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Original Article

Effect of Tai Chi on bone mineral density in postmenopausal women: A systematic review and meta-analysis of randomized control trials

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Abstract

Background: This meta-analysis of relative randomized control trials (RCTs) aimed to investigate whether Tai Chi exercise is able to alleviate bone mineral density (BMD) loss in postmenopausal women.
Methods: Electronic databases including PubMed, Embase, Springer link, Cochrane library, Wanfang and China National Knowledge Infrastructure (CNKIi) were used to search the eligible literature up to January 28, 2016. The pooled weighted mean difference (WMD) method combined with 95% confidence interval (CI) was used as the effect size of BMD values. The quality assessment of the included articles was performed by the Cochrane Collaboration Risk of Bias Tool (CCRBT).
Results: Total of six eligible articles with 182 participants in the Tai Chi intervention group and 168 participants in the control group were included in this study. Compared with control group, the overall analysis with the fixed-effect model showed no significant difference in BMD at the lumber spine between the intervention and control groups (WMD = 0.02, 95% *CI*: −0.00 to 0.05, $P = 0.09$). Moreover, there was no obvious difference in BMD at the femoral neck between Tai Chi interventions and controls (WMD = 0.01, 95% *CI* = −0.03 to 0.05, $P = 0.51$) via the pooled analysis with the random effects model.
Conclusion: Tai Chi exhibits no significant role in attenuating BMD loss in postmenopausal women at the lumber spine and femoral neck.

Keywords: Bone mineral density; Meta-analysis; Postmenopausal women; Randomized control trial; Tai Chi

1. Introduction

In postmenopausal women, osteoporosis is one prevalent bone remodeling disease, and it is characterized by a low bone mass and high risks of fractures.[1] Osteoporosis in postmenopausal women is attributed to the decrease of estrogen levels which results in the out control of osteoclast activity and further leads to bone resorption over bone formation.[2] Currently, several medicines have been developed for the treatment of osteoporosis, however, many patients have low adherence to these medicines due to long-term treatments, high medical costs and severe side-effects.[3,4] Recently, regular physical exercise with a positive influence on quality of life, has been suggested as a potential regimen against involutional bone loss.[5]

Tai Chi, as a mild-body activity for health and fitness, has gained increasing popularity in China and worldwide.[6,7] A previous study has pointed out that Tai Chi is a therapeutic intervention with safety and efficacy for various health concerns, such as postmenopausal bone mineral density (BMD) loss.[8] Moreover, a significant retardation of bone loss has been observed in both trabecular and distal tibia after Tai Chi intervention in a randomized study.[9] Besides, an increased

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

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level of BMD at the lumbar spine and proximal femur in postmenopausal women is detected after Tai Chi intervention.[10,11] However, some studies indicate the positive effects of Tai Chi on BMD are modest and no convincing evidence has been found for Tai Chi in the improvement of bone mass.[12,13] In such circumstances, a thorough analysis is required to evaluate whether Tai Chi is beneficial for retarding BMD loss in postmenopausal women.

In this study, to provide sufficient evidence for clarifying the discrepancies, a meta-analysis of randomized controlled trials (RCTs) was carried out to compare BMD in postmenopausal women received with and without Tai Chi intervention. The results were expected to increase the precision of assessment of Tai Chi intervention benefit to bone health in postmenopausal women.

2. Methods

2.1. Literature search

The eligible literatures were retrieved by systematically searching through English databases (PubMed, Embase, Springer link, Cochrane library) and Chinese databases (Wanfang, China National Knowledge Infrastructure (CNKI)) based on their reception until January 28, 2016. Searching keywords included “Tai Ji” or “Tai Chi” or “Tai Ji quan” and “Osteoporosis” or “Bone density” and “Postmenopausal” or “Menopause” or “elderly”. There was no language restriction. References of the retrieved studies and reviews were scanned to obtain additional relevant articles. Besides, the manual search strategy was also performed to identify more potentially eligible citations published in paper.

2.2. Inclusion and exclusion criteria

Articles would be included in this meta-analysis if they met the following inclusion criteria: (1) all studies were RCTs; (2) the participants in the studies were postmenopausal women; (3) the interventions were Tai Chi or Tai Chi pushing hand, and the participants in the control group were not intervened with designed exercises; (4) BMD in lumbar spine, femoral neck or distal tibia was measured; (5) BMD was measured by dual energy X-ray absorptiometry (DEXA); (6) no significant difference at baseline was observed in BMD between the interventions and controls.

The exclusion criteria were as follows: (1) articles with incomplete data or the results of BMD measurement were unavailable for statistical analysis; (2) reviews, letters or comments were irrespective.

2.3. Data extraction and quality assessment

After the completion of article screening, two investigators independently extracted the data from the eligible studies according to the predesigned protocol. The extracted information was as follows: the first author's name, publication year, geographical area of study population, age and gender of the participants, sample size of the intervention and control groups, training frequency and results of each article. Disagreements among them were resolved by discussion with a third investigator to reach an agreement.

The quality of the included articles was assessed objectively and comprehensively using the following 9 items that were used in the study of Wayne et al.,[8] as recommended by Alperson and Berger,[14] including randomization (yes or no); details of randomization methods; clear inclusion and exclusion criteria; blinding of outcomes assessors; description of withdrawal and dropouts; sample size estimates and justification; use of appropriate statistical analyses; details of Tai Chi intervention (e.g. style, training schedule); and experience of Tai Chi instructors (Table 1).

2.4. Statistical analysis

The pooled weighted mean difference (WMD) combined with 95% confidence interval (CI) was used to calculate the pooled effect size of continuous data in order to estimate BMD values in the intervention and control groups after follow-up. Heterogeneity across studies was assessed by Cochran Q statistic and the I^2 test. If significant heterogeneity was identified ($P < 0.05$, $I^2 > 50\%$), the random-effect model was performed. Otherwise, the fixed-effect model was used for homogeneous outcomes ($P > 0.05$, $I^2 < 50\%$).

In order to test the reliability of our meta-analysis, we performed a sensitivity analysis by removing each study one time. All analyses were performed using Review Manager

Table 1
Quality of design and methodologic features of studies evaluating Tai Chi for low bone mineral density.

Features	Chan 2004[1]	Zhou 2004[2]	Wayne 2012[3]	Mao 2009[4]	Zhou 2005[5]	Zhou 2003[6]
Randomization employed	√	√	√	√	√	√
Randomization methods	–	–	√	–	–	–
Clear inclusion/exclusion criteria	√	–	√	√	√	√
Outcome assessors blinded	–	–	√	–	–	–
Withdrawal and dropouts reported	√	–	√	√	√	√
Sample size justified/estimated	√	–	–	–	–	–
Appropriate data analysis	√	√	√	√	√	√
Tai Chi intervention described	√	√	√	√	√	√
Qualifications of Tai Chi instructors	–	–	–	–	–	–

√, design and methodology feature adequately reported; –, design and methodology feature not adequately reported.

Version 5.2 (RevMan 5.2; The Cochrane Collaboration, Oxford, UK).

3. Results

3.1. Eligible studies

The process of search strategy was shown in Fig. 1. The original search yielded 291 citations (PubMed: 42, Embase: 64, Springer link: 117, Cochrane library: 11, Wanfang: 69, CNKI: 48). First, there were 202 articles excluded after removing the duplicates. Then, 190 articles were excluded because of obvious irrelevance after screening the title and abstract. Six among the remained 12 articles were removed after full-text review: 1 for case-control articles; 5 for absent of available data. Manual searching did not contribute additional articles. Finally, 6 articles[9,15–19] were included in this meta-analysis.

3.2. Characteristics of eligible articles

The relevant data from the selected articles were summarized in Table 2. The 6 articles were published from 2004 to 2012, and included 350 participants (182 in the Tai Chi intervention group and 168 in the control). Participants were Chinese except the ones in the article by Wayne.[15] The duration of experimental intervention ranged from 20 weeks to 12 months. In addition, two experimental interventions (Tai Chi and Tai Chi pushing hand) were included in the study of Zhou.[19] The quality assessment of the included articles was illustrated in Table 1. All of included studies utilized randomization, provided appropriate data analysis and details of Tai Chi intervention. Except the study of Zhou,[19] other studies used clear inclusion/exclusion criteria and described withdrawal and dropouts. Except the study of Wayne,[15] the remained studies did not specify the randomization methods and indicate that outcome assessors were blinded. Besides, all of studies did not specify whether Tai Chi instructors had qualifications. On the whole, the study of Wayne[15] had a relatively higher quality (Table 1).

3.3. Study outcomes

No significant differences at baseline of BMD were found between interventions and controls. The fixed-effect model was utilized to analyze BMD at the lumber spine due to the homogeneous outcomes ($I^2 = 0\%$, $P = 0.82$). The pooled analysis revealed that there was no significant difference (WMD = 0.02, 95% *CI*: −0.00 to 0.05, $P = 0.09$) in BMD at the lumber spine between the interventions and controls in the six included articles (Fig. 2A). While, significant heterogeneity ($I^2 = 60\%$, $P = 0.12$) was observed in the meta-analysis of BMD at the femoral neck, and thus, random-effect model was applied to the pooled analysis of BMD at femoral neck. There was no significant difference in BMD at the femoral neck (WMD = 0.01, 95% *CI*: −0.03 to 0.05, $P = 0.51$) between interventions and controls in the studies of Chan and Wayne[9,15] (Fig. 2B).

3.4. Publication bias and sensitivity analysis

Because the number of included articles was small, publication bias analysis was not conducted. The sensitivity analysis showed that after excluding the study of Wayne et al.,[15] there was significant difference in BMD at the lumber spine between the interventions and controls in the other five studies ($P_A = 0.03$, Table 3).

4. Discussion

BMD loss is a common event in postmenopausal women. Previous studies showed Tai Chi exercise relieved BMD loss

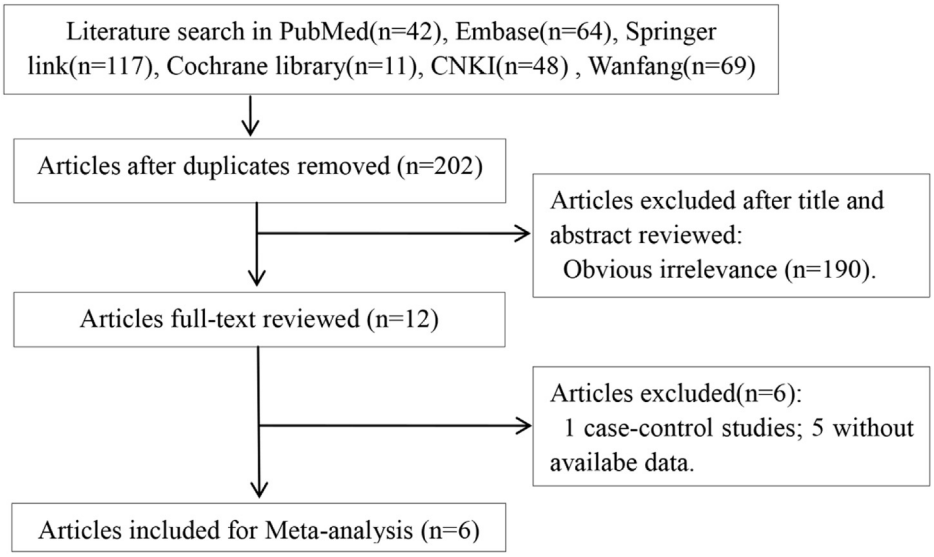

Fig. 1. The process of literature search and study selection. CNKI, China National Knowledge Infrastructure.

Table 2
Characteristics of articles included in this meta-analysis.

Author and year	Area	Follow up	Treatment schedule of interventions	Treatment schedule of controls	Number of participants (intervention/control)	Age (years, intervention/control)	Main outcomes
Chan et al., 2004[9]	China	12 months	Tai Chi (Yang style) for 50 min a day, 5 times a week, over 12 months	Sedentary lifestyle	67/65	54.4 ± 3.3/53.6 ± 3.2	BMD (lumbar spine + femoral neck + distal tibia)
Zhou 2004[19]	China	None	One group: Tai Chi; another group: Tai Chi pushing hand; 45–60 min, 5–7 times weekly for 10 months	No treatment	(12, 12)/12	55.94 ± 2.83/55.94 ± 2.83	BMD (lumbar spine)
Wayne et al., 2012[15]	USA	9 months	Tai Chi; a total of 99.5 h over the 9 month	Usual care	43/43	58.8 ± 5.6/60.4 ± 5.3	BMD (lumbar spine + femoral neck + hip)
Mao 2009[16]	China	20 weeks	Tai Chi; 45–50 min per times for 20 weeks	No treatment	20/20	56.78 ± 2.91/56.78 ± 2.91	BMD (lumbar spine)
Zhou et al., 2005[18]	China	6 months	Tai Chi pushing hand; 45–60 min, 5–7 times weekly for 6 months	No treatment	16/16	57.21 ± 3.41/57.21 ± 3.41	BMD (lumbar spine)
Zhou 2003[17]	China	None	Tai Chi pushing hand; 45–60 min, 5–7 times weekly for 6 months	No treatment	12/12	57.10 ± 2.71/55.93 ± 2.84	BMD (lumbar spine)

BMD, bone mineral density.

in postmenopausal women,[10,11] but other studies reported that Tai Chi had no significant efficacy in BMD loss.[12,13] In the present meta-analysis, a quantitative analysis of available RCTs was performed to investigate the effect of Tai Chi intervention on BMD loss in postmenopausal women. The overall results showed that BMD at both the lumbar spine and femoral neck intervened by Tai Chi or Tai Chi pushing hand had no remarkable difference compared with the controls. These findings suggest that Tai Chi may have no efficacy for improving BMD at lumbar spine and femoral neck in postmenopausal women.

A previous meta-analysis has showed no significant positive effect of Tai Chi on BMD at the spine compared with no treatment in postmenopausal women.[13] In an intent-to-treat analysis, the difference of BMD at the femoral neck between Tai Chi intervention group and usual care group is not statistically significant.[15] These studies support the result of this study. Moreover, it has been indicated walking has significant, positive effects on increase the BMD at the femoral neck in postmenopausal women but no significant effects on lumbar spine,[20] which leads us to conjecture that different exercise therapy may affect BMD loss in postmenopausal women at different body part. Therefore, Tai Chi may effectively contribute to the variations of BMD at other regions but not at the lumbar spine and femoral neck. However, more experimental researches are needed to confirm this conclusion.

Furthermore, it takes more than 3 years for Tai Chi to increase BMD at the spine and hip and improve neuromuscular function in postmenopausal women through retardation of the age-related bone loss.[21] Sandlund and Norlander have pointed out that time is one of the most important factors during the study of physical and psychological interventions.[22] However, in the included RCTs of this study, the duration of Tai Chi exercise is short (just ranging from 20 weeks to 12 months), which may not be sufficient to exhibit the positive effect of Tai Chi on BMD. Thus, we suppose that the benefit effects of Tai Chi on bone mass may be time-dependent and further analysis on longer-term practice of Tai Chi for variation of BMD is needed.

In this study, the sensitivity analysis showed that there was a significant difference of BMD between the interventions and controls after excluding the study of Wayne et al.[15] Wayne et al. compared the BMD of the proximal femur and lumbar spine between Tai Chi training plus usual care and usual care alone using intent-to-treat analyses and per-protocol analyses respectively. They found that the difference of BMD at the femoral neck between Tai Chi intervention group and usual care group is not statistically significant when assessed by an intent-to-treat analysis.[15] This result is different to those in other five articles, which is likely responsible for the result of this study. However, the quality assessment showed that the study of Wayne et al.[15] had a higher quality, which partly suggested that the result of this meta-analysis had a certain credibility.

In this meta-analysis, although the included articles with fewer confounding factors may enhance the reliability of the results, there are several limitations to be recognized in this

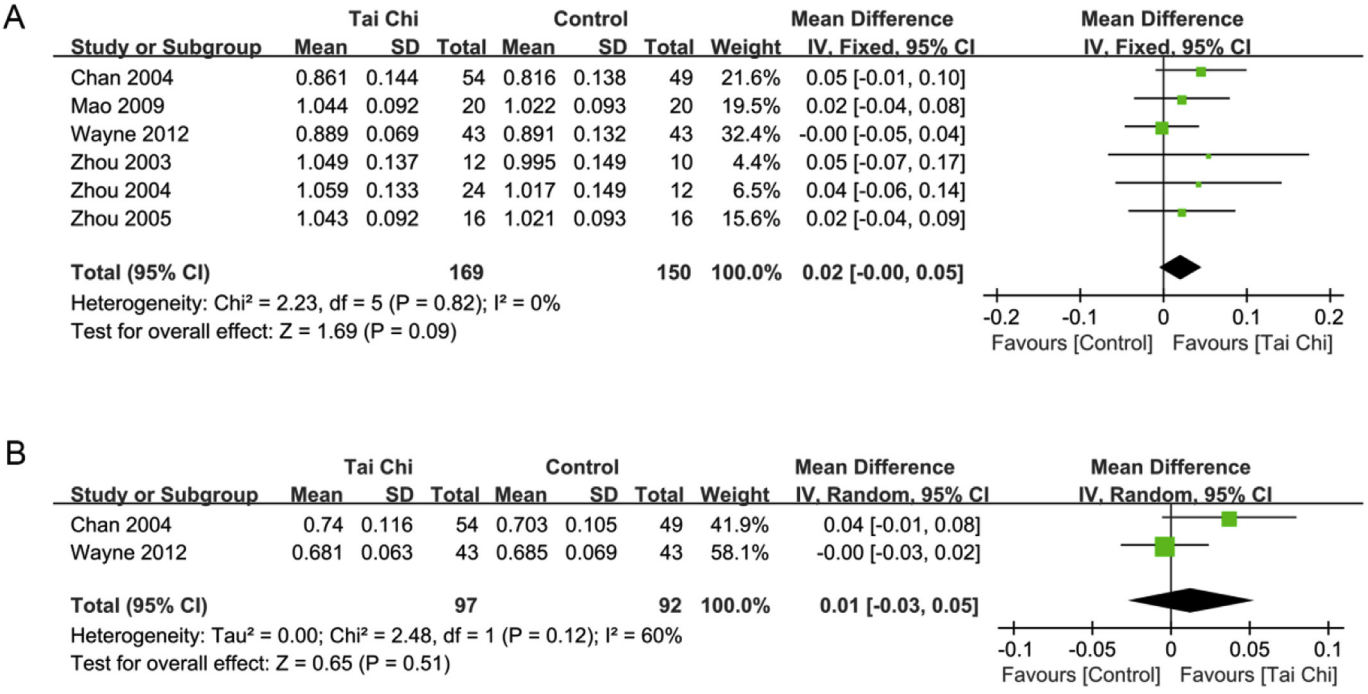

Fig. 2. Meta-analysis of bone mineral density (Tai Chi vs. control). (A) Meta-analysis of bone mineral density at the lumber spine. (B) Meta-analysis of bone mineral density at the femoral neck.

Table 3
Sensitivity analysis by omitting each study.

Omitted study	WMD (95% *CI*)	I^2 (%)	P_H	P_A
None	0.02 (−0.00, 0.05)	0	0.82	0.09
Chan 2004	0.02 (−0.01, 0.04)	0	0.85	0.29
Mao 2009	0.02 (−0.01, 0.05)	0	0.69	0.13
Wayne 2012	0.03 (0.00, 0.06)	0	0.96	0.03
Zhou 2003	0.02 (−0.01, 0.05)	0	0.75	0.12
Zhou 2004	0.02 (−0.01, 0.05)	0	0.72	0.12
Zhou 2005	0.02 (−0.01, 0.05)	0	0.69	0.12

WMD, weighted mean difference; *CI*, confidence interval; P_H, P value of heterogeneity test; P_A, P value of significance.

meta-analysis. Firstly, the limited included studies and small sample size does not eliminate the possibility that the results we observed resulted from chance. Therefore, further study with a larger sample size is required to validate our result. Secondly, all of studies did not specify whether Tai Chi instructors had qualifications, thus, the data reported in those studies might be unreliable if the participants received unprofessional Tai Chi treatment. Thirdly, the duration time of Tai Chi exercise was short in these included RCTs, as a result, the strengthen effect on BMD might be inconspicuous.

In conclusion, our literature-based meta-analysis suggests that Tai Chi has no statistically significant effects on attenuating BMD loss in postmenopausal women at lumbar spine and femoral neck. However, more RCTs with longer-term Tai Chi exercise managed by Tai Chi instructors having qualifications are imperative. This study was conceived as a preliminary study, and it may provide the data for a future study that will be conducted with a larger sample and longer period of intervention and observation.

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