



**The effectiveness of tai chi for chronic musculoskeletal pain conditions: an updated systematic review and meta-analysis.**

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1     **Title:** The effectiveness of tai chi for chronic musculoskeletal pain conditions: an  
2     updated systematic review and meta-analysis.  
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## Abstract

**Background:** Tai chi is recommended for musculoskeletal conditions, however, the evidence for its clinical effectiveness is uncertain. **Purpose:** To determine whether tai chi is beneficial for clinical outcomes in people with musculoskeletal pain. **Data sources:** Seven databases EMBASE, PEDro, AMED, MEDLINE, CINAHL, Sport Discus, and the Cochrane Central Register of Controlled Trials. **Study Selection:** Randomized controlled trials of tai chi for people with a chronic musculoskeletal condition were included. **Data extraction:** Two reviewers extracted data and rated risk of bias. Standardised mean differences and 95% confidence intervals (CI) were calculated for individual trials and pooled effect sizes were calculated using a random effects model. **Data Synthesis:** 15 studies were identified including people with osteoarthritis (80%), back pain (13%) and headache (7%). Using the GRADE approach, we found moderate quality evidence that tai chi is more effective than no treatment or usual care at short term on pain (SMD -0.66 (-0.85, -0.48)) and disability (SMD -0.66 (-0.85, -0.46)). The evidence for other outcomes was of low or very low quality and there was little information regarding long-term effects. Thus, while the number of publications in this area has increased, the rigor has not, hindering our ability to provide reliable recommendations for clinical practice. **Limitations:** The evidence provided in this review is limited by trials with small sample sizes, low methodological quality and lack of long-term assessment. **Conclusions:** In order for tai chi to be recommended as an effective intervention, more high quality trials with large sample sizes assessing tai chi versus other evidence-based treatments at short and long-term are needed.

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1     **Introduction**

2     Chronic musculoskeletal pain conditions such as low back pain and osteoarthritis are  
3     leading causes of disability worldwide [1]. These conditions affect millions of people’s  
4     ability to perform work-related tasks or important daily activities, leading to a poor  
5     quality of life [2]. While some pharmacological therapies are used to help control pain;  
6     physical function and disability remain a persistent problem. As a result, there is  
7     consistent advice that treatment should include interventions aimed at improving function  
8     and general physical activity levels [3].

9  
10    Many non-pharmacological interventions have been designed to reduce pain-related  
11    disability and some have been evaluated in large clinical trials. Systematic reviews have  
12    identified psychological therapies, multidisciplinary therapies and exercise therapy as  
13    being effective treatments for reducing disability [4]. Tai chi has been endorsed as a safe  
14    and beneficial form of exercise therapy for people with musculoskeletal pain by several  
15    advocate groups, such as The Arthritis Foundation® in the United States [5]. However  
16    there is uncertainty about its effectiveness as a treatment for pain and disability. A review  
17    was undertaken in 2009 [6]; which identified 7 trials conducted almost exclusively on  
18    patients with arthritis and the meta-analysis indicated small short-term effects on pain and  
19    disability with few reported adverse events. While the results indicated that tai chi is a  
20    likely feasible and safe treatment option, there was insufficient data regarding long-term  
21    effects and our conclusions were cautious to reflect the limited evidence. Since that  
22    review, there has been continued research on tai chi interventions and thus, it is timely to  
23    assess the current evidence and make recommendations for the need (or not) for future  
24    trials of tai chi within musculoskeletal populations.

25

# *Description of the intervention and how it might work*

Tai chi is a multicomponent intervention and has been well defined elsewhere [6-8].

While the exact mechanisms for how tai chi might reduce pain and disability are not confirmed, it is plausible that for musculoskeletal conditions, the mechanisms might be largely behavioural in nature. For example, practising tai chi involves the use of graded activity principles (e.g. introducing activities/exercises in graded manner from easiest to more complex) that may reduce fear of movement and pain catastrophising [9, 10].

Additionally, many movements in tai chi require consistent double-leg and single-leg squatting activity, which may lead to improved lower limb strengthening, mobility, and mechanics for activities such as getting in and out of a chair, climbing stairs and walking. Lastly, tai chi teaches participants to use deep diaphragmatic breathing in conjunction with physical movements. Deep breathing is often used in relaxation interventions and may contribute to a reduction in pain by relieving muscle tension [11]. While there has been some exploratory research in these areas [12-14], the mechanisms have yet to be rigorously evaluated and thus remain unconfirmed.

The aim of this systematic review was to update the evidence since the previous review regarding the effectiveness of tai chi in decreasing pain and disability, and improving physical function and quality of life, in people with chronic musculoskeletal pain. The review used a meta-analytical approach.

## **Methods**

### *Data sources and searches*

A sensitive search of seven electronic databases (EMBASE, PEDro, AMED, MEDLINE, CINAHL, Sport Discus, and the Cochrane Central Register of Controlled Trials) using

1 the search terms tai chi, Taiji.mp was performed to identify all articles on tai chi  
2 published subsequent to the earlier review conducted in 2009. Thus, in addition to the 7  
3 trials included in the earlier review, the publication window for the updated search was  
4 August 2008 until November 2015. All search results were imported into EndNote X7<sup>1</sup>  
5 for screening.

6  
7 *Study selection*

8 From these titles, only original studies were included if they had (i) a randomised  
9 controlled trial design, (ii) included patients with a primary complaint of musculoskeletal  
10 pain, (iii) tai chi exercise as the main intervention and (iv) at least one outcome measure  
11 of either pain, self-reported disability, physical performance or health-related quality of  
12 life. Grey research including non peer-reviewed literature, theses and letters to the editor  
13 were not included. Non-English language trials were included if an appropriate  
14 translation was possible. Forward and backward citation tracking was performed from the  
15 included trials to identify any studies missed in the electronic database search.

16  
17 *Data extraction*

18 Two authors extracted and checked data on trial characteristics including population,  
19 sample size, comparator(s) description, outcomes assessed and assessment time-points.  
20 The Template for Intervention Description and Replication (TIDieR) was used to extract  
21 data on intervention details [15]; this data was used to describe how well intervention  
22 details were reported for replication in other trials and future translation and  
23 implementation in clinical practice.

<sup>1</sup> EndNote X7 software licence supplied by The University of Oxford.

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5 2 For each included trial, one investigator extracted the group mean and standard deviation  
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7 3 of the change scores for all relevant outcomes at three time points post randomisation;  
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9 4 short-term less than 3 months (if there are multiple eligible time points we chose the time  
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11 5 point closest to 6 weeks), medium-term is at least 3 months but less than 12 months (if  
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13 6 there were multiple eligible time points we chose the time point closest to 6 months), and  
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15 7 long-term is 12 months or more (if there were multiple eligible time points we chose the  
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17 8 time point closest to 12 months). All data were extracted using a standardised data  
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19 9 extraction form and were double-checked by a second investigator. Where outcome data  
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21 10 were not reported, attempts were made to obtain data from authors. In cases where data  
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23 11 were not able to be obtained, one of the following methods was used to provide data: (i)  
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25 12 standard deviations were imputed from the 95% confidence interval or standard error, or  
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27 13 (ii) the change scores and SD were estimated according to methods endorsed in the  
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29 14 Cochrane Handbook for Systematic Reviews of Intervention [16]. If no usable data were  
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31 15 listed or able to be retrieved the trial was not included in the meta-analysis.  
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#### 40 17 *Quality assessment*

41 18 Risk of bias was assessed using the 12 point Cochrane risk of bias (RoB) tool: (i) random  
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43 19 sequence generation, (ii) allocation concealment, blinding of (iii) participants, (iv)  
44  
45 20 providers and (v) assessors, (vi) incomplete outcome data, (vii) intention to treat analysis,  
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47 21 (viii) selective reporting, (ix) baseline prognostic indicators, (x) co-interventions, (xi)  
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49 22 compliance and (xii) timing of outcome assessment. We used risk of bias assessments for  
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51 23 the sensitivity analyses, using scores from five of the items (items ii, iii, v, vi and vii) to  
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53 24 rate the study as low or high risk of bias; studies rated as low on 3 or more of these items  
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55 25 were judged to be low RoB and included in the sensitivity analysis.  
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2     The quality of the evidence was assessed using the GRADE (Grading of

3     Recommendations, Assessment, Development and Evaluations) approach. Quality was

4     downgraded based on four factors; (i) methodological quality; downgraded if 25% or

5     more of the participants were from studies rated as having a high risk of bias, (ii)

6     inconsistency in the results; downgraded if >25% of studies had treatment effects in a

7     different direction or if  $I^2 \geq 50\%$ ; (iii) indirectness of evidence; downgraded if more than

8     50% of the participants were outside the target group, and (iv) imprecision of evidence;

9     downgraded if fewer than 400 participants were included in the comparison.

10    Additionally, for outcomes with only a single study evidence was downgraded. We

11    reduced the quality of the evidence for a specific outcome by one level, according to

12    these five factors and described them using the 5 GRADE categories: *high quality*

13    *evidence*: there are consistent findings among at least 75% of RCTs with low risk of bias,

14    consistent, direct and precise data and no known or suspected publication biases. Further

15    research is unlikely to change either the estimate or our confidence in the results;

16    *moderate quality evidence*: one of the domains is not met. Further research is likely to

17    have an important impact on our confidence in the estimate of effect and may change the

18    estimate; *low quality evidence*: two of the domains are not met. Further research is very

19    likely to have an important impact on our confidence in the estimate of effect and is

20    likely to change the estimate; *very low quality evidence*: three of the domains are not met.

21    We are very uncertain about the results; *no evidence*: no RCTs were identified that

22    addressed this outcome

23

24    *Data synthesis and analysis*



We investigated the contrasts of (i) tai chi vs. no treatment (including usual care or minimal care) and (ii) tai chi vs. another treatment (exercise, physiotherapy, multidisciplinary therapy). This review included all styles of tai chi. A meta-analysis of the included trials was performed where it was deemed sensible to combine trials. Meta-analyses were performed using random effects models in RevMan V5.3. Standardised mean differences and corresponding 95% confidence intervals were calculated using Hedges' *g*, which adjusts for small sample bias [17]. Effect sizes were interpreted as follows: 0.2 representing a small effect, 0.5 a moderate effect and 0.8 a large effect [18]. Sub-group analyses on specific musculoskeletal conditions (e.g. knee osteoarthritis) were conducted where there were sufficient trials. Secondary exploratory sensitivity analyses based on methodological quality were performed.

## **Results**

### ***Search Strategy***

A total of 2100 titles were identified after duplicates had been removed. Following the exclusion process a total of 8 RCTs [19-26] met the inclusion criteria; thus in addition to the 7 RCTs from the previous review, a total of 15 RCTs [19-33] were included in the analysis and described in the results (Figure 1). For 4 studies, change score data were not provided and were calculated according to section 8.5.2.10 in the Cochrane Handbook for Systematic Reviews of Interventions [16].

### ***Description of included trials (Table 1)***

#### ***Participants***

1 The most common condition was chronic arthritis (12 trials), specifically osteoarthritis in  
2 10 trials [20-23, 25, 29-33] and rheumatoid arthritis in 2 trials [26, 27], followed by  
3 chronic low back pain in 2 trials [19, 24] and chronic tension-type headache in 1 trial  
4 [28]. We have analysed the data separately for these three conditions. Recruitment for 8  
5 [19, 21, 23, 28-32] of the 15 trials used community volunteers, with 7 trials recruiting  
6 patients from public health centres [20, 22, 24-27, 33].

7  
8 *Intervention description using the TIDieR Guidelines*

9 *Summary of reporting*

10 Of the 12 items on the TIDieR checklist, all studies reported information on the style of  
11 tai chi used and stated the aim of tai chi was primarily to reduce disability or improve  
12 function. All studies provided information on the delivery mode, dose, duration and  
13 schedule of the intervention. However, information on the provider characteristics,  
14 provider training and intervention setting was lacking in over 50% of studies.  
15 Additionally, while many studies provided a list of intervention components, such as if a  
16 warm-up/cool down was used and the number and name of specific tai chi movements  
17 taught, insufficient procedural information was reported (e.g. teaching style, elements for  
18 progression) and less than 25% of studies provided clear information on or access to  
19 teaching materials. Lastly, no studies reported the tai chi instructor's fidelity to the  
20 intervention protocol and only 60% of studies reported participant adherence. A detailed  
21 description of the intervention details is provided below.

22  
23 *Who, What and How (provider, content, dose, procedures and materials)*

24 Descriptions of the tai chi interventions were variable across studies and are described  
25 using the TIDieR framework in Table 2. In terms of tai chi style, 53% used yang style,

33% used sun style, 7% used Chen, and 7% used Wu style. Half of the studies provided information on the tai chi instructor, all of which had previous experience teaching tai chi and 6 of the studies reported having additional provider training. All studies used a group format, but group size and location were rarely reported. Duration ranged from 6-20 weeks and included between 8 and 60 sessions of 40-60 minutes. The most common dosage was 2x/week for 10-12 weeks. In terms of specific intervention content, the number of tai chi movements ranged from 9 to 24 movements; most studies included a warm-up/cool down and recommended home practice on a daily basis. While deep breathing techniques are integrated with each tai chi movement, 4 studies reported teaching deep breathing and relaxation techniques as additional components. Most studies did not report any information on the use of provider or patient materials, 4 studies reported using a treatment manual for the instructor and 7 studies reported providing patient handouts or audio-visual materials. Although none of the interventions were tailored specifically to participants on an individual basis, all studies used simplified shortened versions of the original tai chi programmes. Most adaptations were made to suit elderly or arthritic populations at a beginner level of tai chi; particularly ensuring the movements required less deep knee bending to avoid aggravating joint pain while still improving muscle strength and mobility, and using an exercise progression of easy to difficult movements. In terms of replication, several studies included either a list of the tai chi movement names in the manuscript [20, 24, 25] or in a separate instructor's manual [19, 21, 22, 25]. A smaller sample provided the name of an instructional DVD that is available for purchase [19, 31].

*How well (Participant Adherence to treatment and intervention fidelity)*

1 Few studies reported information on participant adherence or treatment fidelity. Two  
2 studies reported they would assess treatment fidelity [19, 21] (how well the instructor  
3 followed the intervention protocol) either using a self-report checklist or an objective  
4 observer; however no studies reported the results of this assessment. Thus it is not known  
5 how well instructors adhered to the intended treatment protocol. Similarly, only 60% of  
6 studies reported participant intervention adherence measured by in-session attendance,  
7 however the assessment method varied so an overall total could not be calculated.  
8 Additionally, two studies reported participant adherence to home practice.

9  
10 *Methodological quality*

11 Based on the 5 key RoB items, 7 studies were rated as low [19-22, 26, 29, 31]. With  
12 respect to blinding, subjects and practitioners administering treatment in all trials were  
13 unblinded to treatment. For the self-reported outcomes of pain, disability and quality of  
14 life, the patient is considered the outcome assessor and was thus unblinded in all studies.  
15 Other common reasons for high or unclear risk of bias were lack of concealed allocation  
16 (53%), lack of intention to treat analysis (47%), and greater than 20% data loss at short-  
17 term follow-up (33%). A list of the risk of bias ratings for each study on the 5 key items  
18 is presented in Table 1 and for all 12 items in an additional online file.

19  
20 *Tai chi versus no treatment (usual care, attention control, wait-list control)*

21 *Arthritis*

22 Eleven RCTs [20-23, 25, 29-34] compared the effects of tai chi and a no treatment control  
23 arm, which was defined as no prescribed treatment within the study, however,  
24 participants were free to seek and receive care at the discretion and direction of their  
25 health care provider. The type of treatments received by participants in the control arm

1 was not reported in any study. The most commonly used assessment tool was the  
2 WOMAC to assess pain (64%), disability (88%) and stiffness (45%). The physical and  
3 mental subscales of the Short-form Health Questionnaire (36-item or 12-item) were used  
4 to assess quality of life. Performance of physical tasks concentrated on common  
5 problematic activities including getting in and out of a chair and walking function, these  
6 were assessed with a variety of performance tests including; the *Get-up and Go test* [21,  
7 23, 25, 31], the *Sit to stand test* [21, 22, 32], the 50 ft walk test [31, 32] and the 6 min  
8 walk test [22, 23, 25]. Since each of these tests assesses a different aspect of function  
9 they are reported separately.

11 For short term pain (11 RCTs, n=497) and disability (9 RCTs, n=430) we found moderate  
12 quality evidence that tai chi was more effective than no treatment [pain: SMD -0.66; 95%  
13 CI: -0.85, -0.48, disability: SMD -0.66; 95% CI: -0.85, -0.46]. For short term quality of  
14 life (3 RCTs, n=181), we found low quality evidence that tai chi was more effective for  
15 improving physical health [SMD -0.61; 95% CI: -1.08, -0.15] and had no effect on  
16 mental health. For short-term stiffness (5 studies, n=188), we found very low quality  
17 evidence that tai chi may be more effective although the results were not statistically  
18 significant [SMD -0.50; 95% CI: -0.80, 0.20]. At medium and long term, there were  
19 fewer studies that assessed these outcomes; the summary effect sizes tended to be smaller  
20 and no longer statistically significant, the quality of the evidence was reduced to low or  
21 very low based on high risk of bias, inconsistency and imprecision of the results.

23 For short term performance tests, Get Up and Go (4 RCTs, n=229), Sit-to-Stand (3 RCTs,  
24 n=125), 50 Foot Walk (2 RCTs, n=130) and 6 Minute Walk (3 RCTs, n=117) we found  
25 low quality evidence that tai chi may be more effective than no treatment although the

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1 results were only statistically significant for Get Up and Go and Sit-to-Stand. No studies  
2 assessed these outcomes at medium or long-term follow-up.

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10 4 *Low Back Pain*

11 Two studies [19, 24] enrolled people with low back pain, both assessed pain and one  
12 assessed disability [19]. Outcomes of quality of life and physical performance were not  
13 assessed. The 0-10 numerical rating scale was used to assess pain in both studies and the  
14 RMDQ was used to assess disability.

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23 10 For short-term pain (2 RCTs, n=348) we found very low quality evidence that tai chi may  
24 be more effective than no treatment [SMD -1.58; 95% CI -3.45, 0.25], however the  
25 difference was not statistically significant. For short-term disability (1 RCT, n=160), we  
26 found low quality evidence that tai chi was more effective than no treatment [SMD -0.64;  
27 95% CI -0.98, -0.31]. At medium term only pain was assessed (1 RCT, n=188), and we  
28 found very low evidence for tai chi to be more effective. Outcomes were not assessed at  
29 long-term.

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41 18 *Tension headache*

42 One trial (n=47) assessed patients with tension headache[28], this trial used the SF-36v2  
43 to assess both quality of life with mental and physical health summary scores and  
44 disability with physical function subscale. For short term pain we found very low quality  
45 evidence that tai chi was more effective than control [pain: SMD -1.85 (-2.73, -0.97) and  
46 for quality of life we found very low evidence that tai chi may be more effective but the  
47 results were not statistically significant [SMD -0.67 (-1.42, 0.07)].

### *Tai chi versus another treatment*

We found three randomised controlled trials that compared tai chi to another intervention [23, 26, 31]. These studies all included populations of arthritis; no studies were found for this contrast for any other musculoskeletal condition. The comparison treatments were predominantly exercise-based, one hydrotherapy, one resistance training and one education plus a stretching programme. These studies assessed pain, disability and physical performance. For short-term pain, disability and performance we found very low quality evidence to suggest there was no difference in effect between tai chi or any of these interventions; with the possibility that tai chi may be more effective than education and stretching on improving self-report disability [26]. However, as the comparison groups were very different they provide little understanding of the relative effectiveness of tai chi versus other exercise based-treatments.

### **Discussion**

The previous systematic review included seven studies and suggested that tai chi was effective for reducing pain and disability for arthritis, however the evidence quality was low. Despite including a further eight studies in this current review, the quality of evidence remains poor due to small sample sizes and low methodological quality. Thus, the additional studies have failed to improve the robustness of our estimates. Consequently, the increased research in this area does not seem to be advancing our knowledge for providing evidence-based recommendations regarding the use of tai chi for musculoskeletal conditions. In particular, studies need to improve their follow-up rates, reporting of allocation concealment methods, and if they used an intention to treat analysis. In order for tai chi to be recommended as an effective intervention, more high quality trials with large sample sizes assessing tai chi versus other evidence-based

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1 treatments at short and long-term are needed.

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3 *Statement of principal findings*

4 The majority of trials in this review studied populations with arthritis and our results are  
5 similar to that of our previous review. For arthritis, we found that tai chi was more  
6 effective than no treatment in improving pain and disability (moderate quality evidence)  
7 and quality of life (low quality evidence) in the short term. Comparatively, we found that  
8 tai chi is likely no more effective than no treatment for improving performance outcomes  
9 such as getting in and out of a chair and walking (very low quality evidence). However,  
10 performance outcomes were impeded by a lack of reliable measurement tools for this  
11 population. Lastly, there were too few studies to draw any conclusions regarding the  
12 effects of tai chi versus other treatments, nor to ascertain if effects are sustained over  
13 time. Moreover, less is known about its effectiveness for other musculoskeletal pain  
14 populations.

15

16 *Outcome significance in relation to other research*

17 Despite including eight additional studies from the previous review, our knowledge  
18 regarding the effectiveness of tai chi is still limited. However, this current review has  
19 furthered our understanding with regards to the short-term effects of tai chi on pain and  
20 disability for arthritis populations in comparison to no intervention. The effect sizes for  
21 these outcomes were moderate with narrow 95% confidence intervals that were  
22 statistically significant, suggesting adequate precision and significance of the effect  
23 estimates. These results are similar to other commonly used exercise regimens for lower-  
24 limb arthritis such as combined exercise programs of strengthening, flexibility and  
25 aerobic exercise [35]. Interestingly, these effects are larger than single component



1 exercise programmes such as flexibility or strength training which have small effects on  
2 pain and disability in the short term [35].

3  
4 Importantly we found very little evidence regarding tai chi versus no intervention or  
5 another treatment for other musculoskeletal conditions. Our estimates for back pain and  
6 tension headaches are much less precise and are derived from only one or two studies  
7 with variable quality, thus it is hard to provide a judgement of their significance.  
8 However, for back pain, the magnitude of the effects on pain and disability are similar to  
9 those reported from general exercise programmes [36] as well as more expensive forms  
10 of treatment such as multidisciplinary treatments [37], or cognitive behavioural treatment  
11 [38].

### 12 13 *Strengths*

14 Our review used a rigorous methodology including independent full text screening and  
15 data extraction/checking to ensure accuracy. We increased our level of intervention  
16 information to align with recommendations from the TIDieR Guidelines to assess if tai  
17 chi interventions are described in sufficient detail for replication. We used the GRADE  
18 protocol recommended by the Cochrane Handbook to add a more robust assessment to  
19 our interpretation of results, allowing us to provide reliable recommendations for future  
20 research in this area. Lastly, we sub-grouped our analyses by disease conditions to  
21 account for heterogeneity in population type.

### 22 23 *Limitations*

24 Meta-analysis necessarily involves assumptions of homogeneity with respect to  
25 outcomes, treatment, sample and data. While most of our estimates of effect had low

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1 statistical heterogeneity, we recognise that there may be clinical heterogeneity in all these  
2 areas. For example, there were differences observed in the tai chi interventions such as  
3 the style of tai chi, number of sessions, and total treatment duration, these differences  
4 may account for some of the variation in treatment effects between studies. However, we  
5 believe that the included trials were sufficiently similar to support our choice of  
6 methodology.

7  
8 *Clinical Implications*

9 Our findings support the use of tai chi as a treatment for people with arthritis and  
10 potentially for low back pain. However, we have only very low quality or no evidence to  
11 suggest that it is as effective, or more effective, than any other treatment for these  
12 populations. With no direct comparison of tai chi to other treatments, we can only  
13 speculate that, since our findings appear to be within a similar range to those reported for  
14 other commonly used exercise regimes for musculoskeletal conditions, tai chi could  
15 produce similar effects if compared. Thus, we cannot provide useful or confirmatory  
16 evidence to recommend this approach over others used in clinical practice settings until a  
17 robust, direct comparison study has been conducted.

18  
19 *Recommendations for improving future research*

20 We recommend that studies proposing a trial of tai chi for musculoskeletal conditions  
21 should be considered for funding if they show that their methodology would be  
22 advancing the current state of evidence. In terms of study design, this would involve  
23 robust randomised controlled trials, comparing tai chi to other commonly used  
24 interventions with assessments at medium and long-term follow-ups. In terms of  
25 outcomes, it is necessary to assess core outcomes of pain, disability and quality of life as

well as a range of objective and validated assessments of physical performance. The cost-effectiveness of tai chi has not yet been investigated, thus future studies that assess cost-effectiveness of tai chi should be prioritised to inform its potential for cost-savings in health care settings. Additionally, the Medical Research Council (MRC) highlights the importance of conducting a process evaluation that includes assessing both process factors such as treatment delivery fidelity and patient adherence as well as proposed mediators of treatment outcome within complex interventions to provide insights that will aid implementation and improve clinical outcomes in practice [39]. Few studies have assessed these variables with respect to tai chi and thus we recommend that future research include a robust process evaluation.

## Conclusions

The research question addressed in this review is of significant importance for the clinical community as musculoskeletal pain conditions such as arthritis and back pain are among the leading reasons for seeking care and are highly prevalent in the ageing population. This review provides clear evidence that tai chi is effective in the short term for reducing pain and disability in arthritis populations. Further conclusions regarding the effectiveness of tai chi on additional outcomes and across other health conditions cannot be drawn due to the poor quality and limited evidence in these areas.

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1 Table 1. Characteristics of included studies

Study	Complaint	n	Age (yrs) (SD)	Comparison	Outcomes			Risk of Bias†					
					Pain	Disability	QoL	1	2	3	4	5	H/L
<b>Arthritis:</b>													
Adler 2000	OA (hip, knee)	16	77 (6)	(i) usual care*	✓		✓	L	H	H	L	L	L
Brismée 2007	OA (knee)	41	71 (10)	(i) attention control	✓	✓		H	H	H	H	U	H
Fransen 2007	OA (hip, knee)	197	70 (6)	(i) waitlist control (ii) hydrotherapy	✓	✓	✓	L	H	H	L	L	L
Hartman 2000	OA (hip, knee, ankle, spine)	35	67 (8)	(i) attention control	✓	✓	✓	H	H	H	L	U	H
Lee 2006	RA	61	n/a	(i) usual care	✓			U	H	H	L	H	H
Lee 2009	OA (knee)	44	69 (5)	(i) waitlist control	✓	✓	✓	L	H	H	L	L	L
Song 2007	OA (knee)	72	65 (6)	(i) usual care	✓	✓		U	H	H	H	L	H
Tsai 2013	OA (knee)	55	79 (8)	(i) attention control	✓	✓		L	H	H	L	L	L
Wang 2008	RA	20	50 (14)	(i) education + stretches	✓	✓	✓	L	H	H	L	L	L
Wang 2009	OA (knee)	40	65 (8)	(ii) attention control	✓	✓	✓	L	H	H	L	L	L
Wortley 2013	OA (knee)	39	70 (5)	(i) usual care (ii) strength training	✓	✓		U	H	H	H	U	H
Zeng 2015	OA (hip)	97	65 (3)	(i) usual care	✓	✓		U	H	H	H	H	H
<b>Back pain:</b>													
Hall 2011	NSLBP	160	44 (13)	(i) waitlist control	✓	✓		L	H	H	L	L	L
Weifen 2013	NSLBP	188	38 (5)	(i) TC + active control	✓			U	H	H	L	U	H
<b>Headache:</b>													
Abbott 2007	Tension	47	44 (13)	(i) wait-list control	✓	✓	✓	U	H	H	H	H	H
*Usual care indicates a control group in which patients were free to seek care as usual but did not receive a specific course of treatment as part of the study. †Risk of Bias items and answers are: 1=allocation concealment, 2=blinding of participants, 3=blinding of outcome assessor, 4=loss to follow-up, 5=intention to treat, L=Low risk of bias, H=High risk of bias, U=unclear risk of bias													

Table 2. Description of the tai chi interventions for replication

Study	Style	Provider		Location	When and How Much				Materials Used			Procedures: Components Used						How well	
	Name / style	Years experience	Training provided	location	# of Sessions	Time (mins)	Frequency (#/wk)	Duration (wks)	Treatment manual	Patient Materials	Materials accessible	Warm-up/cool down	# of TC movements	Additional Breathing / relaxation	Additional stretch/strength	Home practice	Specific Instruction	Fidelity reported	In-class attendance reported
Abbott 2007	Yang	20	N	Local Park	8	NR	1x / 2wk	15	N	Y	N	NR	24	Y	NR	NR	NR	NR	NR
Adler 2000	Wu	NR*	NR	Community centre	10	60	1x	10	NR	Y	N	Y	16	NR	NR	Y	Y	NR	88%
Brismée 2007	Yang	NR	NR	NR	18	40	3x	6	NR	Y	N	Y	24	NR	NR	Y	Y	NR	89%
Fransen 2007	Sun	NR	Y	NR	24	60	2x	12	NR	Y	Y	Y	24	NR	NR	Y	NR	NR	61%
Hall 2011/2009	Sun	NR	Y	Community centre	18	40	2x 1x	8 2	Y	Y	Y	Y	12	N	NR	Y	Y	NR	58%
Hartman 2000	Yang	NR	Y	NR	24	60	2x	12	NR	NR	NR	Y	9	Y	NR	Y	Y	NR	100%
Lee 2009	Yang	NR	NR	NR	16	60	2x	8	NR	NR	Y	Y	18	N	NR	NR	Y	NR	NR
Lee 2006	Sun	NR	Y	Health centre	16	60	2x	8	NR	NR	N	Y	12	N	NR	NR	Y	NR	90%
Song 2007	Sun	NR	NR	University room	16	60	3x 1x	2 10	NR	Y	N	Y	12	NR	NR	Y	Y	NR	NR
Tsai 2013	Sun	6	Y	NR	60	20-40	3x	20	Y	NR	N	NR	12	NR	NR	NR	Y	NR	NR
Wang 2008	Yang	NR	NR	Health centre	24	60	2x	12	NR	NR	N	Y	10	Y	N	Y	NR	NR	NR
Wang 2009	Yang	20	NR	NR	24	60	2x	12	Y	Y	N	Y	10	Y	NR	Y	Y	NR	85%
Weifen 2013	Chen	NR	NR	NR	NR	45	5x	NR	NR	NR	Y	NR	24	NR	NR	Y	NR	NR	NR
Wortley 2013	Yang	35	NR	NR	20	60	2x	10	NR	NR	N	NR	12	NR	NR	NR	Y	NR	82%
Zeng 2015	Yang	5	Y	Health centre	NR	45	5x NR	2 10	Y	NR	Y	Y	10	NR	Y	Y	Y	NR	88%
*NR = not reported																			

Table 3. Summary of findings table organized by population

Tai Chi compared with no intervention for musculoskeletal pain conditions			
<b>Patient or population:</b> people with chronic musculoskeletal pain conditions			
<b>Settings:</b> community or health care settings			
<b>Intervention:</b> tai chi			
<b>Comparison:</b> no intervention control group			
Outcome	Standardised Mean Difference (95% CI)	Participants (studies)	Quality of evidence (GRADE)
<b>Arthritis</b>			
<b>Short term</b>			
Pain	SMD -0.66 (-0.85, -0.48)	497 (11)	⊕⊕⊕□ moderate <sup>1</sup>
Disability	SMD -0.66 (-0.85, -0.46)	430 (9)	⊕⊕⊕□ moderate <sup>1</sup>
Quality of Life (physical)	SMD -0.61 (-1.08, -0.15)	181 (3)	⊕⊕□□ low <sup>2,4</sup>
Quality of Life (mental)	SMD -0.19 (-0.61, 0.23)	181 (3)	⊕⊕□□ low <sup>2,4</sup>
Stiffness	SMD -0.50 (-0.80, 0.20)	188 (5)	⊕□□□ very low <sup>1,2,4</sup>
<i>Performance:</i>			
Sit-to-stand (reps)	SMD -0.91 (-1.52, -0.30)	125 (3)	⊕□□□ very low <sup>1,2,4</sup>
Get up and go (speed)	SMD -0.87 (-1.72, -0.03)	229 (4)	⊕□□□ very low <sup>1,2,4</sup>
50ft walk test (speed)	SMD -0.28 (-0.86, 0.29)	130 (2)	⊕□□□ very low <sup>1,2,4</sup>
6 Min walk test (distance)	SMD -0.86 (-1.90, 0.19)	117 (3)	⊕□□□ very low <sup>1,2,4</sup>
<b>Medium term</b>			
Pain	SMD -0.45 (-0.97, 0.08)	126 (3)	⊕□□□ very low <sup>1,2,4</sup>
Disability	SMD -0.59 (-0.95, -0.23)	126 (3)	⊕□□□ very low <sup>1,2,4</sup>
Quality of Life (physical)	SMD -0.59 (-1.23, 0.04)	40 (1)	⊕⊕□□ low <sup>5</sup>
Quality of Life (mental)	SMD 0.01 (-0.61, 0.63)	40 (1)	⊕⊕□□ low <sup>5</sup>
Stiffness	SMD -0.09 (-0.59, 0.40)	71 (2)	⊕□□□ very low <sup>1,2,4</sup>
<b>Long term</b>			
Pain	SMD -0.46 (-1.09, 0.17)	40 (1)	⊕⊕□□ low <sup>5</sup>
Disability	SMD -0.36 (-0.99, 0.26)	40 (1)	⊕⊕□□ low <sup>5</sup>
Quality of Life (physical)	SMD -0.83 (-1.48, -0.18)	40 (1)	⊕⊕□□ low <sup>5</sup>
Quality of Life (mental)	SMD -0.49 (-1.12, 0.14)	40 (1)	⊕⊕□□ low <sup>5</sup>
<b>Low Back Pain</b>			
<b>Short term</b>			
Pain	SMD -1.58 (-3.45, 0.25)	348 (2)	⊕□□□ very low <sup>1,2,3,4</sup>
Disability	SMD -0.64 (-0.98, -0.31)	160 (1)	⊕⊕□□ low <sup>5</sup>
Quality of Life	--	--	No evidence
<b>Medium Term</b>			
Pain	SMD -3.21 (-3.67, -2.74)	188 (1)	⊕□□□ very low <sup>1,5</sup>
Disability	--	--	No evidence
Quality of Life	--	--	No evidence
<b>Tension headaches</b>			
<b>Short term</b>			
Pain	SMD -1.85 (-2.73, -0.97)	47 (1)	⊕□□□ very low <sup>1,5</sup>
QoL	SMD -0.67 (-1.42, 0.07)	47 (1)	⊕□□□ very low <sup>1,5</sup>

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<sup>1</sup> downgraded due to risk of bias, <sup>2</sup> downgraded due to inconsistency, <sup>3</sup> downgraded due to indirectness, <sup>4</sup> downgraded due to imprecision, <sup>5</sup> downgraded due to being a single study with less than 400 participants

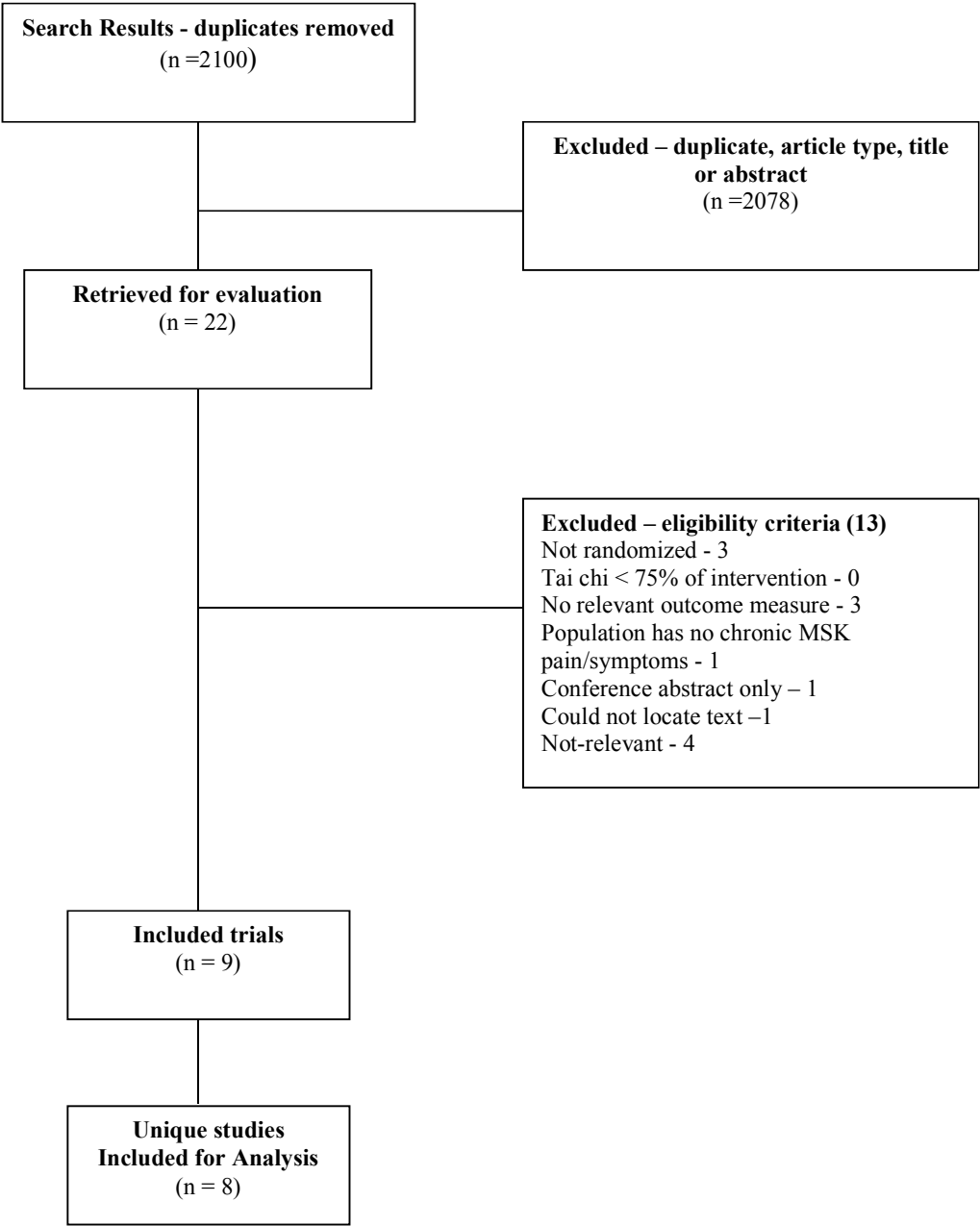
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9 4 **Figure 2. The effect of tai chi versus no treatment on pain**  
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11 6 **Figure 3. The effect of tai chi versus no treatment on disability**  
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1     **Figure 1. Study flow chart**



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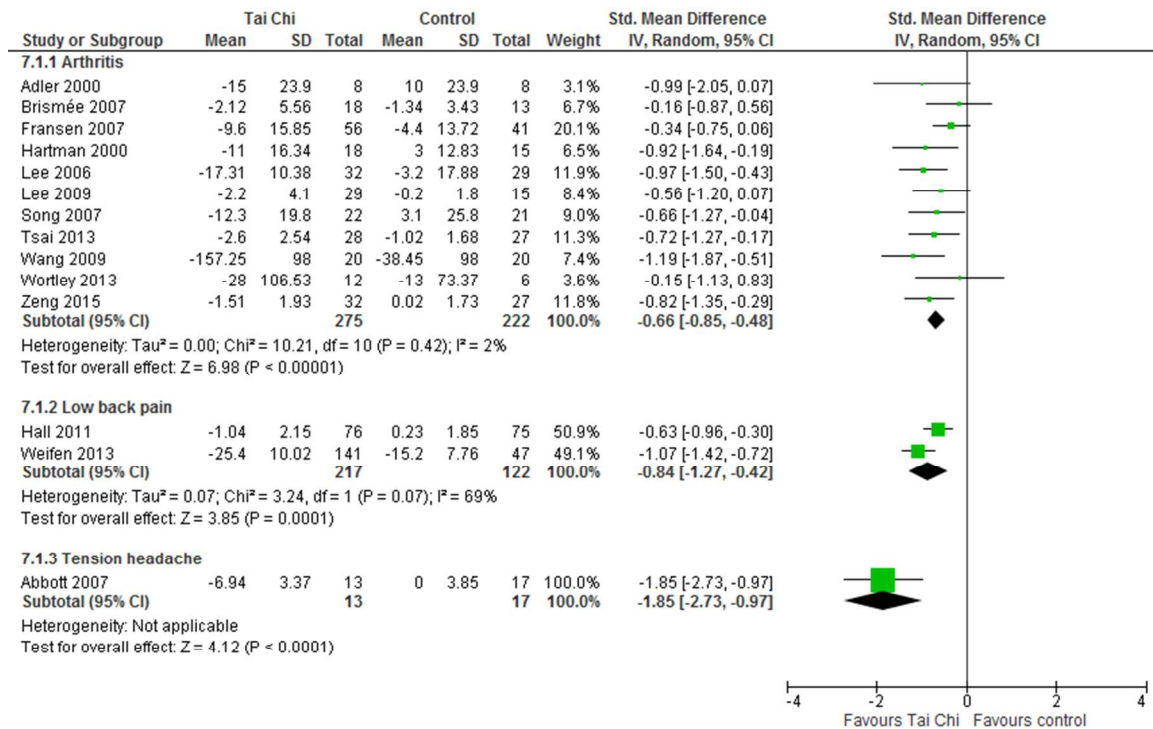
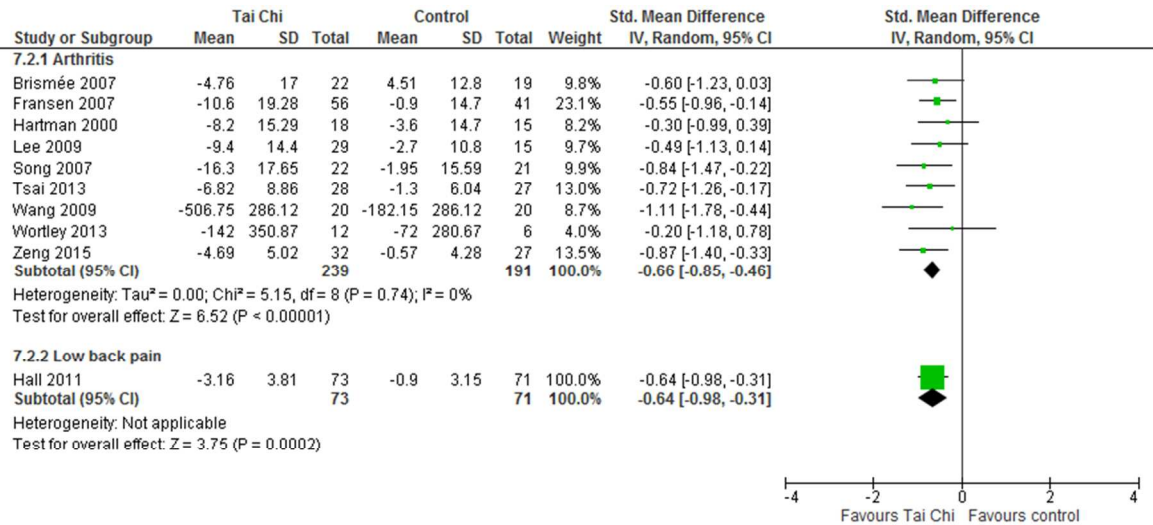
**Figure 2. The effect of tai chi versus no treatment on pain**

Figure 3. The effect of tai chi versus no treatment on disability





## Appendix A. 12 item Risk of Bias

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of provider	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Intention to treat	Selective reporting (reporting bias)	Baseline prognostic indicators	Co-interventions	Compliance	Other bias
Abbott 2007	?	?	-	-	-	-	-	?	-	-	?	+
Adler 2000	+	+	-	-	-	+	+	+	-	+	?	+
Brismée 2007	+	-	-	-	-	-	?	+	+	+	?	+
Fransen 2007	+	+	-	-	-	+	+	+	+	+	?	+
Hall 2011	+	+	-	-	-	+	+	?	+	+	-	+
Hartman 2000	+	-	-	-	-	+	?	+	-	+	?	+
Lee 2006	?	?	-	-	-	+	-	?	+	+	?	+
Lee 2009	+	+	-	-	-	+	+	+	+	+	?	+
Song 2007	+	?	-	-	-	-	+	+	?	?	?	+
Tsai 2013	+	+	-	+	-	+	+	+	+	+	?	+
Wang 2008	+	+	-	-	-	+	+	+	-	+	+	+
Wang 2009	+	+	-	-	-	+	+	?	?	+	+	+
Weifen 2013	+	?	-	?	-	+	?	+	+	+	?	+
Wortley 2013	?	?	-	-	-	-	?	+	+	+	?	+
Zeng 2015	+	?	-	-	-	-	-	+	?	+	+	+

**Title:** The effectiveness of tai chi for chronic musculoskeletal pain conditions: an updated systematic review and meta-analysis.

**Authors:** Amanda Hall<sup>1</sup>, Bethan Copsey<sup>2</sup>, Helen Richmond<sup>2</sup>, Jacqueline Thompson<sup>2</sup>, Manuela Ferreira<sup>3,4</sup>, Jane Latimer<sup>3</sup>, Chris G Maher<sup>3</sup>

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## Abstract

**Background:** Tai chi is recommended for musculoskeletal conditions, however, the evidence for its clinical effectiveness is uncertain. **Purpose:** To determine whether tai chi is beneficial for clinical outcomes in people with musculoskeletal pain. **Data sources:** Seven databases EMBASE, PEDro, AMED, MEDLINE, CINAHL, Sport Discus, and the Cochrane Central Register of Controlled Trials. **Study Selection:** Randomized controlled trials of tai chi for people with a chronic musculoskeletal condition were included. **Data extraction:** Two reviewers extracted data and rated risk of bias. Standardised mean differences and 95% confidence intervals (CI) were calculated for individual trials and pooled effect sizes were calculated using a random effects model. **Data Synthesis:** 15 studies were identified including people with osteoarthritis (80%), back pain (13%) and headache (7%). Using the GRADE approach, we found moderate quality evidence that tai chi is more effective than no treatment or usual care at short term on pain (SMD -0.66 (-0.85, -0.48)) and disability (SMD -0.66 (-0.85, -0.46)). The evidence for other outcomes was of low or very low quality and there was little information regarding long-term effects. Thus, while the number of publications in this area has increased, the rigor has not, hindering our ability to provide reliable recommendations for clinical practice. **Limitations:** The evidence provided in this review is limited by trials with small sample sizes, low methodological quality and lack of long-term assessment. **Conclusions:** In order for tai chi to be recommended as an effective intervention, more high quality trials with large sample sizes assessing tai chi versus other evidence-based treatments at short and long-term are needed.

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1     **Introduction**

2     Chronic musculoskeletal pain conditions such as low back pain and osteoarthritis are  
3     leading causes of disability worldwide [1]. These conditions affect millions of people’s  
4     ability to perform work-related tasks or important daily activities, leading to a poor  
5     quality of life [2]. While some pharmacological therapies are used to help control pain;  
6     physical function and disability remain a persistent problem. As a result, there is  
7     consistent advice that treatment should include interventions aimed at improving function  
8     and general physical activity levels [3].

9  
10    Many non-pharmacological interventions have been designed to reduce pain-related  
11    disability and some have been evaluated in large clinical trials. Systematic reviews have  
12    identified psychological therapies, multidisciplinary therapies and exercise therapy as  
13    being effective treatments for reducing disability [4]. Tai chi has been endorsed as a safe  
14    and beneficial form of exercise therapy for people with musculoskeletal pain by several  
15    advocate groups, such as The Arthritis Foundation® in the United States [5]. However  
16    there is uncertainty about its effectiveness as a treatment for pain and disability. It is for  
17    this reason we undertook our 2009 systematic review and meta-analysis of tai chi for  
18    musculoskeletal conditions [6]. The original review identified 7 trials conducted almost  
19    exclusively on patients with arthritis and the meta-analysis indicated small short-term  
20    effects on pain and disability with few reported adverse events. While the results  
21    indicated that tai chi is a likely feasible and safe treatment option, there was insufficient  
22    data regarding long-term effects and our conclusions were cautious to reflect the limited  
23    evidence. Since that review, there has been continued research on tai chi interventions  
24    and thus, it is timely to assess the current evidence and make recommendations for the  
25    need (or not) for future trials of tai chi within musculoskeletal populations.

1

2 *Description of the intervention and how it might work*

3 Tai chi is a multicomponent intervention and has been well defined elsewhere [6-8].

4 While the exact mechanisms for how tai chi might reduce pain and disability are not  
5 confirmed, it is plausible that for musculoskeletal conditions, the mechanisms might be  
6 largely behavioural in nature. For example, practising tai chi involves the use of graded  
7 activity principles (e.g. introducing activities/exercises in graded manner from easiest to  
8 more complex) that may reduce fear of movement and pain catastrophising [9, 10].

9 Additionally, many movements in tai chi require consistent double-leg and single-leg  
10 squatting activity, which may lead to improved lower limb strengthening, mobility, and  
11 mechanics for activities such as getting in and out of a chair, climbing stairs and walking.

12 Lastly, tai chi teaches participants to use deep diaphragmatic breathing in conjunction  
13 with physical movements. Deep breathing is often used in relaxation interventions and  
14 may contribute to a reduction in pain by relieving muscle tension [11]. While there has  
15 been some exploratory research in these areas [12-14], the mechanisms have yet to be  
16 rigorously evaluated and thus remain unconfirmed.

17

18 The aim of this systematic review was to update the evidence regarding the effectiveness  
19 of tai chi in decreasing pain and disability, and improving physical function and quality  
20 of life, in people with chronic musculoskeletal pain. The review used a meta-analytical  
21 approach.

22

23 **Methods**

24 *Data sources and searches*

1 A sensitive search of seven electronic databases (EMBASE, PEDro, AMED, MEDLINE,  
2 CINAHL, Sport Discus, and the Cochrane Central Register of Controlled Trials) using  
3 the search terms tai chi, Taiji.mp was performed to identify all articles on tai chi  
4 published subsequent to our earlier review. The publication window for the search was  
5 August 2008 until November 2015. All search results were imported into EndNote X7<sup>1</sup>  
6 for screening.

7  
8 *Study selection*

9 From these titles, only original studies were included if they had (i) a randomised  
10 controlled trial design, (ii) included patients with a primary complaint of musculoskeletal  
11 pain, (iii) tai chi exercise as the main intervention and (iv) at least one outcome measure  
12 of either pain, self-reported disability, physical performance or health-related quality of  
13 life. Grey research including non peer-reviewed literature, theses and letters to the editor  
14 were not included. Non-English language trials were included if an appropriate  
15 translation was possible. Forward and backward citation tracking was performed from the  
16 included trials to identify any studies missed in the electronic database search.

17  
18 *Data extraction*

19 Two authors extracted and checked data on trial characteristics including population,  
20 sample size, comparator(s) description, outcomes assessed and assessment time-points.  
21 The Template for Intervention Description and Replication (TIDieR) was used to extract  
22 data on intervention details [15]; this data was used to describe how well intervention

<sup>1</sup> EndNote X7 software licence supplied by The University of Oxford.

1 details were reported for replication in other trials and future translation and  
2 implementation in clinical practice.

3  
4 For each included trial, one investigator extracted the group mean and standard deviation  
5 of the change scores for all relevant outcomes at three time points post randomisation;  
6 short-term less than 3 months (if there are multiple eligible time points we chose the time  
7 point closest to 6 weeks), medium-term is at least 3 months but less than 12 months (if  
8 there were multiple eligible time points we chose the time point closest to 6 months), and  
9 long-term is 12 months or more (if there were multiple eligible time points we chose the  
10 time point closest to 12 months). All data were extracted using a standardised data  
11 extraction form and were double-checked by a second investigator. Where outcome data  
12 were not reported, attempts were made to obtain data from authors. In cases where data  
13 were not able to be obtained, one of the following methods was used to provide data: (i)  
14 standard deviations were imputed from the 95% confidence interval or standard error, or  
15 (ii) the change scores and SD were estimated according to methods endorsed in the  
16 Cochrane Handbook for Systematic Reviews of Intervention [16]. If no usable data were  
17 listed or able to be retrieved the trial was not included in the meta-analysis.

### 18 *Quality assessment*

19 Risk of bias was assessed using the 12 point Cochrane risk of bias (RoB) tool: (i) random  
20 sequence generation, (ii) allocation concealment, blinding of (iii) participants, (iv)  
21 providers and (v) assessors, (vi) incomplete outcome data, (vii) intention to treat analysis,  
22 (viii) selective reporting, (ix) baseline prognostic indicators, (x) co-interventions, (xi)  
23 compliance and (xii) timing of outcome assessment. We used risk of bias assessments for  
24 the sensitivity analyses, using scores from five of the items (items ii, iii, v, vi and vii) to  
25

rate the study as low or high risk of bias; studies rated as low on 3 or more of these items were judged to be low RoB and included in the sensitivity analysis.

The quality of the evidence was assessed using the GRADE (Grading of Recommendations, Assessment, Development and Evaluations) approach. Quality was downgraded based on four factors; (i) methodological quality; downgraded if 25% or more of the participants were from studies rated as having a high risk of bias, (ii) inconsistency in the results; downgraded if >25% of studies had treatment effects in a different direction or if  $I^2 \geq 50\%$ ; (iii) indirectness of evidence; downgraded if more than 50% of the participants were outside the target group, and (iv) imprecision of evidence; downgraded if fewer than 400 participants were included in the comparison.

Additionally, for outcomes with only a single study evidence was downgraded. We reduced the quality of the evidence for a specific outcome by one level, according to these five factors and described them using the 5 GRADE categories: *high quality evidence*: there are consistent findings among at least 75% of RCTs with low risk of bias, consistent, direct and precise data and no known or suspected publication biases. Further research is unlikely to change either the estimate or our confidence in the results; *moderate quality evidence*: one of the domains is not met. Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate; *low quality evidence*: two of the domains are not met. Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate; *very low quality evidence*: three of the domains are not met. We are very uncertain about the results; *no evidence*: no RCTs were identified that addressed this outcome



### *Data synthesis and analysis*

We investigated the contrasts of (i) tai chi vs. no treatment (including usual care or minimal care) and (ii) tai chi vs. another treatment (exercise, physiotherapy, multidisciplinary therapy). This review included all styles of tai chi. A meta-analysis of the included trials was performed where it was deemed sensible to combine trials. Meta-analyses were performed using random effects models in RevMan V5.3. Standardised mean differences and corresponding 95% confidence intervals were calculated using Hedges' *g*, which adjusts for small sample bias [17]. Effect sizes were interpreted as follows: 0.2 representing a small effect, 0.5 a moderate effect and 0.8 a large effect [18]. Sub-group analyses on specific musculoskeletal conditions (e.g. knee osteoarthritis) were conducted where there were sufficient trials. Secondary exploratory sensitivity analyses based on methodological quality were performed.

## **Results**

### *Search Strategy*

A total of 2100 titles were identified after duplicates had been removed. Following the exclusion process a total of 8 RCTs [19-26] met the inclusion criteria; thus in addition to the 7 RCTs from the previous review, a total of 15 RCTs [19-33] were included in the analysis and described in the results (Figure 1). For 4 studies, change score data were not provided and were calculated according to section 8.5.2.10 in the Cochrane Handbook for Systematic Reviews of Interventions [16].

### *Description of included trials (Table 1)*

#### *Participants*

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1 The most common condition was chronic arthritis (12 trials), specifically osteoarthritis in  
2 10 trials [20-23, 25, 29-33] and rheumatoid arthritis in 2 trials [26, 27], followed by  
3 chronic low back pain in 2 trials [19, 24] and chronic tension-type headache in 1 trial  
4 [28]. We have analysed the data separately for these three conditions. Recruitment for 8  
5 [19, 21, 23, 28-32] of the 15 trials used community volunteers, with 7 trials recruiting  
6 patients from public health centres [20, 22, 24-27, 33].

7  
8 *Intervention description using the TIDieR Guidelines*

9 *Summary of reporting*

10 Of the 12 items on the TIDieR checklist, all studies reported information on the style of  
11 tai chi used and stated the aim of tai chi was primarily to reduce disability or improve  
12 function. All studies provided information on the delivery mode, dose, duration and  
13 schedule of the intervention. However, information on the provider characteristics,  
14 provider training and intervention setting was lacking in over 50% of studies.  
15 Additionally, while many studies provided a list of intervention components, such as if a  
16 warm-up/cool down was used and the number and name of specific tai chi movements  
17 taught, insufficient procedural information was reported (e.g. teaching style, elements for  
18 progression) and less than 25% of studies provided clear information on or access to  
19 teaching materials. Lastly, no studies reported the tai chi instructor's fidelity to the  
20 intervention protocol and only 60% of studies reported participant adherence. A detailed  
21 description of the intervention details is provided below.

22  
23 *Who, What and How (provider, content, dose, procedures and materials)*

24 Descriptions of the tai chi interventions were variable across studies and are described  
25 using the TIDieR framework in Table 2. In terms of tai chi style, 53% used yang style,

33% used sun style, 7% used Chen, and 7% used Wu style. Half of the studies provided information on the tai chi instructor, all of which had previous experience teaching tai chi and 6 of the studies reported having additional provider training. All studies used a group format, but group size and location were rarely reported. Duration ranged from 6-20 weeks and included between 8 and 60 sessions of 40-60 minutes. The most common dosage was 2x/week for 10-12 weeks. In terms of specific intervention content, the number of tai chi movements ranged from 9 to 24 movements; most studies included a warm-up/cool down and recommended home practice on a daily basis. While deep breathing techniques are integrated with each tai chi movement, 4 studies reported teaching deep breathing and relaxation techniques as additional components. Most studies did not report any information on the use of provider or patient materials, 4 studies reported using a treatment manual for the instructor and 7 studies reported providing patient handouts or audio-visual materials. Although none of the interventions were tailored specifically to participants on an individual basis, all studies used simplified shortened versions of the original tai chi programmes. Most adaptations were made to suit elderly or arthritic populations at a beginner level of tai chi; particularly ensuring the movements required less deep knee bending to avoid aggravating joint pain while still improving muscle strength and mobility, and using an exercise progression of easy to difficult movements. In terms of replication, several studies included either a list of the tai chi movement names in the manuscript [20, 24, 25] or in a separate instructor's manual [19, 21, 22, 25]. A smaller sample provided the name of an instructional DVD that is available for purchase [19, 31].

*How well (Participant Adherence to treatment and intervention fidelity)*

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1 Few studies reported information on participant adherence or treatment fidelity. Two  
2 studies reported they would assess treatment fidelity [19, 21] (how well the instructor  
3 followed the intervention protocol) either using a self-report checklist or an objective  
4 observer; however no studies reported the results of this assessment. Thus it is not known  
5 how well instructors adhered to the intended treatment protocol. Similarly, only 60% of  
6 studies reported participant intervention adherence measured by in-session attendance,  
7 however the assessment method varied so an overall total could not be calculated.  
8 Additionally, two studies reported participant adherence to home practice.

9

10 *Methodological quality*

11 Based on the 5 key RoB items, 7 studies were rated as low [19-22, 26, 29, 31]. With  
12 respect to blinding, subjects and practitioners administering treatment in all trials were  
13 unblinded to treatment. For the self-reported outcomes of pain, disability and quality of  
14 life, the patient is considered the outcome assessor and was thus unblinded in all studies.  
15 Other common reasons for high or unclear risk of bias were lack of concealed allocation  
16 (53%), lack of intention to treat analysis (47%), and greater than 20% data loss at short-  
17 term follow-up (33%). A list of the risk of bias ratings for each study on the 5 key items  
18 is presented in Table 1 and for all 12 items in an additional online file.

19

20 *Tai chi versus no treatment (usual care, attention control, wait-list control)*

21 *Arthritis*

22 Eleven RCTs [20-23, 25, 29-34] compared the effects of tai chi and a no treatment control  
23 arm, which was defined as no prescribed treatment within the study, however,  
24 participants were free to seek and receive care at the discretion and direction of their  
25 health care provider. The type of treatments received by participants in the control arm

was not reported in any study. The most commonly used assessment tool was the WOMAC to assess pain (64%), disability (88%) and stiffness (45%). The physical and mental subscales of the Short-form Health Questionnaire (36-item or 12-item) were used to assess quality of life. Performance of physical tasks concentrated on common problematic activities including getting in and out of a chair and walking function, these were assessed with a variety of performance tests including; the *Get-up and Go test* [21, 23, 25, 31], the *Sit to stand test* [21, 22, 32], the 50 ft walk test [31, 32] and the 6 min walk test [22, 23, 25]. Since each of these tests assesses a different aspect of function they are reported separately.

For short term pain (11 RCTs, n=497) and disability (9 RCTs, n=430) we found moderate quality evidence that tai chi was more effective than no treatment [pain: SMD -0.66; 95% CI: -0.85, -0.48, disability: SMD -0.66; 95% CI: -0.85, -0.46]. For short term quality of life (3 RCTs, n=181), we found low quality evidence that tai chi was more effective for improving physical health [SMD -0.61; 95% CI: -1.08, -0.15] and had no effect on mental health. For short-term stiffness (5 studies, n=188), we found very low quality evidence that tai chi may be more effective although the results were not statistically significant [SMD -0.50; 95% CI: -0.80, 0.20]. At medium and long term, there were fewer studies that assessed these outcomes; the summary effect sizes tended to be smaller and no longer statistically significant, the quality of the evidence was reduced to low or very low based on high risk of bias, inconsistency and imprecision of the results.

For short term performance tests, Get Up and Go (4 RCTs, n=229), Sit-to-Stand (3 RCTs, n=125), 50 Foot Walk (2 RCTs, n=130) and 6 Minute Walk (3 RCTs, n=117) we found low quality evidence that tai chi may be more effective than no treatment although the

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1 results were only statistically significant for Get Up and Go and Sit-to-Stand. No studies  
2 assessed these outcomes at medium or long-term follow-up.

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10 4 *Low Back Pain*

11 Two studies [19, 24] enrolled people with low back pain, both assessed pain and one  
12 assessed disability [19]. Outcomes of quality of life and physical performance were not  
13 assessed. The 0-10 numerical rating scale was used to assess pain in both studies and the  
14 RMDQ was used to assess disability.

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23 10 For short-term pain (2 RCTs, n=348) we found very low quality evidence that tai chi may  
24 be more effective than no treatment [SMD -1.58; 95% CI -3.45, 0.25], however the  
25 difference was not statistically significant. For short-term disability (1 RCT, n=160), we  
26 found low quality evidence that tai chi was more effective than no treatment [SMD -0.64;  
27 95% CI -0.98, -0.31]. At medium term only pain was assessed (1 RCT, n=188), and we  
28 found very low evidence for tai chi to be more effective. Outcomes were not assessed at  
29 long-term.

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41 18 *Tension headache*

42 One trial (n=47) assessed patients with tension headache[28], this trial used the SF-36v2  
43 to assess both quality of life with mental and physical health summary scores and  
44 disability with physical function subscale. For short term pain we found very low quality  
45 evidence that tai chi was more effective than control [pain: SMD -1.85 (-2.73, -0.97) and  
46 for quality of life we found very low evidence that tai chi may be more effective but the  
47 results were not statistically significant [SMD -0.67 (-1.42, 0.07)].

### *Tai chi versus another treatment*

We found three randomised controlled trials that compared tai chi to another intervention [23, 26, 31]. These studies all included populations of arthritis; no studies were found for this contrast for any other musculoskeletal condition. The comparison treatments were predominantly exercise-based, one hydrotherapy, one resistance training and one education plus a stretching programme. These studies assessed pain, disability and physical performance. For short-term pain, disability and performance we found very low quality evidence to suggest there was no difference in effect between tai chi or any of these interventions; with the possibility that tai chi may be more effective than education and stretching on improving self-report disability [26]. However, as the comparison groups were very different they provide little understanding of the relative effectiveness of tai chi versus other exercise based-treatments.

### **Discussion**

Our previous systematic review included seven studies and suggested that tai chi was effective for reducing pain and disability for arthritis, however the evidence quality was low. Despite including a further eight studies in this current review, the quality of evidence remains poor due to small sample sizes and low methodological quality. Thus, the additional studies have failed to improve the robustness of our estimates. Consequently, the increased research in this area does not seem to be advancing our knowledge for providing evidence-based recommendations regarding the use of tai chi for musculoskeletal conditions. In particular, studies need to improve their follow-up rates, reporting of allocation concealment methods, and if they used an intention to treat analysis. In order for tai chi to be recommended as an effective intervention, more high quality trials with large sample sizes assessing tai chi versus other evidence-based

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1 treatments at short and long-term are needed.

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3 *Statement of principal findings*

4 The majority of trials in this review studied populations with arthritis and our results are  
5 similar to that of our previous review. For arthritis, we found that tai chi was more  
6 effective than no treatment in improving pain and disability (moderate quality evidence)  
7 and quality of life (low quality evidence) in the short term. Comparatively, we found that  
8 tai chi is likely no more effective than no treatment for improving performance outcomes  
9 such as getting in and out of a chair and walking (very low quality evidence). However,  
10 performance outcomes were impeded by a lack of reliable measurement tools for this  
11 population. Lastly, there were too few studies to draw any conclusions regarding the  
12 effects of tai chi versus other treatments, nor to ascertain if effects are sustained over  
13 time. Moreover, less is known about its effectiveness for other musculoskeletal pain  
14 populations.

15

16 *Outcome significance in relation to other research*

17 Despite including eight additional studies from our previous review, our knowledge  
18 regarding the effectiveness of tai chi is still limited. However, this current review has  
19 furthered our understanding with regards to the short-term effects of tai chi on pain and  
20 disability for arthritis populations in comparison to no intervention. The effect sizes for  
21 these outcomes were moderate with narrow 95% confidence intervals that were  
22 statistically significant, suggesting adequate precision and significance of the effect  
23 estimates. These results are similar to other commonly used exercise regimens for lower-  
24 limb arthritis such as combined exercise programs of strengthening, flexibility and  
25 aerobic exercise [35]. Interestingly, these effects are larger than single component



1 exercise programmes such as flexibility or strength training which have small effects on  
2 pain and disability in the short term [35].

3  
4 Importantly we found very little evidence regarding tai chi versus no intervention or  
5 another treatment for other musculoskeletal conditions. Our estimates for back pain and  
6 tension headaches are much less precise and are derived from only one or two studies  
7 with variable quality, thus it is hard to provide a judgement of their significance.  
8 However, for back pain, the magnitude of the effects on pain and disability are similar to  
9 those reported from general exercise programmes [36] as well as more expensive forms  
10 of treatment such as multidisciplinary treatments [37], or cognitive behavioural treatment  
11 [38].

### 12 13 *Strengths*

14 Our review used a rigorous methodology including independent full text screening and  
15 data extraction/checking to ensure accuracy. We increased our level of intervention  
16 information to align with recommendations from the TIDieR Guidelines to assess if tai  
17 chi interventions are described in sufficient detail for replication. We used the GRADE  
18 protocol recommended by the Cochrane Handbook to add a more robust assessment to  
19 our interpretation of results, allowing us to provide reliable recommendations for future  
20 research in this area. Lastly, we sub-grouped our analyses by disease conditions to  
21 account for heterogeneity in population type.

### 22 23 *Limitations*

24 Meta-analysis necessarily involves assumptions of homogeneity with respect to  
25 outcomes, treatment, sample and data. While most of our estimates of effect had low

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1 statistical heterogeneity, we recognise that there may be clinical heterogeneity in all these  
2 areas. For example, there were differences observed in the tai chi interventions such as  
3 the style of tai chi, number of sessions, and total treatment duration, these differences  
4 may account for some of the variation in treatment effects between studies. However, we  
5 believe that the included trials were sufficiently similar to support our choice of  
6 methodology.

7  
8 *Clinical Implications*

9 Our findings support the use of tai chi as a treatment for people with arthritis and  
10 potentially for low back pain. However, we have only very low quality or no evidence to  
11 suggest that it is as effective, or more effective, than any other treatment for these  
12 populations. With no direct comparison of tai chi to other treatments, we can only  
13 speculate that, since our findings appear to be within a similar range to those reported for  
14 other commonly used exercise regimes for musculoskeletal conditions, tai chi could  
15 produce similar effects if compared. Thus, we cannot provide useful or confirmatory  
16 evidence to recommend this approach over others used in clinical practice settings until a  
17 robust, direct comparison study has been conducted.

18  
19 *Recommendations for improving future research*

20 We recommend that studies proposing a trial of tai chi for musculoskeletal conditions  
21 should be considered for funding if they show that their methodology would be  
22 advancing the current state of evidence. In terms of study design, this would involve  
23 robust randomised controlled trials, comparing tai chi to other commonly used  
24 interventions with assessments at medium and long-term follow-ups. In terms of  
25 outcomes, it is necessary to assess core outcomes of pain, disability and quality of life as

well as a range of objective and validated assessments of physical performance. The cost-effectiveness of tai chi has not yet been investigated, thus future studies that assess cost-effectiveness of tai chi should be prioritised to inform its potential for cost-savings in health care settings. Additionally, the Medical Research Council (MRC) highlights the importance of conducting a process evaluation that includes assessing both process factors such as treatment delivery fidelity and patient adherence as well as proposed mediators of treatment outcome within complex interventions to provide insights that will aid implementation and improve clinical outcomes in practice [39]. Few studies have assessed these variables with respect to tai chi and thus we recommend that future research include a robust process evaluation.

## Conclusions

The research question addressed in this review is of significant importance for the clinical community as musculoskeletal pain conditions such as arthritis and back pain are among the leading reasons for seeking care and are highly prevalent in the ageing population. This review provides clear evidence that tai chi is effective in the short term for reducing pain and disability in arthritis populations. Further conclusions regarding the effectiveness of tai chi on additional outcomes and across other health conditions cannot be drawn due to the poor quality and limited evidence in these areas.

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1 Table 1. Characteristics of included studies

Study	Complaint	n	Age (yrs) (SD)	Comparison	Outcomes			Risk of Bias†					
					Pain	Disability	QoL	1	2	3	4	5	H/L
<b><u>Arthritis:</u></b>													
Adler 2000	OA (hip, knee)	16	77 (6)	(i) usual care*	✓		✓	L	H	H	L	L	L
Brismée 2007	OA (knee)	41	71 (10)	(i) attention control	✓	✓		H	H	H	H	U	H
Fransen 2007	OA (hip, knee)	<sup>1</sup> 97	70 (6)	(i) waitlist control (ii) hydrotherapy	✓	✓	✓	L	H	H	L	L	L
Hartman 2000	OA (hip, knee, ankle, spine)	35	67 (8)	(i) attention control	✓	✓	✓	H	H	H	L	U	H
Lee 2006	RA	61	n/a	(i) usual care	✓			U	H	H	L	H	H
Lee 2009	OA (knee)	44	69 (5)	(i) waitlist control	✓	✓	✓	L	H	H	L	L	L
Song 2007	OA (knee)	72	65 (6)	(i) usual care	✓	✓		U	H	H	H	L	H
Tsai 2013	OA (knee)	55	79 (8)	(i) attention control	✓	✓		L	H	H	L	L	L
Wang 2008	RA	20	50 (14)	(i) education + stretches	✓	✓	✓	L	H	H	L	L	L
Wang 2009	OA (knee)	40	65 (8)	(ii) attention control	✓	✓	✓	L	H	H	L	L	L
Wortley 2013	OA (knee)	39	70 (5)	(i) usual care (ii) strength training	✓	✓		U	H	H	H	U	H
Zeng 2015	OA (hip)	97	65 (3)	(i) usual care	✓	✓		U	H	H	H	H	H
<b><u>Back pain:</u></b>													
Hall 2011	NSLBP	160	44 (13)	(i) waitlist control	✓	✓		L	H	H	L	L	L
Weifen 2013	NSLBP	188	38 (5)	(i) TC + active control	✓			U	H	H	L	U	H
<b><u>Headache:</u></b>													
Abbott 2007	Tension	47	44 (13)	(i) wait-list control	✓	✓	✓	U	H	H	H	H	H
*Usual care indicates a control group in which patients were free to seek care as usual but did not receive a specific course of treatment as part of the study. †Risk of Bias items and answers are: 1=allocation concealment, 2=blinding of participants, 3=blinding of outcome assessor, 4=loss to follow-up, 5=intention to treat, L=Low risk of bias, H=High risk of bias, U=unclear risk of bias													

Table 2. Description of the tai chi interventions for replication

Study	Style	Provider		Location	When and How Much				Materials Used			Procedures: Components Used						How well	
	Name / style	Years experience	Training provided	location	# of Sessions	Time (mins)	Frequency (#/wk)	Duration (wks)	Treatment manual	Patient Materials	Materials accessible	Warm-up/cool down	# of TC movements	Additional Breathing / relaxation	Additional stretch/strength	Home practice	Specific Instruction	Fidelity reported	In-class attendance reported
Abbott 2007	Yang	20	N	Local Park	8	NR	1x / 2wk	15	N	Y	N	NR	24	Y	NR	NR	NR	NR	NR
Adler 2000	Wu	NR*	NR	Community centre	10	60	1x	10	NR	Y	N	Y	16	NR	NR	Y	Y	NR	88%
Brismée 2007	Yang	NR	NR	NR	18	40	3x	6	NR	Y	N	Y	24	NR	NR	Y	Y	NR	89%
Fransen 2007	Sun	NR	Y	NR	24	60	2x	12	NR	Y	Y	Y	24	NR	NR	Y	NR	NR	61%
Hall 2011/2009	Sun	NR	Y	Community centre	18	40	2x 1x	8 2	Y	Y	Y	Y	12	N	NR	Y	Y	NR	58%
Hartman 2000	Yang	NR	Y	NR	24	60	2x	12	NR	NR	NR	Y	9	Y	NR	Y	Y	NR	100%
Lee 2009	Yang	NR	NR	NR	16	60	2x	8	NR	NR	Y	Y	18	N	NR	NR	Y	NR	NR
Lee 2006	Sun	NR	Y	Health centre	16	60	2x	8	NR	NR	N	Y	12	N	NR	NR	Y	NR	90%
Song 2007	Sun	NR	NR	University room	16	60	3x 1x	2 10	NR	Y	N	Y	12	NR	NR	Y	Y	NR	NR
Tsai 2013	Sun	6	Y	NR	60	20-40	3x	20	Y	NR	N	NR	12	NR	NR	NR	Y	NR	NR
Wang 2008	Yang	NR	NR	Health centre	24	60	2x	12	NR	NR	N	Y	10	Y	N	Y	NR	NR	NR
Wang 2009	Yang	20	NR	NR	24	60	2x	12	Y	Y	N	Y	10	Y	NR	Y	Y	NR	85%
Weifen 2013	Chen	NR	NR	NR	NR	45	5x	NR	NR	NR	Y	NR	24	NR	NR	Y	NR	NR	NR
Wortley 2013	Yang	35	NR	NR	20	60	2x	10	NR	NR	N	NR	12	NR	NR	NR	Y	NR	82%
Zeng 2015	Yang	5	Y	Health centre	NR	45	5x NR	2 10	Y	NR	Y	Y	10	NR	Y	Y	Y	NR	88%
*NR = not reported																			

Table 3. Summary of findings table organized by population

<b>Tai Chi compared with no intervention for musculoskeletal pain conditions</b>			
<b>Patient or population:</b> people with chronic musculoskeletal pain conditions			
<b>Settings:</b> community or health care settings			
<b>Intervention:</b> tai chi			
<b>Comparison:</b> no intervention control group			
<b>Outcome</b>	<b>Standardised Mean Difference (95% CI)</b>	<b>Participants (studies)</b>	<b>Quality of evidence (GRADE)</b>
<b>Arthritis</b>			
<b>Short term</b>			
Pain	SMD -0.66 (-0.85, -0.48)	497 (11)	⊕⊕⊕□ moderate <sup>1</sup>
Disability	SMD -0.66 (-0.85, -0.46)	430 (9)	⊕⊕⊕□ moderate <sup>1</sup>
Quality of Life (physical)	SMD -0.61 (-1.08, -0.15)	181 (3)	⊕⊕□□ low <sup>2,4</sup>
Quality of Life (mental)	SMD -0.19 (-0.61, 0.23)	181 (3)	⊕⊕□□ low <sup>2,4</sup>
Stiffness	SMD -0.50 (-0.80, 0.20)	188 (5)	⊕□□□ very low <sup>1,2,4</sup>
<b>Performance:</b>			
Sit-to-stand (reps)	SMD -0.91 (-1.52, -0.30)	125 (3)	⊕□□□ very low <sup>1,2,4</sup>
Get up and go (speed)	SMD -0.87 (-1.72, -0.03)	229 (4)	⊕□□□ very low <sup>1,2,4</sup>
50ft walk test (speed)	SMD -0.28 (-0.86, 0.29)	130 (2)	⊕□□□ very low <sup>1,2,4</sup>
6 Min walk test (distance)	SMD -0.86 (-1.90, 0.19)	117 (3)	⊕□□□ very low <sup>1,2,4</sup>
<b>Medium term</b>			
Pain	SMD -0.45 (-0.97, 0.08)	126 (3)	⊕□□□ very low <sup>1,2,4</sup>
Disability	SMD -0.59 (-0.95, -0.23)	126 (3)	⊕□□□ very low <sup>1,2,4</sup>
Quality of Life (physical)	SMD -0.59 (-1.23, 0.04)	40 (1)	⊕⊕□□ low <sup>5</sup>
Quality of Life (mental)	SMD 0.01 (-0.61, 0.63)	40 (1)	⊕⊕□□ low <sup>5</sup>
Stiffness	SMD -0.09 (-0.59, 0.40)	71 (2)	⊕□□□ very low <sup>1,2,4</sup>
<b>Long term</b>			
Pain	SMD -0.46 (-1.09, 0.17)	40 (1)	⊕⊕□□ low <sup>5</sup>
Disability	SMD -0.36 (-0.99, 0.26)	40 (1)	⊕⊕□□ low <sup>5</sup>
Quality of Life (physical)	SMD -0.83 (-1.48, -0.18)	40 (1)	⊕⊕□□ low <sup>5</sup>
Quality of Life (mental)	SMD -0.49 (-1.12, 0.14)	40 (1)	⊕⊕□□ low <sup>5</sup>
<b>Low Back Pain</b>			
<b>Short term</b>			
Pain	SMD -1.58 (-3.45, 0.25)	348 (2)	⊕□□□ very low <sup>1,2,3,4</sup>
Disability	SMD -0.64 (-0.98, -0.31)	160 (1)	⊕⊕□□ low <sup>5</sup>
Quality of Life	--	--	No evidence
<b>Medium Term</b>			
Pain	SMD -3.21 (-3.67, -2.74)	188 (1)	⊕□□□ very low <sup>1,5</sup>
Disability	--	--	No evidence
Quality of Life	--	--	No evidence
<b>Tension headaches</b>			
<b>Short term</b>			
Pain	SMD -1.85 (-2.73, -0.97)	47 (1)	⊕□□□ very low <sup>1,5</sup>
QoL	SMD -0.67 (-1.42, 0.07)	47 (1)	⊕□□□ very low <sup>1,5</sup>

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<sup>1</sup> downgraded due to risk of bias, <sup>2</sup> downgraded due to inconsistency, <sup>3</sup> downgraded due to indirectness, <sup>4</sup> downgraded due to imprecision, <sup>5</sup> downgraded due to being a single study with less than 400 participants

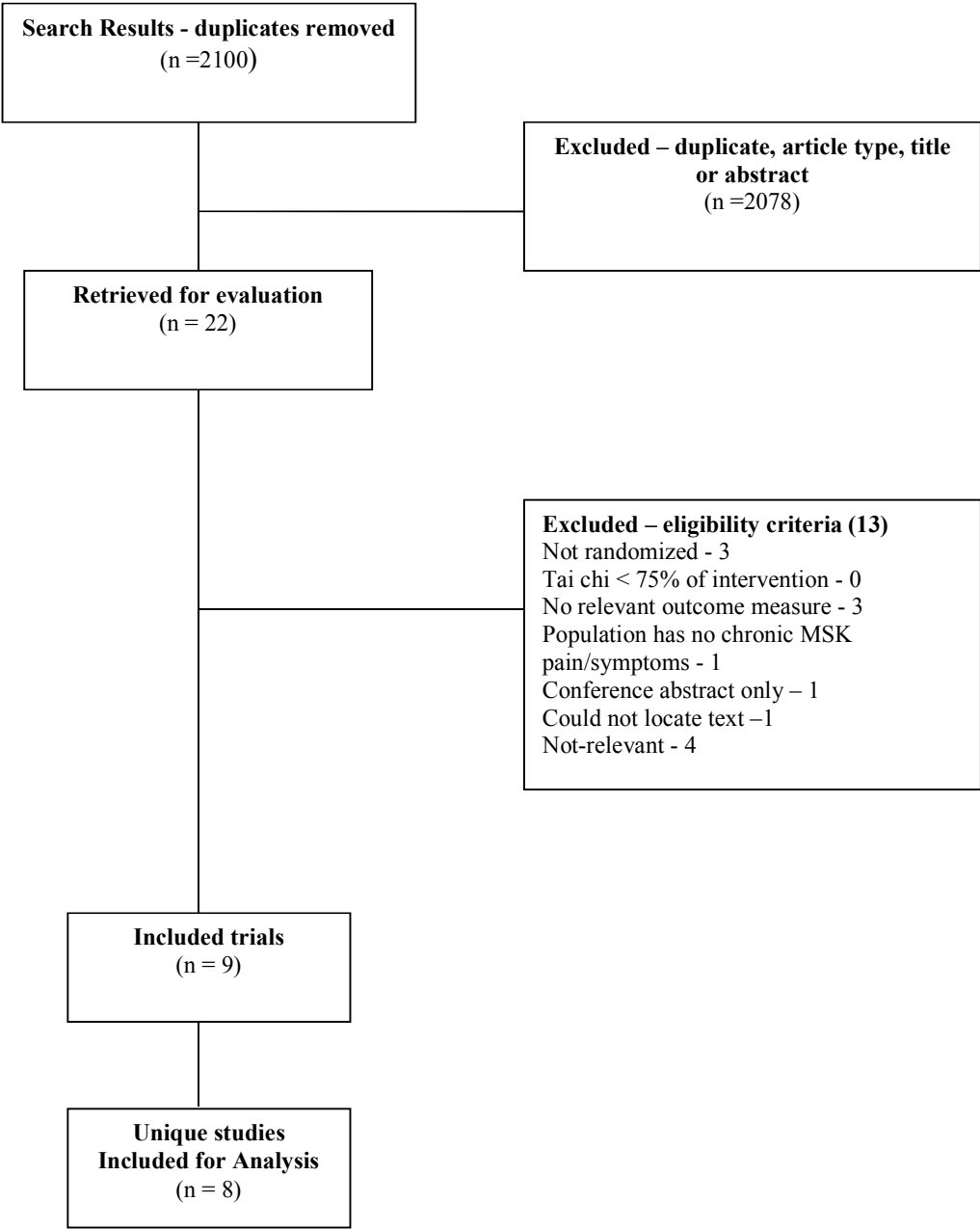
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6 3 **Figure 1. Study flow chart**  
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1     **Figure 1. Study flow chart**



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Figure 2. The effect of tai chi versus no treatment on pain

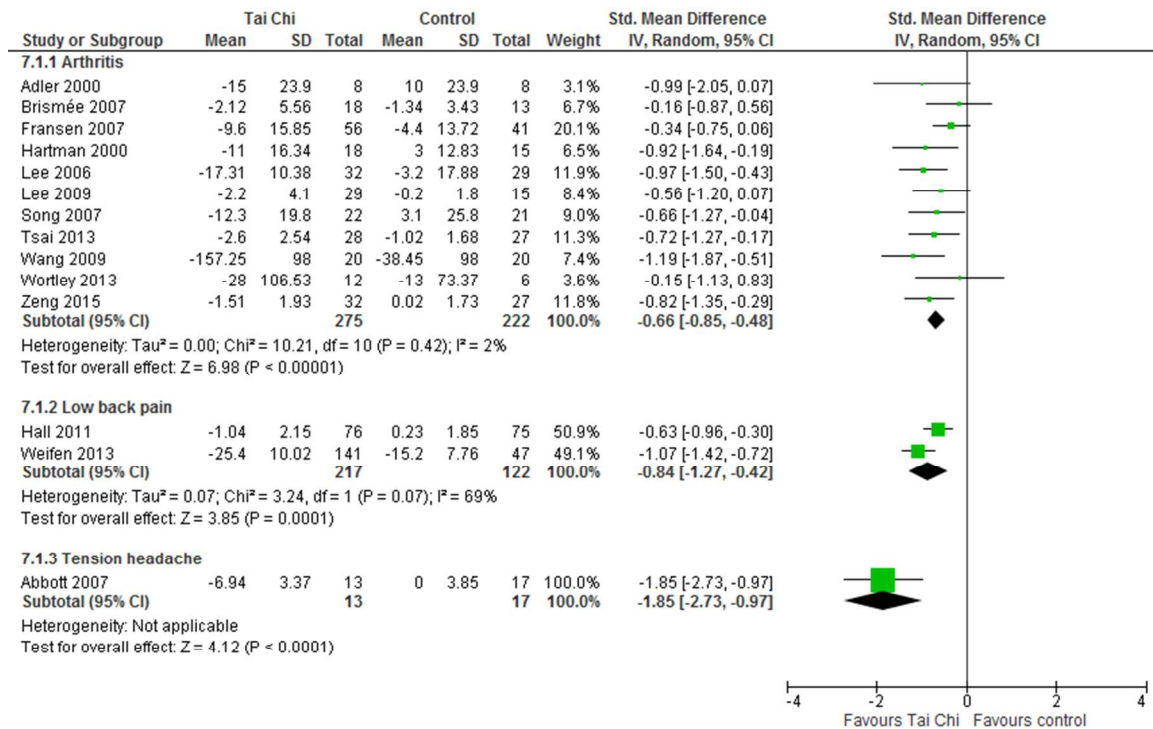
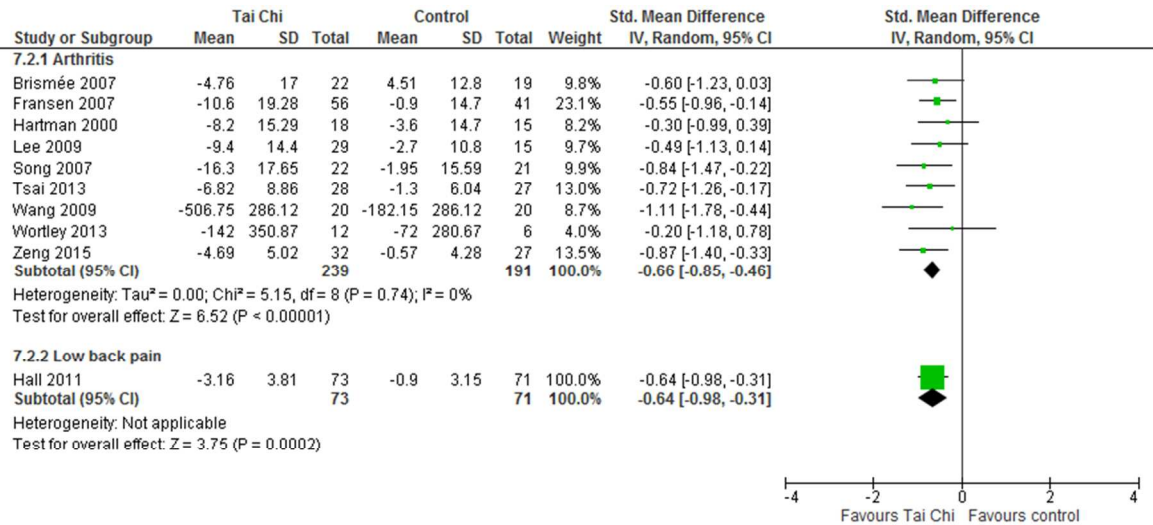


Figure 3. The effect of tai chi versus no treatment on disability





## Appendix A. 12 item Risk of Bias

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of provider	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Intention to treat	Selective reporting (reporting bias)	Baseline prognostic indicators	Co-interventions	Compliance	Other bias
Abbott 2007	?	?	-	-	-	-	-	?	-	-	?	+
Adler 2000	+	+	-	-	-	+	+	+	-	+	?	+
Brismée 2007	+	-	-	-	-	-	?	+	+	+	?	+
Fransen 2007	+	+	-	-	-	+	+	+	+	+	?	+
Hall 2011	+	+	-	-	-	+	+	?	+	+	-	+
Hartman 2000	+	-	-	-	-	+	?	+	-	+	?	+
Lee 2006	?	?	-	-	-	+	-	?	+	+	?	+
Lee 2009	+	+	-	-	-	+	+	+	+	+	?	+
Song 2007	+	?	-	-	-	-	+	+	?	?	?	+
Tsai 2013	+	+	-	+	-	+	+	+	+	+	?	+
Wang 2008	+	+	-	-	-	+	+	+	-	+	+	+
Wang 2009	+	+	-	-	-	+	+	?	?	+	+	+
Weifen 2013	+	?	-	?	-	+	?	+	+	+	?	+
Wortley 2013	?	?	-	-	-	-	?	+	+	+	?	+
Zeng 2015	+	?	-	-	-	-	-	+	?	+	+	+