10 ± 24.69	0.16	.69
SF-12 Mental Summary Score (range 1–100)	69.96 ± 21.56	66.52 ± 24.87	0.65	.42

SF-12 = 12-item short form.

Table 3. Primary and Secondary Outcome Measures at Baseline Through 6 Months by Intervention Condition

Outcome	Tai Chi (n = 62) Baseline	Tai Chi (n = 62) 6 Months	Tai Chi (n = 62) Change	Low-Impact Exercise (n = 56) Baseline	Low-Impact Exercise (n = 56) 6 Months	Low-Impact Exercise (n = 56) Change	Change Score Difference (95% Confidence Interval)*	*P*-value
Primary								
Pittsburgh Sleep Quality Index								
Subjective sleep quality	1.39 ± 0.84	0.47 ± 0.59	-0.92 ± 1.01	1.38 ± 0.92	1.20 ± 0.79	-0.18 ± 1.09	−0.74 (−1.13 to −0.35)	<.001
Sleep latency, minutes	39.65 ± 28.45	16.21 ± 0.950	-23.44 ± 29.21	38.48 ± 31.38	32.93 ± 17.43	-5.55 ± 29.75	−17.88 (−28.64 to −7.12)	.001
Sleep duration, hours	6.58 ± 1.27	7.45 ± 0.90	0.87 ± 1.041	6.51 ± 1.41	6.57 ± 1.18	0.06 ± 1.68	0.81 (0.25–1.37)	.005
Habitual sleep efficiency	1.11 ± 1.23	0.40 ± 0.81	-0.71 ± 1.16	1.18 ± 1.31	1.13 ± 1.19	-0.05 ± 1.58	−0.65 (−1.59 to −0.15)	.01
Habitual sleep efficiency, %†	77.94 ± 19.60	92.02 ± 18.79	14.07 ± 22.46	75.76 ± 19.56	77.48 ± 16.66	1.72 ± 21.13	12.36 (4.39–20.33)	.003
Sleep disturbances	1.37 ± 0.66	0.98 ± 0.46	-0.39 ± 0.64	1.36 ± 0.61	1.29 ± 0.46	-0.07 ± 0.68	−0.32 (−0.56 to −0.08)	.01
Daytime dysfunction	1.09 ± 0.69	0.89 ± 0.36	-0.21 ± 0.70	1.14 ± 0.72	1.030 ± 0.53	-0.11 ± 0.80	−0.10 (0.38–0.17)	.46
Sleeping medication	0.48 ± 0.92	0.33 ± 0.62	-0.15 ± 0.90	0.48 ± 0.83	0.50 ± 0.93	0.02 ± 0.77	−0.16 (−0.47–0.15)	.29
Global score (range 0–24)	13.32 ± 2.32	11.26 ± 1.52	-2.06 ± 2.40	13.35 ± 2.66	12.48 ± 2.59	-0.51 ± 2.63	−1.55 (−2.47 to −0.64)	.001
Epworth Sleepiness Scale (range 1–24)	9.02 ± 4.06	6.35 ± 2.89	-2.66 ± 4.24	8.96 ± 3.59	8.36 ± 2.91	-0.61 ± 2.68	−2.05 (−3.36 to −0.75)	.002
Secondary								
Right leg-stand, seconds	7.47 ± 8.84	12.31 ± 10.51	4.84 ± 7.06	8.62 ± 12.57	8.94 ± 11.21	0.32 ± 6.22	4.52 (2.08–6.95)	<.001
Left leg-stand, seconds	7.12 ± 6.97	12.48 ± 0.09	5.36 ± 5.01	8.01 ± 10.68	8.97 ± 10.65	0.95 ± 5.12	4.40 (1.92–6.88)	.001
Chair rise, seconds	12.49 ± 3.60	10.09 ± 3.66	-2.39 ± 3.11	12.42 ± 3.53	11.85 ± 4.61	-0.58 ± 3.28	−1.82 (−2.98 to −0.65)	.003
50-foot walk, seconds	15.04 ± 5.76	11.86 ± 3.70	-3.32 ± 5.32	14.59 ± 4.61	14.38 ± 7.68	-0.22 ± 6.71	−2.97 (−5.17 to −0.74)	.009
SF-12 Physical Score (range 1–100)	50.28 ± 24.68	60.82 ± 19.75	10.53 ± 17.51	52.10 ± 24.69	54.10 ± 5.69	1.99 ± 17.60	8.54 (2.13–14.95)	.009
SF-12 Mental Score (range 1–100)	69.95 ± 21.56	75.05 ± 15.61	5.09 ± 19.13	66.52 ± 24.87	72.08 ± 22.85	5.56 ± 20.81	−0.47 (−7.76–6.81)	.89

*Between-group differrences in change scores (post-minus pre-test scores).
† Calculated as the number of hours slept divided by the number of hours spent in bed times 100.
SF-12 = 12-item short form.

Because of the small cell size (three in tai chi, six in low-impact exercise) in the low adherence category, no subgroup analysis was performed to compare differences in the low- and high-attendance categories on the primary outcomes.

The research staff closely monitored exercise training sessions during the course of the intervention. The exercise instructors were first-aid certified, and they were encouraged to report any negative symptoms or signs resulting from exercise in their classes. No exercise-related injuries occurred in study participants during the trial.

Intervention Effects on Primary Outcomes

The intervention effects on the primary outcomes are presented in Table 3. Tai chi participants reported significant pre- to postintervention improvements in subjective sleep quality ($P < .001$), sleep latency ($P < .001$), sleep duration ($P < .001$), sleep efficiency ($P < .001$), sleep disturbances ($P < .001$), and sleep dysfunction ($P = .02$), but no significant change in the sleep medication subscale was observed ($P = .21$). Tai chi participants also reported significant improvements in the ESS scores ($P < .001$). Participants in the low-impact exercise program showed no improvement on any of the primary outcome scores.

Tai chi participants reported better improvements on the subjective sleep quality ($P < .001$), sleep latency ($P = .001$), sleep duration ($P = .005$), sleep efficiency ($P = .01$), and sleep disturbances subscales ($P = .01$) than did those in the low-impact exercise group. When the sleep efficiency subscale scores were analyzed using the PSQI items of usual hours of sleep per night, divided into the usual number of hours spent in bed times 100, tai chi participants showed significantly better improvements than participants in the low-impact exercise program ($P = .003$). Overall, tai chi participants had better scores on the PSQI global sleep index than did the low-impact exercise participants ($P = .001$). No statistical difference was observed between the intervention groups on the sleep dysfunction subscale ($P = .46$) or the use of sleep medication subscale ($P = .29$). Finally, tai chi participants reported significantly lower ESS scores than did low-impact exercise participants ($P = .002$).

Intervention Effects on Secondary Outcome Measures

The intervention effects on the secondary outcomes are presented in the bottom portion of Table 3. Tai chi participants recorded significant pre- to postintervention improvements in the two standing tests (right leg-stand: $P < .001$, left leg-stand: $P < .001$), chair rise ($P < .001$), 50-foot speed walk ($P < .001$), SF-12 physical summary score ($P < .001$), and SF-12 mental summary score ($P = .04$). Participants in the low-impact exercise program showed no improvement on any of the secondary outcome scores, with the exception of the SF-12 mental summary score ($P = .05$).

Tai chi participants showed significantly better improvements on all four physical performance measures (single-leg stand (right: $P < .001$; left: $P = .001$), chair rise ($P = .003$), and 50-foot speed walk ($P = .009$)) than did the low-impact exercise participants (Table 3). Tai chi participants also reported better improvement on SF-12 physical summary scores than did the low-impact participants ($P = .009$). As indicated previously, a significant improvement from baseline in the SF-12 mental summary scores was observed for the tai chi and low-impact exercise groups; there was no group difference ($P = .89$).

DISCUSSION

This study examined the effect of tai chi exercise on the primary outcomes of self-reported sleep quality and daytime sleepiness in a randomized, controlled trial of adults aged 60 and older. The participants in this study reported an overall PSQI score of greater than 5 at baseline, which met the criteria for disturbed sleep,[39] and a longer mean sleep latency (approximately 40 minutes) than that reported by another study.[16] In addition, the sample had a higher mean level of daily sleepiness on the ESS at baseline (mean = 8.99) than a random sample of noninstitutionalized Medicare enrollees (mean = 6.28).[10] This study sample therefore represented a group of individuals who had moderate sleep complaints.

The major findings of this study were that older adults with moderate sleep complaints benefited from tai chi exercise. No improvements in the low-impact exercise group were evident. Improvements in tai chi with respect to sleep quality were observed in five subscales of the PSQI. The findings are particularly evident in sleep latency (reduced by about 18 minutes per night) and sleep duration (increased by about 48 minutes per night). These results are generally congruent with the other study[16] findings, which showed that a 16-week exercise intervention was able to reduce sleep-onset latency by about 12 minutes and increase sleep duration by roughly 42 minutes per night. However, the current study also showed reductions in daytime sleepiness as measured using the validated ESS, which addresses the likelihood of feeling drowsy or falling asleep in daily situations. Although daytime sleepiness is being recognized increasingly as a significant public health problem,[47] few behavioral interventions have been reported to examine the usefulness of exercise in reducing levels of daytime sleepiness in older adults. Thus, results from this trial provide preliminary evidence linking benefits of exercise (tai chi) to decreased daytime sleepiness.

Little evidence emerged from this study to support the usefulness of low-impact exercise on sleep measures. This exercise was chosen as a comparison group because it represented a simple, light, commonly recommended exercise modality[14,15] that was temporally comparable with the tai chi program. The low-intensity exercises, primarily consisting of stretching activities, did not lead to improvements in sleep quality and physical function measures.

This study also found a concomitant change in functional performance measures. Compared with participants in the low-impact exercise program, tai chi participants showed significant improvements on all physical performance measures and the SF-12 physical summary scores, as reported in a previous study,[30] but both groups showed improvements on the SF-12 mental summary scores, which was possibly attributable to the fact that both programs offered the participants the opportunity for social interaction and companionship, which were expected to have a positive effect on measures of mental well-being.

The underlying mechanisms that govern improvements in sleep related to tai chi remain to be investigated. Tai chi movements are performed slowly and gently, with deep diaphragmatic breathing and relaxation coupled with smooth, flowing movements (postures), characteristics conducive to an enhanced feeling of well-being and altered mental state, which may possibly lead to improved sleep quality. Tai chi may also help to modify circadian rhythm[2,14] in a manner beneficial to improved quality of sleep. Findings from this study suggest that tai chi may serve as a useful nonpharmacological approach to sleep problems in older adults. Beyond these benefits, tai chi has additional advantages of being low cost[30] and easy to implement (e.g., indoors or outdoors) in clinical care or community settings and can be performed at low to moderate intensity.[20] Given the general consensus that physical activity is beneficial for sleep disorders, current evidence suggests that tai chi can be considered a useful behavioral regime, or healthy exercise routine, for older adults with sleep complaints. Consistent with this general recommendation, tai chi should be performed during the day and not late in the evening.[15]

LIMITATIONS

The results of this study should be interpreted in the context of several limitations. First, the study recruitment was targeted at elderly individuals from the general community who had self-reported sleep complaints, as opposed to clinic-based patients with diagnosed sleep disorders. The results may be more clinically meaningful had individuals with known diagnosed sleeping disorders (e.g., insomnia) been targeted and studied. Although the possibility cannot be excluded that the results might have differed had a clinic population been considered, two reasons make this possibility less likely; the sample participants were screened per established sleep screening protocols,[38] which allowed for the specific identification of those with at least moderate sleep complaints, and the sample of participants recruited had PSQI scores that indicated poor sleep quality. Certainly, the generalizability of the findings to clinically diagnosed patients will be strengthened if future studies are able to replicate the results with a clinic population. Second, all primary measures were self-ratings, making the results potentially prone to reporting or recall bias. It would be useful to obtain objective measures of sleep quality (e.g., actigraphy) to provide an objective record for tracking and documenting treatment effectiveness in trials of this type. In this regard, future exercise intervention trials that involve the use of a mixture of self-report and objective measures will provide broader support for the results. Third, the study involved two experimental groups. Therefore, the precise magnitude of effect from tai chi on sleep quality compared with that of a nontreatment program cannot be determined. Nevertheless, future trials should consider inclusion of no-exercise, attention-only control groups and alternative physical activity groups such as walking. Fourth, a substantial proportion of screened individuals (63%) did not meet the entry criteria or were not recruited. Thus, the results should be considered in the context of the specific eligibility criteria set by the study. Finally, the lack of minority representation limits understanding of the effect of this intervention on ethnically diverse individuals. In addition, participants were well educated and from one geographic location. Given the current level of health disparities in ethnic/low income groups, future studies examining tai chi benefits for underserved population groups (e.g., African Americans, low income seniors) are warranted.

In conclusion, this study demonstrates that tai chi is effective in improving self-rated sleep quality, particularly with respect to improved sleep duration and latency, and reduced daytime sleepiness, in sedentary community-dwelling older adults reporting moderate sleep complaints. Therefore, tai chi may be considered an effective nonpharmacological approach to improving the quality of sleep and reducing daytime sleepiness of the elderly.

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