Regular Tai Chi Chuan Exercise May Retard Bone Loss in Postmenopausal Women: A Case-Control Study

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Objective: To evaluate the potential benefits of regular Tai Chi Chuan exercise on the weight-bearing bones of postmenopausal women.

Design: Case-control study.

Setting: University medical school in Hong Kong.

Participants: Postmenopausal women (age range, 50–59y), including 17 self-selected regular Tai Chi Chuan exercisers (TCE) with over 4 years of regular exercise, and 17 age- and gender-matched nonexercising controls (CON).

Interventions: Not applicable.

Main Outcome Measures: Bone mineral density (BMD) in the lumbar spine and proximal femur was measured at baseline and at follow-up 12 months later by using dual-energy x-ray absorptiometry (DXA) and in the distal tibia using multislice peripheral quantitative computed tomography (pQCT).

Results: Baseline results showed that the TCE group had significantly higher BMD (10.1%–14.8%, all P<.05) than the CON group in the lumbar spine, proximal femur, and the ultradistal tibia. The follow-up measurements showed generalized bone loss in both groups. Although both DXA and pQCT measurements revealed decelerated rates of bone loss in the TCE group, only the more sensitive pQCT showed significantly reduced rate of bone loss in trabecular BMD of the ultradistal tibia (TCE vs CON: −1.10%±1.26% vs −2.18%±1.60%, P<.05) and of cortical BMD of the distal tibial diaphysis (TCE vs CON: −0.90%±1.36% vs −1.86%±0.93%, P<.05).

Conclusion: This is the first case-control study to show that regular Tai Chi Chuan exercise may help retard bone loss in the weight-bearing bones of postmenopausal women.

Key Words: Bone density; Exercise; Osteoporosis, postmenopausal; Rehabilitation; Tai Chi; Women.

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OSTEOPOROSIS IS A MAJOR health problem for postmenopausal women, accounting for the association between low bone mineral density (BMD) and fractures. In women, bone loss begins after they enter the fourth decade of life and accelerates after the onset of menopause. The magnitude of the problem, however, calls for a preventive approach that will protect the majority of women at least at the beginning of menopause or perhaps earlier. It is still not known whether the postmenopausal acceleration in bone loss is just an effect of aging or is secondary to factors such as malnutrition, various hormones, changes, hormonal deficits, or decreases in physical activity and associated muscle mass. Whatever the etiology, exercise has a beneficial effect on BMD and helps to prevent osteoporosis.

Evidence regarding the association of exercise with BMD largely comes from cross-sectional studies involving athletes. In young adults, the highest BMD values have been found in power-trained athletes such as weight lifters, whereas endurance activities such as long distance running and swimming appear less effective in achieving higher peak bone mass. High-impact or strengthening exercises such as weight lifting or jumping may cause a sufficient degree of bone strain to have a measurable positive effect on peak bone mass, at least at weight-bearing sites. However, such high-impact or strengthening exercise is not appropriate for the elderly. Lifetime leisure sports or low-impact aerobic exercises in adult life have been shown in many studies to promote the maintenance of bone mass or deceleration of bone loss in pre-, peri-, and postmenopausal women. This inconsistency may result from differences in study design, subject selection, numbers of subjects selected for statistical analysis, the types of densitometers used, and the skeletal sites selected for the BMD measurements.

All of the previously referenced studies into the effects of exercise on BMD used single-photon absorptiometry (SPA), dual-photon absorptiometry, and/or dual-energy x-ray absorptiometry (DXA), which may not be sufficiently sensitive or accurate. The most frequently measured skeletal sites were the spine, hip, and distal radius; SPA, dual-photon absorptiometry, and DXA measure areal (2-dimensional) BMD in g/cm² using bone mineral content in grams or g/cm over the projected bone area (cm²). The precision error of these measurement tools is consistently reported to be 1% to 2%. Peripheral quantitative computed tomography (pQCT), which has been developed and used intensively in the recent years, measures the volumetric BMD in mg/cm³ for both cortical BMD (cBMD) and proportionally more domain and metabolically more active trabecular BMD (tBMD) in the distal extremities, such as distal radius and tibia, separately. In addition, the peripheral location of the human forearm or tibia, with its relatively small amount of surrounding soft tissue, improves the accuracy and the precision of bone mass measurements. Particularly, the highly precise and multiple-slice pQCT has been reported to have a long-term in vivo precision error of 0.3%, suggesting a 3-fold more sensitive bone densitometer than the SPA or DXA. Therefore, pQCT is frequently used for...
the early detection of bony changes by monitoring metabolically high turnover trabecular BMD. 5,6,22-24

Tai Chi Chuan is a low-weight-bearing exercise and a major physical exercise regularly practiced worldwide by elderly populations of Chinese origin. Previous studies27-34 showed that Tai Chi Chuan exercise was effective for elderly people in maintaining neuromuscular coordination—an effective approach for fall prevention, muscle strength, flexibility, and functions of cardiorespiratory and immunoendocrine systems.27-34 However, scientific evidence has been lacking as to whether regular Tai Chi Chuan exercise in elderly people may also have the potential to prevent osteoporosis.

The present study was designed to use the highly precise multislice pQCT technique with DSA to study the possible beneficial effects of Tai Chi Chuan in preventing bone loss in postmenopausal women who practiced Tai Chi Chuan as their major daily physical activity.

METHODS

Participants

Postmenopausal women who had stopped menstruating for 1 to 9 years and who had reported doing regular Tai Chi Chuan exercise for more than 4 years and women without histories of regular exercise were recruited through women’s health clubs in our local communities and through newspaper advertisements. A total of 143 women responded and completed a questionnaire about their current health, diet, medical history, lifestyle, and menstrual status. Seventeen women met the inclusion criteria as healthy, regular Tai Chi Chuan exercisers, that is, they regularly participated in Tai Chi Chuan at women’s health clubs, in hobby groups, or individually for more than 3.5h/wk for at least the past 4 years (avg duration, 8.7y; maximal duration, up to 24y). They did not take calcium or multivitamin supplements or hormone replacement therapy, did not participate in regular vigorous exercise other than Tai Chi Chuan in earlier life, and had not had conditions affecting bone metabolism (eg, hypo- or hyperthyroidism) or other thyroid disease (hypo- or hyperparathyroidism) or renal or liver disease. Current or previous smokers and women with a body mass index (BMI) greater than 29kg/m2 were excluded. Using these same exclusion criteria, 17 age- and anthropometrically matched healthy, but nonexercising, postmenopausal women were recruited as controls. These women were physically inactive or engaged in only minor irregular physical exercise (ie, <0.5h/wk). All subjects gave written consent before the anthropometric and BMD measurements were taken. The Clinical Research Ethics Committee of the Chinese University of Hong Kong approved the study protocol.

Anthropometric Measurements

Body height and weight were measured and BMI was calculated.

BMD Measurement at Baseline

DXA measurements. Areal BMD measurements were made at the anteroposterior lumbar spine (L2–4) and nondominant proximal femur (neck, Ward’s triangle, intertrochanter) using DXA (Norland XR36).6 Quality control scans were performed daily with a manufacturer-supplied anthropomorphic spine phantom, composed of 4 simulated lumbar vertebrae, each with a known amount of hydroxyapatite embedded in a cubical epoxy block, which showed a long-term precision error of 1.2%.6

pQCT measurements. Volumetric BMD of the nondominant distal tibia was measured with a highly precise and
Follow-Up Protocols

Monitoring of the subjects. The Tai Chi Chuan exercisers committed to continue their regular exercise for at least 3.5h/wk in the 12 months after the baseline measurements and to undergo monitoring of their compliance; the nonexercising controls did not participate in any physical exercise. A research assistant monitored the follow-up of the subjects regularly by telephone.

BMD measurements. Both DXA and pQCT measurements were repeated 12 months after their baseline measurements. The DXA follow-up measurement for calculating the areal BMD changes repeated the same procedure described previously. Computer software, designed for continuous pQCT thintomograms, evaluated the results of the baseline and repeat measurements and their changes within the common region through an anatomic pattern recognition program. Two subject from the Tai Chi Chuan exercisers (TCE) group and 2 from the nonexercising controls (CON) group were dropped from the study either because they were lost to contact or because they missed their appointment for BMD measurement. Only those subjects who completed their follow-up pQCT measurements either for DXA or pQCT (table 1) were included in the calculation of BMD changes.

Statistics

Independent 2-tailed Student t tests were used to detect differences in the anthropometric variables and the densitometric variables between the 2 groups at baseline and follow-up. Paired t tests were used to compare the changes in each group between the follow-up and baseline measurements. The statistical significance level was set at P < .05. The SPSS statistical program, version 9.0, for Windows was used for the tests.

RESULTS

Comparison of Subject Distribution

Table 2 shows the homogeneity in age, anthropometric variables, and menstruation status between the TCE and CON groups.

Comparison of Areal and Volumetric BMD

Table 3 summarizes the differences between the 2 groups at baseline. Independent Student t tests revealed that the baseline areal BMD of the lumbar spine, neck, intertrochanter, and Ward’s triangle of proximal femur in the TCE group were, respectively, 13.7%, 10.1%, 10.7%, and 14.8% higher (all P < .05) than in the CON group. pQCT measurements of the ultradistal tibia demonstrated a mean 13.7% higher tBMD compared with the CON group (P < .05).

Changes of Areal and Volumetric BMD at 12-Month Follow-Up

The follow-up measurements revealed a generalized bone loss in both areal and volumetric BMD in both groups (table 1). DXA measurements showed inconsistent changes in BMD in the various regions. Although there was a significant decrease of 3.0% (P = .01) in femoral neck measurements in the TCE group as compared with a nonsignificant 1.6% decrease in the CON group, a significant decrease of 2.9% (P < .05) was found in the Ward’s triangle of the CON group. No significant changes in BMD were found in the other regions in either group. The pQCT measurements demonstrated a greater decrease in BMD generally in the CON group. In both groups, a significant decrease in BMD was found in the tBMD and iBMD of the ultradistal tibia and the cBMDT or cBMDO of the distal diaphysis. When the differences in the changes in BMD measured by pQCT were compared, the only significant differences were in the tBMD of the ultradistal tibia (TCE vs CON: −1.10% ± 1.26% vs −2.18% ± 1.60%, P < .05) and the cBMDT of the distal tibial diaphysis (TCE vs CON: −0.90% ± 1.36% vs −1.86% ± 0.93%, P < .05) (table 1).

DISCUSSION

This case-control study found overall higher baseline BMD values in the weight-bearing skeletons of postmenopausal women. This is consistent with the findings of other studies that Tai Chi Chuan may provide overall greater increases in BMD compared with the CON group.

Table 2: Homogenous Distribution of Subjects Regarding Anthropometric Variables and Postmenopausal State Between the Exercisers and the Controls

<table>
<thead>
<tr>
<th>Measurement Region and Variables</th>
<th>TCE Group</th>
<th>CON Group</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>54.1 ± 3.7</td>
<td>53.8 ± 3.6</td>
<td>.779</td>
</tr>
<tr>
<td>Body height (cm)</td>
<td>153.6 ± 7.5</td>
<td>153.8 ± 7.4</td>
<td>.936</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>56.8 ± 10.0</td>
<td>55.7 ± 10.2</td>
<td>.739</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.1 ± 3.7</td>
<td>23.8 ± 3.8</td>
<td>.853</td>
</tr>
<tr>
<td>Years since menopause</td>
<td>5.8 ± 3.1</td>
<td>5.8 ± 3.6</td>
<td>1.000</td>
</tr>
</tbody>
</table>

NOTE. Data are mean ± SD.

* Independent Student t test.
women who did regular Tai Chi Chuan exercise long-term than in the nonexercising gender- and age-matched controls. The significant differences found in the TCE group included a 10% to 15% higher areal BMD in the spine and proximal femur and an approximately 14% higher volumetric BMD in trabecular compartment of the ultradistal tibia.

Our 12-month follow-up measurements showed that the areal and volumetric BMD were generally reduced in both groups. That Tai Chi Chuan exercise did not increase BMD in postmenopausal women may be explained by its low-impact weight-bearing nature and because bone may become less responsive to vigorous exercise in later life.1,13 We found, however, that exercise effects about a 2-fold reduction of bone loss in the tBMD of the ultradistal tibia and the cBMD in the distal tibial diaphysis of the TCE group relative to the nonexercising group. Higher baseline BMD values in the TCE group may be explained by the reduced rate of bone loss, as shown in the follow-up measurements.

At follow-up, the differences in areal BMD, as measured by DXA, in the spine and 3 regions of the proximal femur between the groups were not consistent. Thus, while there was a significantly lower (mean, 3.0%) BMD at the femoral neck in the TCE group, BMD was significantly higher (mean, 2.9%) in Ward’s triangle compared with the CON group. One explanation for this inconsistency is the relatively low measurement precision of this technique for reliably detecting bone loss in these subjects within 12 months, despite the BMD being measured with daily phantom calibration for quality assurance. In comparison with the DXA measurements, BMD measured by pQCT showed relatively consistent results in tBMD, iBMD, and cBMD between the 2 groups. This may suggest the superior measurement precision of pQCT of 0.3%, which enables a 3-fold earlier detection of BMD difference or change of .85% or more with a confidence level of 95%, as compared with a precision error of 1% to 2% with DXA.22-24 The high precision of our pQCT measurements is partially because we used an anatomic pattern recognition program to calculate changes in BMD.22 Higher sensitivity has also been reported recently by evaluating metabolically more active trabecular bone with pQCT as compared with the DXA technique that measures areal BMD—an iBMD of both cBMD and tBMD.21-25,26 It is thus not surprising that some previous controlled studies of relatively short duration in postmenopausal women, which used DXA to monitor areal BMD change, did not show any benefits of regular aerobic exercise.16,17 However, if the follow-up had been long enough, we believe that the beneficial effects of regular and moderate exercise would have been demonstrable not only in volumetric BMD measured by pQCT but also in areal BMD measured by DXA.18,19 This was shown in previous studies9-14,15 that showed that lifetime leisure sports or low-impact aerobic exercises in adult life promoted the maintenance of bone mass or the deceleration of bone loss in pre-, peri-, and postmenopausal women when BMD was measured by using DXA.

A few large-scale, long-term follow-up studies3-5 have shown that an 8% to 10% higher areal BMD would suggest an approximate 50% decreased risk of osteoporotic fracture. Regular participation in Tai Chi Chuan exercise has been reported to benefit neuromuscular coordination and thus to reduce fall incidences and fall-related fractures.29,30 Our small-scale and short-term study was unable to show to what extent the higher BMD found at baseline and the slower rate of bone loss found at follow-up was beneficial in reducing future fracture risks. Large-scale, long-term, and prospective intervention studies are needed to investigate the effect of regular Tai Chi Chuan exercise in preventing osteoporosis and osteoporotic fractures. Nevertheless, results of this study suggest that there are beneficial effects of regular participation in Tai Chi Chuan exercise on skeletal bone health of postmenopausal women. Also, it suggests the potential of Tai Chi Chuan exercise in rehabilitation programs to prevent estrogen deficiency or inactivity-induced adverse effects on skeletons resulting from menopause, aging, musculoskeletal degeneration, or trauma. Tai Chi Chuan exercise is a unique form of physical activity of neuromuscular coordination, low velocity of muscle contraction, and low impact that involves no jumping. Therefore, Tai Chi Chuan exercise has been recommended as a suitable exercise for elderly people or patients with rheumatoid arthritis and osteoporotic conditions.29,30,32

Our case-control study was retrospective in nature and subject to self-selection bias. The following might influence the interpretation of our results at both baseline and follow-up in terms of the pure intervention effects of Tai Chi Chuan exercise on BMD or rate of bone loss. First, our study lacked a programed Tai Chi intervention of defined intensity, duration, and frequency of the exercise. The study was designed only to detect any beneficial effects on bone among regular elderly Tai Chi Chuan practitioners in the general Hong Kong population. Second, the number of subjects recruited for the study was relatively small because of the “contamination of subjects” in a society with a relatively better awareness of osteoporosis and its prevention (ie, a high percentage of respondents who did not meet the inclusion criteria). Third, TCE subjects who were included for the case-control follow-up might also have had a generally more active lifestyle, apart from a potentially increased physical activity required to travel between home and Tai Chi Chuan practice sessions, than did the CON group.
CONCLUSION

Early postmenopausal women with a history of exercising regular Tai Chi Chuan exercise had higher areal as well as volumetric BMD at baseline in their weight-bearing skeletons, as compared with nonexercising control subjects. This difference might be explained by exercise-induced deceleration of bone loss, which was confirmed by a significantly slower decrease in tBMD in the ultradistal tibia and cBMD in the bone loss, which was significantly slower as compared with nonexercising control subjects. This difference with the BMD measurements, Mr. Siuwoon Ng for statistical advice, and Prof. Julian Critchley for help with English and text interpretation of this manuscript.

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Suppliers

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