

# The role of Tai Chi Chuan exercise on osteoporosis prevention and treatment in postmenopausal women

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## Abstract

Osteoporosis is a disease characterized by fragile bones and high susceptibility to low trauma fractures. Tai Chi, an ancient Chinese mind-body exercise that is reported to enhance muscle function, balance and flexibility, and to reduce pain, depression and anxiety, may safely and effectively be used to prevent or treat osteoporosis. The aim of this review is to evaluate the evidence for Tai Chi as an intervention to reduce rate of bone loss in postmenopausal women. A literature search on randomized controlled trials (RCTs), prospective cohort studies, and cross-sectional studies that included Tai Chi as an intervention, and had at least 1 outcome related to measurement of bone metabolism were identified in PubMed/Medline. Twenty-one controlled studies were identified in the database, which suggested Tai Chi slowed down the loss of bone mineral density in most postmenopausal women, improved balance and strength, relieves pain from arthritis, and improved mental strength so they can cope better with chronic diseases. Regular Tai Chi Chuan exercise is beneficial for retarding bone loss in the weight-bearing bones of postmenopausal women.

## Introduction

### Osteoporosis and pathophysiology

Osteoporosis, as a serious metabolic bone disease, is characterized by low mineral density (BMD) and microarchitectural deterioration, resulting in an increased risk for osteoporotic fractures. In 1994, the WHO (World Health Organization)<sup>1</sup> defined osteoporosis in terms of BMD and previous fracture, as shown in Table 1.1 Osteoporosis is now recognized as a *silent epidemic disorder* and affects an estimated 75 million people in Europe, the USA and Japan.<sup>2</sup> In the USA it affects more than 25 million people, predisposes to more than 1.3 million fractures annually and costs the nation in excess of US \$20 billion. In white population, about 50% of women and 20% of men older

than 50 years will have a fragility fracture in their remaining life.<sup>3</sup> In China, there were about 83.9 million patients with osteoporosis in 1997, and so far 6.97% of Chinese people (about 88 million) suffer from primary osteoporosis.<sup>2</sup> It is recognized as a major public health problem in both developed and developing countries.

In postmenopausal osteoporosis, the primary defect is estrogen deficiency, with a resultant increase in bone resorption.<sup>4</sup> During the first five years of menopause, bone loss at the spine happens at a rapid rate of 2-6% each year. It then slows down and remains steady for about ten years. Hormone replacement therapy (HRT) is the first choice for prevention of postmenopausal osteoporosis. In China, data are relatively sparse regarding the prevention of postmenopausal osteoporosis by means of percutaneous estrogen. Chinese women have a higher bone loss rate during the first several years after menopause. It seems that Asians are more *estrogen-resistant* and *vitamin sensitive* than Caucasians. These race-specific effects may depend at least on different allelic frequencies of drug target genes that potentially contribute to individual drug response.<sup>3</sup>

### Osteoporosis and epidemical prevalence

The most serious clinical complication of osteoporosis is osteoporotic fracture, which has huge impact economically.<sup>5</sup> These fractures typically occur at the spine, hip and distal forearm. Hip fractures contribute most to hospitalization (Table 2).<sup>5</sup> As far as vertebral fractures are concerned, it is clinically difficult to definitely diagnose them due to the lack of universally accepted criteria, which may hamper the calculation and comparison of its incidence in epidemiological studies.

Lau *et al.*<sup>6</sup> concluded the prevalence of vertebral fracture was similar in Hong Kong Chinese (29%) and American Caucasians (25%). In contrast, both vertebral fracture prevalence and incidence were reported to be higher in Japanese women than American Caucasian women.<sup>7,8</sup> Thus, no confident conclusions about racial differences in vertebral fracture rates until standard morphometric definitions of vertebral fracture are employed.

Hip fractures are associated with significantly increased morbidity and mortality rates. Almost all of the studies consistently reported that the age and sex-adjusted annual rate of hip fracture was lower in Asians than in Caucasians.<sup>9</sup> Table 3 lists the age-adjusted rate of hip fracture per 100,000 individuals in Asians and Caucasians.<sup>9</sup>

There is some evidence to suggest that forearm fracture is much less frequent in Asians than in Caucasians. Hagino *et al.*<sup>10</sup> addressed that the age- and gender-specific incidence rates

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of distal radius and proximal humerus fractures among Japanese were substantially lower than those of Caucasians living in North America or northern Europe, e.g., the incidences (per 100,000 person-years) of distal radius and proximal humerus fractures were 196 and 52 in the Japanese, 438 and 161 in the USA, as well as 766 and 211 in Sweden, respectively.<sup>10</sup>

### Osteoporosis and exercise

A lack of physical activity and poor muscle strength were found to be important risk factors for osteoporosis among the elderly.<sup>11,12</sup> Weight-bearing exercise is advocated as a strategy for preventing osteoporosis. Studies in Caucasian populations showed weight-bearing exercises to be effective in maintaining BMD, and mixed type exercises for preventing hip fracture. In 2000, a review of 24 randomized controlled exercise trials in postmenopausal women found that both impact and nonimpact exercise prevented bone loss in the lumbar spine and femoral neck.

One mechanism through which physical activity could increase bone strength is by increasing muscle mass. Lean body mass is thought to increase bone mineral density through mechanical loading of the skeleton. Muscle, a component of lean mass, is important because muscle contractions exert a greater force on bones than other weight-associated gravitational forces.<sup>13</sup> Furthermore, recent research in humans and animals has suggested that muscle contractions resulting from applying mechanical vibrations can increase the amount and quality of bone.<sup>14</sup>

### Osteoporosis and Tai Chi

Over the past two decades, Tai Chi, a form of mind-body therapy, has spread worldwide for health and fitness. Tai Chi combines deep

diaphragmatic breathing and relaxation with many fundamental postures that flow imperceptibly and smoothly from one to the other through slow, gentle, graceful movements. Significant improvements have been reported in balance, strength, flexibility, cardiovascular and respiratory function, and reduction of pain, depression, anxiety and arthritic symptoms in a variety of patient populations including knee osteoarthritis.<sup>15</sup>

Thus, this review examines the use of Tai Chi as a potential intervention feasible way of providing standardized exercises with complementary mind-body approach to the management of osteoporosis. The physical component provides exercise that is consistent with recommendations for osteoporosis (range of motion, flexibility, muscle conditioning, and aerobic cardiovascular exercise), while the mind component has the potential to increase psychological well-being, life satisfaction, and perceptions of health.<sup>16</sup> These effects are especially pertinent for the treatment of older adults who have osteoporosis and poor physical function.

## Materials and Methods

To systematically review the evidence evaluating Tai Chi for reducing rates of postmenopausal bone loss, randomized controlled trials (RCTs), prospective cohort studies, and cross-sectional studies that included Tai Chi as an intervention were identified through a literature search conducted in PubMed/Medline. Search strategies included using the following statements and key words: Tai Chi or Tai Chi Chuan or Tai Ji combined with pathophysiology, epidemical prevalence, bone, osteoporosis or menopause. The database searches from MedPud/ Medline identified a total of 187 citations. Titles and abstracts of these citations were manually reviewed and considered eligible only if they described a prospective or cross-sectional study that employed Tai Chi as an intervention. A total of 59 citations met these criteria. Twenty-eight of these 59 citations were reviews or limited to abstracts of proceedings from scientific meetings or published in other languages were thus excluded; the remaining 21 were included in this review. Two additional eligible citations were identified using the China Biological Medicine Database for Chinese-language randomized trials.

## Results

Results across the 21 studies summarized in Table 4 suggest the followings:

**Bone loss.** Tai Chi slowed down the loss of bone mineral density in most postmenopausal women.<sup>17,21,23,25,28,29,31-33,35</sup> People who practice Tai Chi regularly sustain higher bone mineral density and better flexibility, muscle strength and balance than those sedentary life style ones.

**Fall prevention.** In line with previous studies Tai Chi reduces falls.<sup>18,22,24,26,27,36</sup> This is especially important because when people with osteoporosis fall they are more like to sustain a fracture. A fracture can be a very serious problem, for example hip fractures have a mortality rate of approximately 50%. It also seriously affects quality of life. Tai Chi has been shown to improve balance and strength so even if people fall, they have a less chance of serious injury.

**Associated Conditions.** People with osteoporosis often have arthritis, loss of function due to age and weakness. Tai Chi relieves pain from arthritis, improves balance and the ability to do daily activities which improve their life quality and self-esteem.<sup>22,24-26,36,37</sup>

**Stress.** People with chronic conditions such

as osteoporosis are more likely to be mentally stressed and depressed because of the increasing inability to function normally on a day-to-day basis. Tai Chi has been shown to improve the mind, help people feel more relaxed and improve mental strength so they can cope better with chronic diseases.<sup>19,30,34,36,37</sup>

Tai Chi program is based on the classical Yang Style<sup>38</sup> with 24 forms (Figure 1). The exercise prescription consisted of at least 60 min Tai Chi session of moderate-intensity exercise, 5 d/wk for 12 months (Table 5). Each session includes: i. warm up and review of Tai Chi principles and techniques; ii. Tai Chi exercises; iii. breathing techniques; iv. Mind-body relaxation. Participants were required to attend three supervised sessions per week at a study facility (a community center) during months 1-3 and to exercise 2 d/wk at home. For months 4-12, they were required to attend at least one of the three sessions offered weekly at a study facility and to exercise 4 d/wk either at home or at the facility. The instructions are carried out by a Tai Chi master who has over 20 years experience conducting Tai Chi Mind-

**Table 1. Diagnostic categories for osteoporosis based on WHO criteria.**

Category	Definition by BMD
Normal	A value for BMD that is not more than 1 SD below the young adult mean value
Low bone mass (Osteopenia)	A value for BMD that lies between 1 and 2.5 SD below the young adult mean value
Osteoporosis	A value for BMD that is more than 2.5 SD below the young adult mean value

SD, standard deviation

**Table 2. Impact of osteoporosis-related fracture.**

	Hip	Spine	Wrist
Lifetime risk (%)			
Women	14	28	13
Men	3	12	2
Cases/year	70,000	120,000	50,000
Hospitalization (%)	100*	2-10	5
Relative survival	.83	.82	1.00

Lifetime risk: The risk of developing a disease during one's lifetime or dying of the disease.

**Table 3. Aged adjusted rate of hip fracture (Adapted from Lei *et al.*, 2006).**

Ethnic groups	Sites	Female	Male	Female to male ration
Asina	Hong Kong	389	196	2.0
	Hong Kong	179	113	1.6
	Tottori, Japan	227	79	2.9
	Okinawa, Japan	325	86	3.8
	New Zealand	212	121	1.8
Caucasians	Sweden	730	581	1.3
	Malmö, Sweden	468	153	3.1
	Norway	737	298	2.5
	Edinburg, Scotland	529	174	3.0
	Oxford, England	603	114	5.3
	California, USA	617	215	2.9
	Hawaii, USA	645	205	3.1
New Zealand	466	139	3.4	

Body exercise programs. Several forms are emphasized by the Tai Chi master to achieve the physical (body) and mental (mind) goals of accommodation osteoporosis symptoms and limit discomfort. For example, the 90 degree knee-flexor joint stance used in the traditional Tai Chi exercise that would place stress on the knees, etc. Patients perform 2 sets: one with the legs together and one with legs apart to further strengthen various muscles around the knee. In addition, the ability to tap into the power of the mind is developed further by having patients perform visualizations while sitting on the edge of a chair.

The exercise intensity of Tai Chi depends on its training style, posture and duration. Variation in training approaches result in substantial differences in exercise intensity. Lan *et al.*<sup>39,40</sup> have measured heart rate (HR) and oxygen uptake ( $VO_2$ ) simultaneously during classical Yang style Tai Chi practice in 15 male subjects, their heart rate (HR) during Tai Chi practice was 58% of the heart rate reserve (HRR), and oxygen uptake ( $VO_2$ ) was 55% of the peak oxygen uptake ( $VO_{2peak}$ ). The level of blood lactate immediately after Tai Chi practice was 3.8 mM, which reflected the level of lactate during Tai Chi approximated the onset of blood lactate accumulation (OBLA). In order to evaluate the relative exercise intensity of classical Yang style Tai Chi, they measured HR responses during TC practice in 100 subjects with age of 25-80 yrs (M/F: 54/46). These subjects were separated into three groups: young (25-44 y/o), middle-aged (45-64 y/o) and elderly (65-80 y/o). During the Tai Chi practice, the mean HR of men was  $141 \pm 12$ ,  $132 \pm 9$  and  $120 \pm 10$  bpm (beat per minute) in the young, middle-aged and elderly groups, respectively. Meanwhile, the mean HR of women was  $136 \pm 10$ ,  $126 \pm 11$  and  $115 \pm 12$  bpm in the young, middle-aged and elderly groups, respectively. Men practiced Tai Chi with mean HR corresponding to  $57.8 \pm 3.7$ ,  $56.6 \pm 3.4$  and  $55.1 \pm 3.1$ % of heart rate reserve (HRR) in the three groups; while that of women corresponding to  $52.7 \pm 2.8$ ,  $51.5 \pm 2.6$ , and  $50.3 \pm 2.9$ % of HRR in the three age groups. The results demonstrate that classical Yang style Tai Chi is an exercise with moderate intensity, and its exercise intensity is similar across different ages in each gender.

Main outcome BMD was measured in the lumbar spine, hip and proximal femur by using dual-energy x-ray absorptiometry (DXA) and in the distal tibia by using multisite peripheral quantitative computed tomography (pQCT), which is the most convincing results. Serum samples might be collected for bone formation or resorption makers' biochemistry assay. Fracture/fall rate, life quality and self-efficacy were also documented through the questionnaire. Body balance was assessed using a Computer Posturographic System PE 90 which

the capacity to perform specific tasks was analyzed. Muscle strength index grip strength was measured using a handgrip dynamometer GripD (Takei Scientific Instruments, Tokyo, Japan). A quadriceps device (Isometric Dynamometer Baseline, Genova, Italy) was used to measure the strength of the quadriceps femoris (vastus medialis, vastus lateralis, vastus intermedius, and rectus femoris) muscles. Balance and coordination were measured by A SMART Balance Master (NeuroCom International Inc., Clackamas, OR, USA).

The impact of Tai Chi practice on osteoporosis is likely to be mediated by improvement in muscle function,<sup>41,42</sup> faster neuromuscular reactions in leg muscles resulting in more efficient protection in postural disturbances, balance, and fear of falling. Therefore, Tai Chi is an important intervention in the maintenance of bone health, muscle strength and balance, thereby reducing the risk of falls and fractures. In elderly people, exercises of a strenuous or intense nature with documented evidence of health benefits may not be feasible. It has been

**Table 4. Summary of studies evaluating Impact of Tai Chi on osteopenic menopausal Women.**

Studies	Study design	Interventions	Results
Peppone <i>et al.</i> , 2010 <sup>17</sup>	RCT	TC vs. Control	↑ bone formation markers
Chyu <i>et al.</i> , 2010 <sup>18</sup>	RCT	TC vs. Control	↑ stride width, ↓ fall risk
Shen <i>et al.</i> , 2010 <sup>19</sup>	RCT	TC vs. GTP vs. Con	↑ role-emotional, mental health
Shen <i>et al.</i> , 2010 <sup>20</sup>	RCT	TC vs. RT	↑ bone formation markers
Song <i>et al.</i> , 2010 <sup>21</sup>	RCT	TC vs. Control	↑ BMD, muscle endurance
Maciaszek <i>et al.</i> , 2007 <sup>22</sup>	RCT	TC vs. Control	↑ body balance
Woo <i>et al.</i> , 2007 <sup>23</sup>	RCT	TC vs. RTE vs. Control	↓ BMD loss
Wolf <i>et al.</i> , 2006 <sup>24</sup>	RCT	TC vs. Control	↑ gait speed, cardiovascular performance
Qin <i>et al.</i> , 2005 <sup>25</sup>	Cross-sectional	TC vs. Control	↑ BMD & neuromuscular function
Murphy <i>et al.</i> , 2005 <sup>26</sup>	RCT	TC vs. Control	↑ balance, mobility, strength
Li <i>et al.</i> , 2005 <sup>27</sup>	RCT	TC vs. Control	↓ fall, ↑ balance
Chan <i>et al.</i> , 2004 <sup>28</sup>	RCT	TC vs. Control	↓ bone loss
Yeh <i>et al.</i> , 2004 <sup>29</sup>	RCT	TC vs. Control	↑ BNP, O <sub>2</sub> uptake
Mustian <i>et al.</i> , 2004 <sup>30</sup>	RCT	TC vs. Control	↑ HRQL
Xu <i>et al.</i> , 2004 <sup>31</sup>	Paired crossover	TC vs. Acp vs. CH	↑ bone formation
Zhou <i>et al.</i> , 2004 <sup>32</sup>	RCT	TC vs. RS vs. MB vs. Con	↑ BMD
Gong <i>et al.</i> , 2003 <sup>33</sup>	Cross-sectional	TC vs. Control	↑ BMD
Wolf <i>et al.</i> , 2003 <sup>34</sup>	RCT	TC vs. Control	No effect on RR of falling
Qin <i>et al.</i> , 2002 <sup>35</sup>	RCT	TC vs. Control	↑ BMD
Li <i>et al.</i> , 2001 <sup>36</sup>	RCT	TC vs. Control	↑ physical functioning
Hartman <i>et al.</i> , 2000 <sup>37</sup>	RCT	TC vs. Control	↑ arthritis self-efficacy, functional mobility

RCT, randomized control trial; TC, Tai Chi; GTP, green tea polyphenols; RT, resistance training; BNP, serum B-type natriuretic peptide levels; RTE, resistance exercise; Acp, Acupuncture; CH, Chinese herbs; RS, rope skipping; MB, Mulan boxing; RR, risk ratio; HRQL, health-related quality of life.

**Table 5. The exercise prescription for postmenopausal women to prevent osteoporosis.**

Activity selection	Tai Chi Yang style 24 forms
Duration	60 minutes
Frequency	5 times per week, up to 12 months
Intensity	50-55% $VO_{2max}$
Emergence expenditure	Estimated 4 METs for Tai Chi ; For example: 58 yrs women, weighed 80kg and measured $VO_{2max}$ = 25 ml/kg/min; $EE = [(25-4) * 0.5 + 4] / 4 * 80 = 290$ kcal/h
Exercise Session	1. Warm up; 2. Tai Chi exercise; 3. Breathing techniques; 4. Relaxation methods.
Progression	1. Initial conditioning phase: 4-6 wks; 2. Improvement conditioning phase: 4-6 months; 3. Maintenance conditioning phase: after 6 months

suggested that Tai Chi is a suitable form of exercise in balance and leg strength training,<sup>24,34</sup> and is considered a key intervention in counteracting sarcopenia associated with aging in China.<sup>43</sup> Since Tai Chi is a weight bearing exercise, a beneficial effect may be expected, and this is observed in postmenopausal women between 50 and 60 years of age.<sup>25,28,35</sup> Some studies<sup>22,24,27,34,36</sup> have demonstrated the effectiveness of Tai Chi in maintaining physical functioning and reducing falls among older adults. The slow, rhythmic movements that characterize Tai Chi also provide a holistic approach to exercise that combines mind and body experiences. Several studies have demonstrated improvements in quality of life among older adults with osteoarthritis,<sup>37</sup> patients with chronic heart failure,<sup>29</sup> people who have had breast cancer,<sup>30</sup> and patients with fibromyalgia<sup>44</sup> following Tai Chi practice.

Finally, our results are limited by the literature search merely on the database PubMed/Medline; therefore it may miss other important information that is housed in existing Science Citation Index, Cochrane, CAM database such as MANTIS, CINAHL etc. A further limitation is the methodological quality of most studies was poor; none of them met all the criteria of quality design and methodology features including: i) Randomization employed; ii) Randomization methods; iii) Clear inclusion/exclusion criteria; iv) Outcome assessors blinded; v) Withdrawal or dropouts reported; vi) Sample size justified/estimated; vii) Appropriate data analysis; viii) Tai Chi intervention described; ix) Qualification of Tai Chi instructors. Further research is warranted to include appropriately powered randomized trials that include women representing a variety of races and ethnicities. This research should also explore the use of alternatives to DXA for the measure of BMD, including pQCT. Long term prospective studies and cross-sectional studies should also include data on incidence of fractures. Combining the use of sensitive markers on biomechanical, physiologic, and psychosocial outcomes could provide important insight into the mechanisms by which Tai Chi impacts bone health.

## Conclusions

Based on a few and not entirely comparable studies discussed in this review, the efficacy of Tai Chi for reducing bone loss, fall prevention, associated conditions and stress in postmenopausal women are limited by the small number and generally low quality of studies to date. Acknowledging these limitations, the totality of the available evidence suggests Tai Chi may be an effective, safe, and practical

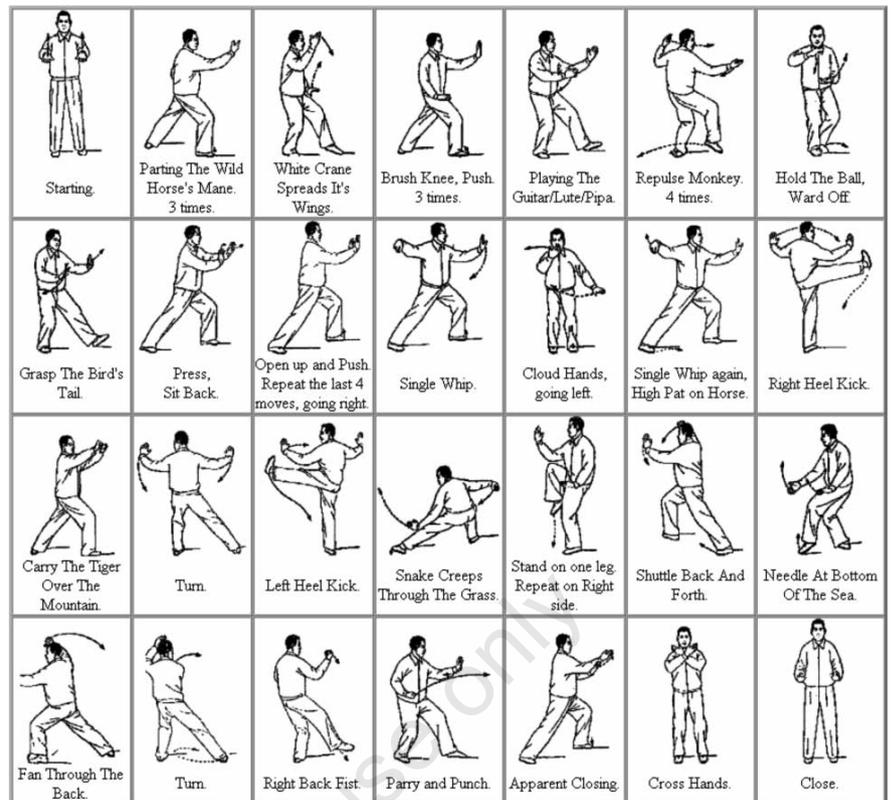


Figure 1. The List of Tai Chi Yang style 24 form postures (China Sports, 1983).

intervention for maintaining bone loss, improving their life quality in postmenopausal women, with or without pharmaceutical therapies. In combination with research that indicates Tai Chi can positively impact other risk factors associated with low BMD (e.g., reduced fall frequency, increased musculoskeletal strength), further methodologically sound research is warranted to better evaluate the impact of Tai Chi practice on BMD and fracture risk in postmenopausal women.

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