

# EFFECT OF 6 MONTHS OF TAI CHI CHUAN AND CALCIUM SUPPLEMENTATION ON BONE HEALTH IN FEMALES AGED 50–59 YEARS

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The objective of this study was to investigate the effects of Tai Chi Chuan, with and without calcium supplementation, on bone mineral density (BMD) and balance in women aged 50–59 years. A total of 80 subjects were randomly allocated into four groups according to calcium supplementation and the presence or absence of Tai Chi Chuan: (1) control; (2) Ca; (3) Tai Chi Chuan (TCC); and (4) TCC+Ca. The TCC and TCC+Ca groups practiced Tai Chi Chuan for longer than 30 minutes per session, 3 sessions per week for 26 weeks, while the control and Ca groups performed no systematic exercise. BMD and one leg standing time were assessed for all subjects before and after the experimental period. BMD was measured using SD-1000 single photon absorptiometry. The Ca and TCC+Ca groups received daily oral supplements of calcium 720 mg. In all subjects, a balance ability index was assessed and was determined as the time (in seconds) for which the subject could remain standing on one leg with her eyes closed. Subjects in the TCC and TCC+Ca groups demonstrated a significantly higher BMD than those in the control and Ca groups after the 6 months of training, while there had been no significant differences between the groups before training. Subjects in the TCC and TCC+Ca groups exhibited significantly improved balance ability compared to the control and Ca groups after the 6 months of training. The present study demonstrated that 6 months of TCC practice can retard bone mass loss and improve the ability to maintain balance.

**Keywords:** age, balance, bone mineral density, Tai Chi

## Introduction

Osteoporosis is a systemic skeletal disease characterized by lower than normal bone mass and microarchitectural deterioration of bone tissue, with a consequent

increase in bone fragility and susceptibility to fracture (Guo et al. 2001). It is well known that maximizing peak bone mineral density (BMD) during the period of bone mass growth and retarding bone mass loss in the period of bone mass decrease are two effective ways to prevent osteoporosis (Xu et al. 1997). Recently, research on the relationship between exercise and osteoporosis suggests that systematic resistance training and weight bearing exercise may maximize peak BMD (in the period of bone mass increase) and retard bone mass loss (in the period of bone mass decrease) (Brown & Josse 2002; Hara et al. 2001; Berard et al. 1997). In contrast, others

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have found no significant effects of systematic exercise (Warren et al. 2002).

Tai Chi Chuan is a popular Chinese conditioning exercise and is well known for its slow and graceful movements (Lan et al. 2002). Recent investigations have found that Tai Chi Chuan is beneficial to cardiorespiratory function (Lan et al. 1999), strength (Lan et al. 2000), balance (Hong et al. 2000), flexibility (Hong et al. 2000), microcirculation (Wang et al. 2001) and recovery from head trauma (Shapira et al. 2001). However, the effects of Tai Chi Chuan on BMD and fragility fracture have not been fully characterized. Previous research has indicated that excessive physical activity, such as long-distance running, can be detrimental to bone health (MacDougall et al. 1992). Further studies are needed to define more appropriate exercise programs for improved functional outcomes in elderly populations at high risk for osteoporosis. For decades, the role of physical activity in preventing or treating the onset of osteoporosis has been of major interest in the medical community. Previous research has identified changes in BMD associated with physical activity (Layne & Nelson 1999; Krall & Dawson-Hughes 1994). The effect of various exercises on bone mass loss in the human body still requires further study.

Because bone fractures are frequently associated with falls, factors that increase the risk of falling should be included in an assessment of risk. Risk factors for falling include those associated with general frailty, such as impaired balance, muscle strength and low body mass (Cummings et al. 1995). Subjects who practiced Tai Chi Chuan had significantly better results in a rhythmic forward-backward weight-shifting test than the control group (Lin et al. 2000). In addition, adequate calcium through diet or supplements is essential for the prevention of osteoporosis (Baeksgaard et al. 1998). Calcium carbonate has a relatively high calcium bioavailability (Martini & Wood 2002) and supplements may counteract a large portion of the additional bone loss attributable to menopause in the aging population (Smith et al. 1989).

The objective of this investigation was to study the effects of 6 months of calcium supplementation only, Tai Chi Chuan only, and Tai Chi Chuan plus calcium supplementation on the BMD of the non-dominant radius and the balance ability of women aged 50–59 years old.

## Methods

### Subjects

A total of 143 potential subjects were contacted and randomly allocated into different groups; 63 were excluded based on the following exclusion criteria: infectious illness, fever, diabetes, nephropathy, hormone replacement therapy, history of eating disorders, smoking, and excess alcohol consumption. The remaining 80 subjects, aged 50–59 years, were recruited from the local community. The inclusion criteria were previous physical activity history and menopause; informed consent was obtained from each subject. Because the number of excluded subjects was not fixed in each group, the final number of subjects in each group varied. This study was approved by the committee on human research of the Chinese Institute of Sport Science.

### Study design

The subjects were divided into four different groups according to calcium supplementation and presence or absence of Tai Chi Chuan: (1) no calcium supplementation and no Tai Chi Chuan exercise (control group); (2) with calcium supplementation and no Tai Chi Chuan exercise (Ca group); (3) Tai Chi Chuan exercise without calcium supplementation (TCC group); and (4) Tai Chi Chuan exercise with calcium supplementation (TCC + Ca group). The results of questionnaires showed that the subjects in each group had not practiced systematic Tai Chi Chuan or any other type of exercise before the study, and there was no significant difference in BMD or balance ability among the groups before the study.

Each Tai Chi Chuan exercise session included approximately 10 minutes of warm-up, at least 30 minutes of Tai Chi Chuan training, and about 5 minutes of cool-down. There was at least three sessions a week, for 26 weeks. Exercise intensity was estimated to exceed 70% of maximal heart rate, and the intensity was monitored by heart rate. Measurements included single leg stance with eyes closed, and BMD of the non-dominant radius.

The Ca and TCC + Ca groups received daily oral supplements of calcium 720 mg. Subjects took the capsules three times a day for 6 months. The capsules were prepared by Zhongshan Jingxiang Pearl Calcium Co. Ltd. (Zhongshan, Guangdong, China) with the use of gelatin capsules, calcium carbonate and lactose filler. One

capsule contains approximately 120 mg of pure calcium according to the National Board of Health in China. In addition, the calcium content of the capsules was independently determined from a random sample of 30 capsules to contain  $119.4 \pm 3.2$  mg of calcium. Meanwhile, control and TCC subjects took placebo capsule made of amylum. Unsolicited verbal reports from the subjects indicated that they were unable to tell whether they had received calcium or placebo. Balance ability index was assessed and was determined as the time (in seconds) for which the subject could remain standing on one leg with her eyes closed.

### Measuring device and instrumentation

BMD and balance ability tests were conducted in the kinesiology laboratory before and after 6 months of treatment. The BMD at the distal third of the radius of the non-dominant hand was measured using the SD-1000 single photon absorptiometry (SPA) method. A professional operator took the measurements. The SD-1000 was obtained from the Beijing Research Institute of Geology of Nuclear Industry. Highly significant correlations were found in BMD of the forearm measured by both dual energy X-ray absorptiometry and SPA and no significant difference was found in the diagnostic results (Wu et al. 1997; Shore et al. 1995). SPA measurements of radial BMD predict future fragility fracture in both men and women (Cummings et al. 1993; Gardsell et al. 1990). Subjects were familiarized with the measurement procedure before formal measurement. For the purposes of accuracy, the equipment was calibrated to the manufacturer's specification. The test-retest reliability for the BMD test in this study was  $r=0.99$ .

Balance ability was assessed using standard procedures of the National Survey of Physical Fitness in

China as described by Chen and Yu (1993). Briefly, each subject stood on one leg, closed her eyes, with arms outstretched and the knee of the opposite leg flexed to approximately 100 degrees. One leg standing time was measured from the time when the position was stable until the subject could no longer maintain the position. The measurement was performed twice, and the better score was recorded on the data sheet. The subjects were familiarized with the measurement procedure before formal measurement. The test-retest reliability of this protocol determined in our laboratory was  $r=0.96$ .

### Statistical analysis

The results are expressed as mean  $\pm$  standard deviation, and independent Student's *t* test was used to test group differences at baseline. Repeated-measures ANOVA was used to test group and time effects for measurements of BMD and balance ability. Results were considered significant when  $p < 0.05$ . All statistical analyses were performed using SPSS version 10.0 (SPSS Inc., Chicago, IL, USA) on a personal computer.

## Results

### Subject characteristics

The control, Ca, TCC and TCC + Ca groups were of similar age, weight and height. Body weight and height did not differ among the four groups before or after the experiment, nor were there significant changes during the experiment (Table 1).

### Effect of Tai Chi Chuan on BMD

Our findings indicate that Tai Chi Chuan exercise significantly enhanced radius BMD values in the women

**Table 1.** Age, weight and height of the 80 subjects before and after the 6-month experiment\*

Group	n	Age (yr)	Weight (kg)		Height (m)	
			Pre-experiment	Post-experiment	Pre-experiment	Post-experiment
Control	26	54.7 $\pm$ 3.5	59.77 $\pm$ 1.65	59.53 $\pm$ 1.63	1.57 $\pm$ 0.04	1.57 $\pm$ 0.04
Ca	12	55.0 $\pm$ 2.4	59.33 $\pm$ 1.42	59.17 $\pm$ 1.43	1.57 $\pm$ 0.03	1.56 $\pm$ 0.02
TCC	21	53.6 $\pm$ 3.2	58.51 $\pm$ 1.23	58.20 $\pm$ 1.19	1.55 $\pm$ 0.03	1.55 $\pm$ 0.03
TCC + Ca	21	56.0 $\pm$ 2.6	58.51 $\pm$ 1.23	58.26 $\pm$ 1.37	1.56 $\pm$ 0.03	1.56 $\pm$ 0.03

\*Data are presented as mean  $\pm$  standard error. Control = no calcium supplementation and no Tai Chi Chuan exercise; Ca = with calcium supplementation and no Tai Chi Chuan exercise; TCC = Tai Chi Chuan exercise without calcium supplementation; TCC + Ca = Tai Chi Chuan exercise with calcium supplementation.

**Table 2.** Bone mineral density of the 80 subjects before and after the 6-month experiment\*

Group	Bone mineral density	
	Pre-experiment	Post-experiment
Control	0.565 ± 0.072	0.531 ± 0.084
Ca	0.597 ± 0.045	0.584 ± 0.053
TCC	0.595 ± 0.025	0.607 ± 0.028 <sup>††</sup>
TCC + Ca	0.596 ± 0.062	0.624 ± 0.074 <sup>††</sup>

\*Data are presented as mean ± standard error; <sup>†</sup>significant group differences in repeated-measures ANOVA,  $p < 0.05$ ; <sup>††</sup>significant difference from control group post experiment,  $p < 0.01$ . Control = no calcium supplementation and no Tai Chi Chuan exercise; Ca = with calcium supplementation and no Tai Chi Chuan exercise; TCC = Tai Chi Chuan exercise without calcium supplementation; TCC + Ca = Tai Chi Chuan exercise with calcium supplementation.

**Table 3.** Effect of Tai Chi Chuan on the balance ability of the 80 subjects before and after the 6-month experiment\*

Group	Balance ability	
	Pre-experiment	Post-experiment
Control	8.8 ± 3.0	8.3 ± 3.2
Ca	9.2 ± 4.4	8.1 ± 4.6
TCC	10.0 ± 2.4	12.6 ± 3.3 <sup>††</sup>
TCC + Ca	9.8 ± 4.0	13.0 ± 5.1 <sup>††</sup>

\*Data are presented as mean ± standard error; <sup>†</sup>significant group differences in repeated-measures ANOVA,  $p < 0.05$ ; <sup>††</sup>significant difference from control group post experiment,  $p < 0.01$ . Control = no calcium supplementation and no Tai Chi Chuan exercise; Ca = with calcium supplementation and no Tai Chi Chuan exercise; TCC = Tai Chi Chuan exercise without calcium supplementation; TCC + Ca = Tai Chi Chuan exercise with calcium supplementation.

(Table 2). There were no significant between-group differences in BMD at baseline. After 6 months of Tai Chi Chuan practice, the mean BMD in the TCC group was significantly higher than in the control group ( $p < 0.01$ ). Mean BMD in the TCC + Ca group was also significantly higher than in the control group ( $p < 0.01$ ). Although the mean BMD in the Ca group was higher than in the control group, this effect did not reach significance ( $p > 0.05$ ). There were significant group differences in repeated-measures ANOVA between the TCC + Ca and control groups ( $p < 0.05$ ).

#### ***Effect of Tai Chi Chuan on balance ability***

Table 3 summarizes the effect of Tai Chi Chuan on balance ability in the subjects aged 50–59 years. There were no significant group differences in any measure of balance ability at baseline. Subjects in the TCC and

TCC + Ca groups exhibited significantly improved balance ability when compared to control subjects post experiment ( $p < 0.01$  for both comparisons). However, the balance abilities of the TCC and TCC + Ca groups did not differ ( $p > 0.05$ ). There were significant group differences in repeated-measures ANOVA between the TCC and control and between the TCC + Ca and control groups ( $p < 0.05$  for both). In addition, calcium supplementation alone did not appear to have any effect on balance ability in the subjects.

## **Discussion**

### ***Effect of Tai Chi Chuan on BMD***

In the past few decades, numerous studies have demonstrated a positive relationship between exercise and high BMD (MacKelvie et al. 2002; Morris et al. 1997). Conversely, some studies have reported little or no effect of exercise on bone density (Courteix et al. 1998; Cassell et al. 1996; Hetland et al. 1993). Pruitt et al. (1995) studied the effects of a 12-month resistance training program, at high and low intensities, on BMD in healthy and older women, and suggested that high-intensity and low-intensity resistance training regimens increase muscular strength, but not in the lumbar spine or total hip BMD. However, Dornemann et al. (1997) suggest that even a short-term weight training program can either maintain or improve the BMD in the femoral neck and lumbar vertebrae in premenopausal women. These differing results may be partially attributable to the study design, intensity and duration of the exercise protocol and the BMD measurement techniques used. Physical activity, particularly weight-bearing exercise, is thought to provide the mechanical stimulus or “loading” that is important for the maintenance and improvement of bone health, whereas physical inactivity has been implicated in bone loss and its associated health decline.

In this study, we found that Tai Chi Chuan demonstrates significant function in retarding bone loss. In view of the fact that the BMD of the subjects was normal at baseline and instructions were given to maintain their normal diet, we could draw the conclusion that Tai Chi Chuan improves human bone health. Other types of exercise that are suitable for the elderly, such as weight-bearing exercise, jogging, low-frequency vibratory

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exercise, may have similar positive function. Data from the Third National Health and Nutrition Examination Survey (NHANES III) showed that jogging (any vs. none) was strongly associated with higher BMD in multivariate models ( $p < 0.01$ ) in both young and middle-aged men (Mussolino et al. 2001). Low-frequency vibratory exercise was found to increase BMD at the femoral neck in untrained postmenopausal women (Gusi et al. 2006).

The primary finding of this investigation was that Tai Chi Chuan may confer benefits in middle-aged (during the period of bone mass decrease) individuals. Although the Ca group had higher mean BMD compared to the control group, the difference did not reach statistical significance ( $p > 0.05$ ), a finding in agreement with previously reported studies. Welten et al. (1994) found that weight-bearing activity during youth is a more important factor for peak bone mass than calcium intake. However, it is well established that calcium supplementation effectively enhances BMD or retards bone mineral loss (Dibba et al. 2000). A possible explanation for the benefits of calcium supplementation is that BMD change has different mechanism or other factors (such as exercise and diet) were not accurately controlled in the different groups. In addition, Tai Chi Chuan accompanied by calcium supplementation in women significantly retarded bone loss in the 50–59 and also in the 60–69-year-old groups. However, the intrinsic mechanism underlying the effects of Tai Chi Chuan on BMD remains to be elucidated.

#### ***Effect of Tai Chi Chuan on balance ability***

We did not find any significant differences in balance ability between the control and Ca groups. This implies that calcium supplementation alone is not likely to positively influence balance ability in middle-aged subjects. In contrast, there was no difference in balance test performance between the TCC and TCC + Ca groups. The positive effect can be attributed to Tai Chi Chuan rather than to calcium supplementation, as the Tai Chi Chuan group performed as well as the TCC + Ca group in the balance test ( $p > 0.05$ ). It is well documented that the balanced body is a principle of Tai Chi Chuan (Shen et al. 1995). Since a practitioner of Tai Chi Chuan often stands on one leg during the movements, which has potential effects on the skeletal, muscular and neural systems, s/he would gradually improve their balance

ability in the course of Tai Chi Chuan learning and training. A previous report indicates that elderly people who regularly practice Tai Chi Chuan show better postural stability than those who do not (e.g. the condition with simultaneous disturbance of vision and proprioception) (Wong et al. 2001). As a coordination exercise, Tai Chi Chuan may reduce the risk of a fall by increasing the ability to maintain postural control. Whether Tai Chi Chuan affects balance ability via muscle support around the joints, endocrine system and/or nervous system needs to be further investigated.

#### **Conclusion**

We have demonstrated that Tai Chi Chuan increases BMD of the non-dominant radius in subjects aged 50–59 years. Furthermore, the significant association between improved balance ability and Tai Chi Chuan suggests that Tai Chi Chuan may prevent osteoporotic fracture and thus enhance bone health. Calcium supplementation alone did not significantly influence BMD and balance ability in these middle-aged subjects.

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