THE JOURNAL OF ALTERNATIVE AND COMPLEMENTARY MEDICINE
Volume 16, Number 3, 2010, pp. 227–233

DOI: 10.1089/acm.2009.0165

Original Articles

A Randomized Study of the Effects of *T'ai Chi* on Muscle Strength, Bone Mineral Density, and Fear of Falling in Women with Osteoarthritis

Rhayun Song, R.N., Ph.D.,[1] Beverly L. Roberts, R.N., Ph.D., F.A.A.N.,[2] Eun-Ok Lee, R.N., D.N.S.,[3] Paul Lam, M.D.,[4] and Sang-Cheol Bae, M.D., Ph.D., M.P.H.[5]

Abstract

Purpose: Individuals with osteoarthritis can experience difficulty walking and poor strength, possibly leading to falls and fractures. Exercise has been found to increase strength and bone mineral density. The purpose of this study was to determine the effects of 6 months of *t'ai chi* on knee muscle strength, bone mineral density, and fear of falling in older women with osteoarthritis.

Methods: Eighty-two (82) women with osteoarthritis, recruited from outpatient clinics and community health centers, were randomly assigned to either a *t'ai chi* group and took part in a *t'ai chi* program, or a control group. Of these, 30 subjects (mean age = 63 years) in the *t'ai chi* group and 35 (mean age = 61 years) in the control group completed post-test measures at 6 months.

Results: After the 6-month study period, subjects in the *t'ai chi* program had significantly greater knee extensor endurance (pre- to post-test mean increase = 36.4 W/kg, versus 1.1 W/kg for the controls), and significantly greater bone mineral density in the neck of the proximal femur (mean change = 0.09, versus −0.10 for the controls), Ward's triangle (mean change = 0.04, versus −0.04 for the controls), and trochanter (mean change = 0.07, versus −0.05 for the controls) than the controls. However, knee extensor and flexor strength did not differ significantly between the groups. The fear of falling during daily activities reduced significantly more in the *t'ai chi* group (mean change = −2.40, versus 0.66 for the controls).

Conclusions: *T'ai chi* increased knee extensor muscle endurance and bone mineral density in older women with osteoarthritis, and decreased their fear of falling during daily activities. Further study with long-term follow-up is needed to substantiate the role of *t'ai chi* exercise in the prevention of fall and its related fracture.

Introduction

Osteoarthritis (OA) is one of the most pervasive diseases and is the leading cause of disability worldwide.[1] The incidence of OA increases with age, women being more susceptible than men, especially in those older than 50 years.[1] Individuals with OA can experience difficulty walking and have a higher relative risk of falling and fall-related fractures.[2] OA has been associated with an increase in bone mineral density (BMD); however, this association remains controversial.[3] Despite a higher bone density, older women with OA are not protected against osteoporotic fracture, possibly due to knee pain, increased bone resorption with menopause and aging, worsened postural stability, and an increased risk of falls.[3–5] Having OA and the associated difficulty walking, together with balance deficit and muscle weakness might increase the risk of falling by threefold.[6]

One of the most effective prevention strategies for reducing the risk of falling is exercise that focuses on improving muscle strength, balance, and coordination.[7] Women, and especially older women with OA, are less likely to participate in any type of physical exercise due to their fear of falling and poor confidence, which leads to deconditioning and loss of function.[8] An exercise intervention for those with OA

[1]Chungnam National University, College of Nursing, Daejeon, South Korea.
[2]University of Florida College of Nursing, Gainesville, FL.
[3]Seoul National University, College of Nursing, Seoul, South Korea.
[4]University of New South Wales, NSW, Australia.
[5]Department of Internal Medicine, Division of Rheumatology, Hanyang University College of Medicine, The Hospital for Rheumatic Diseases, Hanyang University Medical Center, Seoul, South Korea.

should be pursued judiciously because physical exercise, depending upon its nature, can exert either injurious or beneficial effects on the joints.[9]

Various forms of exercise have been prescribed for this population, and Sun-style *t'ai chi*, designed specifically for arthritis, has been considered safe and effective for promoting balance control, flexibility, and bone health in persons with OA.[10] Older adults or those with arthritis can safely perform and enjoy *t'ai chi* exercise because of its slow circular movements with adjustable low-to-moderate intensity that can be performed at any time and place without special equipment.[11] Sun-style *t'ai chi* exercise is characterized by slow, continuous, and gentle motions with a smaller and higher stance (due to agile steps) than other *t'ai chi* styles, and hence may be more suited to older adults with OA.[12]

According to a systematic review of clinical trials, 8–16 weeks of *t'ai chi* training significantly improves balance, flexibility, and knee extensor strength, and reduces the incidence of falls in community-dwelling elderly patients.[13] Although there are only a few randomized clinical trials of *t'ai chi* in those with OA, there is some evidence that this form of exercise is effective for reducing pain and difficulties in performing daily activities,[10,14] which represent major risks for falling in this population. In randomized studies, *t'ai chi* exercise was found to be beneficial for retarding bone loss in postmenopausal women[15] and in community-living elderly women.[16] *T'ai chi* might thus reduce the risk of falls, and hence fall-related fractures, in older women with OA. However, there are no published controlled studies of *t'ai chi* that have examined muscle strength and BMD in this population. The purpose of the present study was therefore to determine the effects of *t'ai chi* on knee muscle strength and endurance, BMD, and fear of falling in persons with OA.

Methods

Study population

In an experimental design with random assignment, women with OA were recruited from the Hospital of Rheumatic Disease and community health centers while applying the following inclusion criteria: (1) age 55 years or older; (2) clinical and radiographic evidence of OA; (3) no chronic disease or disability that would prevent completion of the *t'ai chi* program, such as ischemic heart disease or cerebrovascular attack; and (4) no participation in a regular exercise program during the previous year. A rheumatologist (S.C.B.) reviewed medical records to identify patients with OA, using the classification of OA of the knee from the American College of Rheumatology, with osteophytes exhibiting a Kellgren-Lawrence grade of ≥ 2.[17] For those recruited from the community health centers, the diagnosis of OA was validated by the primary physician of the subjects according to the same classification. Figure 1 depicts the screening procedures of the subjects in this study.

A required sample size of 35 subjects for each group was estimated using GPower 3.0[18] for an *F*-test between two independent samples, with an α of 0.05, an effect size of 0.34, and a power of 0.80. The effect size used was based on a randomized prospective study of *t'ai chi* for BMD in postmenopausal women.[15]

After obtaining approval by an internal review board at the university hospital where the research was conducted, potential subjects were recruited by physician's referrals from the hospital outpatient clinic for rheumatic disease and from community health centers. The potential participants were told that they could be assigned either to the exercise group or the self-help management group, and those who were assigned to the self-help management group would have a chance to participate in an exercise program after the study period. After providing written informed consent to participate, the subjects were randomly assigned to either an experimental or a control group using a computer-generated random number. After pretest measures, those in the *t'ai chi* group exercised twice a week for 3 weeks to learn the *t'ai chi* form, and then once a week for the remainder of the 6-month study period. The control group received a self-help education program designed for arthritic patients for 2 hours once a month for 6 months. The compliance was high with the mean attendance rate at 93.2% (standard deviation [SD] = 4.6%) for the *t'ai chi* group, and at 95.7% (SD = 7.3%) for the control group, which was not significant different between the groups. After 6 months of *t'ai chi*, 30 patients in the experimental (*t'ai chi*) group and 35 in the control group completed post-test measures, indicating that 20% of the subjects had dropped out of the study.

Intervention

The *t'ai chi* program was developed specifically for those with arthritis, using 31 forms of Sun-style *t'ai chi* with *qigong* breathing exercise.[12] To ensure the safety of the participants with OA, *t'ai chi* movements used the following principles: (1) bending knees with a higher stance, (2) keeping both arms lower than the shoulder, (3) moving forward and backward with following steps, and (4) turning the body with smaller steps.[19] Certified *t'ai chi* instructors led the program, which comprised 10 minutes of warming-up exercise from the joint of the neck to the ankles, 40–45 minutes of *t'ai chi*, and 5–10 minutes of cooling-down exercise involving stretching the arm and leg muscles and a breathing exercise. Those in the *t'ai chi* group were also encouraged to practice *t'ai chi* every day for at least 20 minutes at home. The exercise log was distributed to the participants each week to record the amount of time or frequency they performed *t'ai chi* every day, and returned at the following session. The research personnel closely monitored the exercise log every week and called each subject during the week to ensure that the participants practiced *t'ai chi* regularly at home.

Subjects in the control group participated in a self-help education program 2 hours once a month for 6 months, which has been developed for patients with arthritis based on the Arthritis Self-Management Program.[20] This program has been used in Korea since 1997 to enhance the individual's self-management skills and knowledge through increasing self-efficacy.[21] The program comprised (1) principles of the self-help program and goal setting, (2) relaxation and flexibility exercise, (3) endurance and strengthening exercise, (4) prevention of osteoporosis and energy conservation, (5) pain management and folk medicine, and (6) medication and self-control methods. The participants in the control group were encouraged to apply the self-management skills to their daily activities at home, and the research personnel contacted each individual in the control group prior to the monthly session by phone to assess their health status and the performance of

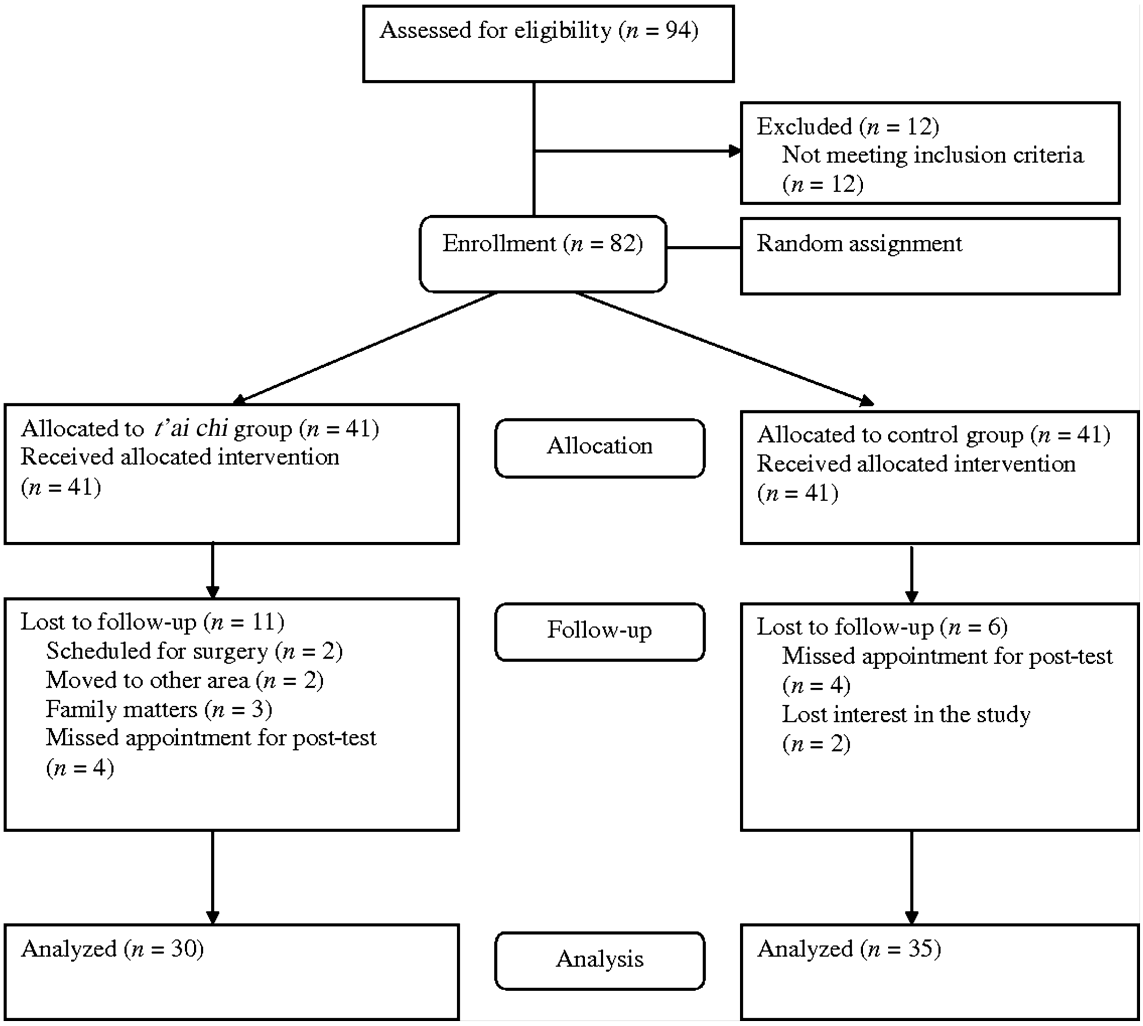

FIG. 1. Screening process and criteria for inclusion in the study.

self-management skills based on the self-management protocol, and to ensure their participation in the following session. Most of those in the control group (95.7%) completed all six sessions of the self-management program.

Outcome assessment

Outcome variables for knee muscle strength and endurance, BMD, and fear of falling were measured at before commencement of the study (pretest) and after the 6-month study period (post-test). An exercise specialist at a university hospital sports center conducted the outcome measurements while being blind to the group assignment. Demographic information and the fear-of-falling scale were obtained during interviews by trained research assistants.

Knee muscle strength and endurance. Knee muscle strength and endurance were measured bilaterally at speeds of 60°/sec and 180°/sec, respectively, using an isokinetic dynamometer (Cybex 770, Lumex, Ronkonkoma, NY). Subjects were positioned with 90° hip flexion, with their hands resting on the arms of the dynamometer. The length of the dynamometer arm, which was fastened to the distal portion of the tibia by a Velcro strap, was adjusted to the length of the subject's leg. The subjects practiced isokinetic movements in submaximal repetitions to familiarize themselves with the equipment before the actual measurements were made. Verbal encouragement was given during the test performance. Knee extensor and flexor muscle strength are presented as peak torque normalized to body weight (Nm/kg). Knee extensor and flexor muscle endurance are presented as average power normalized to body weight (W/kg) at 180°/sec. The scores from the right and left knees were added as a measure of lower body strength in terms of the strength and endurance of knee flexion and extension.

Bone mineral density. The BMD of the left proximal femur was measured by dual-energy x-ray absorptiometry (DEXA) (GE Luna PIXImus, Lunar Corporation, Madison, WI) for the neck, Ward's triangle, and trochanter. DEXA was considered a precise measure for BMD for the conventional clinical regions of interest such as the femoral neck.[22] The standard T score for BMD (i.e., a comparison of a patient's BMD to that of a healthy 30-year-old of the same sex and ethnicity) was used for the analysis. To ensure the accuracy of the DEXA system, the quality control measurement was run to pass a calibration procedure at the beginning of each-day measurement according to the PIXImus series operators

manual. After the calibration, all required information of each individual (birth date, weight and height, sex and ethnicity, ID number) was added at the main screen of the program prior to the measurement. The BMD was measured according to the standard protocol by the specialist at the hospital lab, who was blind to the group assignment.

Fear of falling. The 11-item Korean version of the Survey of Activities and Fear of Falling in the Elderly was used.[23] Subjects rated their fear of falling as a result of performing daily activities from 0 ("not at all worried") to 3 ("very worried"). Cronbach's α was 0.91 for the original study[22] and 0.91 for the Korean version of the scale.[24]

Statistical analysis. Data were analyzed using SPSSWIN V.15 (SPSS Inc., Chicago, IL). Descriptive statistics were used for demographics and outcome variables. Independent *t* tests were used to assess significant group differences in baseline measures. Analysis of covariance was used to compare the group differences at the post-test after adjusting for the baseline measures.

Results

Demographic characteristics of subjects

The mean age of the subjects and their duration of suffering from OA were 62 years and 3 years (range: 6 months–13 years), respectively, and they had a mean of 12 years of education. Most were married ($n = 51$, 78.5%), and only 9% ($n = 6$) of the subjects were still employed. More than half ($n = 39$) reported other chronic diseases beside OA, and about 70% ($n = 49$) of the subjects performed their daily activities with assistance. About 42% ($n = 27$) of the subjects perceived their health as either poor or very poor. There were no significant group differences in the demographic data (Table 1).

Group comparisons for baseline measures

Group comparisons at the pretest revealed that the outcome variables were not significantly different, supporting similar distributions between the groups. Knee strength and endurance were similar between the groups. The subjects were mostly in an osteopenic state, with T scores between −0.78 and −2.31. There were no significant differences between the groups with regard to BMD T scores of the femoral neck, Ward's triangle, and trochanter. Fear of falling also did not differ significantly between the groups (Table 2).

Group comparisons of outcomes at post-test

After controlling for pretest measures (Table 2), the strength (Nm/kg) of the knee flexors and knee extensors did not differ significantly between the *t'ai chi* and control groups. In contrast, muscle endurance in the knee extensors but not in the knee flexors was significantly higher in the *t'ai chi* group (mean change from 223.0 to 259.4, versus 247.7 to 248.8 for the controls, $F = 6.67$, $p = 0.01$).

The change in the BMD over the 6-month study period was significantly higher in the *t'ai chi* group than in the group in the femoral neck (mean change = 0.09, versus −0.10 for the controls, $F = 17.32$, $p < 0.01$), Ward's triangle (mean change = 0.04, versus −0.04 for the controls, $F = 5.68$, $p = 0.02$), and trochanter (mean change = 0.07, versus −0.05 for the controls, $F = 7.36$, $p < 0.01$). Over the 6-month study period, T scores improved by 2% (Ward's triangle), 6% (neck),

Table 1. Demographic Characteristics of the Subjects by Group

Variable		T'ai chi (n = *30*) *Mean (SD)*	*Control* (n = *35*) *Mean (SD)*	t *test*	p
Age (years)		63.03 (7.27)	61.20 (7.96)	0.97	0.33
Time since the diagnosis (months)		45.23 (46.33)	26.42 (31.64)	1.87	0.06
Education (years)		12.73 (2.96)	11.54 (3.21)	1.54	0.12
Admission frequency		1.46 (2.62)	0.91 (1.19)	1.11	0.26
		Frequency (%)	*Frequency (%)*	χ^2	P
Marital status	Married	25 (83.3)	26 (74.3)	0.78	0.54
	Other	5 (16.7)	9 (25.7)		
Economic status	High	1 (3.3)	1 (2.9)	1.24	0.58
	Middle	26 (86.7)	27 (77.1)		
	Low	3 (10.0)	7 (20.0)		
Employed	No	27 (90.0)	32 (91.4)	0.03	0.84
	Yes	3 (10.0)	3 (8.6)		
Chronic disease	No	15 (50.0)	11 (31.4)	2.32	0.13
	Yes	15 (50.0)	24 (68.6)		
Current activities of daily living	Independent	9 (30.0)	7 (20.0)	2.41	0.29
	Need assistance	21 (70.0)	26 (74.3)		
	Dependent	0 (0)	2 (5.7)		
Perceived health	Very poor	3 (10.0)	3 (8.6)	2.06	0.35
	Poor	7 (23.3)	14 (40.0)		
	Good	20 (66.7)	18 (51.4)		

SD, standard deviation.

Table 2. Mean Group Comparisons of Knee Muscle Strength, Bone Mineral Density, and Fear of Falling

	Pretest		*Posttest*			
Variable	T'ai chi (n = *30*) *Mean (SD)*	*Control* (n = *35*) *Mean (SD)*	T'ai chi (n = *30*) *Mean (SD)*	*Control* (n = *35*) *Mean (SD)*	F[a]	P
Knee strength (Nm/kg)						
Flexor	120.1 (35.8)	116.9 (26.1)	129.5 (40.1)	123.9 (29.2)	0.26	0.60
Extensor	222.5 (64.2)	230.0 (54.3)	232.5 (67.0)	229.3 (57.2)	1.69	0.19
Knee endurance (W/kg)						
Flexor	106.2 (44.3)	103.3 (36.5)	117.3 (44.2)	117.4 (52.5)	0.06	0.80
Extensor	223.0 (83.2)	247.7 (73.3)	259.4 (87.4)	248.8 (74.9)	6.67	0.01
Bone mineral density (T score)						
Neck	−1.49 (1.05)	−1.32 (0.78)	−1.40 (1.01)	−1.42 (0.74)	17.32	<0.01
Ward's triangle	−2.27 (1.14)	−2.31 (0.76)	−2.22 (1.19)	−2.37 (0.72)	5.68	0.02
Trochanter	−0.80 (1.03)	−0.78 (0.78)	−0.73 (1.06)	−0.83 (0.72)	7.36	<0.01
Fear of falling	23.06 (6.13)	23.45 (5.27)	20.66 (6.16)	24.11 (5.60)	6.40	0.01

[a]Analysis of covariance with pretest scores as covariates.
SD, standard deviation.

and 8% (trochanter) in the *t'ai chi* group, while the control group showed slightly decreased T scores in all areas.

The fear of falling during daily activities decreased significantly in the *t'ai chi* group (mean change = −2.40, SD = 5.54) but remained unchanged or even slightly increased in the control group (mean change = 0.65, SD = 6.08).

Discussion

The major obstacle to fall prevention for individuals with OA has been recognized as instability affecting their ability to function that results from quadriceps muscle weakness, pain, and altered neuromuscular control.[25] In older women with OA, our 6-month Sun-style *t'ai chi* exercise program produced significantly greater knee extensor muscle endurance and BMD of the proximal femur, and less fear of falling during daily activities than the controls (educational group). Muscle strengthening is a key component of exercise for OA, but traditional muscle-strengthening exercise might not be appropriate for this population. A meta-analysis of exercise interventions for arthritis revealed that balance exercise, including *t'ai chi*, had the most significant impact on lowering fall risk.[7]

Numerous investigators have focused on the mechanisms underlying *t'ai chi* to explain how it could reduce fall-related risks in this population. The slow and controlled body movements of *t'ai chi* require continuous knee flexion and extension during the weight-bearing phase of the movement, and thus increase isokinetic strength in the knee extensors.[26] However, in the present study isokinetic strength was not greater in the *t'ai chi* group, but muscle endurance of the knee extensors was significantly higher. This is consistent with the findings of a study by Tseng and colleagues,[27] who compared muscle activation profiles of the lower extremities between *t'ai chi* stepping and normal gait. Using electromyography, they found that muscle activity in the knee extensors was higher during *t'ai chi* stepping than during normal gait.[27] More importantly, greater isokinetic knee extensor strength has been associated with higher postural stability[26] and improved movement accuracy after practicing *t'ai chi*.[28]

The *t'ai chi* participants in this study showed significantly greater T scores of the proximal femur at 6 months than the participants in the control (education) group. Previous randomized trials of *t'ai chi* found a significantly smaller loss of BMD in the hip in elderly women after 12 months of *t'ai chi*,[16] and in the weight-bearing bones of postmenopausal women.[29] Older women with OA are a high-risk group for fracture because those with knee OA have an even lower hip BMD on the affected leg,[30] and increased bone resorption after menopause.[5] The increase in BMD observed in the early stages of OA patients was not considered a protective factor for overall facture risk for this population.[31] In previous studies, the duration of *t'ai chi* has been varied from 6 months to 12 months to induce beneficial effects on BMD, while the effects were not consistent across the population due to potential variation of the intensity of *t'ai chi*.[15,16] In Woo's study, the *t'ai chi* was beneficial in retarding bone loss in elderly women who are likely to be physically more frail, while it showed no benefit to men with regard to BMD.[16]

Although empirical evidence of the impact of *t'ai chi* on BMD is limited by the quantity and quality of research to date,[32] previous randomized studies have shown the positive effects of relatively shorter duration of exercise on BMD (assessed by DEXA) in various populations. After participating in a high-intensity resistance exercise for 6 months, 35 postmenopausal women improved the lumbar BMD (1.03%) compared to the randomized control group.[33] The healthy elderly men with normal BMD also showed improved BMD ($p < 0.05$) of the proximal femur (Ward's triangle) after 16 weeks of resistance exercise training.[34] A systematic review revealed that the duration of weight-bearing exercise required at least 4–8 months for a result of less bone loss, and over 9 months or longer for an increase in BMD in postmenopausal women as compared to the control group.[35] Therefore, the frail elderly, such as older women with OA, could also benefit from strength exercise or weight-bearing exercise to help preserve bone density by engaging in moderate intensity exercise 2–5 times a week lasting from 45 to 70 minutes a session for at least 4 months or longer.[35]

The underlying mechanism of *t'ai chi* to induce beneficial effects on bone health could be understood by considering characteristics of *t'ai chi* as a weight-bearing exercise. *T'ai chi* increases weight bearing, which might contribute to a greater BMD. The foot–floor impact force is about 2–4 times lower for *t'ai chi* than during normal walking[36] due to the

coordinated activation of the lower extremities.[37] While maintaining a low dynamic impact to the foot, *t'ai chi* movements involve multiple loading and unloading patterns with full weight-bearing movement.[37] *T'ai chi* movement involves maintaining knee flexion while moving in various directions, and is associated with larger peak shear forces and larger peak moments in the lower-extremity joints when compared to normal gait.[36] The biomechanics of *t'ai chi* might explain the improved BMD of the *t'ai chi* participants in the present study, but further studies are needed to confirm these effects in older women with OA.

Fear of falling is a fundamental health problem in elderly people with or without a history of falling for maintaining their physical independence,[38] and it ultimately limits the performance of daily activities.[39] Improvement in confidence regarding avoiding falls has been associated with balance and mobility as independent risk factors for falls in older women, and has become a target of intervention programs for fall prevention.[40] In the present study, the fear of falling after 6 months was lower in the *t'ai chi* group than in the control group. In a randomized fall-prevention study involving 49 community-dwelling elderly, an 8-week *t'ai chi* program also improved balance and reduced fear of falling.[41] Further study is warranted to assess the effects of *t'ai chi* on fall prevention, while also accounting for fall risk factors such as balance, muscle strength, and BMD.

The Sun-style *t'ai chi* program designed for patients with arthritis in the present study was simple and easy to learn for older adults with OA. Participants were able to learn the basic 12 movements in 3 weeks (six sessions), and therefore a 6-month study period could be long enough for them to feel comfortable practicing *t'ai chi* at home in addition to the supervised session. The positive changes in knee muscle endurance and BMD of the hip found in the present study could reduce the risk of falls and fractures, while reducing the fear of falling during daily activities could increase the independence of older adults with OA.

The results of the present study should be interpreted with caution. The small sample size along with the presence of within-group variability might explain insignificant findings in some outcome measures. Moreover, dropout rates of 24% and 15% for the *t'ai chi* and control (education) group, respectively, could have produced biased findings. Although compliance (attendance rates) during the study period was high for both groups, the different levels of face time resulting in more psychosocial interactions with the *t'ai chi* group may have impacted outcomes, and may contribute to observed group differences. The findings of the study show the performance of *t'ai chi* exercise is beneficial for retarding bone loss in weight-bearing bones in women with OA, yet further study with long-term follow-up is needed to substantiate the role of *t'ai chi* exercise in the prevention of fall and its related fracture.

Disclosure Statement

No competing financial interests exist.

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Address correspondence to:
Sang-Cheol Bae, M.D., Ph.D., M.P.H.
Department of Internal Medicine
Division of Rheumatology
Hanyang University College of Medicine
The Hospital for Rheumatic Diseases
Hanyang University Medical Center
Seoul 133-792
South Korea

E-mail: scbae@hanyang.ac.kr