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ORIGINAL ARTICLE

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Beneficial effects of regular Tai Chi exercise on musculoskeletal system

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Abstract This study was performed to evaluate the potential benefits of regular Tai Chi Chun (TCC) exercise on bone mineral density (BMD) and neuromuscular function in postmenopausal women. In this cross-sectional study, 99 healthy postmenopausal women, with a mean age of 55.9 ± 3.1 years and within 10 years after the menopause, were recruited; including 48 subjects who had been regularly practicing TCC exercise for more than 3h/week and 51 age- and sex-matched sedentary controls (CON). BMD was measured in the lumbar spine and proximal femur of the non-dominant leg (femoral neck, greater trochanter, and Ward's triangle), using dual-energy X-ray absorptiometry (DXA). Neuromuscular function was evaluated, including magnitude of trunk bend-and-reach, quadriceps muscle strength, and single-stance time on the nondominant leg. The TCC group showed overall higher BMD at all measurement sites, with a significant difference found at the spine (7.1%), greater trochanter (7.2%), and Ward's triangle (7.1%) of the proximal femur (all; $P < 0.05$). Functional tests revealed an average 43.3% significantly greater quadriceps strength ($P < 0.01$), and 67.8% significantly longer single-stance time in the TCC group as compared with the CON group ($P < 0.05$), as well as a greater magnitude of trunk bend-and-reach in the TCC group ($P = 0.08$). Bivariate linear correlation analysis showed that quadriceps muscle strength was significantly correlated with the single-stance time ($r = 0.41$; $P < 0.01$). This study revealed that regular TCC exercise may have an association with higher BMD and better neuromuscular function in early postmenopausal women.

Key words Tai-Chi Chun · Postmenopausal women · BMD · Neuromuscular function

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Introduction

The structure and function of the human locomotor system deteriorate with advancing age, including bone loss, reduction of muscle mass and strength, impaired mobility and neuromuscular coordination, and increased risk of falls, factors that are more predominant in the female population after the onset of menopause [1–3]. It is not clear whether the postmenopausal acceleration of bone loss is just an effect of estrogen deficiency and age itself, or whether it is associated with secondary factors such as malnutrition, vascular changes, or decrease or deterioration of neuromuscular function and structure. No matter what underlies the etiology, adequate exercise has shown beneficial effects on the locomotor system, including the prevention of osteoporosis and muscle weakness, and the improvement of neuromuscular coordination, thereby reducing fracture risks in postmenopausal women [4–15].

Evidence in humans regarding osteogenic effects and muscle strength largely comes from studies involving athletes who participated in high-impact exercises or power training, such as jumping or weightlifting [16–20]. However, such high impact or strengthening exercise is not appropriate for the elderly. Tai Chi Chun (TCC) is a low-impact weight-bearing exercise appreciated and regularly practiced by older people [11,15,21]. The aim of the present study was to explore whether or not early postmenopausal women can benefit from regular participation in TCC exercise, in terms of whether this results in higher BMD, measured at weight-bearing skeletal sites, and improved neuromuscular function.

Methods

Subject recruitment

Two hundred and eleven healthy Hong Kong Chinese postmenopausal women, aged between 50 and 65, who had been without menstruation for 1 to 10 years from the onset of menopause were recruited through local communities and newspaper advertisements.

After completing a questionnaire on health condition, diet, medical history, lifestyle, and menstrual status, 48 women were recruited into the TCC group, (i.e., those who had been practicing TCC exercise regularly for more than 3 years [5.2 ± 3.0 years] and over 3 h a week, without participating in other forms of sports activities). Another 51 anthropometrically matched women who had not participated in regular habitual exercises (not more than 0.5 h/week) were recruited as the sedentary control group (CON). Subjects who had sports injuries affecting the body function tests described below and subjects who were receiving hormone replacement therapy, or calcium supplementation, or drug treatment known to affect bone and muscle metabolism; and those who had conditions such as hypo- or hyperparathyroidism and hypo-hyperthyroidism, or renal or liver disease, were excluded. A short version of the Health Habits and History Questionnaire (HHHQ) was used to calculate physical activity, in terms of outdoor walking (h/week) and dietary calcium intake (mg/week) [22]. All subjects gave their written consent before the measurement. The study protocol was approved by the Clinical Research Ethics Committee of the Chinese University of Hong Kong (Ref. No. CRE-660).

Anthropometric measurements

Body height and body weight were measured. Body mass index (BMI), in kg/m^2, was also calculated.

Bone mineral density (BMD) measurement

BMD measurements were made at the anterior-posterior lumbar spine (L2-L4) and the nondominant proximal femur, including femoral neck, greater trochanter, and Ward's triangle, using dual-energy X-ray absorptiometry (DXA; Norland XR36; Norland, Fort Atkinson, WI, USA). Quality control scans were performed daily with a manufacturer-supplied anthropometric spine phantom.

Functional testing

Quadriceps muscle strength

Quadriceps muscle strength was measured for the nondominant leg, with an isometric dynamometer (Baseline, Genova, Italy). The subject was asked to sit on a chair with both feet above ground level, while raising the nondominant leg 45° forwards. The dynamometer was placed just above the ankle and the subject was asked to push that leg forward with maximum force. Measurements were repeated three times and the maximum value was used for evaluation [23].

Magnitude of trunk bend-and-reach

Body flexibility was measured by a simple trunk bend-and-reach test. The subject was asked to stand on the measuring board, keeping the knees straight, with no gaps between the feet. The lowest level their fingers could reach after trunk bending forwards and downwards was recorded; three attempts were made and the lowest level or greatest forward reach was used for data analysis [24].

Time of single stance

Body balance was evaluated using a single-stance test for the nondominant leg, with three repeated measurements, and a time interval of 30 s between each measurement. The longest stance time was recorded for data analysis [14].

Statistics

Independent two-tailed Student's *t*-tests were used to detect differences in age, anthropometric variables, menstruation status, BMD measurements, and functional tests between the TCC and the CON groups. Bivariate linear correlation was used to study the correlation between quadriceps muscle strength and single-stance time. The statistical significance level was set at $P \leq 0.05$. The SPSS 9.0 statistical program (SPSS, Chicago, IL, USA) for Windows was used for data evaluation.

Results

Comparison of distribution of variables in the TCC and CON groups

Table 1 shows the homogeneity of age, anthropometric variables, and menstruation status between the TCC exercisers and the nonexercising age- and sex-matched sedentary controls. No significant differences were found in habitual activities other than TCC (outdoor walking) or in the dietary calcium profile based on the HHHQ.

Comparison of bone mineral density (BMD)

Table 2 summarizes the BMD measured at both spine and proximal femur. Subjects with regular TCC exercise showed overall 3.4%–7.2% higher BMD at all measurement sites or regions of interest as compared with the sedentary controls. Significantly higher BMD was shown at the spine (L2–L4; TCC vs CON, 0.861 ± 0.142 vs 0.804 ± 0.122 g/cm^2; $P < 0.05$), greater trochanter (TCC vs CON, 0.613 ± 0.091 vs 0.572 ± 0.085 g/cm^2; $P < 0.05$), and Ward's triangle

Table 1. Homogeneous distribution of anthropometric variables, menopausal status, dietary intake, and daily activity in the Tai Chi Chun (TCC) and sedentary control (CON) groups

	TCC group (n = 48)	CON group (n = 51)	P Value
Age (years)	55.8 ± 3.5	55.1 ± 2.7	0.228
Height (cm)	153.6 ± 6.4	153.1 ± 6.6	0.721
Weight (kg)	55.3 ± 8.3	54.5 ± 9.8	0.681
BMI (kg/m^2)	23.4 ± 3.0	23.2 ± 3.8	0.795
Age at menopause	50.0 ± 3.1	50.0 ± 3.2	0.948
Years since menopause	5.8 ± 3.0	5.1 ± 3.6	0.304
Calcium intake (mg/week)	6344 ± 607	6512 ± 719	0.305
Outdoor walking (h/week)	9.2 ± 8.2	9.1 ± 6.3	0.938

Data values are means ± SD

Table 2. Comparison of bone mineral density (BMD) measured at various skeletal sites between Tai Chi Chun (TCC) and sedentary control (CON) groups

Sites of measurement of BMD (g/cm^2)	TCC group	CON group	Percent difference between TCC and CON	P Value
Spine L2–L4	0.861 ± 0.142	0.804 ± 0.122	7.1%	0.03*
Femoral neck	0.740 ± 0.098	0.716 ± 0.095	3.4%	0.22
Greater trochanter	0.613 ± 0.091	0.572 ± 0.085	7.2%	0.02*
Ward's triangle	0.555 ± 0.086	0.518 ± 0.102	7.1%	0.05*

* $P < 0.05$
Data values are means ± SD

Table 3. Comparison of function testing in Tai Chi Chun (TCC) and Control (CON) groups

Functional tests	TCC group	CON group	Percent difference between TCC and CON	P Value
Quadriceps (kgf^{-1})	20.2 ± 4.6	14.1 ± 4.6	43.3%	0.00**
Trunk bend-and-reach (cm)	−2 ± 9.1	2.6 ± 9.2	176.9%	0.08
Single-stance time (s)	114.3 ± 68.1	68.1 ± 75.5	67.8%	0.02*

* $P < 0.05$; ** $P < 0.01$
Data values are means ± SD

(TCC vs CON, 0.555 ± 0.086 vs 0.518 ± 0.102 g/cm^2; $P <$ 0.05).

Comparison of functional testing results

Table 3 summarizes the differences in function testing results between the two groups. The TCC group showed 43.3% significantly higher quadriceps muscle strength (TCC vs CON, 20.2 ± 4.6 vs 14.1 ± 4.6 Kgf^{-1}; $P < 0.01$) and 67.8% longer single-stance time (TCC vs CON, 114.3 ± 68.1 vs 68.1 ± 75.5 s; $P < 0.05$). The TCC group also revealed higher magnitude of trunk bend-and-reach, although this was only marginally significant (TCC vs CON, −2.0 ± 9.1 vs 2.6 ± 9.2 cm; $P = 0.08$).

Bivariate linear correlation analysis

Bivariate linear correlation analysis showed a significant correlation between quadriceps muscle strength and the single-stance time of the nondominant leg ($r = 0.413$; $P <$ 0.01).

Discussion

The findings of this study revealed an overall higher BMD at spine and hip, as well as better neuromuscular function, in postmenopausal women who had been practicing regular TCC exercise for more than 3 years (average, 5 years) as compared with sex- and age-matched sedentary controls. These findings may be explained partially by retardation of the menopause- and age-related bone loss in TCC practitioners, as reported in a previous small-scale case-control study (with sample size $n = 17$) [25], as well as the maintenance and even improvement of neuromuscular function [10–15, 26].

It has been reported that high-impact loading is more osteogenic than muscle-strengthening exercise in athletes

[17,20]. TCC is a low-weight-bearing exercise with muscle-strengthening elements, especially for the lower extremities [11,14,15,27]. The present study demonstrated significantly higher quadriceps muscle strength in the TCC group. This may explain the regional variations in BMD found in the present study, i.e., the significantly higher BMD at the greater trochanter, a place where the insertions of the hip muscle groups such as the gluteus muscles, are located. A recent 1-year prospective and randomized study of weight-lift strength training in postmenopausal women also supports our findings; that study showed that an increase in femoral greater trochanter BMD, but not in femoral neck BMD, was positively related to total weight lifted [6]. When high-impact exercise, e.g., stepwise running, was introduced as an exercise intervention in postmenopausal women, better protective effects on bone loss were demonstrated at the femoral neck, and this result was explained by the large bending moment at the femoral neck generated by running or jumping impact. [28]

Menopause- and age-related deterioration in the musculoskeletal system result in osteoporosis and fragility fractures. A few previous large-scale, long-term follow-up studies have suggested that higher baseline or increased BMD resulting from pharmaceutical or non-pharmaceutical approaches to the prevention of osteoporosis were associated with decreased risk of fragility fracture [1,29]. However, these studies did not delineate whether if the reduced fracture occurrence was attributable to BMD alone, or whether it was attributable to the potential beneficial effects in fall prevention. It has been reported that approximately 30% of people over 65 sustain a fall annually, and about 10% to 15% of falls result in serious injuries such as hip and distal radius fracture or soft-tissue injuries; 90% of fragility fractures were largely the result of falls due to impaired neuromuscular function with aging [5,30].

As compared with high-impact exercise, low-weight-bearing TCC exercise is a unique form of physical activity that involves neuromuscular coordination, low velocity of muscle contraction, and low impact; it involves no jumping, and is recommended for elderly people to practice regularly, even for the elderly with osteoporotic and other musculoskeletal chronic conditions [11,12,21]. In the present study, the TCC group showed significantly better quadriceps muscle strength and correspondingly significantly better body balance, in terms of longer single-stance time. The body flexibility test, using trunck bend-and-reach, only showed a tendency to be better in the TCC group, which may imply that this body flexibility test may not be specific, as TCC exercise does not include movements for improving the magnitude of trunk bend-and-reach. Available studies of other groups show that regular participation in TCC exercise has improved or maintained muscle strength and neuromuscular coordination by improving balance, posture stability, and flexibility, and thereby reducing fall incidence and fall-related fractures among older individuals [7,10–15,21,25]. Therefore, physical exercises that are suitable for older individuals to prevent osteoporosis should have beneficial effects not only in retarding bone loss but also in decreasing the risks of fall and fragility fractures.

As compared with a prospective and randomized study, the current cross-sectional study had known limitations, in terms of "pure" TCC exercise intervention effects on BMD and musculoskeletal function, although this study was designed only to detect any beneficial effects on bone among elderly regular TCC practitioners from a general Hong Kong population. These limitations included a lack of programmed TCC intervention in terms of defined intensity, duration, and frequency of the TCC exercise; uncontrolled nutrition patterns; and self-reporting bias. In order to elaborate the protective effects of programmed TCC intervention in postmenopausal bone loss, and deterioration of neuromuscular function, a prospective and randomized trial is desired for subjects with no current participation in physical exercises. Lifestyle factors, such as potential TCC intervention-induced changes in daily physical activities and changes in dietary patterns, should also be included in the evaluation of BMD changes.

In conclusion, this cross-sectional study has revealed general beneficial effects of regular participation in TCC exercise, including beneficial effects on the BMD of the weight-bearing skeleton and on body functions such as muscle strength, balance, and flexibility in early post-menopausal women. These results may also imply the protective effects of regular participation in TCC exercise in the retardation of menopause- and age-related deterioration of the musculoskeletal system. Long-term follow-up studies are desirable to investigate the effects of TCC exercise in reducing fragility fractures resulting from osteoporosis and falls.

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