Effects of Tai Chi Exercise on Pain, Balance, Muscle Strength, and Perceived Difficulties in Physical Functioning in Older Women with Osteoarthritis: A Randomized Clinical Trial

RHAYUN SONG, EUN-OK LEE, PAUL LAM, and SANG-CHEOL BAE

ABSTRACT. ***Objective.*** Twelve forms of Sun-style tai chi exercise have been developed specifically to reduce the symptoms and improve the physical functioning of arthritic patients, and this randomized study examined the changes in symptoms and physical characteristics in older women with osteoarthritis (OA) at the completion of a 12-week tai chi exercise program.

Methods. Seventy-two patients with OA were randomly assigned into 2 groups. Due to a 41% overall dropout rate, 22 experimental subjects and 21 controls completed pre- and post-test measures over a 12 week interval. Outcome variables were physical symptoms and fitness, body mass index, cardiovascular functioning, and perceived difficulties in physical functioning. The independent t test was used to examine group differences.

Results. The homogeneity test confirmed that there were no significant group differences in demographic data and pretest measures. Mean comparisons of the change scores revealed that the experimental group perceived significantly less pain ($t = –2.19$, $p = 0.034$) and stiffness ($t = –2.13$, $p = 0.039$) in their joints, and reported fewer perceived difficulties in physical functioning ($t = –2.81$, $p = 0.008$), while the control group showed no change or even deterioration in physical functioning after 12 weeks. In the physical fitness test, there were significant improvements in balance ($t = 3.34$, $p = 0.002$) and abdominal muscle strength ($t = 2.74$, $p = 0.009$) for the tai chi exercise group. No significant group differences were found in flexibility and upper-body or knee muscle strength in the post-test scores.

Conclusion. Older women with OA were able to safely perform the 12 forms of Sun-style tai chi exercise for 12 weeks, and this was effective in improving their arthritic symptoms, balance, and physical functioning. A longitudinal study with a larger sample size is now needed to confirm the potential use of tai chi exercise in arthritis management. (J Rheumatol 2003;30:2039–44)

Key Indexing Terms:
TAI CHI EXERCISE PHYSICAL FITNESS OSTEOARTHRITIS
WOMEN SIGNS AND SYMPTOMS

Osteoarthritis (OA) is one of the most common chronic conditions in the elderly, and is the largest single cause of longterm disability in this group[1]. Using a broad definition of arthritis, the US Centers for Disease Control and Prevention found that the number of people with arthritis had increased by roughly 750,000 per year since 1990 in the US population, projecting to about one in 5 people having arthritis by 2010[2]. Arthritis affects people in all age groups and of all racial and ethnic origins, but it is more common among women and older people. The 1998 Korean national health survey revealed that arthritis affects 56.5% of Korean individuals over 60 years of age, with 84% of them perceiving difficulties in the activities of daily living (ADL). The prevalence rate of arthritis is much higher for women (74.6%) than for men (30.2%)[3]. More specifically, a survey of 546 Korean rural women reported that 56% of women had knee OA, with incidence increasing to 69% for women aged 60 years or older[4]. The management of OA imposes a major socioeconomic burden on society, especially given that many of the patients are elderly women.

The use of exercise has been proposed for the management of patients with OA, but this needs to be pursued judi-

From the Department of Nursing, Soonchunhyang University, Chon An; College of Nursing, Seoul National University; and Department of Internal Medicine, Division of Rheumatology, Hanyang University College of Medicine, The Hospital for Rheumatic Diseases, Hanyang University Medical Center, Seoul, South Korea.

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R. Song, RN, PhD, Associate Professor, Department of Nursing, Soonchunhyang University; E-O. Lee, RN, DNS, Professor, College of Nursing, Seoul National University; P. Lam, MD, Family Physician, Tai Chi Instructor, Conjoint Lecturer, University of New South Wales, Australia; S-C. Bae, MD, PhD, MPH, Associate Professor, Department of Internal Medicine, Division of Rheumatology, Hanyang University College of Medicine, The Hospital for Rheumatic Diseases, Hanyang University Medical.

Address reprint requests to Dr. S-C. Bae, The Hospital for Rheumatic Diseases, Hanyang University Medical Center, Seoul 133-792, South Korea. E-mail: scbae@hanyang.ac.kr

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ciously since physical exercise can have either injurious or beneficial effects on the joints, depending on the nature of the exercise[5]. The Framingham Study found an association between the duration of heavy physical activity and the risk of knee OA[6]. However, the risk of knee OA might not be increased by recreational running[7] or by light to moderate physical activity[6]. Further, other trial data support the value of exercise as part of the treatment regimen of OA[8]. Various forms of exercise have been prescribed for osteoarthritic patients, including aquatic exercise[9], strength training[10], and aerobic exercise[11]. Although there is research evidence that exercise is beneficial, the selection criteria — in terms of the type, intensity, and duration — for exercises that are safe yet strenuous enough to lead to positive outcomes remain unclear.

Tai chi is an ancient Chinese martial art and exercise, and it has been suggested that its inherent features of isometric exercise, relaxation combined with stretching, and correct body posturing provide a preferred exercise therapy for arthritic patients[12]. Recently, 12 tai chi exercise movements in Sun-style were developed by Lam and his colleagues[13] to meet the specific needs of arthritic patients. These forms of Sun-style tai chi involve slow, continuous, and gentle motions, with higher stance than other tai chi styles to be more suitable to the physical condition of arthritis patients, yet they increase strength and aerobic capacity. While these exercises were developed specifically for arthritic patients, no controlled exercise study has tested the potential effects of tai chi in this population.

The purpose of this randomized study was to examine the changes in physical symptoms and fitness, body mass index (BMI), cardiovascular functioning, and perceived difficulties in physical functioning in older women with OA at the completion of a 12 week tai chi exercise program.

MATERIALS AND METHODS

Study design. Patients at an arthritis outpatient clinic of a university hospital were reviewed by their primary physician according to the inclusion criteria for this study (below). Those who agreed to participate and signed the consent form were randomly assigned to either the tai chi exercise group or the control group; this random process was conducted by a hospital coordination center using a random table with no involvement of the research team. The control group was expected to receive the routine treatment provided at the outpatient clinic without participating in any structured exercise programs during the study period. While the subjects of the exercise group participated in 12 weeks of tai chi sessions, the control subjects were also contacted each week by telephone to confirm they were not taking part in any other exercise activities and to provide attention to keep them in the study. Those in the control group who were interested in tai chi were provided with an exercise program after the study period.

Subjects. The inclusion criteria for patients who agreed to participate were as follows: (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 program or survey communications such as ischemic heart disease or cerebrovascular attack, and (4) no participation in any regular exercise program during the previous year. Definition criteria for the study followed the classification of OA of the knee provided by the American College of Rheumatology[14], with osteophytes exhibiting Kellgren-Lawrence grades ≥ 2[15]. Most subjects were taking medications that remained unchanged during the study period.

According to Cohen's power analysis[16] for a t test between 2 independent samples having parameters of alpha = 0.05 and d (the effect size) = 0.70, a power value of 0.80 is predicted for a study involving 35 subjects in the experimental group and 35 controls. The effect size was calculated based on the pilot study on physical functioning (using the Korean version of the Western Ontario-McMaster Universities OA index, the K-WOMAC)[17] as one of major outcome variables (difference between means = 0.51, SD 0.7). A total of 72 female patients gave consent for the study: 38 were randomly assigned to the experimental group and 34 to the control group. The study dropout rates were 43% and 39% for the experimental and control groups, respectively, so that both pre- and post-test data for 12 weeks of tai chi exercise were available from 22 patients and 21 controls. The main reasons for dropouts were readmission to the hospital for surgery, moving to another city, family commitments, becoming homebound due to falls or traffic accidents, and failure to complete either the survey or the fitness measures. Additional analysis was conducted to compare demographic and pretest data between the dropouts and the remaining members for the exercise group and the controls, and revealed no significant differences ($p > 0.05$).

Data collection procedure. All subjects attended the sports center of a university hospital for pre- and post-test measurements of balance, muscle strength, and cardiovascular functioning by exercise physiologists using blind procedures. A standardized measurement set (Takei Kiki Kogyo, Tokyo, Japan) was used for all tests. An interview was conducted for filling out the questionnaires on demographic characteristics, OA symptoms, and physical functioning.

The study was conducted in 2 phases. The preparation phase involved training exercise leaders for the tai chi programs. The researchers completed a 2 day tai chi workshop for exercise leaders in Hong Kong (provided by one author, P. Lam), who had originally developed the 12 movements of Sun-style tai chi exercise for arthritis. Lam also managed a second tai chi workshop for exercise leaders in Seoul, Korea. During the 2 days of the workshop, the intensity and forms of the 12 tai chi movements of each exercise leader were closely monitored to ensure that each movement would be applied correctly and safely to patients with arthritis. A standardized videotape (ISBN 1-885538-84-7) was provided to exercise leaders prior to the study to guide them in performing each form of tai chi correctly.

The second phase of the study was the application of the tai chi exercise program. The subjects of the exercise group performed tai chi exercise a minimum of 3 times a week for 12 weeks either with instructors or by themselves. During the first 2 weeks, the exercise group came to the class 3 times a week where 2 trained leaders directed each of the tai chi movements to the group, with the aid of the videotape. Six supervised exercise sessions were provided for teaching the movements step by step and repeatedly until the patients felt comfortable enough to perform them correctly by themselves at home. After 2 weeks the exercise group came to the supervised session once a week, while they were expected to perform tai chi exercise 20 min daily at least 3 times a week at home for the following 10 weeks. The exercise leaders used telephone contact to encourage regular performance, and the subjects used a daily exercise log to record the frequency of exercise.

Tai chi exercise program. The Sun-style tai chi exercise program for arthritic patients developed by Lam and colleagues[13] consists of warm-up exercise, 12 main movements, and cool-down exercise. In this study the warm-up and cool-down exercises involved stretching and relaxing the head, neck, upper and lower body, and the whole body, and they were repeated 3–5 times, alternating sides where appropriate. The patients performed each exercise slowly, and walked or moved at their own pace while simultaneously breathing in and out.

The 12 tai chi movements selected from the Sun style — one of the 4 major recognized tai chi styles — combines deep diaphragmatic breathing and relaxation with slow and gentle movements, both isometric and isotonic, while maintaining good posture. Tai chi exercise involves many

forward and backward movements with full weight-bearing on both lower extremities and qigong exercise with deep diaphragmatic breathing. Basic movements consisted of opening and closing hands, single whips, waving hands, and commencement and closing forms. Advanced movements included brushing the knee and twist stepping, playing the lute, stepping forward to deflect downwards, blocking and closing, pushing the mountain, opening and closing hands, and closing forms. The patients performed each movement from a standing position with the knees bent at varying degrees of flexion, but those who felt pain or discomfort were allowed to perform it at higher stance and to adapt the movements gradually as they became more comfortable.

Patients were expected to stand upright but to be relaxed during the tai chi exercise, and adapt each movement according to their individual capabilities. Traditional instrumental music was used as background music to help patients move and breathe in a slow tempo, and to enjoy their movements more naturally. One set of basic and advanced movements took about 2 min, and the patients performed 10–15 sets of these at a session. Each subject was given an instructional audiotape with the background music to practise the tai chi exercise at home. The background music was chosen from the familiar music to help them relax. The frequency and duration of tai chi performance at home was recorded on their exercise log, which was assessed during every weekly session.

Measurements. All outcome variables were measured before and after the 12 week tai chi program, and they comprised physical symptoms (pain and stiffness in joints), physical fitness (balance, knee flexibility and endurance, and upper and abdominal muscle strengths), BMI, cardiovascular functioning, and perceived difficulties in physical functioning.

The K-WOMAC[17] was used to assess subjects' self-reported symptoms and physical functioning. This is a 24 item questionnaire, consisting of 3 subscales of pain (5 items), stiffness (2 items), and physical functioning (17 items), which uses a 5 point Likert scale ranging from none (0) to extreme (4). Scores are generated for the 3 subscales of pain, stiffness, and physical functioning by summing the coded responses to provide a score within the range of 0–20 for pain, 0–8 for stiffness, and 0–68 for physical functioning. Physical functioning was assessed by the perceived difficulty of performing various ADL. The development process of K-WOMAC along with its psychometric properties has been described[17].

Physiological measurements for the study utilized standardized equipment from a university hospital sports center[18]. Each subject's physical abilities were measured at the pre- and post-test periods by 2 exercise physiologists blinded to their assignment groups. A standard fitness set (Takei Kiki Kogyo) was used to measure balance, flexibility, and upper and abdominal muscle strengths. Balance was assessed by how long (seconds) the subject could stand on one foot with eyes closed. A sensor detected when the subject's other foot touched a floor pad. Flexibility (TKK 1859) was measured by asking the patient to bend at the waist and stretch both hands toward the feet without bending the knees, and the distance (in centimeters) between hands and feet was measured. Abdominal muscle strength (TKK 1204) was measured by the number of sit-ups performed in 30 seconds.

The strengths of the knee extensor and flexor were measured by an isokinetic dynamometer (Cybex 770) 4 times each at 60° for knee flexibility and at 120° for knee endurance assessment. Considering intra-subject variability in the dynamometer measure, the patients were asked to practice 3 times using roughly 70% of maximal force to adjust the machine, and then were tested 4 times at their maximal force. The mean score (in degrees/second) of 4 test results for both legs was calculated from the computer output.

Cardiovascular functioning was assessed by a test of submaximal exercise load with a 13 minute protocol while the subject exercised on a computer monitored bicycle ergometer (TKK 1305). The resistance offered by the ergometer was determined after entering data on sex, age, and body weight by asking the patient to pedal and maintain 50–60 rpm for 13 minutes.

Analysis. Data were analyzed using the SPSS (Windows v10.0) program. Descriptive statistics was used for demographic variables. The homogeneity test confirmed that there were no significant group differences in the demographic data and pretest measures. The independent t test was used to examine group differences in outcome variables.

RESULTS

Subjects' demographic characteristics. There were no significant differences between the groups in any demographic characteristic (Table 1). The subjects had an average age of 63 years, and the average time since diagnosis was 9.8 years. Most were married (67%) and about 30% were either divorced (4.6%) or widowed (25.5%). About 86% had a religion, one-half being Buddhists, 32% Protestant, and 14% Catholic. Only 3 (7%) subjects were still employed. Thirty-two percent of subjects had left employment due to their illness. About 28% of subjects had never performed any type of habitual exercise after their diagnosis, while 19% considered their exercise habits as regular. No subject was participating in any type of regular exercise program. More than half perceived their present health as poor or very poor.

Homogeneity tests between groups before the tai chi exercise program. Group comparisons were made on outcome variables to confirm homogeneity between the exercise and control groups. Table 2 shows that no significant difference was found between the groups, confirming that the group assignments were random. The results of Levene's test for equality of variances also revealed no significant differences for the variables.

Effect of tai chi exercise on K-WOMAC scores, balance, muscle strength, and cardiovascular functioning. Group comparisons were made on change scores of outcome variables between the pre-test and the post-test measures to assess the effects of the tai chi exercise (Table 3). At the completion of 12 weeks of tai chi exercise, the exercise group reported significantly less pain ($p = 0.034$) and stiffness in their joints ($p = 0.039$) and perceived less difficulty in performing ADL ($p = 0.008$), showing significantly improved physical functioning than the control group. Compared with the change scores from the pre-test data, the exercise group exhibited negative scores in their pain, stiffness, and physical functioning scores of –2.45, –0.91, and –11.09, respectively; while the control group had either more pain (K-WOMAC scores increased from 8.90 to 9.52) and stiffness (from 3.57 to 3.81) or slightly less difficulty (from 37.95 to 36.62) in performing ADL (Table 3).

At the post-test, the exercise group exhibited significant improvements in balance and abdominal muscle strength compared to the controls. The tai chi group reported much improved balance by standing longer on one foot (from 5.13 to 12.63 s) and increased frequency of sit-ups (from 6.86 to 8.81), while the control group reported decreased balance control (from 8.14 to 7.14 s) or little improvement (from 6.71 to 6.80) in abdominal muscle strength. However, no

Table 1. Demographic characteristics of subjects by group.

Variable	Exercise (n = 22), mean (SD)	Control (n = 21), mean (SD)	t	p
Age, yrs	64.8 (6.0)	62.5 (5.6)	1.20	0.237
Household monthly income, x 10^3 KW*	1716 (1260)	2096 (1157)	–1.09	0.363
Education, yrs	9.0 (3.8)	8.8 (4.1)	0.11	0.908
Period since the diagnosis, yrs	10.4 (7.1)	9.2 (7.2)	0.53	0.597
	Frequency (%)	Frequency (%)	Chi-square	p
Left employment for health reasons				
Yes	7 (31.8)	7 (33.3)	0.01	0.916
No	15 (68.2)	14 (66.7)		
Exercise habits after diagnosis				
Never	6 (27.3)	6 (28.6)		
Mostly do not exercise	7 (31.8)	6 (28.6)	3.65	0.301
Exercise irregularly	7 (31.8)	3 (14.3)		
Exercise regularly	2 (9.1)	6 (28.6)		
Present health				
Very poor	3 (14.3)	4 (19.0)		
Poor	8 (38.1)	14 (66.7)	5.54	0.062
Good	10 (47.6)	3 (14.3)		
Very good	0 (0)	0 (0)		

* 1 US$ = 1152 Korean Won (KW).

Table 2. Homogeneity test on major study variables between the groups.

Variable	Exercise (n = 22), mean (SD)	Control (n = 21), mean (SD)	t	p
Joint pain	6.91 (4.1)	8.90 (5.1)	–1.40	0.168
Joint stiffness	3.13 (1.7)	3.57 (2.1)	–0.73	0.466
Physical functioning*	37.59 (10.6)	37.95 (12.6)	–0.10	0.919
Balance, seconds	5.13 (3.6)	8.14 (12.9)	–1.05	0.300
Abdominal muscle strength, n/30 seconds	6.86 (4.9)	6.71 (5.3)	0.09	0.925
Knee muscle strength, degrees/second	46.34 (11.2)	45.96 (12.7)	0.10	0.919
Knee muscle endurance, degrees/second	32.02 (7.6)	32.34 (8.2)	–0.13	0.895
Flexibility, cm	17.31 (5.1)	16.32 (5.6)	0.56	0.572
Body mass index, kg/m^2	24.90 (2.6)	26.37 (3.5)	–1.56	0.125
Cardiovascular functioning, ml/kg/min	24.05 (4.3)	23.91 (4.2)	0.10	0.919

* Measured by difficulties in ADL: higher score reflects worse physical functioning.

Table 3. Mean group comparisons in change scores of K-WOMAC, balance, muscle strength, and cardiovascular functioning in groups between pre-test and post-test.

Variable	Exercise (n = 22), mean* (SD)	Control (n = 21), mean* (SD)	t	p
Joint pain	–2.45 (3.9)	0.61 (5.1)	–2.19	0.034
Joint stiffness	–0.91 (1.6)	0.23 (1.8)	–2.13	0.039
Physical functioning†	–11.09 (12.0)	–1.33 (10.6)	–2.81	0.008
Balance, seconds	7.50 (7.8)	–1.00 (8.7)	3.34	0.002
Abdominal muscle strength, n/30 seconds	1.95 (2.7)	0.09 (1.5)	2.77	0.009
Knee muscle strength, degrees/second	6.75 (8.9)	4.25 (6.6)	1.03	0.306
Knee muscle endurance, degrees/second	7.69 (19.0)	1.46 (5.1)	1.44	0.155
Flexibility, cm	1.19 (3.2)	1.32 (3.3)	–0.12	0.903
Body mass index, kg/m^2	–0.20 (0.5)	–0.08 (1.1)	–0.44	0.662
Cardiovascular functioning, ml/kg/min	1.64 (6.0)	0.91 (4.2)	0.45	0.653

* Mean scores were computed as differences between the post-test and the pre-test. ** Measured by difficulties in ADL: higher score reflects worse physical functioning.

significant differences were found in flexibility, cardiovascular functioning (oxygen consumption), BMI, or knee muscle strength and endurance between the groups.

DISCUSSION

Physical exercise can benefit patients with OA when it is of the correct form and intensity[8]. In our study, older women with OA were able to perform the 12 movements of Sun-style tai chi exercise for 12 weeks without worsening of their arthritis related symptoms — indeed, they reported improvements of 35%, 29%, and 29% in their pain, stiffness, and physical functioning, respectively.

Baker and colleagues[10] reported decreases of 36–38% in pain and difficulties of ADL in older adults with knee OA following progressive strength training. In their study, improvements in K-WOMAC physical functioning were correlated with improvements in the extension strength of the affected knee for the exercise group. However, in our study no significant differences were found in knee muscle strength or knee muscle endurance among tai chi exercisers.

Sun-style tai chi is characterized by its higher stance than other tai chi styles, which makes it better suited to the physical condition of arthritic patients[13]. A study involving Yang-style tai chi applied to healthy older adults produced significant increases in the peak torques of knee extensor and flexor after 12 months of training[19]. Therefore, allowing for the lower intensity of weight-bearing on lower extremities from the higher stance in Sun-style tai chi, it may be that the 12 week exercise period of our study was not long enough to induce muscle strengthening, especially in patients with weakened knees.

The osteoarthritic patients showed significantly improved balance and abdominal muscle strength at the completion of 12 weeks of tai chi exercise. The basic tai chi exercise is a series of forward and backward movements that leads the body to constantly shift from foot to foot with a low center of gravity[20]. Studies have confirmed the beneficial effects of tai chi exercise on postural control and balance, and have reported that longterm tai chi practitioners have significantly better postural control and a reduced risk of falls compared to the general population[21,22].

In our study, the changes in cardiovascular functioning and BMI were not significantly different between the exercise and control groups. This may also be attributable to the relatively short duration of low intensity exercise in this study. It is generally accepted that aerobic training may be beneficial to cardiovascular function, but that an overall increase in oxygen consumption is only reported when the period of training is longer than 6 months. Studies have confirmed that moderate intensity tai chi exercise performed for a period of one year can increase oxygen consumption, which would enhance the ability of older adults to live independently[19].

Since most patients had been quite inactive before commencing the exercise program, slight soreness of the knee and leg muscles was reported during the first week of exercise. However, no one reported worsened pain or prolonged exercise related symptoms from after 2 weeks until the completion of the exercise program. Considering that 40–50% of sedentary healthy adults who start exercise programs give up within the first 6 months of involvement[23–25], the arthritic patient dropout rate of 43% in this study seems acceptable. At the completion of the exercise period, the remaining subjects commented that the tai chi movements had been easy to follow, attractive, and even enjoyable. Tai chi exercise is particularly acceptable to arthritic patients since they are often homebound, and it can be practised anywhere and at any time without special equipment[26].

Two limitations need to be addressed in interpreting the results. First, although some significant differences were found by a random trial, a small number of subjects reduces the power due to within-subject variability, which made it more difficult to detect exercise-induced changes. Second, the dropout rate during the study period could limit the generalizability of the findings. The dropouts were mainly due to personal or family matters rather than exercise related factors, but the rate of 43% may still mean that the sample was not representative.

Sun-style tai chi exercise designed specifically for arthritic patients may be beneficial for relieving their arthritis related symptoms and improving balance and physical functioning, which would help patients to perform ADL more easily and safely. However, generalizing the study findings is limited due to the high dropout rate reducing the sample size significantly. Further studies with a larger sample size — perhaps including subjects with types of arthritis other than OA and involving a longer exercise period — are necessary to confirm the potential use of tai chi exercise in arthritis management.

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