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# Effects of *T'ai Chi* on Balance: A Population-Based Meta-Analysis

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## Abstract

***Objective:*** To systematically review and analyze the effects of *t'ai chi* on balance in older adults.
***Methods:*** The literature was searched for randomized clinical trials on the effects of *t'ai chi* on balance, as evaluated by direct, static, dynamic, and mixed measures. The effect sizes (ESs) on balance were calculated by using the standardized mean difference ($d$) and 95% confidence intervals.
***Results:*** Thirty-four studies were included. The overall ES of *t'ai chi* on static balance was medium at 3 months (ES = 0.73) and small at 6 months (ES = 0.33) for participants with a low risk of falling. For those with a high risk of falling, the ES of *t'ai chi* on static balance was small (ES = 0.47) at 3 months but not significant at 6 months. When compared with the no-exercise group, the ES of *t'ai chi* on static balance was medium (ES = 0.66) at 3 months but smaller at 6 months (ES = 0.37). The ES of *t'ai chi* (ES = 0.31) was only significant at 6 months when compared with other exercise.
***Conclusion:*** The findings of this meta-analysis suggest that persons with a low risk of falling should practice *t'ai chi* for 3 months to improve their balance. The effects of *t'ai chi* on balance in those with a high risk of falling were small but significant at 3 months, supporting the safety and effectiveness of *t'ai chi*. It is important to select reliable and sensitive measures for balance to examine the effects of *t'ai chi*.

## Introduction

Poor balance is one of the main risk factors associated with falls and fall-related injuries,[1] and improvement in balance is strongly correlated with a decrease in the incidence of falls; thus, regular exercise is recommended to improve balance and consequently to prevent falls in those with a high risk of falling.[2] Balance involves a complex function and adjustments of muscle activity and joint position to keep the body weight above the base of support.[3] Balance recovery from a slip or trip during walking requires the ability to make coordinated and accurate adjustments of body posture to prevent falling.[4]

Exercise using *t'ai chi*, an ancient Chinese martial art, improves balance in older adults.[5] Indeed, improvement in balance is one of the most commonly observed benefits following practice of *t'ai chi*.[3] *T'ai chi* involves slow, gentle, and continuous movements, incorporating unilateral and bilateral weight transfer while bending the knees. This type of constant weight shifting to different target positions is believed to challenge the balance control system to maintain the center of mass within the base of support, consequently leading to improved balance control.[6] Control of the center of mass is essential for balance control.[4] A slip and backward fall is most likely to occur shortly after heel-strike of the swing leg when the body weight is being transferred forward toward the leading foot; Gatts and Wollacott[4] found that 15 sessions of *t'ai chi* training significantly reduced the incidence of tripping and increased the center of mass anterior/posterior path in older adults with a high risk of falling.

However, the reports included in a meta-analysis on the beneficial effects of *t'ai chi* on balance remain inconclusive.[7] Such inconsistent findings are likely attributable to lack of control over the type, intensity, and duration of *t'ai chi* practiced; the characteristics of the study population and the participants' various health conditions; and the wide variations in the use of balance measures.[8] The significant effects of *t'ai chi* on balance improvement could have occurred as a result of chance, bias, or confounding variables. Various measures have been used to quantify improvement, including self-report tools, dynamic posturography, the Berg Balance Scale, the Tinetti Balance Scale, single-leg stance time, and body sway during quiet stance. Because these

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measures assess different dimensions of balance, their varied use may have contributed to the inconsistent findings.[9]

Furthermore, only a few studies have compared *t'ai chi* with similar forms of movement therapy, such as yoga or other types of aerobic exercise.[10,11] Most randomized studies have obtained better results for *t'ai chi* relative to control groups receiving no treatment.[3] The effects of *t'ai chi* on balance appear to be similar to those of conventional exercise or physical therapy control interventions aimed at improving physical function related to balance. The aforementioned meta-analysis confirmed the beneficial effects of *t'ai chi* in improving the balance of older adults, but it was suggested that *t'ai chi* is not necessarily superior to other interventions.[3] The characteristics of the study population should also be considered for the proper selection of an intervention for fall prevention. Previous studies, applied *t'ai chi* as a low-intensity exercise to older adults, both healthy persons[12,13] and patients with arthritis[14] or other chronic conditions.[15] It is thus necessary to examine the effects of *t'ai chi* on balance relative to the health condition of the target population (i.e., healthy persons versus those with a high fall risk), the duration of exercise, and the types of balance measures used, as well as by comparing *t'ai chi* with other types of exercise. A meta-analysis of this topic would provide a systematic review and statistically comprehensive understanding of the benefits of *t'ai chi* in balance improvement. In the present study, a systematic literature review and analysis of randomized studies on the effects of *t'ai chi* on balance were performed, with the following specific objectives: (1) to determine the effect size (ES) of *t'ai chi* on static balance in groups of patients with low and high risks of falling (referred to henceforth as low-fall-risk and high-fall-risk groups, respectively) at short- and long-term follow-up; (2) to determine the effects of *t'ai chi* on static balance according to the type of control group at short- and long-term follow-up; (3) to determine the effects of *t'ai chi* on balance according to outcome measure (i.e., static, dynamic, mixed, and direct) in the low-fall-risk and high-fall-risk groups at short- and long-term follow-up; and (4) to determine the effects of *t'ai chi* on balance by outcome measures (i.e., static, dynamic, mixed, and direct) according to the type of control group at short- and long-term follow-up.

## Methods

### Search strategy

The present meta-analysis was performed on the basis of a prospective meta-analysis protocol suggested by the Cochrane handbook.[16] A literature search for potentially relevant articles was conducted by using the following databases: PubMed/MEDLINE, CINAHL, ProQuest Central, Science Direct, Scopus, and Cochrane Library for English-language articles and KISS, NDSL, National Central Library, DBPIA, and KoreaMed for Korean-language articles. Additional manual searches using Google Scholar and reference lists completed the search.

### Study selection

Medical Subject Heading (MeSH) terms and Boolean operators were used for the literature search. The most relevant available MeSH terms were ''Tai Ji'' and ''postural balance.'' In addition to the MeSH terms, ''*t'ai chi*, Taiji, T'ai Chi,'' ''balance, stability, equilibrium,'' and ''randomized controlled trial'' (RCT) or ''randomized clinical trials'' were also used to improve the search results from databases where MeSH terms are not used.

The inclusion criteria were (1) articles published in peer-reviewed English-language journals without specified publication date, (2) articles designed to test the effects of *t'ai chi* with or without *qigong* for at least 8 weeks or more (*t'ai chi* combined with other types of exercise or intervention were excluded), and (3) studies that used an RCT research design. The articles were included in the analysis when the statistical values required to calculate the ES were available. Publication bias was considered by including brief reports and research letters when data were available. When duplicated data were confirmed, those with earlier publication dates and with satisfactory quality assessment were prioritized for inclusion. The selection process complied with Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[17]

### Risk of bias assessment

Three review teams, each consisting of 2 researchers, reviewed 20 or 21 articles by using a quality-assessment tool to verify which ones appropriately followed the conditions of RCTs. The quality-assessment tool was used according to the RCT method checklist of the Scottish Intercollegiate Guidelines Network[18] revised based on Cochrane risk of bias.[19] The content analysis and evaluation were also based on the patient, intervention, comparison, and outcome process.[20] The review team evaluated each article independently using the quality-assessment tool and discussed them at a team meeting to decide whether they should be included.

### Data analysis

Comprehensive Meta Analysis software, version 2.0 (Biostat, Englewood, NJ), was used to calculate ESs, for homogeneity testing, and for publication bias assessment. For studies with two or more control groups, the control group used for assessment of the overall effects was selected in the following order of preference: no treatment or wait-list, then active comparator. The standardized difference of means (i.e., ES [$d$]), 95% confidence intervals, and weights were calculated under the assumption of a fixed-effect model. When homogeneity was not confirmed, a random-effect model was used to calculate the ES.[21] The $Z$ value ($p < 0.05$) was used to identify the statistical significance of the ES, and $Q$ statistics ($p > 0.10$) and $I^2$ statistics were calculated to test the homogeneity of ESs among the included variables. ESs of 0.2–0.5, 0.5–0.8, and > 0.8 were defined as small, medium, and large, respectively.[22]

Publication bias was considered by examining the symmetry of the funnel plot, the trim and fill method (< 10%), and fail-safe numbers (Orwin method; trivial effect = 0.20, missing study effect = 0).

The studies were analyzed separately for short- and long-term follow-up. For the purpose of this review, a short-term follow-up was defined as the outcome measures taken closest to 12 weeks from 8 to 13 weeks after the randomization; long-term follow-up consisted of measures taken closest to 6 months from 14 weeks or longer.

The series of subgroup analyses were conducted for the participants' physical condition. For the population-based comparison, the participants were dichotomized according to their health condition in terms of fall risk: healthy or low risk of falling versus deconditioned or high risk of falling.

## Results

### *Search strategy*

The literature search identified 357 articles to be considered for inclusion. The additional manual search using Google Scholar identified 8 additional articles. The full texts of 61 articles appearing to meet the initial criteria were retrieved for further evaluation. In total, 27 articles were excluded because of a lack of data ($n=2$), duplicate samples ($n=5$), *t'ai chi* intervention combined with another type of exercise ($n=4$), insufficient quality ($n=3$), duration of *t'ai chi* less than 8 weeks ($n=1$), no randomized groups ($n=3$), or no measurement for balance ($n=9$). A final set of 34 articles met all of the inclusion criteria and was included in the analysis (Fig. 1).

### *Risk of bias assessment*

Table 1 presents the results of the quality assessment of the studies included in the meta-analysis. Although all 34 studies used random assignment, the method used for randomization was not specified in 9. Allocation concealment was specified in 9 studies, and in 14 studies an intention-to-treat protocol was used. Group homogeneity at baseline was confirmed in most of the studies; activities of daily living significantly differed between the groups in one study.[23] Only 8 of 34 studies discussed adverse effect related to *t'ai chi*, such as mild fatigue (Tsang, Faber), soreness (Song, Tsang), or fall episode (Li).

### *Study characteristics*

Study population. The 34 RCTs were categorized according to population characteristics as healthy elderly with a low risk of falling ($n=20$) or those with a chronic condition and a corresponding high risk of falling ($n=14$) (Table 2).

Intervention. *T'ai chi* was provided for 30–90 minutes per session in 27 of the 34 studies (71.1%). The duration of *t'ai chi* was mostly short term (3–16 weeks, $n=22$) or long term (20–24 weeks, $n=12$).

Outcome. The type of balance measure used was categorized as static balance (one-leg standing and Functional Reach Test), dynamic balance (Timed Up and Go test), mixed measure of balance (for both static and dynamic measures

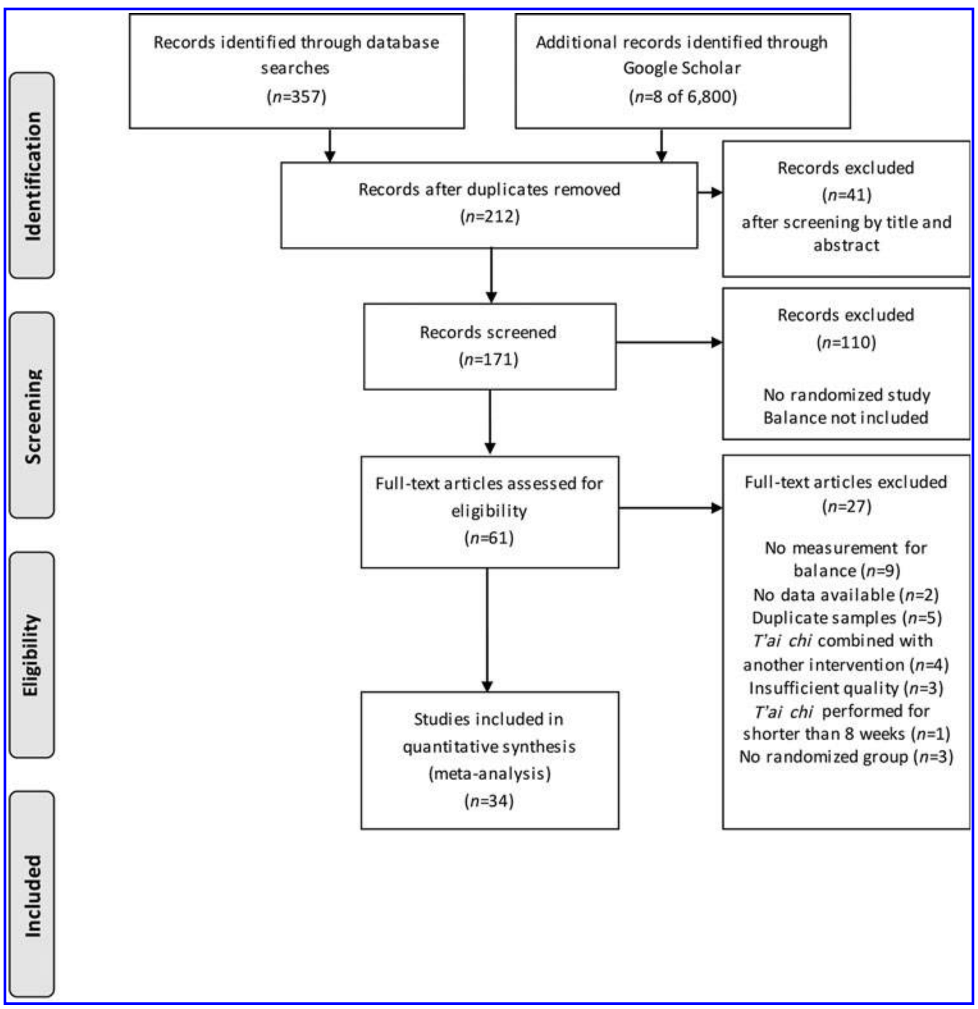


**FIG. 1.** Identification of studies in meta-analysis.

Table 1. Quality Assessment of the Included Studies

| *First author (year)* | *Random assignment* | *Blindness* | *Allocation concealment* | *ITT* | *Groups similar at baseline* | *Adverse effects* |
|---|---|---|---|---|---|---|
| Audette (2006) | Yes (except nonexercise) | Tester blind | NR | No | Yes | No |
| Au-Yeung (2009) | Yes | NR | NR | Yes | Yes | No |
| Chen (2012) | Yes | Tester blind | NR | Yes | Yes | No |
| Chyu (2010) | Yes | Tester blind | Yes | No | Yes | No |
| Dechamps (2010) | Yes | Tester blind | NR | Yes | Yes (except ADL) | No |
| Faber (2006) | Yes | Tester blind | Yes | Yes | Yes | Yes[a] |
| Frye (2007) | Yes | NR | NR | No | Yes | No |
| Hackney (2008) | Yes | Tester blind | NR | No | Yes | No |
| Hall (2009) | Yes (not specified) | Tester blind | NR | No | Yes | No |
| Hartman (2000) | Yes | Tester blind | NR | No | Yes | No |
| Hass (2004) | Yes | Tester blind | NR | No | Yes | No |
| Jones (2012) | Yes | Tester blind | NR | Yes | Yes | No |
| Kim (2009) | Yes (not specified) | NR | NR | NR | Yes | Yes |
| Lelard (2010) | Yes (not specified) | NR | NR | NR | Yes | No |
| Li (2005) | Yes | Tester blind | Yes | Yes | Yes | No |
| Li (2008) | Yes (not specified) | NR | NR | No | Yes | No |
| Li (2012) | Yes | Tester blind | NR | Yes | Yes | Yes[a] |
| Liu (2010) | Yes (not specified) | NR | NR | NR | Yes | No |
| Logghe (2008) | Yes | Tester blind | NR | Yes | Yes | No |
| McGibbon (2004) | Yes (not specified) | Tester blind | NR | No | Yes | No |
| Song (2003) | Yes | Tester blind | NR | No | Yes | Yes[a] |
| Taylor (2012) | Yes | Tester blind | Yes | Yes | Yes | No |
| Taylor-Piliae (2010) | Yes | Tester blind | NR | Yes | Yes | No |
| Taylor-Piliae (2011) | Yes | Tester blind | Yes | No | Yes | Yes |
| Tousignant (2012) | Yes | Tester blind | Yes | Yes | Yes | Yes |
| Tsang (2007) | Yes | Tester blind | Yes | Yes | Yes | Yes[a] |
| Voukelatos (2007) | Yes | Tester blind | NR | No | Yes | No |
| Wallsten (2006) | Yes (not specified) | NR | NR | No | Yes | No |
| Wang (2009) | Yes | Tester blind | Yes | Yes | Yes | Yes |
| Wolf (1997) | Yes (not specified) | NR | NR | No | Yes | No |
| Wolf (2006) | Yes | Tester blind | NR | No | Yes | No |
| Woo (2007) | Yes | Tester blind | Yes | No | Yes | No |
| Yang (2007) | Yes | Tester blind | NR | Yes | Yes | No |
| Zhang (2005) | Yes | NR | NR | No | Yes | No |

[a]Adverse effect reported with mild fatigue, pain, or fall.
ITT, intention to treat; NR, not reported.

combined), or direct measure (mostly computerized measures such as center of pressure and Sensory Organized Test). For research that included various measures of balance, the ES was selected for each representative measure (i.e., for the different categories of measure) or combined (for the same balance measure on the left and right sides). All ESs were analyzed so that they were consistent for direction; a higher score represented better balance. When several measures for balance were investigated in one study, the representative variable was selected for static balance measures, if available, followed by dynamic balance measures or mixed balance measures.

### *Analysis of ES*

A population-based meta-analysis was conducted to determine the ES of *t'ai chi* by comparing short-term (3 months) and long-term (6 months) measures: low risk versus high risk of falling, *t'ai chi* versus no treatment/control, *t'ai chi* versus other exercise, and the four types of balance measure (static, dynamic, direct, and mixed).

Effects of *t'ai chi* on static balance in the low- and high-risk groups at short- and long-term follow-up. A population-based analysis was conducted for the effects of *t'ai chi* on static balance, which was the most common measure of balance in the included studies. There were two groups: The low-risk group comprised elderly, postmenopausal women, and the high-risk group comprised people with a preexisting health condition or a frail physical condition.

The ES on static balance for the low-risk group was medium (ES $=0.73$) at 3 months ($p=0.002$) but small (ES $=0.33$) at 6 months ($p<0.001$) with the random-effect model. However, the ES on static balance for those with a high risk of falling was small at 3 months (ES $=0.47$; $p<0.001$), but not significant at 6 months (ES $=0.46$; $p=0.05$) (Table 3).

Effects of *t'ai chi* on static balance according to the types of control groups at short- and long-term follow-up. Analysis of the 27 studies that compared *t'ai chi* with no treatment/control revealed that the ES on static balance was medium (ES $=0.66$; $p<0.001$) at 3 months and small (ES $=0.37$; $p<0.001$) at 6 months. Seven studies were included in the comparison of *t'ai chi* versus other types of exercise. The analysis revealed no significant difference in the ES of *t'ai chi* on static balance at 3 months when

## Table 2. Overview of the Characteristics of the Included Studies

| First author (date) | Age (range) or mean ± SD (yr) | Participants | Fall risk | Intervention | Frequency (min or h/session per /wk) | Duration | Measurement points | Balance measurement: Static, Direct | Static, Indirect | Dynamic, Direct | Dynamic, Indirect | Mixed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Audette (2006) | >65 | Healthy elderly women | Low | TC (10-form *Yang*) vs brisk walking vs nonexercise | 55–65 min/3 | 12 wk | 0/12 wk | | OLS (EO/EC, left/right) | | | |
| Au-Yeung (2009) | 63.4 ± 10.7 | Chronic stroke | High | TC (12-form *Sun*) vs usual exercise | 1 h/1 (3 h self) | 12 wk | 0/6/12/18 wk | SOT | | | TUG | |
| Chen (2012) | >70 | Visually impaired elderly | High | TC (8-form *Yang*) vs music instrument | 1.5 h/3 | 16 wk | 0/16 wk | SOT | | | | |
| Chyu (2010) | >65 | Postmenopausal osteopenic women | Low | TC (24-form *Yang*) vs nonexercise | 1 h/3 | 24 wk | 0/12/24 wk | SOT | | | TUG | |
| Dechamps (2010) | >65 | Highly deconditioned elderly | Low | TC (*Yang*) vs cognitive action vs nonexercise | 30 min/4 | 6 min | 0/6/12 mo | | OLS | | TUG | |
| Faber (2006) | >60 | Frail and pre-frail elderly | High | TC vs functional walking vs nonexercise | 1 h/2 | 20 wk | 0/20 wk | | | | | PPS<br>POMA |
| Frye (2007) | >50 | Healthy elderly | Low | TC (10-form *Yang*) vs low-impact exercise vs nonexercise | 1 h/3 | 12 wk | 0/12 wk | | | | TUG | |
| Hackney (2008) | >40 | Patients with Parkinson disease | High | TC (short-style *Yang*) vs nonexercise | 1 h/2 | 13 wk | 0/13 wk | | OLS<br>TS | | TUG | BBS |
| Hall (2009) | >60 | Fall risk elderly | High | TC (24-form *Yang*) vs nonexercise | 90 min/2 | 12 wk | 0/12 wk | SOT | | | | |
| Hartman (2000) | 49–81 | Patients with osteoarthritis | High | TC (9-form *Yang*) vs nonexercise | 1 h/2 | 12 wk | 0/12 wk | | OLS | | | |
| Hass (2004) | 79.6 ± 5.8 | Frail elderly | Low | TC (8-form) vs nonexercise | 50 min/2 | 48 wk | 0/48 wk | | | COP | | |
| Jones (2012) | >40 | Patients with fibromyalgia | Low | TC (8-form *Yang*) vs nonexercise | 90 min/2 | 12 wk | 0/12 wk | | OLS<br>FRT | | TUG | |
| Kim (2009) | >65 | Healthy elderly | Low | TC (12-form) vs nonexercise | 1 h/3 | 12 wk | 0/12 wk | | | COP | | |
| Lelard (2010) | >70 | Healthy elderly | Low | TC (10-form) vs balance training | 30 min/2 | 12 wk | 0/12 wk | | | COP | | |
| Li (2005) | >70 | Healthy elderly | Low | TC (24-form *Yang*) vs stretching exercise | 1 h/3 | 6 min | 0/3/6/12 mo | | OLS (EO/EC)<br>FRT | | TUG | BBS |
| Li (2008) | >60 | Healthy elderly | Low | TC (24-form) vs nonexercise | 1 h/4 | 16 wk | 0/16 wk | | OLS (EO/EC)<br>TS (EC) | | | |
| Li (2012) | 40–85 | Patients with Parkinson disease | High | TC (8-form) vs resistance exercise vs stretching exercise | 1 h/2 | 24 wk | 0/6 mo | | FRT | | TUG | |
| Liu (2010) | NR | Patients with coronary heart disease | Low | TC vs nonexercise | 1 h/2 | 12 wk | 0/12 wk | | OLS | | TUG | |
| Logghe (2008) | >70 | High fall risk elderly | High | TC (10-form *Yang*) vs nonexercise | 1 h/2 | 13 wk | 0/3 mo/6 mo/12 mo | | | | | BBS |
| McGibbon (2004) | *TC*: 58.0 ± 11.2 control: 54.5 ± 11.2 | Vestibular hypofunction | High | TC (5-form *Yang*) vs vestibular rehabilitation | 70 min/1 | 10 wk | 0/10 wk | | | SOT | | |

(*continued*)

TABLE 2. (CONTINUED)

| First author (date) | Age (range) or mean ± SD (yr) | Participants | Fall risk | Intervention | Frequency (min or h/session per /wk) | Duration | Measurement points | Balance measurement | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Static | | Dynamic | | |
| | | | | | | | | Direct | Indirect | Direct | Indirect | Mixed |
| Song (2003) | > 55 | Women with osteoarthritis | High | TC (12-form *Sun*) vs nonexercise | 1 h/1 class and 3 home | 12 wk | 0/12 wk | | OLS (EC) | | | |
| Talyor (2012) | > 65 (Maori > 55) | Participants with at least 1 fall or risk of fall | High | TC (10-form *Sun*) 1 session vs TC 2 session vs low-level exercise | 1 h/1 ~ 2 | 20 wk | 0/20 wk/11 mo/ 17 mo | | | | TUG Step test | |
| Taylor-Piliae (2010) | > 60 | Healthy elderly | Low | TC (12-form *Yang*) vs Western exercise vs nonexercise | 45 min/2 classes and 3 home | 6 min | 0/6/12 mo | | OLS FRT | | | |
| Taylor-Piliae (2011) | > 50 | Patients with chronic stroke | High | TC (24-form *Yang*) vs nonexercise | 1 h/3 | 12 wk | 0/12 wk | | | | | Balance in SPPB |
| Tousignant (2012) | > 65 | Participants with at least 1 fall, admitted to geriatric day hospital | High | TC (8-form) vs conventional PT | 1 h/2 | 15 wk | 0/15 wk/12 mo | | *Foam & dome test* | | TUG | BBS |
| Tsang (2007) | > 50 | Patients with type 2 diabetes mellitus | Low | TC (hybrid form; *Sun* and *Yang*) vs sham exercise | 1 h/2 | 16 wk | 0/16 wk | SOT | OLS (EO/EC) | | Tandem walking | |
| Voukelatos (2007) | > 60 | Healthy elderly | Low | TC (instructor: 83% *Sun*, 3% *Yang*, 14% mixture) vs control | 1 h/1 | 16 wk | 0/16 wk | | Sway Leaning balance Lateral stability | | | |
| Wallsten (2006) | > 60 | Healthy elderly | Low | TC (10-form, early TC group) vs control (late TC group) | 1 h/2 | 20 wk | 0/10/20/40 wk | | | | | PPS |
| Wang (2009) | > 55 | Patients with knee osteoarthritis | High | TC (10-form TC) vs wellness education and stretching exercise | 1 h/2 | 12 wk | 0/12/24/48 wk | | Standing balance (0–5) | | | |
| Wolf (1997) | > 70 | Healthy elderly | Low | TC (10-form) vs computerized balance training vs nonexercise | 1 h/1 | 15 wk | 0/15 wk/7 or 8 mo | COP | | | | |
| Wolf (2006) | > 70 | Frail elderly | Low | TC (6-form) vs nonexercise | 1 h/2 | 48 wk | 0/4/8/12 mo | | FRT | | | |
| Woo (2007) | > 65 | Healthy elderly | Low | TC (24-form *Yang*) vs resistance exercise vs nonexercise | ?/3 | 12 min | 0/12 mo | COP | OLS (dominant mean both legs) | | | |
| Yang (2007) | > 70 | Healthy elderly | Low | TC + *qigong* (7-form *Chen*) vs nonexercise | 1 h/1 | 6 min | 0/2/6 mo | SOT | | | | |
| Zhang (2005) | > 60 | Less robust elderly | Low | TC (24-form) vs nonexercise | 1 h/7 | 8 wk | 0/8 wk | | OLS (dominant EO) | | | |

BBS, Berg Balance Scale; COP, center of pressure; EC, eyes closed; EO, eyes opened; FRT, Functional Reach Test; OLS, one-leg standing; POMA, Performance-Oriented Mobility Assessment; PPS, Physical Performance Scale; SD, standard deviation; SOT, Sensory Organized Test; SPPB, short physical performance battery; TC, *t'ai chi*; TS, tandem standing; TUG, Timed Up and Go test.

Table 3. Population-Based Effect Size on Other Balance Measurements

| | | | Sample size | | | | | | | Publication bias | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Trim and fill | | |
| *Population and balance measure* | *Duration (mo)* | *Participants (n)* | T'ai chi | *Control* | *ES* | 95% CI | Z (p) | Q (p) | $I^2$ | *Nfs* | *Funnel plot* | *Fill (n)* | *Adjusted value* | *Change in value (%)* |
| Low fall risk | | | | | | | | | | | | | | |
| Static | 3 | 8 | 407 | 387 | 0.73[a] | 0.27–1.19 | 3.12 (0.002) | 54.44 (<0.001) | 87.1 | | AS | 1 | 0.91 | 24.7 |
| | 6 | 12 | 761 | 745 | 0.33[a] | 0.16–0.51 | 3.69 (<0.001) | 24.44 (0.011) | 55.0 | | AS | 2 | 0.39 | 17.4 |
| Dynamic | 3 | 7 | 275 | 281 | 0.52[a] | 0.23–0.82 | 3.45 (0.001) | 13.90 (0.031) | 56.8 | | AS | 3 | 0.29 | 43.9 |
| | 6 | 5 | 231 | 248 | 0.66[a] | −0.00 to 1.32 | 1.95 (0.050) | 35.57 (<0.001) | 88.7 | | AS | 1 | 0.86 | 31.2 |
| Mixed | 3 | 2 | 150 | 159 | 0.45 | 0.22–0.67 | 3.87 (<0.001) | 2.08 (0.149) | 52.0 | | | | | |
| | 6 | 2 | 150 | 159 | 0.83 | 0.60–1.06 | 6.99 (<0.001) | 0.07 (0.792) | 0 | | | | | |
| Direct | 3 | 4 | 93 | 76 | 0.47 | 0.16–0.79 | 2.93 (0.003) | 3.74 (0.291) | 19.8 | 6 | AS | 1 | 0.35 | 25.6 |
| | 6 | 7 | 166 | 153 | 0.64[a] | 0.07–1.21 | 2.20 (0.028) | 33.91 (<0.001) | 82.3 | | AS | 2 | 0.92 | 44.3 |
| High fall risk | | | | | | | | | | | | | | |
| Static | 3 | 5 | 117 | 110 | 0.47 | 0.21–0.74 | 3.48 (<0.001) | 5.62 (0.229) | 24.8 | 7 | AS | 2 | 0.28 | 41.8 |
| | 6 | 3 | 132 | 128 | 0.46[a] | −0.00 to 0.92 | 1.94 (0.052) | 6.12 (0.047) | 64.3 | | S | | | |
| Dynamic | 3 | 3 | 85 | 81 | 0.62 | −0.15 to 1.39 | 1.58 (0.113) | 8.16 (0.017) | 75.5 | | S | | | |
| | 6 | 4 | 544 | 561 | 0.10 | −0.02 to 0.22 | 1.70 (0.088) | 1.96 (0.579) | 0 | | AS | 1 | 0.13 | 30.3 |
| Mixed | 3 | 4 | 184 | 176 | 0.44[a] | −0.12 to 1.00 | 1.55 (0.121) | 10.86 (0.012) | 72.3 | | S | | | |
| | 6 | 2 | 113 | 115 | 0.09 | −0.17 to 0.35 | 0.67 (0.500) | 0.01 (0.950) | 0 | | | | | |
| Direct | 3 | 3 | 80 | 75 | 0.33 | 0.02–0.65 | 2.05 (0.040) | 2.25 (0.325) | 11.1 | 3 | S | | | |
| | 6 | 1 | 21 | 19 | 0.83 | 1.18–1.49 | 2.48 (0.013) | | | | | | | |

[a]Meta-analysis based on random-effect model.
AS, asymmetric; CI, confidence interval; ES, effect size; Nfs, fail-safe number; S, symmetric.

Table 4. Intervention-Based Effect Size of Other Balance Measurements

| | | | Sample size | | | | | | | | Publication bias | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | Trim and fill | | |
| *Intervention and balance measure* | *Duration (mo)* | *Participants (n)* | T'ai chi | *Control* | ES | *95% CI* | Z (p) | Q (p) | $I^2$ | *Nfs* | *Funnel plot* | *Fill (n)* | *Adjusted value* | *Change in value (%)* |
| No exercise | | | | | | | | | | | | | | |
| Static | 3 | 12 | 513 | 489 | 0.66[a] | 0.32–0.99 | 3.83 (<0.001) | 60.39 (<0.001) | 81.7 | | AS | 2 | 0.83 | 26.9 |
| | 6 | 15 | 893 | 886 | 0.37[a] | 0.19–0.54 | 4.19 (<0.001) | 36.78 (0.001) | 61.9 | | S | | | |
| Dynamic | 3 | 8 | 333 | 331 | 0.49[a] | 0.19–0.78 | 3.28 (0.001) | 19.67 (0.006) | 64.4 | | AS | 3 | 0.25 | 48.2 |
| | 6 | 7 | 322 | 352 | 0.45[a] | 0.03–0.88 | 2.10 (0.036) | 35.86 (<0.001) | 83.2 | | AS | 2 | 0.65 | 43.5 |
| Mixed | 3 | 6 | 334 | 335 | 0.45[a] | 0.12–0.79 | 2.62 (0.009) | 16.39 (0.006) | 69.5 | | AS | 2 | 0.23 | 48.4 |
| | 6 | 4 | 263 | 289 | 0.46[a] | 0.03–0.88 | 2.08 (0.037) | 16.40 (0.001) | 81.7 | | AS | 1 | 0.30 | 34.9 |
| Direct | 3 | 5 | 146 | 124 | 0.32 | 0.08–0.57 | 2.57 (0.010) | 3.53 (0.473) | 0 | 4 | S | | | |
| | 6 | 8 | 187 | 173 | 0.56[a] | 0.05–1.07 | 2.14 (0.032) | 36.90 (<0.001) | 81.0 | | AS | 2 | 0.78 | 39.2 |
| Other exercise | | | | | | | | | | | | | | |
| Static | 3 | 1 | 11 | 8 | 0.55 | −0.38 to 1.48 | 1.15 (0.247) | | | | | | | |
| | 6 | 6 | 228 | 228 | 0.31 | 0.13–0.50 | 3.30 (0.001) | 8.00 (0.156) | 37.5 | 4 | AS | 1 | 0.38 | 22.7 |
| Dynamic | 3 | 3 | 50 | 55 | 0.64 | 0.24–1.03 | 3.16 (0.002) | 1.04 (0.594) | 0 | 7 | AS | 2 | 0.44 | 26.7 |
| | 6 | 4 | 567 | 576 | 0.08 | −0.04 to 0.20 | 1.37 (0.171) | 0.23 (0.971) | 0 | | AS | 2 | 0.09 | 16.4 |
| Mixed | 3 | 0 | | | | | | | | | | | | |
| | 6 | 1 | 70 | 54 | 0.05 | −0.31 to 0.40 | 0.24 (0.803) | | | | | | | |
| Direct | 3 | 2 | 27 | 27 | 0.84 | 0.28–1.40 | 2.94 (0.003) | 0.03 (0.848) | 0 | | | | | |
| | 6 | 3 | 77 | 75 | 0.52 | 0.19–0.84 | 3.10 (0.002) | 3.82 (0.148) | 47.7 | 5 | S | | | |

[a]Meta-analysis based on random-effect model.

compared with other types of exercise, but significant effects were found at 6 months (ES = 0.31; $p = 0.001$), indicating that the improvement in balance at 6 months was significantly better for *t'ai chi* than for other types of exercise (Table 4).

**Effects of *t'ai chi* on balance by outcome measures in the low- and high-risk groups at short- and long-term follow-up.** The effects of *t'ai chi* on balance as evaluated using static, dynamic, direct, and mixed measures were analyzed in populations with low and high risks of falling. For the population with a low risk of falling, the ESs at 3 months were 0.73 ($p = 0.002$) for static balance, 0.52 ($p = 0.001$) for dynamic balance, followed by 0.47 ($p = 0.003$) for direct measure, and 0.45 ($p < 0.001$) for mixed measure of balance. At 6 months, the largest ES of *t'ai chi* (0.83; $p < 0.001$) was found by the mixed measure of balance, followed by the direct measure of balance (ES = 0.64; $p = 0.028$) and static balance (ES = 0.33; $p < 0.001$). The ES of *t'ai chi* on dynamic balance was not significant at 6 months.

For the high-risk group, the ESs for *t'ai chi* were small at 3 months: 0.47 ($p < 0.001$) for static balance and 0.33 ($p = 0.04$) for direct measure of balance. The direct measure of balance yielded strong evidence (ES = 0.83; $p = 0.013$) for effects of *t'ai chi* at 6 months. The effects of *t'ai chi* were not significant for measures of dynamic and mixed balance at either 3 or 6 months in this population (Table 3).

**Effects of *t'ai chi* on balance by outcome measures according to the type of control groups at short- and long-term follow-up.** The effects of *t'ai chi* on balance, as measured by static, dynamic, direct, and mixed measures, were compared among the different types of control groups. When compared with the no-treatment group, the ESs of *t'ai chi* were significant at 3 months, regardless of the balance measure used, ranging from 0.66 ($p < 0.001$) for static measures to 0.32 ($p = 0.01$) for direct measure of balance. The small to medium effects of *t'ai chi* on balance remained significant at 6 months.

Compared with other exercise as the control group, the effects of *t'ai chi* on direct measure of balance was large (ES = 0.84; $p = 0.003$) at 3 months and medium (ES = 0.52; $p = 0.002$) at 6 months. The ES of *t'ai chi* on dynamic balance was also significant (ES = 0.64; $p = 0.002$) at 3 months but not significant at 6 months. The effects of *t'ai chi* on static balance were not significant at 3 months, but a small ES was found to be significant at 6 months (ES = 0.31; $p = 0.001$). The number of studies was insufficient to enable analysis of the mixed measure of balance (Table 4).

### Discussion

Prevention of fall for older adults is important with respect to maintenance of their health status and quality of life,[24] and balance is a vital factor of fall prevention. *T'ai chi*, which is known to be an effective method of balance training, is especially suitable for older adults because it can be applied more safely than other forms of exercise in this population.[25] In the present analysis, 34 studies yielding quantitative data were systematically reviewed to examine the effects of *t'ai chi* on balance in older adults with various health conditions. The findings revealed that *t'ai chi* was effective in balance improvement but that its beneficial effects varied according to the fall-risk stratification of the population, the duration of the exercise (i.e., short or long term), the comparator used (i.e., no exercise control or other exercise), and the type of balance measures implemented.

*T'ai chi* exercise was effective on static measures in both the low fall risk group and the high fall risk group, yielding a small to medium ES when practiced for up to 3 months. The strong evidence regarding the effects of *t'ai chi* on static balance was found during the first 3 months for the low-risk group and remained small yet significant when participants continued to practice *t'ai chi* for 6 months or more. The effect of *t'ai chi* on static balance was also significant at 3 months for the high-risk group. The findings of this study confirm that *t'ai chi* is an effective way of improving balance for older adults as well as those at high risk of falling.

The aging process affects muscle strength,[26] the reflexes,[27] flexibility, and body posture maintenance.[28] Therefore, older adults with chronic disease are considered to have poor balance and were thus classified as having a high risk of falling.[29] This population would have a greater potential to improve if they were able to continue practicing *t'ai chi* for at least 3 months. A systematic review by Liu and Frank[5] also found that *t'ai chi* was effective on several measures of static balance. However, Leung and Chan[3] failed to confirm that *t'ai chi* was effective using a static measure of balance: the single-leg stance. This discrepancy may have occurred because their meta-analysis included only 3 studies and used only the single-leg stance as a measure of static balance, while the present investigation analyzed 14 studies along with various measures of static balance.

The present study revealed that the effects of *t'ai chi* vary according to the risk stratification of the population and the type of balance measures implemented. The effects of *t'ai chi* on dynamic balance were medium for those with a low risk of falling but not significant for those with a high risk of falling. Similarly, the ES of *t'ai chi* on mixed measure of balance (static and dynamic) was small at 3 months and became larger at 6 months for the low-risk group, while the effects were not significant for the high-risk group. A few meta-analyses of the population with a high risk of falling have also shown that *t'ai chi* is ineffective for improving the balance of patients with Parkinson disease, as evaluated using mixed measurement (i.e., Berg Balance Scale, Timed Up and Go test).[30] Furthermore, although *t'ai chi* was effective in frail elderly persons at improving balance, as assessed using the Berg Balance Scale, its effects were not significant when measured by the Timed Up and Go test.[31]

The present findings confirm that the effects of *t'ai chi* on dynamic balance is consistent for the low-risk group, yet the ES of *t'ai chi* appears to vary according to the type of balance measures implemented when applied to high-risk populations. One reason for this could be the level of physical functioning or condition of the participants. The characteristic of chronic illness should be considered when choosing the most sensitive and reliable balance measures to examine the effects of *t'ai chi* on populations with a high risk of falling. The present study found that the ES of *t'ai chi* on balance, as assessed by direct measures (posturography or computerized measures), was consistently significantly applied both for the low-risk and the high-risk groups measured up to 6 months. Similarly, Liu and Frank[5] conducted a systematic review of 8 studies on balance evaluated by a direct measure (posturography) and confirmed significant effects on 6 studies. However, another meta-analysis by Logghe and Verhagen[7] concluded that *t'ai chi* was not effective; these authors analyzed two studies using a direct measure of balance. While the short-term effects of *t'ai chi* on balance analyzed by a direct measure were mostly supported by previous studies, the long-term effects seem to be inconclusive because only a few studies have used a direct measure of balance, and even fewer have applied *t'ai chi* for more than 6 months.

The effects of *t'ai chi* on balance may differ according to the comparator: either a no-exercise control group or a group performing other types of exercise. In the present study, the ES of *t'ai chi* on balance was consistently significant when compared with the no-exercise control group, regardless of the type of measure used. However, when compared with other types of exercise, the ES of *t'ai chi* was significant only on direct measure of balance both at 3 and 6 months. The effects of *t'ai chi* on static balance was not significant at 3 months when compared with other exercises but became significant when the participants performed *t'ai chi* for more than 6 months. The review by Leung and his colleagues[3] also confirmed that a positive effect of *t'ai chi* was found with varying degrees when compared with other treatments. The present study showed that that *t'ai chi* could be safely and effectively applied even to persons with a high risk of falling, but the effects of *t'ai chi* were not conclusive in their analysis when compared with other types of exercise. The positive effects on balance improvement varied when compared with those of other types of exercise according to the type of measures of balance.

In conclusion, the effects of *t'ai chi* on static balance were consistently supported in 34 randomized clinical trials, yet these effects still need to be scrutinized according to the risk of falling and the type of balance measures implemented. It is important to select the most reliable and sensitive balance measures to examine the effects of *t'ai chi* while simultaneously considering the risk-of-falling category of the participants. The effects of short-term *t'ai chi* were mostly small on direct measure of balance, both for participants with low and high risks of falling, but increased when they continued practicing *t'ai chi* for 6 months or more, and especially among those with a high risk of falling. The short-term effects of *t'ai chi* on balance tend to be medium or large when compared with other types of exercise, but the long-term effects are inconclusive for those with a high risk of falling due to the variation among the type of balance measures.

Several limitations should be considered in interpreting the findings of the present study. Although an extended search was conducted to minimize the publication bias, the search language was limited to English and Korean, leading to a potential language bias. The tests for funnel plot asymmetry to determine publication bias were not conducted because of the small number of studies in subgroup analysis. Only randomized clinical studies were selected for quality assurance, leading to the small number of studies in subgroup analysis. In addition to the small fail-safe number, the changing values in most studies were more than 10% according to the trim and fill method, which should be considered when applying the findings of the present study.

## Conclusion

Balance is one of the essential factors for fall prevention, and exercise interventions, including muscle strengthening, should be applied for a sufficient duration and safely to those with a high risk of falling.[32] The findings of the present study suggest that *t'ai chi* can be safely and effectively applied for improving balance among those with both low and high risks of falling, even on a short-term basis, and that this improvement mostly persists for the longer term. While those with a low risk of falling need to practice *t'ai chi* for 3 months to improve their balance, the effects of *t'ai chi* on balance improvement for those with a high risk of falling were also significant even during the short term, supporting the safety and effectiveness of *t'ai chi* in this population. The effects of *t'ai chi* on dynamic and mixed measure of balance were inconclusive in the present study; thus, further analysis is warranted to confirm the effectiveness of this type of balance measure with different populations.

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## References

1. Verhagen AP, Immink M, van der Meulen A, Bierma-Zeinstra SM. The efficacy of Tai Chi Chuan in older adults: a systematic review. Fam Pract 2004;21:107–113.
2. Moyer VA, on behalf of the US Preventive Services Task Force. Prevention of falls in community-dwelling older adults: US Preventive Services Task Force Recommendation Statement. Ann Intern Med 2012;157:197–204.
3. Leung DP, Chan CK, Tsang HW, Tsang WW, Jones AY. Tai chi as an intervention to improve balance and reduce falls in older adults: a systematic and meta-analytical review. Altern Ther Health Med 2011;17:40–48.
4. Gatts SK, Woollacott MH. How Tai Chi improves balance: biomechanics of recovery to a walking slip in impaired seniors. Gait Post 2007;25:205–214.
5. Liu H, Frank A. Tai chi as a balance improvement exercise for older adults: a systematic review. J Geriatr Phys Ther 2010;33:103–109.
6. Tsang WW, Hui-Chan CW. Effects of tai chi on joint proprioception and stability limits in elderly subjects. Med Sci Sport Exer 2003;35:1962–1971.
7. Logghe IH, Verhagen AP, Rademaker AC, et al. The effects of Tai Chi on fall prevention, fear of falling and balance in older people: a meta-analysis. Prev Med 2010;51: 222–227.
8. Li J, Lawpoolsri S, Zhang Y, et al. Using Tai Chi to promote balance and prevent falls—a review from an epidemiological perspective. J AlternMed 2009;7:12p.

9. Wu G. Evaluation of the effectiveness of Tai Chi for improving balance and preventing falls in the older population—a review. J Am Geriatr Soc 2002;50:746–754.
10. Field T. Tai Chi research review. Complement Ther Clin Pract 2011;17:141–146.
11. Jahnke R, Larkey L, Rogers C, Etnier J, Lin F. A comprehensive review of health benefits of qigong and tai chi. Am J Health Promot 2010;24:e1–e25.
12. Audette JF, Jin YS, Newcomer R, Stein L, Duncan G, Frontera WR. Tai Chi versus brisk walking in elderly women. Age Ageing 2006;35:388–393.
13. Li JX, Xu DQ, Hong Y. Effects of 16-week Tai Chi intervention on postural stability and proprioception of knee and ankle in older people. Age Ageing 2008;37:575–578.
14. Song R, Lee EO, Lam P, Bae SC. Effects of tai chi exercise on pain, balance, muscle strength, and perceived difficulties in physical functioning in older women with osteoarthritis: a randomized clinical trial. J Rheumatol 2003;30:2039–2044.
15. Li F, Harmer P, Fitzgerald K, et al. Tai chi and postural stability in patients with Parkinson's disease. N Engl J Med 2012;366:511–519.
16. Schünemann HJOA, Vist GE, Higgins JPT, et al. Prospective meta-analysis. In: Higgins JPT, Green S, eds. Cochrane Handbook for Systematic Reviews of Interventions, Version 5.0.1. Oxford: The Cochrane Collaboration, 2008.
17. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. J Clin Epidemiol 2009; 62:1006–1012.
18. SIGN 50: A Guideline Developer's Handbook. 2008. Online document at: www.sign.ac.uk/guidelines/fulltext/50/.
19. Schünemann HJOA, Vist GE, Higgins JPT, et al. Assessing risk of bias in included studies In: Higgins JPT, Green S, eds. Cochrane Handbook for Systematic Reviews of Interventions, Version 5.0.1. Oxford: The Cochrane Collaborationm 2008.
20. Higgins JPT, Green S. Cochrane Handbook for Systematic Reviews of Interventions. Oxford: The Cochrane Collaboration, 2008.
21. Rothstein HR, Sutton AJ, Borenstein M. Publication Bias in Meta-Analysis, Prevention, Assessment and Adjustments. West Sussex: John Wiley & Sons, 2005.
22. Schünemann HJOA, Vist GE, Higgins JPT, et al. Interpreting results and drawing conclusions. In: Cochrane Handbook for Systematic Reviews of Interventions. Oxford: The Cochrane Collaboration, 2008.
23. Dechamps A, Diolez P, Thiaudiere E, et al. Effects of exercise programs to prevent decline in health-related quality of life in highly deconditioned institutionalized elderly persons: a randomized controlled trial. Arch Intern Med. 2010;170:162–169.
24. Muir SW, Berg K, Chesworth B, Klar N, Speechley M. Quantifying the magnitude of risk for balance impairment on falls in community-dwelling older adults: a systematic review and meta-analysis. J Clin Epidemiol 2010;63:389–406.
25. Sherrington C, Whitney JC, Lord SR, et al. Effective exercise for the prevention of falls: a systematic review and meta-analysis. J Am Geriatr Soc 2008;56:2234–2243.
26. Vandervoort AA, Kramer JF, Wharram ER. Eccentric knee strength of elderly females. J Gerontol 1990;45:B125–128.
27. Erim Z, Beg MF, Burke DT, de Luca CJ. Effects of aging on motor-unit control properties. J Neurophysiol 1999;82: 2081–2091.
28. Rose DJ, Jones CJ, Lucchese N. Predicting the probability of falls in community-residing older adults using the 8-foot up-and-go: a new measure of functional mobility. J Aging Phys Activ 2002;10:466–475.
29. Fransen M, Nairn L, Winstanley J, Lam P, Edmonds J. Physical activity for osteoarthritis management: a randomized controlled clinical trial evaluating hydrotherapy or Tai Chi classes. Arthritis Rheum 2007;57:407–414.
30. Allen NE, Sherrington C, Paul SS, Canning CG. Balance and falls in Parkinson's disease: a meta-analysis of the effect of exercise and motor training. Move Dis 2011;26: 1605–1015.
31. Chou CH, Hwang CL, Wu YT. Effect of exercise on physical function, daily living activities, and quality of life in the frail older adults: a meta-analysis. Arch Phys Med Rehab 2012;93:237–244.
32. Sherrington C, Tiedemann A, Fairhall N, Close JC, Lord SR. Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. NSW Public Health Bull 2011;22:78–83.

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