The efficacy of Tai Chi Chuan in older adults: a systematic review

Arianne P Verhagen, Monique Immink, Annemieke van der Meulen and Sita MA Bierma-Zeinstra

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Objectives. The purpose of this study was to assess the effect of Tai Chi Chuan (TCC) on fall prevention, balance and cardiorespiratory functions in the elderly.

Methods. A systematic review was carried out according to the Cochrane standards. A computerized literature search was carried out. Studies were selected when they had an experimental design; the age of the study population was >50; one of the interventions was a form of TCC; and when falls, balance or cardiorespiratory functions were used as an outcome measure. A total of seven studies were included, with in total 505 participants, of whom all but 27 were healthy seniors, age between 53 and 96 years.

Results. In most studies, the intervention of TCC is a modified Yang style, varying from 10 to 24 forms. The intensity of TCC varies from 1 h weekly for 10 weeks to 1 h every morning for 1 year. One study used falls as outcome measure and reported a beneficial effect of 47% in the TCC group. All studies mention a beneficial effect of TCC, but in most studies this conclusion was based on a pre–post analysis.

Conclusion. There is limited evidence that TCC is effective in reducing falls and blood pressure in the elderly.

Keywords. Elderly, fall prevention, systematic review, Tai Chi Chuan.

Introduction

Falls are a significant public health problem. A third to half of all people >65 years old fall each year.[1–3] Estimates vary, but studies suggest that ~20% of all fall incidents require medical attention.[3] Poor balance capacity, decreased muscle strength and flexibility, and the changes in gait that come with ageing are some of the risk factors associated with falls.[4] The risk of falling is strongly associated with previous falls and with an increased stride-to-stride variability.[5] Fall survivors experience a reduction in activities of daily living (ADL) and in physical and social activities compared with non-fallers.[6] Increasing physical difficulties as a result of ageing and inactivity may cause older people to move from independence to disability and dependence.[7]

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Department of General Practice, Erasmus Medical Centre Rotterdam, PO Box 1738, 3000 DR Rotterdam, The Netherlands; E-mail: a.verhagen@erasmusmc.nl

Studies evaluating falls in the elderly focus on preventing falls by assessing environmental risk factors on the one hand, or on exercise treatment aimed at increasing mobility on the other.[3] In this Cochrane review, one trial (including 200 participants) evaluating the effects of Tai Chi Chuan (TCC) sees it as a potentially very beneficial exercise intervention with an estimated reduction in fall risk of 47% (risk ratio 0.51, 95% confidence interval 0.36–0.73).[3] Exercise is an often proposed intervention for preventing falls and fall-related injuries. Forms of exercise have been associated with a wide range of health benefits, physiological as well as psychosocial.[8,9] If balance, strength and flexibility are risk factors, it is plausible to believe that exercise might result in fewer falls.

In most of the English literature, TCC, also called Tai Chi (TC), is described as a traditional Chinese form of exercise derived from a martial arts form, practised primarily in China by elderly citizens.[4,10] It represents a class of exercise that differs from the routine strengthening and stretching programmes currently employed in physical medicine. The practice of TCC was originally related to concerns about physical fitness and

the capacity for self-defence.[4] TCC exercise emphasizes continuous slow (flowing) movements, with small to large expressions of motion, unilateral to bilateral shifts of body weight, and rotation of the trunk, head and extremities, combined with a deep diaphragmatic breathing and relaxation. During these movements, TCC practitioners have to control their centre of gravity and remain very stable. Several studies have shown that TCC can be classified as moderate exercise, as its intensity does not exceed 55% of maximum oxygen intake, and 60% of the individual maximum heart rate.[4] A variety of health-related benefits for older people are attributed to TCC, including improved balance control, improved cardiorespiratory functions, enhanced psychosocial well-being and reduced risk of falling.[4] TCC is a suitable exercise for older adults because of its low impact and low velocity.[10] Moreover TCC is a low-technology approach to conditioning that can be implemented with low costs. During the past 20 years, TCC has spread throughout Western countries and is offered in many local community services.

The aim of this study is to summarize systematically the evidence of the effect of TCC on fall prevention and physical function in older adults.

Methods

Search strategy

A broad computerized literature search of Medline, Cinahl and Psychlit was carried out. Only keywords used to describe the intervention were used. First, titles and abstracts of identified published articles were reviewed in order to determine the relevance of the articles. Next, references in relevant reviews and identified randomized controlled trials (RCTs) were screened.

Study selection

Studies were selected when: (i) the design was an RCT or a concurrent controlled trial (CCT); (ii) the age of the study population was >50; (iii) one of the interventions was a form of TCC; and (iv) falls (our primary outcome measure), balance and cardiorespiratory functions (our secondary outcome measures as possible predictors of risk of falling) were used as an outcome measure. For feasibility reasons, the publication had to be written in English, French, German or Dutch. All criteria were applied independently by two reviewers (MI and AM) to the full text of the articles that had passed the first eligibility screening, in order to make a final selection of the studies for the review.

Quality assessment

Two reviewers (MI and AM) performed the methodological scoring of the trials independently, using the methodological quality checklist (the Delphi list, see Table 1) developed by Verhagen *et al*.[11] The Delphi list is a comprehensive criteria list of nine items and is regarded to be valid for the assessment of the methodological quality of clinical trials.[12] It consists of two items related to the treatment allocation, three items to blinding procedures, two items to data presentation and analysis, and two items to the eligibility of the study population and the prognostic comparability of the study groups. A pilot assessment of one RCT, which was not included in the review, was done in order to test the list of criteria. Differences in scores were resolved by discussion by the two reviewers, and a third reviewer (APV) was consulted if disagreements could not be resolved. In cases of multiple publications of one trial, information on Delphi quality items was derived from all publications.

TABLE 1 *The Delphi list*[11]

Delphi items
1. Was a method of randomization performed?
2. Was the treatment allocation concealed?
3. Were the groups similar at baseline regarding the most important prognostic indicators?
4. Were the eligibility criteria specified?
5. Was the outcome assessor blinded?
6. Was the care provider blinded?
7. Was the patient blinded?
8. Were point estimates and measures of variability presented for the primary outcome measures?
9. Did the analysis include an intention-to-treat analysis?

Data extraction

Explicit information about patient population, interventions and outcome measures was recorded using standardized abstracting forms. Only outcome measures such as falls, balance or cardiorespiratory functions were assessed.

Analysis

The Delphi criteria list consists of nine items (see Table 1), all having a 'yes'/'no'/'don't know' answer option. If bias was unlikely, the criterion was rated positive ('yes'). In cases where information was lacking or insufficient or if bias was likely, the criterion was rated negative ('no' or 'don't know'). All 'yes' scores were summed to produce an overall quality score.

Clinical homogeneity was evaluated by exploring the differences between the RCTs with regard to study population, types of reference treatments and outcomes. Whenever studies are considered heterogeneous, we decided not to perform statistical pooling but to summarize the results using a rating system for 'levels of evidence'.[13] The rating system consisted of five levels of

scientific evidence which have been used in previous systematic reviews in the field of back pain and which are based on the quality and the outcome of the studies: (i) strong evidence, provided by generally consistent findings in multiple (two or more) high quality RCTs; (ii) moderate evidence, provided by generally consistent findings in one high quality RCT and one or more low quality RCT or by generally consistent findings in multiple low quality RCTs; (iii) limited evidence, only one RCT (either high or low quality); (iv) conflicting evidence, inconsistent findings in multiple RCTs; and (v) no evidence, no RCTs.

In this review, high quality is defined as: (i) being randomized using an adequate (preferably concealed) randomization schedule and use of a method of blinding; or (ii) a quality score of at least 50% of the maximum available score.

Results

Search strategy

The search up to July 2001 resulted in 56 references of potential studies. Based on title and abstract, 30 references were selected and a full copy of the paper was applied for and used for a final decision. Reference checking resulted in another four papers for which a full copy was retrieved.

Of these 34 references, 31 full papers could be retrieved, of which 22 were excluded. Seven papers were excluded because of the design; these were case–control studies or before–after trials. Nine were excluded because of the age of the study population; in four papers TCC was not a part of the intervention but was additional during the follow-up period or the intervention was based upon TCC but differed greatly; and in two papers no outcome measures were presented.

Finally, nine papers[10,14–21] in total were included in this systematic review, of which three concerned the same study, namely the Atlanta FICSIT trial (Frailty and Injuries: Co-operative Studies of Intervention Techniques).[14,18,19]

Quality assessment

Disagreement mainly occurred because of reading errors and differences in interpretation of the methodological criteria list. After the consensus meeting, no disagreement persisted. The third reviewer was not called upon to make a final decision. The results of the methodological assessment are presented in Table 2.

Study characteristics

The study characteristics are presented in Table 3. In total, 505 people of ⩾50 years were included in this review, of which all but 27 were healthy seniors, aged between 53 and 96 years. The largest study included is the Atlanta FICSIT trial which is one of the seven FICSIT trials performed in the USA to assess the efficacy of short-term exercises on reducing falls and fall-related injuries in the elderly.[2]

The TCC intervention is often a modified Yang style varying from 10 to 24 forms. The intensity of TCC varies between 1 h weekly for 10 weeks[17] to 1 h every morning for 1 year.[10,15] Most studies divided the study population into two groups, with an intervention group receiving TCC and a control group receiving no treatment or a walking programme. In the study of Young *et al.*,[21] the control group received an aerobic exercise programme, and in the Atlanta FICSIT trial two control groups were included of which one group received computer-aided balance training and the other was a discussion group. In four studies, a compliance rate was mentioned which appeared to be rather high.

The outcome measures used in the studies varied greatly. Five studies[10,15,17–19,21] measured cardiorespiratory variables, one study measured balance[17] and only one study measured falls and fall-related injuries.[14/18/19] Only one study[14] mentioned a follow-up, of 4 months. All studies mention a beneficial effect of TCC on their main outcome measure, but this conclusion in most

TABLE 2 *Methodological quality of the included studies*

Study	D1	D2	D3	D4	D5	D6	D7	D8	D9	Total
Lan (1998)	No	No	Yes	Yes	DK	DK	DK	Yes	No	3
Lan (1999)	No	No	Yes	Yes	DK	DK	DK	Yes	DK	3
Li (2001)	Yes	DK	Yes	Yes	DK	DK	DK	Yes	Yes	5
Schaller (1996)	No	No	Yes	No	DK	DK	No	Yes	DK	2
Wolf/Kutner (1996, 1997)	Yes	DK	Yes	Yes	Yes	DK	DK	Yes	No	5
Yan (1999)	No	No	Yes	Yes	DK	DK	DK	No	DK	2
Young (1999)	Yes	DK	Yes	Yes	Yes	DK	DK	Yes	Yes	6

DK = don't know.

TABLE 3 *Characteristics of included studies*

Study	Methods	Participants	Intervention	Outcome (measuring instrument)	Notes
Kutner (1997)[14]	RCT	Healthy community-living seniors, *n* = 200, mean age 76.2 years Atlanta FICSIT trial follow-up	Tai Chi (TC), *n* = 72; 10 forms described by Wolf (1997), twice weekly for 15 weeks. Balance training (BT), *n* = 64; training on balance platform, weekly for 15 weeks. Education (ED), *n* = 64; discussion control group weekly for 15 weeks Follow-up: 4 months	Benefit (exit interview); self-esteem scale; five scales from SF-36. TC significantly more benefit compared with ED (OR = 5.9; 95% CI 1.1–31.6).	68 drop-out (34%): 19 in TC, 25 in BT, 24 in ED. See also Wolf (1996, 1997)
Lan (1998)[10]	CCT, allocation on patient preference	Healthy community-living seniors, *n* = 52, age 58–70 years	Tai Chi (TC), *n* = 28; classical Yang style every morning, 1 h for 1 year. Control group (C), *n* = 24; no training.	Cardiorespiratory variables, muscle strength. TC: 16–21% increase in cardio-respiratory function (C: 1% decrease).	14 drop-outs (27%): 8 in TC, 6 in C
Lan (1999)[15]	CCT	Men with coronary artery bypass surgery, *n* = 27, age 53–64 years	Tai Chi (TC), *n* = 12; classical Yang style every morning, 1 h for 1 year. Control group (C), *n* = 15; walking programme, three times weekly, 1 h for 1 year.	Cardiorespiratory variables. TC: 10% increase in cardio-respiratory function (C: no changes).	7 drop-outs (26%): 3 in TC, 4 in C
Li (2001)[16]	RCT, random numbers	Healthy seniors, *n* = 98, age 65–96 years	Tai Chi (TC), *n* = 49, Yang style (24 forms), 1 h, twice a week for 6 months. Compliance >90%. Control group (C), *n* = 45, maintain activities.	Physical functioning (SF-20) TC: significant improvement in functional status compared with control.	21 drop-outs (21%): 9 in TC, 13 in C
Schaller (1996)[17]	CCT, allocation on patient preference	Healthy seniors, *n* = 46, mean age 70 years (SD 5.9)	Tai Chi (TC), *n* = 24, 20 forms, 1 h weekly for 10 weeks. Compliance TC >80% Control group (C), *n* = 22, normal activities.	Balance (SLST); flexibility (SRT); mood (POMS); health status (SF-36); blood pressure. TC: 50% improvement on balance; C: 2% decrease on balance.	At baseline, control group was more active
Wolf (1996)[18] Wolf (1997)[19]	RCT, Computer-generated fixed Randomization procedure, blinded Outcome assessment	Healthy community-living seniors, *n* = 200, mean age 76.2 years Atlanta FICSIT trial	Tai Chi (TC), *n* = 72; 10 forms described by Wolf (1997), twice weekly for 15 weeks. Balance training (BT), *n* = 64; training on balance platform, weekly for 15 weeks. Education (ED), *n* = 64; discussion control group, weekly for 15 weeks.	Biomedical variables; functional variables, psychosocial well-being. TC: reduced blood pressure, tendency of reduced fear of falling, reduced risk of falling (with 47%), all compared with ED	13 drop-outs (6.5%) at end of intervention: 6 in TC, 4 in BT, 3 in ED. See Kutner (1997)
Yan (1999)[20]	CCT, allocation on patient preference	Healthy seniors, *n* = 20, age: 76–88 years	Tai Chi (TC), *n* = 12, 24-form simplified Yang style Locomotor activity (LA), *n* = 8, walking or jogging Both interventions: three times per week, 45 min for 8 weeks. Compliance >80%.	Arm movement performance ('digitizer'). TC: reduced pressure variability in arm movements.	No data provided
Young (1999)[21]	RCT, blocks of four, fixed randomization scheme, blinded outcome assessment	Healthy seniors, *n* = 62, age: 60–80 years	Tai Chi (TC): *n* = 31, Yang style (13 movements) Aerobic exercise (AE): *n* = 31, exercises at 40–60% HRR Both interventions 4 days per week, 30 min, for 12 weeks. Compliance > 80%.	Blood pressure, cardiorespiratory fitness, physical activity (PAR, YPAS). In both groups, reduction in blood pressure. No significant differences between groups on all outcome measures.	2 drop-outs (3%) 1 in each group

RCT = randomized clinical trial; CCT = controlled clinical trial; HRR = heart rate reserve; OR = odds ratio; 95% CI = 95% confidence interval; PAR = Stanford 7-day Physical Activity Recall; YPAS = Yale Physical Activity Survey; SLST = single limb stance test; SRT = sit and reach test; POMS = profile of mood states, SF-36 = short form 36.

studies was based on a pre–post analysis instead of a between-group analysis.

Methodological characteristics

Three trials had a randomized design[14/18/19,16,21] and provided information about their randomization method. In three studies, the groups were formed based on patient preference,[10,17,20] but the baseline characteristics between the groups did not differ much. Blinding the participants and the care giver is difficult in these kind of studies, and only two studies mentioned blinding of outcome assessment.[14/18/19,21]

Four studies were of low power, meaning a sample size of <25 participants in one or more study groups. In most studies, only a within-group analysis was performed instead of a between-group analysis. Only one study[21] mentioned performing an intention-to-treat analysis. Drop-out rates were rather high: in four studies, the drop-out rate was >20%, while in two studies no data concerning drop-outs were presented. A high drop-out rate can cause serious bias in the results because of possible selective drop-out.

The overall quality score varied between 2 and 6 (out of 9 points) with a mean of 3.7, which indicates an overall poor methodological quality.

Characteristics of the high quality trials

The trial of Li *et al*.[16] was designed to "determine whether a 6-month Tai Chi exercise program can improve self-reported physical functioning limitations among healthy, physically inactive older individuals". In this study, people over 65 years old were randomly divided into two groups. People in the intervention group ($n = 49$) received TCC exercises; a classical Yang style (24 forms) with two 60-min sessions each week for 6 months. People in the other group ($n = 45$) were placed on a waiting list (waiting list control group) and were promised a 4-week programme at the end of the study. Primary outcome was 'physical functioning' using the SF-20, and measurements were performed at baseline, and 12 and 24 weeks after randomization. No follow-up measurement was performed. During the study, the mean improvement of physical functioning limitations in the TCC group was 19.8% compared with the improvement in the control group of 8.2%. These differences appeared to be statistically significant.

Three publications present (parts of) the results of the Atlanta FICSIT trial.[14,18,19] In the FICSIT trial, a total of 200 healthy people of 70 years or older participated. They were randomly allocated to one of three study groups: (i) a Tai Chi (TC) group ($n = 72$) where the 108 forms were shortened into 10 forms, during 15 weeks, twice a week for 1 h; (ii) computerized balance training (BT) ($n = 64$) using a force platform for 15 weeks, once a week for 1 h; and (iii) an educational control (ED) group ($n = 64$) with discussions for 15 weeks, once a week for 1 h. A lot of primary and secondary outcome measures were measured at baseline, 15 weeks after randomization and at 4 months (follow-up). Among the outcome measures of interest were falls and fear of falling. Wolf *et al*.[18] presents the main outcomes of the total trial. In the TC group, 56 falls were noted, while in the other two groups 76 and 77 falls occurred during a 4-month follow-up, meaning a significant reduction of fall risk of 47.5% in the TC group.

In the publication of Wolf *et al*.,[19] the focus is on postural stability as an outcome measure. In the FICSIT trial, TC does not improve the postural ability of the subjects, but reduces falls; therefore, their conclusion is that postural stability is probably not associated with fall risk.

Kutner *et al*.[14] present from the FICSIT trial mainly the results of the 'self-reported benefits' outcome measure, measured using a questionnaire during an exit interview. A total of 130 out of the 200 subjects (65%) returned the questionnaire. In the TC group, 86% experienced a noticeable effect of their intervention on their life, compared with 69 and 60% in the BT and ED groups, respectively. In total, 96% in the TC group benefited from participating compared with 90 and 82% in the BT and ED groups, respectively.

The study receiving the highest quality score is that of Young *et al*.[21] The objective of this study wass to compare the effects of TC (compared with aerobic exercises) on blood pressure in 62 subjects of ⩾60 years suffering from high blood pressure. The TC group ($n = 31$) received a low intensity Yang style of 13 forms. In the control group ($n = 31$), aerobic exercises were performed at 40–60% of heart rate reserve. All exercises were performed during 12 weeks, twice a week for 1 h. The main outcome measure was blood pressure change, and in both groups significant reductions in blood pressure but no differences between the groups were found.

Analysis

Because of the wide variety of outcome measures used, we refrained from statistical pooling. Only three studies were considered of high quality.[16,14/18/19,21] Their method of randomization was described and was regarded to be adequate; two of these studies described a blinded outcome assessment and all three scored >50% of the maximum quality score. All three studies mention a beneficial effect of TCC in the elderly. TCC is probably as beneficial as aerobic exercises in reducing blood pressure and improving physical activities. There is a significant improvement of functional activities and a reduction in blood pressure in the TCC group when compared with no treatment, and a reduction of falls of 47% is mentioned in the Atlanta FICSIT trial when compared with a discussion group.

Based on the 'levels of evidence' decision rule, we conclude that there is limited evidence for the effect of TCC in reducing risk of falls, reducing blood pressure and improving functional status.

Discussion and conclusion

The results of this systematic review indicate limited evidence of several health benefits, such as fall reduction and reduction of blood pressure of TCC in the elderly.

A systematic review is a form of observational research and therefore susceptible to bias; in our systematic review, especially publication and language bias. TCC is an ancient Chinese form of exercise and its health claims are often seen in Western countries as a form of complementary medicine. Therefore, it is likely that research concerning health benefits of TCC will be published in Chinese or in journals not included in regular databases. Because of time constraints, we were unable to perform an extensive literature search outside the computerized databases and of other languages besides English, French, German or Dutch. Therefore, our systematic review may suffer from publication and language bias.

We tried to avoid other forms of possible bias, such as heterogeneity (differences in study population, interventions, outcome measures, etc.) and bias caused by design characteristics, by using a rigorous method of quality assessment and analysis.

Seven studies concerning the efficacy of TCC were found, and their design, choice of outcome measures and methodological quality differ greatly. Most studies did not use a randomized design and none of the randomized studies mentioned a concealed randomization procedure. Empirical research has shown that lack of adequate allocation concealment may be associated with bias.[22–24] Three of the included studies assigned the study population to the study groups based on patient preferences. Although in all studies the study groups were regarded as comparable at baseline on most important prognostic variables, patient preference is important in the effect of TCC and could therefore have led to selection bias and may well be responsible for a favourable outcome of TCC.

Blinding is often difficult in studies using exercise as the intervention. Nevertheless, blinding is important to prevent performance and detection bias.[23,24] In only two studies is a blinded outcome assessment mentioned. In most studies, blinding is not mentioned as a method to prevent bias, so it is unclear whether the authors even tried to keep patients, care givers or outcome assessors unaware of other trial procedures. Patients and care providers can in theory be kept unaware (naïve) concerning information about the characteristics of the other intervention or control intervention under study. In this way, the possibility of bias caused by a lack of blinding decreases.

Only one study[14/18/19] used our main outcome measure (fall reduction) as outcome measure, and in three studies[14/18/19,16,21] one of the outcome measures was physical activity. Most often cardiorespiratory variables were used as the outcome measure. In the literature, TCC is held responsible for long-term effects.[4] Unfortunately, no trials included follow-up measurements of sufficient time (>1 year), so no conclusion can be drawn considering these long-term effects. One study[20] used 'arm movement performance' as an outcome measure. From the literature, it is unclear whether TCC has any (beneficial) effect on 'arm movement performance'.[4]

Evaluating the effectiveness of exercises or balance training such as TCC depends on the participation of patients or compliance with the treatment to which they are allocated. Often compliance rates are unknown, but in this review four studies mentioned their compliance rates. These rates appeared to be high; >80%. The studies included in this review are all pragmatic trials, meaning they investigate interventions as used in normal daily life (no laboratory circumstances). Compliance rates of 80–90% are realistic, so these compliance rates mirror those in normal daily life.

Only two studies[16,21] mentioned an 'intention-to-treat' analysis, and most studies provided mean and standard deviations or confidence intervals. Surprisingly, most studies performed a pre–post analysis as the main analysis technique. It appeared to be difficult to extract clear between-group differences out of the included studies necessary for our conclusions using a 'best evidence synthesis'.

Our conclusion is less firm compared with that of the Cochrane review of Gillespie *et al*.[3] who stated that the evidence for effectiveness of group exercise interventions on fall prevention "remains limited, apart from the Tai Chi intervention of Wolf *et al*."[18] which they concluded was "likely to be beneficial". Although the fall reduction in this trial is significant, just one RCT on this intervention is available as yet. Although a large Cochrane review was performed on interventions to reduce falls, we conclude that more RCTs are required to evaluate the effect of TCC in fall prevention and to evaluate other health care benefits.

References

1 Blake AJ, Morgan K, Bendall MJ *et al*. Falls by elderly people at home: prevalence and associated factors. *Age Ageing* 1988; **17:** 365–372.

2 Province MA, Hadley EC, Hornbrook MC *et al*. The effects of exercise on falls in elderly patients. A pre-planned meta-analysis of the FICSIT trials. Frailty and Injuries: Cooperative Studies on Intervention Techniques. *J Am Med Assoc* 1995; **273:** 1341–1347.

3 Gillespie LD, Gillespie WJ, Cummings R *et al*. Interventions for preventing falls in the elderly (Cochrane Review). In *The Cochrane Library*, Issue 1. Oxford: Update Software; 2000.

4 Li JX, Hong Y, Chan KM. Tai chi: physiological characteristics and beneficial effects on health. *Br J Sports Med* 2001; **35:** 148–156.

5 Maki BE. Gait changes in older adults: predictors of falls or indicators of fear. *J Am Geriatr Soc* 1997; **45:** 313–320.

6 Kiel DP, O'Sullivan P, Teno JM *et al*. Health care utilization and functional status in the aged following a fall. *Med Care* 1991; **29:** 221–228.

[7] Shephard RJ. Exercise and aging: extending independence in older adults. *Geriatrics* 1993; **48:** 61–64.
[8] Buchner DM, Beresford SA, Larson EB *et al*. Effects of physical activity on health status in older adults. II. Intervention studies. *Annu Rev Public Health* 1992; **13:** 469–488.
[9] McAuley E, Blissmer B, Marquez DX *et al*. Social relations, physical activity, and well-being in older adults. *Prev Med* 2000; **31:** 608–617.
[10] Lan C, Lai JS, Chen SY, Wong MK. 12-month Tai Chi training in the elderly: its effect on health fitness. *Med Sci Sports Exerc* 1998; **30:** 345–351.
[11] Verhagen AP, de Vet HCW, de Bie RA *et al*. The Delphi list: a criteria list for quality assessment of randomised clinical trials for conducting systematic reviews developed by Delphi consensus. *J Clin Epidemiol* 1998; **51:** 1235–1241.
[12] Verhagen AP, de Vet HCW, de Bie RA *et al*. The art of quality assessment of RCTs for systematic reviews. *J Clin Epidemiol* 2001; **54:** 651–654.
[13] Van Tulder MW, Esmail R, Bombardier C *et al*. Back schools for non-specific low back pain (Cochrane Review). In *The Cochrane Library*, Issue 4. Oxford: Update Software; 2000.
[14] Kutner NG, Barnhart H, Wolf SL *et al*. Self-reported benefits of Tai Chi practice by older adults. *J Gerontol B Psychol Sci Soc Sci* 1997; **52:** 242–246.
[15] Lan C, Chen SY, Lai JS *et al*. The effect of Tai Chi on cardio respiratory function in patients with coronary artery bypass surgery. *Med Sci Sports Exerc* 1999; **31:** 634–638.
[16] Li F, Harmer P, McAuley E *et al*. An evaluation of the effects of Tai Chi exercise on physical function among older persons: a randomised controlled trial. *Am Behav Med* 2001; **23:** 139–46.
[17] Schaller KJ. Tai Chi Chih: an exercise option for older adults. *J Gerontol Nurs* 1996; **22:** 12–17.
[18] Wolf SL, Barnhart HX, Kutner NG *et al*. Reducing frailty and falls in older persons: an investigation of Tai Chi and computerized balance training. Atlanta FICSIT Group. Frailty and Injuries: Cooperative Studies on Intervention Techniques. *J Am Geriatr Soc* 1996; **44:** 489–497.
[19] Wolf SL, Barnhart HX, Ellison GL *et al*. The effect of Tai Chi Quan and computerized balance training on postural stability in older subjects. Atlanta FICSIT Group. Frailty and Injuries: Cooperative Studies on Intervention Techniques. *Phys Ther* 1997; **77:** 371–381.
[20] Yan JH. Tai chi practice reduces movement force variability for seniors. *J Gerontol A Biol Sci Med Sci* 1999; **54:** M629–M634.
[21] Young DR, Appel LJ, Jee SH *et al*. The effects of aerobic exercises and Tai Chi on blood pressure in older people: results of a randomised trial. *J Am Geriatr Soc* 1999; **47:** 277–284.
[22] Chalmers TC, Celano P, Sacks HS *et al*. Bias in treatment assignment in controlled clinical trials. *N Engl J Med* 1983; **309:** 1358–1361.
[23] Moher D, Pham B, Jones A *et al*. Does quality of reports of randomised trials affect estimates of intervention efficacy reported in meta-analyses? *Lancet* 1998; **352:** 609–613.
[24] Schulz KF, Chalmers I, Hayes RJ *et al*. Empirical evidence of bias. *J Am Med Assoc* 1995; **273:** 408–412.