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SYSTEMATIC REVIEW

Physical therapies for improving balance and reducing falls risk in osteoarthritis of the knee: a systematic review

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Abstract

Introduction: osteoarthritis (OA) of knee has been reported as a risk factor for falls and reduced balance in the elderly. This systematic review evaluated the effectiveness of physical therapies in improving balance and reducing falls risk among patients with knee OA.
Methods: a computerised search was performed to identify relevant studies up to November 2013. Two investigators identified eligible studies and extracted data independently. The quality of the included studies was assessed by the PeDro score.
Results: a total of 15 randomised controlled trials involving 1482 patients were identified. The mean PeDro score was 7. The pooled standardised mean difference in balance outcome for strength training = 0.3346 (95% CI: 0.3207–0.60, $P = 0.01 < 0.00001$, P for heterogeneity = 0.85, $I^2 = 0\%$). Tai Chi = 0.7597 (95% CI: 0.5130–1.2043, $P <= 0.0014$, P for heterogeneity = 0.26, $I^2 = 0\%$) and aerobic exercises = 0.6880 (95% CI: 0.5704–1.302, $P < 0.00001$, P for heterogeneity = 0.71, $I^2 = 0\%$). While pooled results for falls risk outcomes in, strength training, Tai chi and aerobics also showed a significant reduction in reduced risk of falls significantly with pooled result 0.55 (95% CI: 0.41–0.68, $P < 0.00001$, P for heterogeneity = 0.39, $I^2 = 6\%$).
Conclusion: strength training, Tai Chi and aerobics exercises improved balance and falls risk in older individuals with knee OA, while water-based exercises and light treatment did not significantly improve balance outcomes. Strength training, Tai Chi and aerobics exercises can therefore be recommended as falls prevention strategies for individuals with OA. However, a large randomised controlled study using actual falls outcomes is recommended to determine the appropriate dosage and to measure the potential benefits in falls reduction.

Keywords: *osteoarthritis, falls, elderly, exercises, Tai Chi, older people*

Introduction

Each year, one in every three adults aged 65 and older, and almost half of those over 80 years, experience at least one fall annually [1]. Unintentional injuries due to falls are major causes of mortality and have been reported to be on the rise [2]. Fall-related costs have been estimated as 0.85 to 1.5% of total healthcare expenditures [3]. Osteoarthritis (OA), on the other hand, is the most prevalent type of arthritis among older people worldwide, with knee involvement more common than hip involvement [4]. The relationship between knee OA and falls is controversial, but gait and balance disorder secondary to OA may increase falls risk [5].

The mainstay of therapeutic approach for OA is weight loss and exercise. Systematic reviews have demonstrated that regular physical activity and exercise were effective interventions for knee OA [6]. However, the primary outcomes evaluated in the above review articles were pain and function. No previous systematic review article has addressed the effects of physical therapy on falls or fall-related measures in individuals with OA.

This review systematically evaluated all eligible studies that included balance outcomes and falls risk following physical therapy in individuals with knee OA. Our objective was to determine whether physical therapy improves balance and falls risk in individuals with knee OA.

Methods

Criteria for considering studies for this systematic review

The study question was built on the PICOS (participants, interventions, comparisons, outcomes and study design) framework. We included randomised controlled trials (RCTs) and quasi-randomised trials published in the English language. All studies involving individuals with knee OA in which the mean age of participants was 60 years and above were considered. Studies which included participants with co-existing hip or spine OA were excluded, as we were interested in the effects of physical therapy on knee OA alone.

Only studies that investigated or compared the physical therapy interventions were selected. Studies would be included if they evaluated physical therapy with other forms of therapy such as disease-modifying OA drugs, analgesics and joint injection. Studies that evaluated other forms of therapy without exercise or other physical interventions were excluded. The authors considered all interventions that involved an element of physical training such as walking, strength training, endurance training and physiotherapy interventions such as physical therapy. Studies that employed objective balance-related outcomes and/or falls risk were included. Balance outcomes used by these studies included timed up and go (TUG), Berg's balance scale (BSS), Step test, Sit to stand (STS) and gait speed. Falls outcome measures employed included falls risk assessment and fear of falling.

Search methods for identification of studies

We searched for RCTs from CINAHL (Cumulative Index to Nursing and Allied Health Literature) (up to November 2013), Cochrane Library, PubMed and Web of Science by using the following keywords: (*aged OR elderly OR older adults*) *AND* (*knee osteoarthritis*) *AND* (*falls OR falls risk*) *AND* (*balance*). Only English language articles were selected. In MEDLINE (OvidSP) subject-specific search terms were combined with the sensitivity-maximising version of the MEDLINE trial search strategy (Lefebvre 2008). The strategy was modified for use in CINAHL, Cochrane Library, PubMed and Web of Science. We inspected reference lists of articles and reviewed the abstracts of potentially relevant articles based on the title of references. The full articles were also sourced from conference proceedings, back issues of relevant journals, bibliographies of retrieved publications, books and relevant websites.

Data collection and analysis

One review author screened the title, abstract and descriptors of identified studies for possible inclusion. From the full text, two authors independently assessed potentially eligible RCTs for inclusion and resolved any disagreement through discussion. We contacted the authors of full articles for additional information if necessary. The data were independently extracted by pairs of review authors using a pre-tested data extraction form. Disagreement was resolved by consensus or third party adjudication.

To assess the quality of the methodology used in the studies, we used the PEDro scale that contains 11 items [7]. We added six more items—rationale of the study, recruitment method, setting and location of the study, intervention, objective(s), defined outcome measure(s) and sample size determination to assess the quality of the included studies.

The meta-analyses that examined the effects of interventions on balance were performed using RevMan 5.2. Analysis of changes in gait velocity and velocity derived from six minute walk test (6MWT) data as improvement in falls risk was also performed. The difference in change score between intervention and control group for each outcome of interest was computed and divided by the pooled standard deviation using the random effects model. All data mean differences were calculated using standard mean difference (SMD) with the associated 95% confidence interval. Heterogeneity across selected studies was tested using I^2 statistic. Adjustments were performed in negative data by multiplying −1 to ensure that all scales point in the same direction.

Results

The initial search yielded 130 relevant publications, 96 of which were excluded on the basis of titles, abstracts, duplicate studies and other reasons (reviews, non-randomised studies or not relevant to our analysis) (Figure 1). Thirty-four potentially relevant studies were identified for full-text analysis. Four RCTs were excluded because they lacked control subjects [8–11]. Seven RCTs were excluded because the outcome measures did not include balance measurement tools (TUG, STS, Step test, 6MWT and gait velocity) or falls [10, 12–17]. Two other RCTs were excluded because the study population included subjects with hip OA [18, 19]. One study was excluded because the study population included participants with rheumatoid arthritis [20]. Finally, 15 RCTs were selected for this systematic review, with the main characteristics summarised in Supplementary data available in *Age and Ageing* online, Appendix Table S1.

Participants

A total of 1482 participants were included in the 15 studies. The included studies were RCTs and were published in 1997–2013. The mean age of participants in all 15 studies was ≥60 years. All the participants had knee OA. The sample sizes of included trials ranged from 32 to 437 [21, 22]. The median sample size was 72 participants. The trials were carried out in nine countries: USA [23–26], Taiwan [27–29], South Korea [30, 31], Brazil [22, 32], Japan [33], New Zealand [34], Denmark [35] and Columbia [21].

Intervention

The duration of intervention and follow-up ranged between 2 weeks and 18 months. The studies employed a large variety

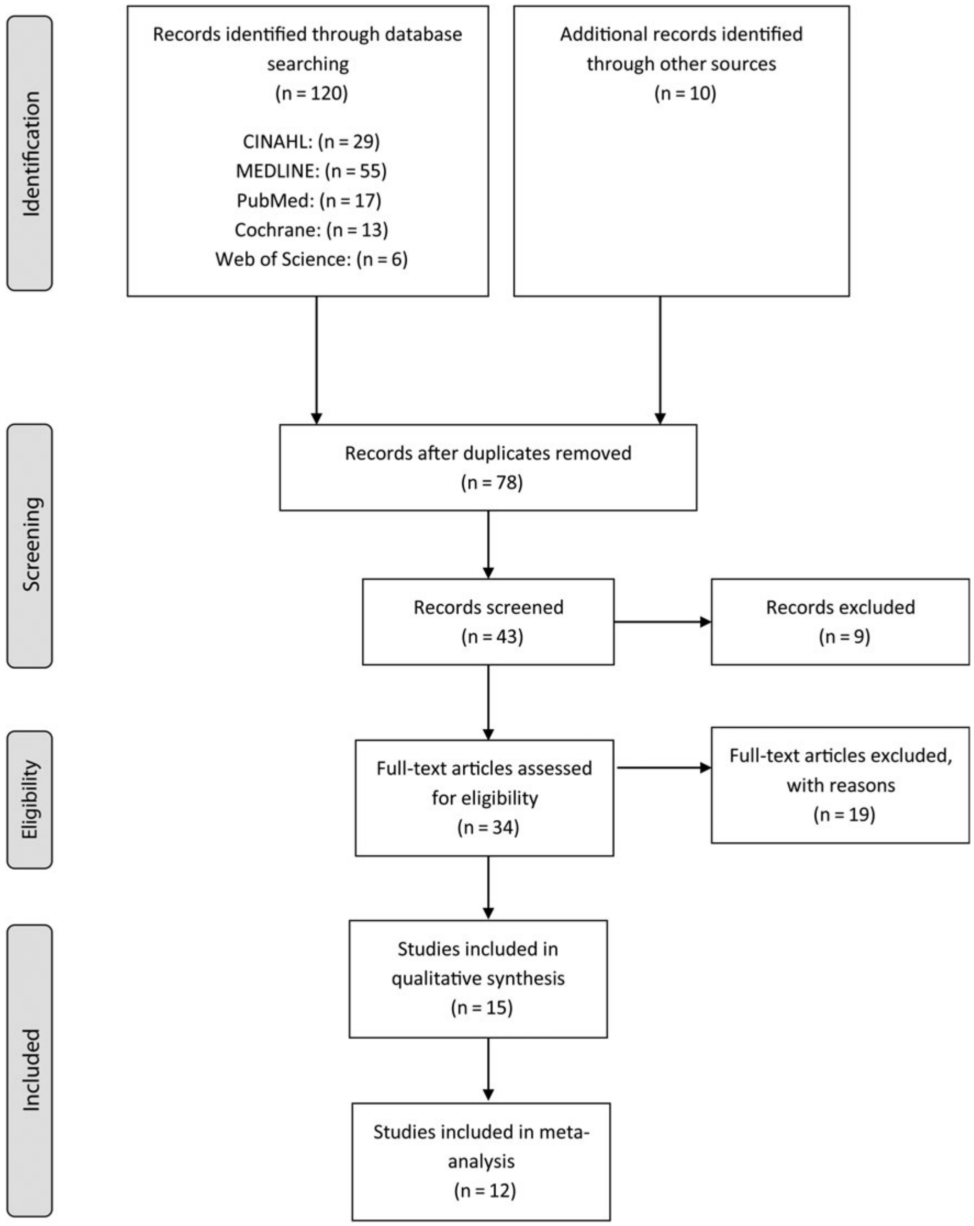

Figure 1. Search strategy of the systematic review.

of physical therapy interventions. Tai Chi was used in three studies [23, 30, 36], while the remaining employed water-based exercise [34], walking programme [33], aerobic and resistance exercises [24], home-based progressive and manual physical therapy of strength training [25, 26], weight-bearing exercises [28], high-speed and slow-speed power training [21], squat exercise with whole-body vibration [22], aquatic and land-based exercise [29, 35], neuromuscular electrical stimulation (NMSE) with strength training [32] and light therapy (exposure to 890 nm radiation) [27].

Common assessment tools (TUG, BBS, Walking speed, 6MWT and STS) were employed in 12 out of 15 studies. Five studies used 6MWT, five studies used STS, three studies used the TUG test, three studies measured gait speed and two studies used the BBS test. One study used a balance platform to measure standing balance, one study measured balance by standing on one foot with eyes closed and another study used the Step test. One study measured falls risk using the Physiological Profile Assessment (PPA) and the 11-item Korean version of the Survey of Activities and Fear of Falling in the Elderly.

Methodological quality assessment

Supplementary data available in *Age and Ageing* online, Appendix Table S2 summarised the quality component checklist and the PEDro score for each study. The mean PEDro score for all studies was 7, indicating high-quality RCTs were selected, high quality of trial design, with intention-to-treat analysis and allocation concealment would improve the quality of the RCTs as well as reduce potential biases.

Intervention effects

Balance

Only 7 out of 11 studies demonstrated that the selected interventions significantly improved the balance in subjects with knee OA. One of the studies that involved Tai Chi demonstrated benefits in balance improvement by reducing STS time, after 12 weeks with continued benefits at 48 weeks [23]. Simao *et al.* [22] showed squat exercise and whole-body vibration significantly improved balance (BSS: $P < 0.05$). Two-way ANOVA analysis showed that the walking group had better performance in balance when compared with the control group, in terms of TUG ($F(1,38) = 11.1$, $P = 0.002$) and tandem gait ($F(1,38) = 4.7$, $P = 0.034$) [33]. High-speed power training was associated with a significant improvement in the STS test after combining exercise groups ($P < 0.05$) but no intergroup differences were found. Water-based exercises [34, 35] and short-term light treatment [27] did not show intergroup differences. Individuals receiving NMSE showed significant improvement in the TUG test compared with the control group ($P = 0.05$). Home-based strength exercise significantly improved STS performance compared with the control group (−1.03 s is −0.18 s, $P < 0.05$) [25].

Falls risk

Hale *et al.* [34] showed that water-based exercise did not reduce falls risk but interestingly showed that the reaction time ($P < 0.03$) and contrast sensitivity ($P < 0.05$) components of the PPA improved significantly in the control group post-intervention [34]. Song *et al.* [30] demonstrated a significant intergroup difference in fear of falling, with $F = 6.40$ ($P = 0.01$), after Tai Chi. Fear of falling score decreased significantly in the Tai Chi group with mean change of −2.40 (±5.54) after intervention and no changes were found in the control group. Gait velocity from direct measurements and derived from the 6MWT data was considered a falls risk measurement. Individuals who performed squat exercises and whole-body vibration showed significant improvements in gait performance (gait speed and 6MWT; $P < 0.05$ and $P < 0.001$, respectively) [22]. Individuals who trained on a platform had significantly faster gait speed compared with the squat group ($P < 0.01$). The weight-bearing exercise group from Jan *et al.* [28] displayed significantly greater improvements in walking speed on the figure-of-8 and spongy surface as well as reposition error, when compared with the non-weight-bearing exercise and control groups ($P = 0.008$). Compared with the control group, both aerobic and resistance exercises were associated with better performance in gait velocity ($P < 0.05$) [24]. There was an average improvement of 13.1% in walking speed in the intervention groups [26].

Meta-analysis of outcome measures

Meta-analyses of study outcomes were possible in 12 out of the 15 selected studies. Subgroup analyses were conducted according to the three main types of interventions, namely strength training, Tai Chi and aerobic exercises. The four RCTs that involved strength training consisted of six types of exercises and the aggregated result showed a significant improvement in balance (SMD = 0.33, 95% CI: 0.07–0.60, $P = 0.01$, P for heterogeneity = 0.85, $I^2 = 0\%$) (Figure 2a). A similar trend was found in the pooled results of Tai Chi and aerobic exercise (SMD = 0.97, 95% CI: 0.51–1.43, $P < 0.0014$, P for heterogeneity = 0.26, $I^2 = 0\%$) and (SMD = 0.68, 95% CI: 0.04–1.32, $P < 0.00001$, respectively). Pooled results for falls risk outcomes in strength training, Tai chi and aerobics also showed a significant reduction in risk of falls (SMD = 0.55, 95% CI: 0.41–0.68, $P < 0.00001$, P for heterogeneity = 0.39, $I^2 = 6\%$) (Figure 2b). The pooled results for all 12 studies suggested that these three types of interventions significantly improved balance and reduced falls risk in subjects with knee OA.

In addition, we also performed a meta-analysis for common outcome measure used in included RCTs. Changes on actual velocity derived from 6MWT and gait velocity from pooled data from total of six studies showed significant intergroup difference with aggregated result (SMD = 0.52, 95% CI: 0.35–0.69, $P < 0.00001$ P for heterogeneity = 0.28, $I^2 = 0\%$) (Figure 3b). Pooled data from the three studies which reported the TUG test showed a significant intergroup difference which favours the exercise group (SMD = −0.60, 95% CI: −1.11-−0.09, $P = 0.02$, P for heterogeneity = 0.08, $I^2 = 59\%$) (Figure 3c). However, the studies which reported the BBS, which consist of four types of interventions and the three studies which reported the STS were non-significant with pooled results (SMD = 0.30, 95% CI: −0.11 to 0.72, $P = 0.15$, P for heterogeneity = 0.48, $I^2 = 0\%$) (Figure 3d) and (SMD = −0.95, 95% CI −1.35 to0.55, $P = 0.07$, P for heterogeneity <0.00001, $I^2 = 87\%$), respectively (Figure 3a).

Discussion

OS causes deficits in gait and balance which increases the risk of falls [5]. Postural instability in individuals with OA may result from quadriceps muscle weakness, pain or altered neuromuscular control [37]. Strengthening exercise can improve muscle strength and proprioception which may reduce the progression of OA [37]. Thus, in order to improve balance and reduce falls risk in individuals with knee OA, any RCTs should include interventions that can improve muscle strength, reduce pain and improve neuromuscular control. Previous studies, however, did not include falls outcome as assessing real falls will require far larger studies and much longer follow-up periods. Such studies are may no longer be possible in many advanced countries in view of the high number of knee replacements in these patients, but may still be possible in settings where knee replacements are not widely taken up.

Our systematic review of 15 studies that evaluated balance and falls risk measures following physical interventions in patients with knee OA has found that strength training

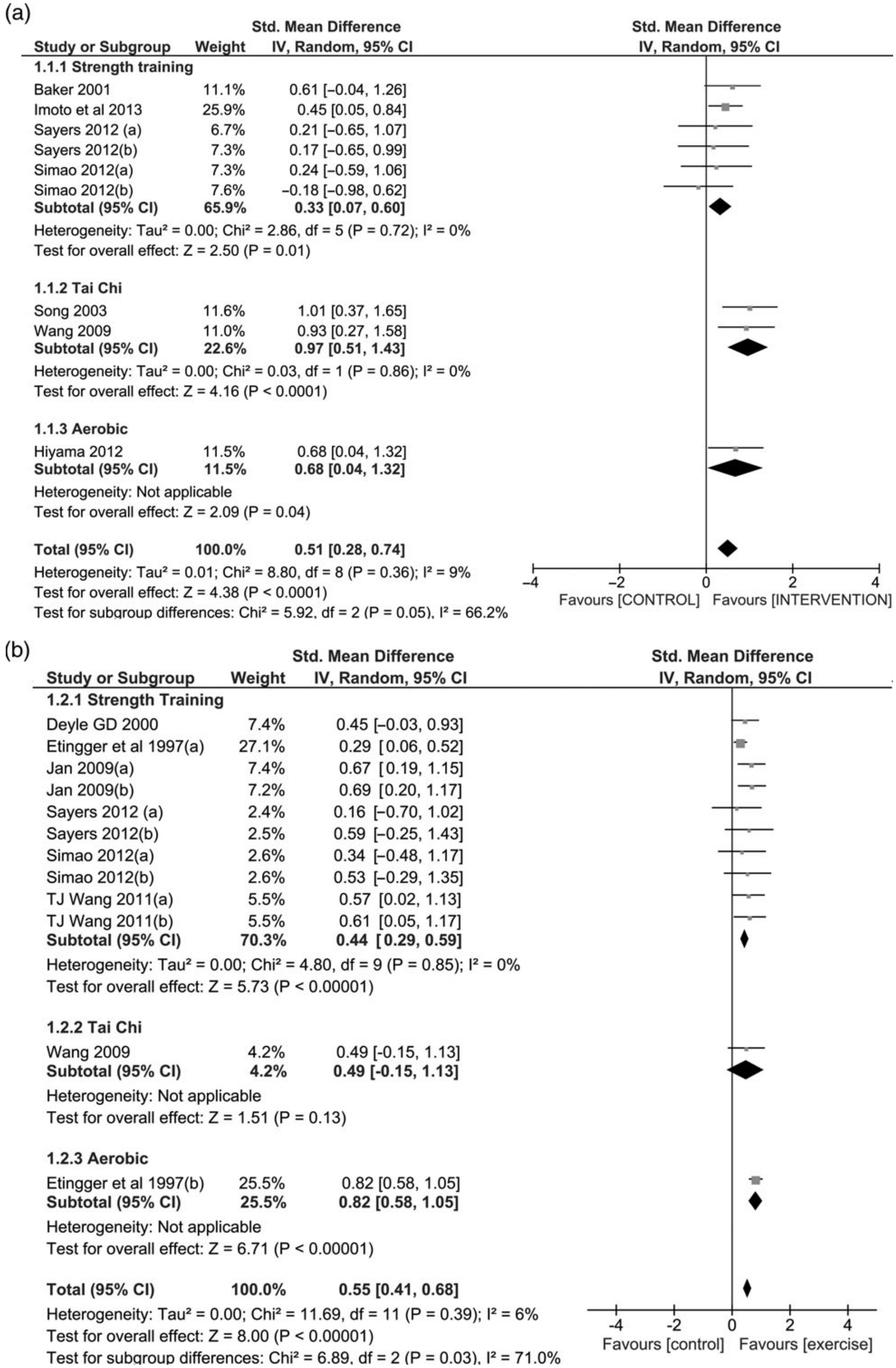

Figure 2. Forest plots of the meta-analysis of RCTs comparing various interventions with control groups for change in (a) balance outcomes (b) and falls risk. Etingger 1997(a), resistance training; Etingger 1997(b), aerobic; Jan 2009(a),Weight-bearing exercise; Jan 2009(b), non-weight-bearing exercise; Sayers 2012(a), high-speed power training; Sayers 2012(b), slow-speed power training; Simao 2012(a), squat exercise; Simao 2012(b), squat exercise with whole-body vibration; Wang 2011(a), land-based exercise; Wang 2011(b) aquatic exercise.

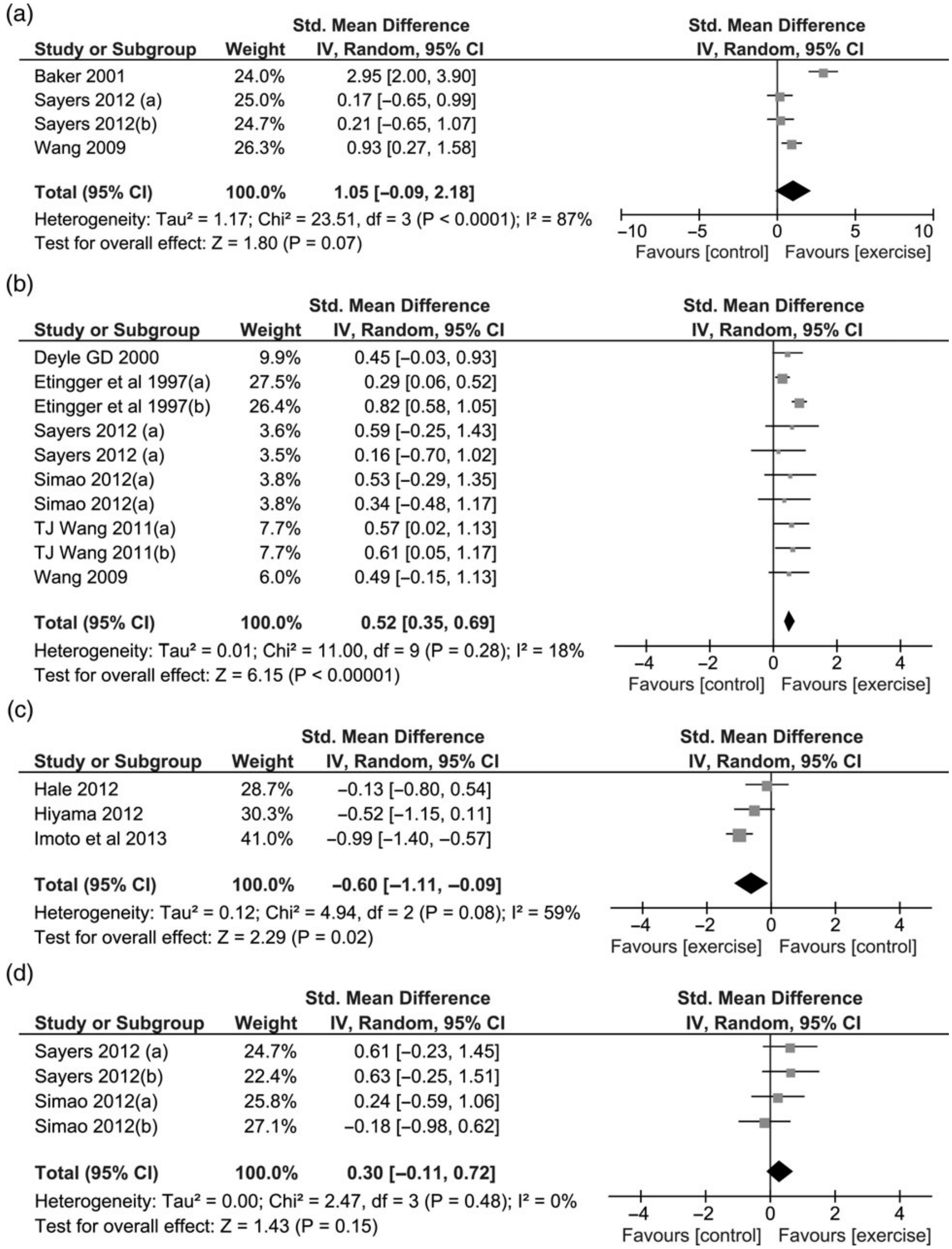

Figure 3. A Forest plot of the subgroup analyses of RCTs comparing results from various interventions with control groups according to different types of outcome measures. (a) STS, (b) Gait speed, (c) TUG, (d) BBS. Etingger 1997(a), resistance training; Etingger 1997(b), aerobic; Jan 2009(a), weight-bearing exercise; Jan 2009(b), non-weight-bearing exercise; Sayers 2012(a), high-speed power training; Sayers 2012(b), slow-speed power training; Simao 2012(a), squat exercise; Simao 2012(b), squat exercise with whole-body vibration ; Wang 2011(a), land-based exercise; Wang 2011(b) aquatic exercise.

exercises, Tai Chi and aerobics exercises significantly improved balance and falls risk outcomes in 11 of the 15 studies. The addition of vibration or NMSE in strength training also benefited balance significantly. Water-based exercises were beneficial in only one out of three studies. Light therapy did not improve balance outcome. In terms of difference in tools used for outcome measurements, STS and BBS did not showed significant intergroup differences in our meta-analyses in contrast to gait speed, TUG and 6MWT, which demonstrated significant differences between groups. However, the lack of improvement in BBS seen among intervention subjects may due to ceiling effect of the assessment [38].

Various types of physical therapies have been employed in previously published RCTs. In addition to strengthening exercises, aerobics and Tai Chi, there were also studies which added vibration or neuromuscular electrical stimulation to their exercise programmes. One study used light therapy alone as their intervention. The results were highly varied, with some studies demonstrating significant improvements with their interventions while others did not. Seven studies which involved strength training, two studies of aerobics training and three studies of Tai Chi were classified as positive studies [22–26, 28–30, 32, 33]. Three RCTs were classified as negative studies. Water-based exercises in two studies [34, 35] and short-term light treatment using radiation showed no significant improvement in balance and falls risk [27]. One study was classified as both positive and negative study because high-speed power training as the intervention showed improvement but no more than the slow-speed training and control groups [21].

While the PEDro scores for individual RCTs were considered acceptable, none of the studies we selected used falls occurrence and frequency of falls as their outcomes measures. The outcome measures employed for balance and falls risk used were heterogeneous which limited the applicability of the comparisons. The studies which measured falls risk employed surrogate measures of falls like the PPA and fear of falling [30, 34]. However, actual falls measured in real-life require adequate periods of follow-up and usually involve the use of fall diaries [39]. To possess adequate statistical power to detect true falls, much larger studies than the ones currently reported will be required.

Aerobics, resistance training, NMES with squat exercises, weight-bearing exercises and squat exercises with vibration showed significant intergroup differences. The common factor among these exercises is likely to be lower limb girdle strength training. As quadriceps and limb girdle weakness is one of the factors related to progression of knee OA, strength training is vital in increasing muscle power [40]. In addition, weight-bearing and aerobic exercises improved walking speed of the intervention group, possibly by optimising neuromuscular control of the knee joint that leads to reduced falls risk [41]. The addition of whole-body vibration and NMES in squat exercises improved balance by increasing muscle strength in the lower limbs [22, 32]. Even though no significant intergroup differences were found in the study by Sayers *et al.*, it is worth mentioning that high-speed power training, slow-speed power training and stretching (control) had benefited patients with knee OA.

Tai Chi is a safe exercise that requires no special equipment, independent to weather and can be administered at no cost [42]. The three Tai Chi studies [23, 30, 31] showed significant improvements in balance and risk of falls. Tai Chi exercises improved fear of falling and STS time in these studies [28, 30]. From discriminant analyses, STS identified 65% of subjects with balance dysfunction; thus, STS measurements are considered an acceptable measure of balance function [43]. As fear of falling is linked to future falls in older people [44], the reduction in fear of falling associated with Tai Chi exercises suggests that Tai Chi may be an effective strategy for falls prevention for individuals with knee OA.

Water-based exercises showed no significant improvement in balance and falls risk between groups for participants with knee OA [27, 34, 35]. We postulated that it was due to lack of strength-based exercises. The study by Hale *et al.* [34] did not include any strength training while Lund *et al.* [35], which compared aquatic and land-based exercises involved little resistance exercises in the aquatic exercise group. The exercise duration was inadequate in the study by Hale *et al.* which might have led to the lack of improvement in their frail participants [34]. Therefore, future studies on water-based programmes should include strength training and longer duration (>12 weeks) of intervention.

Limitations

An overestimation of the treatment effect is possible because our systematic review only contained nine studies of limited sample sizes as only a few published studies fitted the inclusion criteria. Secondly, heterogeneity in the tools of assessment used made comparison of all the outcomes difficult. We also encountered difficulties in evaluating the studies that did not report allocation concealment in their trials. This may contribute an element of bias. Finally, some studies only involved women as their participants, which contributed to gender bias.

Suggestion for future

To improve the empirical knowledge on this field, this systematic literature search conducted has highlighted certain areas of recommendation. Firstly, a more robust, adequately powered randomised controlled study should be conducted in order to provide vital data on type and dosage of exercises required as well as a measurement of the size of benefit to enable economic evaluations and resource planning. Falls occurrence and frequency should be used as primary outcomes in this future, potential RCT. Secondly, we recommend a consensus on a standardised assessment tools in measuring balance and falls risk to enable structured comparisons be made between studies. Next, we suggest another systematic review to be conducted in examining other factors such the OA symptoms (pain, stiffness and functional limitation), quality-of-life domains and other functional measurement as the determinants of balance. Lastly, we also recommend that future studies should investigate the other types of intervention or add on more novel method of enhancing popular interventions like Tai Chi and water-based exercises.

Conclusion

Strength training, Tai Chi and aerobics exercises improved balance and falls risk in older individuals with knee OA, while water-based exercises and light treatment did not significantly improve balance outcomes. However, none of the studies so far has evaluated exercise therapy in large enough samples to determine actual falls reduction. Larger RCTs with a longer duration of study are needed to reaffirm current findings to investigate the long-term effect of these interventions.

Key points

- Strength training, Tai Chi and aerobics exercise improved balance and falls risk in older individuals with knee OA.
- Water-based exercise and light treatment did not significantly improve balance outcomes.
- Previous studies did not include falls outcomes.

Conflicts of interest

None declared.

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Supplementary data

Supplementary data mentioned in the text is available to subscribers in *Age and Ageing* online.

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