Hazel J. Jenkins, Aron S. Downie, Matthew Fernandez, Mark J. Hancock (2021) Decreasing thoracic hyperkyphosis – Which treatments are most effective? A systematic literature review and meta-analysis, *Musculoskeletal Science and Practice*, Vol. 56, 102438.

Access to the published version:

https://doi.org/10.1016/j.msksp.2021.102438

Decreasing thoracic hyperkyphosis – which treatments are most effective? A systematic literature review and meta-analysis

Authors:

Hazel J. Jenkins (corresponding author); PhD; Department of Chiropractic, Macquarie University, Sydney, Australia; Mailing address: Rm 347, 17 Wally's Walk, Macquarie University, NSW, Australia, 2109; Email: hazel.jenkins@mq.edu.au; Ph: +61298509383

Aron S. Downie; PhD; Department of Chiropractic, Macquarie University, Sydney, Australia

Matthew Fernandez; PhD; Department of Chiropractic, Macquarie University, Sydney, Australia

Mark J. Hancock; PhD; Department of Health Professions, Macquarie University, Sydney, Australia

Introduction

Mean thoracic kyphosis measurements range from 20 to 45 degrees, increasing in females and with increased age[1]. Thoracic hyperkyphosis is an increased curvature above normal values (commonly defined as greater than 40 degrees[2,3]) and incidence rates range from 20% to 40% in the population[4]. Hyperkyphosis may have a genetic link[5], and has been associated with underlying pathology such as Scheuermann's disease and osteoporosis, but many cases are idiopathic or age-related[2-4]. Kyphotic postural changes may also progress with increasing age, as degenerative changes, lack of mobility, and reduced postural muscle strength lead to an increase in flexed posture[2].

The clinical importance of thoracic hyperkyphosis is much debated. While associations with increased pain, lack of mobility or function, poor balance, reduced quality of life, increased risk of falls, and increased risk of osteoporotic fracture have been found[2-4], findings are conflicting and causation has not been demonstrated[6,7]. Hyperkyphosis is a common presentation within musculoskeletal care with 78% of Australian physiotherapists reporting seeing a patient with hyperkyphosis at least weekly[8], and 60% of Australian chiropractors reporting that they often see patients with postural disorders including hyperkyphosis[9]. Hyperkyphosis is often associated with poor posture, including forward head posture and rounded shoulders[10]. Regardless of associations with pain and function, patients may also want to improve posture for cosmetic appearance and may seek the most appropriate treatment modality. However, physiotherapists report uncertainty in the evidence-base regarding effective treatments to reduce thoracic hyperkyphosis[8].

Many treatments have been reportedly used to reduce thoracic hyperkyphosis, including exercise[8,11,12], manual therapy[8,13,14], bracing[8,15], and surgery[16]. Two previous systematic reviews have been performed to assess the effectiveness of exercise to reduce thoracic hyperkyphosis[17,18]. Bansal et. al. (2014) assessed the effectiveness of exercise in older adults only, but included non-randomised study designs and was not able to perform a meta-analysis or make clear recommendations[17]. Gonzalez-Galvez et. al. (2019) reported that exercise was effective in reducing thoracic kyphosis but did not evaluate the strength of evidence, or report separately for different age groups or length of treatment duration[18]. Therefore, the quality of evidence demonstrating the effectiveness of exercise is uncertain, it is unclear whether exercise is equally effective at different age ranges or with different lengths of exercise program duration, and there is a lack of clarity on which other interventions may be effective to reduce thoracic kyphosis. The aims of this systematic review and meta-analysis were to:

1. Describe conservative interventions that have been assessed to reduce thoracic hyperkyphosis

2. Assess the effectiveness of individual conservative interventions to reduce thoracic hyperkyphosis

3. Synthesise the effectiveness of conservative interventions to reduce thoracic hyperkyphosis by intervention, control characteristics, and study population (including age and likelihood of osteoporosis).

Methods

The protocol was determined in advance and registered with PROSPERO (http://www.crd.york.ac.uk/PROSPERO); registration number: CRD42018089835. The review was reported in accordance with the PRISMA statement[19].

Data sources

MEDLINE, EMBASE, CINAHL and CENTRAL were searched from inception to 23 March 2021 using terms related to kyphosis or spinal curvature; thoracic spine; treatment; and randomised controlled trial (Supplementary file 1). Forward and backward citation tracking of the included studies and any relevant review articles was performed.

Inclusion criteria

Eligible studies needed to be full-text articles of randomised controlled trials published in a peer review journal. Abstracts and conference proceedings were excluded. Articles not written in English were translated where possible. The specific inclusion criteria were:

Population: adults over 18 years of age with hyperkyphosis (study specifically defined hyperkyphosis or forward posture as an inclusion criteria or, where not defined, the mean baseline kyphosis angle was greater than 40 degrees[2,3]). Participants with osteoporosis, with or without, osteoporotic compression fracture were eligible for inclusion. Studies were excluded if the thoracic hyperkyphosis was secondary to acute traumatic injury or underlying serious pathology.

Intervention: any conservative (non-surgical) intervention aiming to reduce thoracic hyperkyphosis.

Comparator: any of placebo, minimal treatment or no treatment. Studies were excluded if two active conservative treatments (e.g. exercise and manual therapy) were compared, unless the trial also included an appropriate control group.

Outcome: valid and reliable measures of thoracic kyphosis as reported in the original study, including X-ray analysis (e.g. Cobb angle) or external measurement (e.g. kyphometer, inclinometer, flexicurve ruler, spinal mouse[20]). Measures of forward posture, such as occiput-to-wall distance which have been shown to be a valid and reliable measure of thoracic kyphosis[21,22], were also included.

Study selection

Study titles were screened by one member of the research team and clearly irrelevant titles were excluded. Abstracts and full-texts were independently reviewed by two members of the research team. Inter-rater reliability of initial decisions for full-text inclusion was calculated using Cohen's kappa. At all stages, disagreements that could not be resolved between the two researchers were arbitrated by a third member of the research team.

Data extraction

Two members of the research team independently extracted descriptive and outcome data into a data collection form that was piloted prior to use. Descriptive data included study design, participant and practitioner characteristics, description of intervention and control, and description and timing of the outcome measure. Outcome data extracted included the number of participants in the intervention and control groups, and measurements of thoracic kyphosis. Where incomplete data was presented or clarification of data was required the original study authors were contacted by email.

Quality assessment

Two members of the research team independently performed risk of bias (ROB) assessment of each included study using the Cochrane ROB tool[23]. The Cochrane ROB tool is recommended by the Cochrane collaboration[24] and assesses risk of bias across six domains: selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias. Any discrepancies in decisions were discussed and a third researcher was consulted if discrepancies could not be resolved.

Summary measures

Mean change scores and standard deviation for thoracic kyphosis were collected. Where not provided, and could not be obtained from the contacting the study authors, the mean change score was calculated as the difference in measurements (post-treatment minus pre-treatment) and the standard deviation for the change score was calculated from the confidence interval as described in the Cochrane Handbook[24]. Review Manager 5.4 was used to calculate standardised mean differences (SMD) (intervention minus control group), to account for the different outcome measures used in the studies. A negative result favoured the intervention group. As there are no units to give context to the effect size when interpreting SMD, the cut-off points postulated by Cohen of 0.2, 0.5, and 0.8 to indicate small, medium and large effect sizes[25] were used.

Data synthesis

Some clinical heterogeneity was expected due to variation between study populations and interventions. To explore heterogeneity, studies were sub-grouped for meta-analysis based on study population (higher risk of osteoporosis or age-related hyperkyphosis, over 55-years; younger age, less than 55-years); intervention type (e.g. exercise, bracing); control group (no treatment; minimal treatment); and duration of intervention (three months or less, greater than three months). Thoracic kyphosis tends to increase in the general population after age 55, likely due to age-related changes and association with osteoporosis compression fractures[3], which was considered to potentially impact the effectiveness of interventions. Control groups were separated depending on the potential likelihood of impacting thoracic kyphosis or posture, into those unlikely to have any effect (e.g. no treatment, general health education unrelated to posture) and those that may have a minimal effect (e.g. postural education, general exercise). Studies that could not be pooled were analysed descriptively. Studies reporting different outcome measures for thoracic kyphosis on the same group of participants were only included once in each meta-analysis. When a study had multiple intervention groups and two or more could be included in the same meta-analysis, results from the intervention groups were combined to create a single pair-wise comparison, as recommended in the Cochrane Handbook to prevent a unit-of-analysis error[24]. Meta-analyses were performed using a random-effects model within Review Manager 5.4.

Quality of evidence

Assessment of the quality of evidence for each meta-analysis was performed using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) system[26] with previously reported modifications[27]. Quality of evidence was rated as 'High', 'Moderate', 'Low', or 'Very low' certainty that the true effect size is close to the estimated effect size. To assess study limitations, overall ROB for each study included in the meta-analysis was assessed as 'High' or 'Low' in keeping with previous research[27]. A study was assessed as having overall low ROB if four or more of the individual domains (selection, performance, detection, attrition, and reporting bias) were considered to be of low ROB. Confidence in the evidence was downgraded for: study limitations if less than 50% of the study weightings were assessed as low ROB; inconsistency of results if variability in the results was large, as indicated by an I^2 value greater than 80% with wide visual inconsistency in results that would substantially alter clinical implications; imprecision if there was either of (i) less than 400 people included within the meta-analysis, or (ii) the 95% confidence interval included the line of no effect and crossed an effect size of 0.5 in either direction; indirectness of evidence if there was important variation in the included study population, intervention, control, or outcomes that would limit the generalisability of the results; and publication bias if there was an asymmetrical funnel plot (for meta-analyses with at least 10 included studies), studies finding negative results were insufficiently reported, insufficient data was reported to be included in meta-analysis, or more than half of included trials were from small sponsored studies or reported investigator conflict of interest. The GRADE score was not downgraded for study design as this was accounted for in the inclusion criteria.

Results

Study selection

Search strategies identified 6637 distinct records (Figure 1). Ninety-six full-text articles were assessed for eligibility with 28 included in the final review. There was moderate initial agreement in full-text inclusion (kappa=0.53). Twenty-one studies (22 comparisons) were included in the meta-analyses. Three full-texts were translated to English for assessment, none of which met inclusion criteria[28-30]. Only one non-English paper was unable to be translated as it was written in Arabic script[31]; this was a preliminary study prior to a full-scale study published by the same authors and included in the review[32]. Study authors were contacted for two studies[33,34]; however, the necessary outcome data to include in meta-analysis was not available.

Study characteristics

Characteristics of the included studies are presented in Table 1. Eighteen studies targeted populations over 55-years of age or with a higher risk of osteoporosis[11,13-15,32-45]. Ten studies targeted younger age ranges[12,46-54]. Thoracic kyphosis was measured using radiographic measurements in four studies[36-38,41]. The remaining studies used external measures to measure the degree of kyphosis[12-15,32,34,35,37-43,45,47-49,51-54], kyphotic index[33,41,46], posture number[50], or amount of forward head posture[11,44]. Only three studies performed follow-up measurements, at three-months[54], six-months[47], or one-year[42,47].

Description of interventions assessed to reduce thoracic hyperkyphosis

Exercise

Exercise was the most common intervention to be assessed, in 21 studies[11,12,33-39,41,42,44,45,47-54] as summarised in Table 1. Exercise programs ranged from simple programs such as daily hamstring stretches[48], and home strengthening exercises[36], but most programs included a combination of strength and flexibility exercises targeting the thoracic spine. Strengthening exercises generally aimed to improve strength in the postural and back extensor muscles. Most programs involved supervised individual or group exercise sessions ranging from six times in eight months[44] to four times a week[52], supplemented by a home exercise program. Only two studies used an unsupervised home-based exercise program alone[36,48]. The duration of the exercise program ranged from six-weeks[45,47] to two-years[36], with the most common duration being three-months[11,37,39,42,48,49,52,53].

Bracing

Four studies[15,32,33,40] used rigid bracing to improve upright posture and reduce thoracic hyperkyphosis. In all studies a variety of a Spinomed brace was used for either three-months[32] or six-months[15,33,40].

Multimodal therapy

Four studies[13,14,42,46] assessed short-term (three-months or less duration) programs combining an exercise program with other interventions, including manual therapy[13,14,42,46] and taping[13,14,42]. The included exercise programs were similar in content, frequency, and duration to those described when testing exercise alone. Manual therapy was generally included joint mobilisation or manipulation to increase thoracic spine mobility and taping was performed with the aim to improve upright posture.

Other interventions

Single studies assessed the use of taping[43], electrical stimulation[51], or biofeedback training[51]. Electrical stimulation was used to stimulate the thoracic spine postural muscles, for 20-minutes at a time, three-days a week, for eight-weeks. Biofeedback training involved wearing a harness which beeped or vibrated when a slumped posture was moved into to reinforce upright posture. The harness was worn for 20-minutes at a time, three-days a week, for eight-weeks.

Risk of bias

Risk of bias of the included studies is presented in Table 2. Due to the nature of the interventions, the majority of studies could not blind participants or practitioners, leading to performance bias. Selection bias was also common, with inconsistent reporting of the method of randomisation and whether allocation was concealed. All studies used objective outcome measures and/or assessors were blinded to group allocation.

Effectiveness of interventions to reduce thoracic kyphosis: results of individual studies

Descriptive analysis of the treatment effects in all studies and comparisons is presented in Table 3. Three studies (not included in meta-analysis) assessing exercise[51], bracing[32], and multimodal care[46] demonstrated evidence of effectiveness. Taping alone[43], electrical stimulation[51], biofeedback training[51], and home-based exercises[36,48] were not effective in reducing thoracic hyperkyphosis. In studies assessing long-term follow-up[42,47,54] or different methods of outcome measurement at the same time point[35,37,38,41] results were consistent across the different comparisons.

Effectiveness of interventions to reduce thoracic kyphosis: meta-analysis

Five meta-analyses were conducted across 17 studies sub grouped by intervention and population: (i) structured strengthening and flexibility exercise programs of three months or less duration in a younger population (six studies[12,47,49,52-54]); (ii) structured strengthening and flexibility exercise programs of three months or less duration in an older population (four studies[37,39,42,45]); (iii) structured strengthening and flexibility exercise programs of more than three months duration in an older population (three studies[38,42,44]); (iv) bracing of more than three months duration in an older population (two studies[15,40]); and (v) multimodal care of three months or less duration in an older population (three studies[13,14,42]). All studies included no treatment control groups. Results are presented in Figure 2.

Younger age population

One meta-analysis, including six studies (n=413) assessed younger participants undergoing structured strengthening and flexibility exercise programs of three months or less duration[12,47,49,52-54]. Low-quality evidence found that exercise has a large effect in reducing thoracic hyperkyphosis (SMD -2.8; 95%CI -4.3 to -1.3). Strength of evidence was downgraded for inconsistency of results and indirectness.

Older age population

Four of the meta-analyses assessed older participants. Interventions assessed included short- and long-term structured exercise programs, bracing, and multimodal care.

<u>Short-term structured exercise programs</u>[37,39,42,45]: four studies (n=502) assessed structured exercise programs of three months or less duration as an intervention. Moderate-quality evidence found that short-term exercise has a small effect in reducing thoracic hyperkyphosis (SMD -0.3; 95%CI -0.6 to 0.0). Strength of evidence was downgraded for indirectness.

<u>Long-term structured exercise programs</u>[38,42,44]: three studies (n=345) assessed structured exercise programs of more than three months duration as an intervention. Low-quality evidence found that long-term exercise is not effective in reducing thoracic hyperkyphosis

(SMD -0.2; 95%CI -0.5 to 0.2). Strength of evidence was downgraded for indirectness and publication bias. Bergstrom et al. and Kaijser et al. met inclusion for this meta-analysis but insufficient data was presented to allow calculation of SMD[33,34].

Bracing: two studies (n=170) assessed bracing for three months or more as an intervention[15,40]. Low-quality evidence found that bracing has a large effect in reducing thoracic hyperkyphosis (SMD -1.0; 95%CI -1.3 to -0.7). Strength of evidence was downgraded for imprecision and publication bias. Kaijser et al. met inclusion for this meta-analysis but insufficient data was presented to allow calculation of SMD[33].

Multimodal care[13,14,42]: three studies (n=408) assessed the combination of manual therapy and exercise as a multimodal intervention. Low-quality evidence found that multimodal therapy is not effective in reducing thoracic hyperkyphosis (SMD -0.6; 95%CI -1.6 to 0.4). Strength of evidence was downgraded for inconsistency of results and indirectness.

Discussion

Main findings

This systematic review and meta-analysis found moderate-quality evidence that short-term structured exercise programs in older adults have a small effect in reducing thoracic hyperkyphosis (SMD -0.3; 95%CI -0.6 to 0.0), and low-quality evidence that short-term structured exercise programs in younger adults (SMD -2.8; 95%CI -4.3 to -1.3) and bracing in older adults (SMD -1.0; 95%CI -1.3 to -0.7) have a large effect in reducing thoracic hyperkyphosis. Structured exercise programs of over three-months and multimodal care, with the addition of manual therapy to exercise, did not show evidence of effectiveness in older adults.

In single studies, multimodal care was effective in younger adults (-0.6; 95%CI: -1.2 to -0.1). Other interventions, including electrical stimulation of muscles, biofeedback training, taping, and home-based exercise programs were not effective.

Comparison with previous literature

Previous systematic reviews have only assessed the effectiveness of exercise programs on decreasing thoracic kyphosis[17,18]. Gonzalez-Galvez et al. (2019) performed a systematic review and meta-analysis of the effect of exercise programs on sagittal curvatures. They included seven studies assessing thoracic kyphosis and performed a meta-analysis which found a significant effect of exercise in reducing thoracic kyphosis (SMD: -1.4; 95%CI: -2.15, -0.66). However, no analysis of the quality of evidence of the meta-analysis was performed. Their findings are in alignment with the findings of this review; however, they are not directly comparable as we performed separate meta-analyses for younger and older participants and for duration of the intervention. Only four studies were included in both this review and that by Gonzalez-Galvez[37,38,48,49]. We excluded three studies included by Gonzalez-Galvez due to a lack of, or inappropriate, control groups[55,56], or the full-text paper not being found[57]. Eleven of the studies included in this review were not included in that by Gonzalez-Galvez[11,12,33-35,39,41,47,50-52], likely due to a difference in inclusion criteria or search strategy. Bansal et. al. (2014) performed a systematic review of exercise for improving age-related hyperkyphosis. They only included studies of participants over 45 years and did not perform a meta-analysis due to study heterogeneity. They concluded that there was mixed evidence of effectiveness and more high-quality studies were required. Bansal et.al. included 12 studies, six of which were included in this review[11,13,14,34-36]. The other six studies were excluded from this review due to lack of or inappropriate control groups[58-61], or publication only as conference proceedings or within a dissertation[62,63].

Strengths and limitations

Strengths of this review include the study selection and data analysis. We included all conservative interventions aiming to reduce thoracic hyperkyphosis. We limited included studies to randomised controlled trials. To limit heterogeneity within meta-analyses, we considered characteristics of the intervention, control, and the participant population. To address the wide variety of outcome measures used across studies, SMD was calculated for comparisons in meta-analysis[64]. All outcome measures included in this review have demonstrated validity and inter-rater reliability in the measurement of thoracic kyphosis[20,22].

Study limitations include the low number of studies for some intervention types and lack of outcome measure reporting. Whilst demonstrating effectiveness in a single study, the lack of additional studies assessing multimodal therapy in younger adults limits confidence in this result. The strength of evidence for meta-analyses for bracing of in older adults was downgraded for imprecision, reflective of the small sample size included within this meta-analysis. Two studies, assessing structured exercise programs or bracing in older adults, did not report specific results to allow inclusion within the relevant meta-analyses[33,34]. Both studies reported that the interventions tested did not show evidence of effectiveness, but no outcome data was reported, thus the associated meta-analyses do not include these results and strength of evidence was downgraded for publication bias due to this limitation.

When estimating pooled effect sizes, it is possible that the inclusion of studies scored with high risk of bias or substantial baseline differences may have influenced the veracity of results. To investigate this, post-hoc sensitivity analyses were performed by excluding (i) high risk of bias studies or (ii) studies with substantial baseline differences in outcome measures from the meta-analyses. Results were similar except when one study with high risk of bias[39] was removed from the exercise of three months or less duration in older adults sub-group, where the pooled estimate changed from just significant (-0.3; 95%CI: -0.6, 0.0) to non-significant (-0.2; 95%CI: -0.5, 0.1). Therefore, the magnitude and significance of pooled effects are largely insensitive to the risk of bias rating or baseline differences.

Implications for clinical practice

The results of this review provide low to moderate-quality evidence that short-term structured exercise programs (of up to three months) should be considered as a treatment option to reduce thoracic hyperkyphosis in both younger and older adults. The completeness of reporting and exact exercise program used differed between studies, but generally included a structured, physiotherapist supervised exercise program, performed one to four times per week, combining thoracic strength/stabilisation and mobility/flexibility exercises. No specifics of the optimal exercise program to be used can be determined from this review, but these common features should be taken into consideration.

Bracing also showed evidence of effectiveness in older adults. Although larger effect size was found compared to exercise in the same population, results are limited by low quality evidence. Another study assessing bracing did not show evidence of effectiveness[33], but specific outcome measurements were not reported to allow inclusion in meta-analysis. Therefore, we suggest exercise should be considered as an initial treatment option, but bracing may be an appropriate alternative in older adults if exercise is unsuccessful.

The clinical significance of the magnitude of change in thoracic kyphosis needs to be considered when determining effective interventions. Trials are encouraged to report effect sizes in relation to established minimal clinically important difference (MCID) values to assess clinical significance. However, MCID values for the different outcome measures assessing thoracic kyphosis are unknown. In this review, in order to compare between different outcome measures, SMD was reported, and effects were therefore reported as small, medium, and large in accordance with the cut-off points suggested by Cohen[25]. However, the clinical relevance of these cut-off points in relation to changes in thoracic kyphosis have not been established, limiting discussion of the clinical relevance of the results.

Implications for future research

Future studies assessing interventions to reduce thoracic hyperkyphosis should address the gaps or limitations identified in this review. Multimodal care in younger adults requires further investigation before the addition of manual therapy to a structured exercise program can be recommended. Bracing in older adults and exercise in younger adults are supported only by low-quality evidence and further studies with larger sample sizes and more complete reporting of results need to be undertaken to improve the quality of the evidence. Complete reporting of interventions is important to accurately describe effective interventions and allow replication in clinical practice. It is recommended that future studies use established tools, such as the TIDieR checklist[65], to ensure complete reporting of intervention characteristics.

In this review we did not assess for whether changes in hyperkyphosis were also associated with a change in clinical symptoms. Some patients with thoracic hyperkyphosis also report increased pain and lack of mobility or function[2-4]; however, results are not consistent across studies, and it is unclear whether thoracic hyperkyphosis has a direct causative association with clinical symptoms, or whether reducing thoracic hyperkyphosis improves clinical symptoms[6,7]. No conclusions related to clinical symptoms can be made from this review. Future studies investigating the relationship between changes in hyperkyphosis and changes in clinical symptom are important to further inform clinical practice.

Conclusion

Low to moderate-quality evidence indicates that structured exercise programs should be considered as a treatment option to reduce thoracic hyperkyphosis in both younger and older adults. Low-quality evidence indicates that bracing may also be considered in older adults. A single study suggests that multimodal care in younger adults may also be effective, but more evidence is required.

References

1. Fon GT, Pitt MJ, Thies Jr AC. Thoracic kyphosis: range in normal subjects. *American Journal of Roentgenology* 1980;134:979-83.
2. Roghani T, Zavieh MK, Manshadi FD, et al. Age-related hyperkyphosis: update of its potential causes and clinical impacts—narrative review. *Aging clinical and experimental research* 2017;29:567-77.
3. Katzman WB, Wanek L, Shepherd JA, et al. Age-related hyperkyphosis: its causes, consequences, and management. *journal of orthopaedic & sports physical therapy* 2010;40:352-60.
4. Kado DM, Prenovost K, Crandall C. Narrative review: hyperkyphosis in older persons. *Annals of internal medicine* 2007;147:330-8.
5. Yau MS, Demissie S, Zhou Y, et al. Heritability of thoracic spine curvature and genetic correlations with other spine traits: the Framingham study. *Journal of Bone and Mineral Research* 2016;31:2077-84.
6. Christensen ST, Hartvigsen J. Spinal curves and health: a systematic critical review of the epidemiological literature dealing with associations between sagittal spinal curves and health. *Journal of Manipulative and Physiological Therapeutics* 2008;31:690-714.
7. Barrett E, O'Keeffe M, O'Sullivan K, et al. Is thoracic spine posture associated with shoulder pain, range of motion and function? A systematic review. *Manual Therapy* 2016;26:38-46.
8. Perriman DM, Scarvell JM, Hughes AR, et al. Thoracic hyperkyphosis: a survey of Australian physiotherapists. *Physiotherapy Research International* 2012;17:167-78.

9. Adams J, Lauche R, Peng W, et al. A workforce survey of Australian chiropractic: the profile and practice features of a nationally representative sample of 2,005 chiropractors. *BMC complementary and alternative medicine* 2017;17:14-.

10. Singla D, Veqar Z. Association Between Forward Head, Rounded Shoulders, and Increased Thoracic Kyphosis: A Review of the Literature. *Journal of Chiropractic Medicine* 2017;16:220-9.

11. Benedetti MG, Berti L, Presti C, et al. Effects of an adapted physical activity program in a group of elderly subjects with flexed posture: Clinical and instrumental assessment. *Journal of NeuroEngineering and Rehabilitation* 2008;5 (no pagination).

12. Toprak Celenay S, Ozer Kaya D. An 8-week thoracic spine stabilization exercise program improves postural back pain, spine alignment, postural sway, and core endurance in university students: A randomized controlled study. *Turkish Journal of Medical Sciences* 2017;47:504-13.

13. Bautmans I, Arken J, Mackelenberg M, et al. Rehabilitation using manual mobilization for thoracic kyphosis in elderly postmenopausal patients with osteoporosis. Journal of rehabilitation medicine [serial online]2010;42:129-35. Accessed.

14. Bennell KL, Matthews B, Greig A, et al. Effects of an exercise and manual therapy program on physical impairments, function and quality-of-life in people with osteoporotic vertebral fracture: a randomised, single-blind controlled pilot trial. *BMC Musculoskeletal Disorders* 2010;11:36.

15. Pfeifer M, Kohlwey L, Begerow B, et al. Effects of two newly developed spinal orthoses on trunk muscle strength, posture, and quality-of-life in women with postmenopausal osteoporosis: a randomized trial. American journal of physical medicine & rehabilitation [serial online]2011;90:805-15. Accessed.

16. Farrokhi MR, Alibai E, Maghami Z. Randomized controlled trial of percutaneous vertebroplasty versus optimal medical management for the relief of pain and disability in acute osteoporotic vertebral compression fractures. *Journal of Neurosurgery: Spine* 2011;14:561-9.

17. Bansal S, Katzman WB, Giangregorio LM. Exercise for improving age-related hyperkyphotic posture: a systematic review. *Archives of physical medicine and rehabilitation* 2014;95:129-40.

18. González-Gálvez N, Gea-García GM, Marcos-Pardo PJ. Effects of exercise programs on kyphosis and lordosis angle: A systematic review and meta-analysis. *PloS one* 2019;14:e0216180.

19. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Annals of internal medicine* 2009;151:264-9.

20. Barrett E, McCreesh K, Lewis J. Reliability and validity of non-radiographic methods of thoracic kyphosis measurement: A systematic review. *Manual Therapy* 2014;19:10-7.

21. Wongsa S, Amatachaya P, Saengsuwan J, et al. Concurrent validity of occiput-wall distance to measure Kyphosis in communities. *J Clin Trials* 2012;2:2167-0870.1000111.

22. Wiyanad A, Chokphukiao P, Suwannarat P, et al. Is the occiput-wall distance valid and reliable to determine the presence of thoracic hyperkyphosis? *Musculoskeletal Science and Practice* 2018;38:63-8.

23. Higgins JPT, Altman DG, Gotzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ* 2011;343:d5928-d.

24. Higgins J, Green S, (editors). Cochrane Handbook for Systematic Reviews of Interventions. [serial online]2011. Available from: The Cochrane Collaboration. Accessed 12 January 2014.

25. Fritz CO, Morris PE, Richler JJ. Effect size estimates: current use, calculations, and interpretation. *Journal of experimental psychology: General* 2012;141:2.

26. Guyatt GH, Oxman AD, Vist GE, et al. Rating quality of evidence and strength of recommendations: GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ: British Medical Journal* 2008;336:924.

27. Parreira P, Heymans MW, van Tulder MW, et al. Back schools for chronic non‐specific low back pain. *Cochrane Database of Systematic Reviews* 2017.

28. Müller C, Gösling T, Mameghani A, et al. Vertebral fractures due to osteoporosis. Kyphoplasty and vertebroplasty vs conservative treatment. *Der Orthopade* 2010;39:417-24.

29. Moon H-H, Jung S-Y, Park SS, et al. The effect of corrective exercise on Cobb's angle, static and dynamic foot pressure of patients with kyphosis. *Korean Journal of Sport Biomechanics* 2014;24:103-9.
30. Wiedenhöfer B, Fürstenberg C, Schröder K, et al. Dreidimensionale Korrekturprinzipien einer dreidimensionalen Deformität. *Der Orthopäde* 2011;40:672-81.
31. Hosseinabadi M, Kamyab M, Azadinia F, et al. The effect of spinal orthosis on trunk muscle force control in hyperkyphotic elderly. *Tehran University Medical Journal TUMS Publications* 2019;77:179-85.
32. Hosseinabadi M, Kamyab M, Azadinia F, et al. Effect of a Spinomed orthosis on balance performance, spinal alignment, joint position sense and back muscle endurance in elderly people with hyperkyphotic posture: A randomized controlled trial. *Prosthetics and Orthotics International* 2020;44:234-44.
33. Kaijser Alin C, Uzunel E, Grahn Kronhed AC, et al. Effect of treatment on back pain and back extensor strength with a spinal orthosis in older women with osteoporosis: a randomized controlled trial. *Archives of Osteoporosis* 2019;14:5.
34. Bergstrom I, Bergstrom K, Kronhed A-C, et al. Back extensor training increases muscle strength in postmenopausal women with osteoporosis, kyphosis and vertebral fractures. Advances in physiotherapy [serial online]2011;13:110-7. Accessed.
35. Greendale G, Huang M, Karlamangla A, et al. Yoga decreases kyphosis in senior women and men with adult-onset hyperkyphosis: results of a randomized controlled trial. Journal of the american geriatrics society [serial online]2009;57:1569-79. Accessed.
36. Itoi E, Sinaki M. Effect of back-strengthening exercise on posture in healthy women 49 to 65 years of age. *Mayo Clinic Proceedings* 1994;69:1054-9.
37. Katzman W, Parimi N, Gladin A, et al. Sex differences in response to targeted kyphosis specific exercise and posture training in community-dwelling older adults: a randomized controlled trial. BMC musculoskeletal disorders [serial online]2017;18. Accessed.
38. Katzman W, Vittinghoff E, Lin F, et al. Targeted spine strengthening exercise and posture training program to reduce hyperkyphosis in older adults: results from the study of hyperkyphosis, exercise, and function (SHEAF) randomized controlled trial. Osteoporosis international [serial online]2017:1-11. Accessed.
39. Naderi A, Rezvani MH, Shaabani F, et al. Effect of Kyphosis Exercises on Physical Function, Postural Control and Quality of Life in Elderly Men With Hyperkyphosis. *Iranian Journal of Ageing* 2019;13:464-79.
40. Pfeifer M, Begerow B, Minne H. Effects of a new spinal orthosis on posture, trunk strength, and quality of life in women with postmenopausal osteoporosis: a randomized trial. American journal of physical medicine & rehabilitation [serial online]2004;83:177-86. Accessed.
41. Watson SL, Weeks BK, Weis LJ, et al. High-intensity exercise did not cause vertebral fractures and improves thoracic kyphosis in postmenopausal women with low to very low bone mass: the LIFTMOR trial. *Osteoporosis International* 2019;30:957-64.
42. Barker KL, Newman M, Stallard N, et al. Physiotherapy rehabilitation for osteoporotic vertebral fracture—a randomised controlled trial and economic evaluation (PROVE trial). *Osteoporosis international* 2020;31:277‑89.
43. Bulut D, Dilek B, Kilinc A, et al. An investigation into the effects of kinesiotaping for posture correction on kyphosis angle, pain, and balance in patients with postmenopausal osteoporosis-associated thoracic kyphosis. *Archives of Osteoporosis* 2019;14:89.
44. Gibbs JC, McArthur C, Wark JD, et al. The Effects of Home Exercise in Older Women With Vertebral Fractures: a Pilot Randomized Controlled Trial. *Physical therapy* 2020;100:662‑76.
45. Cergel Y, Topuz O, Alkan H, et al. The effects of short-term back extensor strength training in postmenopausal osteoporotic women with vertebral fractures: comparison of supervised and home exercise program. *Archives of Osteoporosis* 2019;14:82.

46. Balbas-Alvarez L, Candelas-Fernandez P, Del Corral T, et al. Effect of Manual Therapy, Motor Control Exercise, and Inspiratory Muscle Training on Maximum Inspiratory Pressure and Postural Measures in Moderate Smokers: a Randomized Controlled Trial. *Journal of manipulative and physiological therapeutics* 2018;41:372–82.
47. Jaromi M, Nemeth A, Kranicz J, et al. Treatment and ergonomics training of work-related lower back pain and body posture problems for nurses. *Journal of Clinical Nursing* 2012;21:1776-84.
48. Muyor J, López-Miñarro P, Casimiro A. Effect of stretching program in an industrial workplace on hamstring flexibility and sagittal spinal posture of adult women workers: a randomized controlled trial. Journal of back and musculoskeletal rehabilitation [serial online]2012;25:161-9. Accessed.
49. Seidi F, Rajabi R, Ebrahimi I, et al. The efficiency of corrective exercise interventions on thoracic hyper-kyphosis angle. Journal of back and musculoskeletal rehabilitation [serial online]2014;27:7-16. Accessed.
50. Senthil P, Sudhakar S, Radhakrishnan R, et al. Efficacy of corrective exercise strategy in subjects with hyperkyphosis. *Journal of Back and Musculoskeletal Rehabilitation* 2017;30:1285-9.
51. Toprak Çelenay Ş, Özer Kaya D, Özüdoğru A. Spinal postural training: Comparison of the postural and mobility effects of electrotherapy, exercise, biofeedback trainer in addition to postural education in university students. *Journal of Back & Musculoskeletal Rehabilitation* 2015;28:135-44.
52. Vaughn D, Brown E. The influence of an in-home based therapeutic exercise program on thoracic kyphosis angles. Journal of back and musculoskeletal rehabilitation [serial online]2007;20:155-65. Accessed.
53. Tarasi Z, Rajabi, R., Minoonejad, H. and Shahrbanian, S., . The effect of spine strengthening exercises and posture training on functional thoracic hyper kyphosis in young individuals. *Journal of Advances in Medical and Biomedical Research* 2019;27:23–31.
54. Seidi F, Bayattork M, Minoonejad H, et al. Comprehensive corrective exercise program improves alignment, muscle activation and movement pattern of men with upper crossed syndrome: randomized controlled trial. *Scientific Reports* 2020;10:20688.
55. Kamali F, Shirazi SA, Ebrahimi S, et al. Comparison of manual therapy and exercise therapy for postural hyperkyphosis: a randomized clinical trial. *Physiotherapy theory and practice* 2016;32:92-7.
56. Jang H-J, Hughes LC, Oh D-W, et al. Effects of corrective exercise for thoracic hyperkyphosis on posture, balance, and well-being in older women: a double-blind, group-matched design. *Journal of geriatric physical therapy* 2019;42:E17-E27.
57. Junges S, Dias Molina R, Sartori J, et al. Mudança da pressão expiratória com a aplicação do método Pilates em mulheres adultas com hipercifose. *Fisioterapia Brasil* 2017;18.
58. Katzman WB, Sellmeyer DE, Stewart AL, et al. Changes in flexed posture, musculoskeletal impairments, and physical performance after group exercise in community-dwelling older women. *Archives of physical medicine and rehabilitation* 2007;88:192-9.
59. Greendale GA, McDivit A, Carpenter A, et al. Yoga for women with hyperkyphosis: results of a pilot study. *American Journal of Public Health* 2002;92:1611-4.
60. Kuo Y-L, Tully EA, Galea MP. Sagittal spinal posture after Pilates-based exercise in healthy older adults. *Spine* 2009;34:1046-51.
61. Renno AC, Granito RN, Driusso P, et al. Effects of an exercise program on respiratory function, posture and on quality of life in osteoporotic women: a pilot study. *Physiotherapy* 2005;91:113-8.
62. Abreu DC, Matos MS, Costa GC, et al. The effect of physical exercise on thoracic hyperkyphosis in osteoporotic elderly women. *Osteoporosis International*: SPRINGER LONDON LTD 236 GRAYS INN RD, 6TH FLOOR, LONDON WC1X 8HL, ENGLAND, 2012:S120-S.
63. Schuerman S. Relationships between postural exercise and risk factors for falling in individuals with osteoporosis [dissertation]. *Omaha: University of Nebraska* 1998:22-35.
64. Sedgwick P, Marston L. Meta-analyses: standardised mean differences. *Bmj* 2013;347:f7257.

65. Hoffmann TC, Glasziou PP, Boutron I, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *Bmj* 2014;348.

Tables

Table 1: Description of included studies

			Intervention group					Control group				
Study	Population	Outcome measure and timing	Description	Intervention duration and timing	Sample size	Mean age in years (SD)	Female %	Description	Sample size	Mean age in years (SD)	Female %	Included in meta-analysis Y/N (Included meta-analysis or reason for exclusion)
Balbas-Alvarez, 2018	Smokers, 18-60 yrs	External measurement (Flexicurve ruler: kyphosis index (%)) at 4 weeks	Multimodal: manual therapy, exercises, and inspiratory muscle training	8 x 1-hour sessions over 4 weeks; Home exercises 4 days per week	26	28.9 (12.1)	20	Inspiratory muscle training	25	32.8 (14.1)	20.6	N (younger age range)
Barker, 2020	Osteoporotic males/females with at least one vertebral compression fracture	External measurement of kyphosis (Flexicurve ruler) at 4 months	Multimodal: Manual therapy, taping and stretching exercises	6 sessions over 12 weeks; Home stretches daily	203	72.4 (9.3)	86	General education session	196	71.9 (9.6)	89	Y (Multimodal care of 3-months or less duration, older patient at risk of osteoporosis)
Barker, 2020	Osteoporotic males/females with at least one vertebral compression fracture	External measurement of kyphosis (Flexicurve ruler) at 12 months	Multimodal: Manual therapy, taping and stretching exercises	6 sessions over 12 weeks; Home stretches daily	203	72.4 (9.3)	86	General education session	196	71.9 (9.6)	89	N (follow-up)
Barker, 2020	Osteoporotic males/females with at least one vertebral compression fracture	External measurement of kyphosis (Flexicurve ruler) at 4 months	Strength, balance, and flexibility exercise program	6 sessions over 12 weeks; Home exercise 3-5 days per week	216	72.2 (8.4)	86	General education session	196	71.9 (9.6)	89	Y (Exercise program of 3-months or less duration, older patient at risk of osteoporosis)

Barker, 2020	Osteoporotic males/females with at least one vertebral compression fracture	External measurement of kyphosis (Flexicurve ruler) at 12 months	Strength, balance, and flexibility exercise program	6 sessions over 12 weeks; Home exercise 3-5 days per week	216	72.2 (8.4)	86	General education session	196	71.9 (9.6)	89	N (follow-up)
Bautman, 2010	Elderly females with osteoporosis	External measurement (Spinal mouse: degree of kyphosis) at 3 months	Multi modal: rehabilitation including spinal manipulation, taping, and strength and flexibility exercises	18 sessions over 12 weeks; Home exercises daily	29	75.2 (1.3)	100	Wait list physiotherapy	19	77.6 (1.6)	100	Y (Multimodal care of 3-months or less duration, older patient at risk of osteoporosis)
Benedetti, 2008	Flexed posture, over 65 yrs	External measurement (Occiput to wall distance (cm)) at 3 months	Strength and flexibility exercises targeting improving a flexed posture	1 hour, 2 days per week over 3 months	15	71.5 (4.3)	80	General postural exercises	13	71.5 (4.9)	76.9	N (no similar control)
Bennell, 2010	Osteoporotic, over 50 yrs	External measurement (Dualer electric inclinometer: degree of kyphosis) at 11 weeks	Multimodal: physiotherapy including manual therapy (massage and spinal mobilisation), taping, and strength and flexibility exercises	10 weekly sessions over 10 weeks; Home exercises daily	11	66.2 (8.0)	64	No treatment	9	68.3 (11.8)	100	Y (Multimodal care of 3-months or less duration, older patient at risk of osteoporosis)
Bergstrom, 2011	Postmenopausal women with kyphosis	External measurement (Debrunner kyphometer: degree of kyphosis) at 4 months	Strength and flexibility exercises targeting improving a flexed posture	1 hour group training 2 days per week over 4 months	15	73.2 (8.9)	100	No treatment	13	74.1 (6.0)	100	N (no outcome measurement data reported)
Bulut, 2019	Females with osteoporosis	External measurement of kyphosis (Inclinometer) at 3 weeks	Taping for 3 weeks and standard home osteoporosis exercises twice a day for 6 weeks	3 weeks	20	63.1 (8.8)	100	Standard home osteoporosis exercises twice a day for 6 weeks	22	64.0 (7.1)	100	N (no similar intervention)

Bulut, 2019	Females with osteoporosis	External measurement of kyphosis (Inclinometer) at 6 weeks	Taping for 3 weeks and standard home osteoporosis exercises twice a day for 6 weeks	3 weeks	20	63.1 (8.8)	100	Standard home osteoporosis exercises twice a day for 6 weeks	22	64.0 (7.1)	100	N (no similar intervention)
Cergel, 2019	Postmenopausal females with osteoporosis	External measurement of kyphosis (Inclinometer) at 6 weeks	Supervised group strengthening exercise program	3 times per week over 6 weeks	20	58.9 (4.7)	100	No treatment	20	59.7 (6.5)	100	Y (Exercise program of 3-months or less duration, older patient at risk of osteoporosis)
Cergel, 2019	Postmenopausal females with osteoporosis	External measurement of kyphosis (Inclinometer) at 6 weeks	Home structured strengthening exercise program	3 times per week over 6 weeks	20	60.2 (7.6)	100	No treatment	20	59.7 (6.5)	100	N (no similar intervention)
Gibbs, 2020	Osteoporotic females with at least one vertebral compression fracture	Occiput to wall distance at 12 months	Individual strengthening, flexibility, and balance exercise program	6 sessions over 8 months; Home exercises daily	71	76.4 (6.4)	100	General home educational sessions	70	77.0 (7.3)	100	Y (Exercise program of more than 3-months duration, older patient at risk of osteoporosis)
Greendale, 2009	Hyperkyphosis, over 60 yrs	External measurement (Debrunner kyphometer: degree of kyphosis) at 6 months	Hatha yoga addressing strength, flexibility, and proprioception	1 hour, 3 times per week over 24 weeks	55	74.5 (7.6)	83	General educational sessions	50	76.5 (7.2)	80	Y (Exercise program of more than 3-months duration, older patient at risk of osteoporosis)
Greendale, 2009	Hyperkyphosis, over 60 yrs	External measurement (Flexicurve ruler: kyphosis index (%)) at 6 months	Hatha yoga addressing strength, flexibility, and proprioception	1 hour, 3 times per week over 24 weeks	55	74.5 (7.6)	83	General educational sessions	50	76.5 (7.2)	80	N (different outcome measure)
Greendale, 2009	Hyperkyphosis, over 60 yrs	External measurement (Flexicurve ruler: degree of kyphosis) at 6 months	Hatha yoga addressing strength, flexibility, and proprioception	1 hour, 3 times per week over 24 weeks	55	74.5 (7.6)	83	General educational sessions	50	76.5 (7.2)	80	N (different outcome measure)

Hosseinabadi, 2020	Over 60 yrs with thoracic angle over 50 degrees	External measurement of kyphosis (Inclinometer) at 13 weeks	Spinomed brace	3 months	22	66.9 (5.7)	Not reported	No treatment	22	68.5 (5.7)	Not reported	N (shorter intervention period)
Itoi, 1994	Estrogen defficient females	Xray measurement (Cobb angle: degree of kyphosis) at 2 years	Home strength exercises	5 times per week over 2 years	32	55.3 (Not reported)	100	No treatment	28	55.9 (Not reported)	100	N (no similar intervention)
Jaromi, 2012	Nurses with chronic low back pain, less than 60 yrs	External measurement (Zebris WinSpine Pointer Posture 3D ultrasonic biomechanical movement analysis system: degree of kyphosis) at 6 weeks	Strength, flexibility, postural exercises and back school	Once per week over 6 weeks; Home exercises 5 times per week	56	32.3 (8.15)	82	Passive physiotherapy (TENS and heat therapy)	55	31.5 (8.25)	85.5	Y (Exercise program of 3-months or less duration, younger patient)
Jaromi, 2012	Nurses with chronic low back pain, less than 60 yrs	External measurement (Zebris WinSpine Pointer Posture 3D ultrasonic biomechanical movement analysis system: degree of kyphosis) at 6 months	Strength, flexibility, postural exercises and back school	Once per week over 6 weeks; Home exercises 5 times per week	56	32.3 (8.15)	82	Passive physiotherapy (TENS and heat therapy)	55	31.5 (8.25)	85.5	N (follow-up)
Jaromi, 2012	Nurses with chronic low back pain, less than 60 yrs	External measurement (Zebris WinSpine Pointer Posture 3D ultrasonic biomechanical movement analysis system: degree of kyphosis) at 1 year	Strength, flexibility, postural exercises and back school	Once per week over 6 weeks; Home exercises 5 times per week	56	32.3 (8.15)	82	Passive physiotherapy (TENS and heat therapy)	55	31.5 (8.25)	85.5	N (follow-up)
Kaijser, 2019	Osteoporotic females, over 60 yrs	External measurement (Flexicurve ruler: kyphosis index (%)) at 6 months	Strength, balance and postural exercises	1 hour once per week over 6 months; Home exercises 4 times per week	38	Median (IQR): 77.6 (67.3-84.1)	100	No treatment	37	Median (IQR): 72.8 (67.5-78.2)	100	N (no outcome measurement data reported)
Kaijser, 2019	Osteoporotic females, over 60 yrs	External measurement (Flexicurve ruler: kyphosis index (%)) at 6 months	Spinomed brace	6 months	38	Median (IQR): 77.9 (68.0-83.4)	100	No treatment	37	Median (IQR): 72.8 (67.5-78.2)	100	N (no outcome measurement data reported)

Katzman Parimi, 2017	Hyperkyphosis, over 60 yrs	Xray measurement (Cobb angle: degree of kyphosis) at 3 months	Strength, flexibility and postural group exercises	1 hour two times per week over 3 months; Home exercises daily	53	69.4 (5.8)	Not reported	Waitlist	48	70.0 (5.7)	Not reported	Y (Exercise program of 3-months or less duration, older patient at risk of osteoporosis)
Katzman Parimi, 2017	Hyperkyphosis, over 60 yrs	External measurement (Debrunner kyphometer: degree of kyphosis) at 3 months	Strength, flexibility and postural group exercises	1 hour two times per week over 3 months; Home exercises daily	53	69.4 (5.8)	Not reported	Waitlist	48	70.0 (5.7)	Not reported	N (different outcome measure)
Katzman Vittinghoff, 2017	Hyperkyphosis, over 60 yrs	Xray measurement (Cobb angle: degree of kyphosis) at 6 months	Strength, flexibility and postural group exercises	1 hour three times per week over 6 months; Home exercises daily	51	71.0 (6.5)	69	General educational sessions	48	70.2 (5.7)	75	Y (Exercise program of more than 3-months duration, older patient at risk of osteoporosis)
Katzman Vittinghoff, 2017	Hyperkyphosis, over 60 yrs	External measurement (Debrunner kyphometer: degree of kyphosis) at 6 months	Strength, flexibility and postural group exercises	1 hour three times per week over 6 months; Home exercises daily	51	71.0 (6.5)	69	General educational sessions	48	70.2 (5.7)	75	N (different outcome measure)
Muyor, 2012	Female with prolonged occupational standing posture, 35-50 yrs	External measurement (Spinal mouse: degree of kyphosis) standing at 12 weeks	Hamstring stretches	Half an hour three times per week over 12 weeks	27	44.9 (9.6)	100	No treatment	31	43.6 (8.6)	100	N (no similar intervention)
Muyor, 2012	Female with prolonged occupational standing posture, 35-50 yrs	External measurement (Spinal mouse: degree of kyphosis) in forward flexion at 12 weeks	Hamstring stretches	Half an hour three times per week over 12 weeks	27	44.9 (9.6)	100	No treatment	31	43.6 (8.6)	100	N (no similar intervention)
Naderi, 2019	Men with hyperkyphosis, over 65 yrs	External measurement (Flexicurve ruler: degree of kyphosis) at 12 weeks	Strength and flexibility exercises	3 sessions per week over 12 weeks	12	68.8 (2.7)	0	No treatment	12	69.5 (2.6)	0	Y (Exercise program of 3-months or less duration, older patient

												at risk of osteoporosis)
Pfeifer, 2004	Osteoporotic females, over 60 yrs	External measurement (3D photomorphometry: degree of kyphosis) at 6 months	Spinomed brace	6 months	31	72.8 (7.1)	100	No treatment	31	72.3 (6.7)	100	Y (Brace, older patient at risk of osteoporosis)
Pfeifer, 2011	Osteoporotic females, over 60 yrs	External measurement (3D photomorphometry: degree of kyphosis) at 6 months	Spinomed brace	6 months	36	72.8 (7.1)	100	No treatment	36	69.7 (8.9)	100	Y (Brace, older patient at risk of osteoporosis, data combined)
Pfeifer, 2011	Osteoporotic females, over 60 yrs	External measurement (3D photomorphometry: degree of kyphosis) at 6 months	Spinomed active brace	6 months	36	72.3 (6.7)	100	No treatment	36	69.7 (8.9)	100	Y (Brace, older patient at risk of osteoporosis, data combined)
Seidi, 2014	Hyperkyphosis, 18-25 yrs	External measurement (Flexicurve ruler: degree of kyphosis) at 12 weeks	Local corrective strength and flexibility exercises	3 sessions per week over 12 weeks	19	Not reported	47	No treatment	19	Not reported	52.6	Y (Exercise program of 3-months or less duration, younger patient; data combined)
Seidi, 2014	Hyperkyphosis, 18-25 yrs	External measurement (Flexicurve ruler: degree of kyphosis) at 12 weeks	Comprehensive corrective strength and flexibility exercises	3 sessions per week over 12 weeks	18	Not reported	50	No treatment	19	Not reported	52.6	Y (Exercise program of 3-months or less duration, younger patient; data combined)
Seidi, 2020	Males with upper cross syndrome, 18-28 yrs	External measurement (Flexicurve ruler: degree of kyphosis) at 8 weeks	Comprehensive corrective strength and flexibility exercises	3 sessions per week over 8 weeks	12	25.3 (2.5)	0	No treatment	12	25.4 (1.5)	0	Y (Exercise program of 3-months or less duration, younger patient)
Seidi, 2020	Males with upper cross syndrome, 18-28 yrs	External measurement (Flexicurve ruler: degree of kyphosis) at 12 weeks	Comprehensive corrective strength and flexibility exercises	3 sessions per week over 8 weeks	12	25.3 (2.5)	0	No treatment	12	25.4 (1.5)	0	N (follow-up)

Senthil, 2017	Hyperkyphosis, 35-55 yrs	External measurement (Posture Pro 8 Postural Analysis photogrammetry: posture number) at 8 weeks	Sspecific strength, flexibility, and postural exercises	Home exercises 3 times per day, 4 days per week over 8 weeks	30	Not reported	Not reported	Isometric strength, flexibility, and postural exercises	30	Not reported	Not reported	N (no similar intervention or control)
Tarasi, 2019	Students with kyphosis over 42 degrees	External measurement of kyphosis (Flexicurve ruler) at 12 weeks	Group strengthing, flexibility, and postural exercise program	3 1 hour sessions per week over 12 weeks	47	23.8 (not reported)	Not reported	No treatment	50	23.8 (not reported)	Not reported	Y (Exercise program of 3-months or less duration, younger patient)
Toprak, 2015	University students, 18-25 yrs	External measurement (Spinal mouse: degree of kyphosis) at 8 weeks	Group spinal stabilisation exercise and postural education	3 days per week over 8 weeks	24	21.0 (1.1)	50	Postural education	24	20.1 (1.0)	33.3	N (no similar control)
Toprak, 2015	University students, 18-25 yrs	External measurement (Spinal mouse: degree of kyphosis) at 8 weeks	Postural education and electrical stimulation	3 days per week over 8 weeks	24	19.7 (1.2)	50	Postural education	24	20.1 (1.0)	33.3	N (no similar intervention)
Toprak, 2015	University students, 18-25 yrs	External measurement (Spinal mouse: degree of kyphosis) at 8 weeks	Postural education and biofeedback training	3 days per week over 8 weeks	24	20.0 (1.0)	63	Postural education	24	20.1 (1.0)	33.3	N (no similar intervention)
Toprak, 2017	University students, 18-25 yrs	External measurement (Spinal mouse: degree of kyphosis) at 8 weeks	Group spinal stabilisation exercise	8 weeks	28	21.0 (1.3)	54	No treatment	25	20.4 (1.2)	48	Y (Exercise program of 3-months or less duration, younger patient)
Vaughn, 2007	University students, 20-65 yrs	External measurement (Flexicurve ruler: degree of kyphosis) at 13 weeks	Strength and flexibility exercises	4 days per week over 13 weeks	32	Not reported	69	No treatment	39	Not reported	66.7	Y (Exercise program of 3-months or less duration, younger patient)
Watson, 2019	Osteoporotic postmenopausal females, over 60 yrs	Xray measurement (Cobb angle (endplate): degree of kyphosis) at 8 months	Specific strength and impact-loading exercises	2 times per week over 8 months	20	64 (4)	100	Low intensity general strength exercise	23	64 (5)	100	N (no similar control)

Watson, 2019	Osteoporotic postmenopausal females, over 60 yrs	Xray measurement (Cobb angle (body): degree of kyphosis) at 8 months	Specific strength and impact-loading exercises	2 times per week over 8 months	20	64 (4)	100	Low intensity general strength exercise	23	64 (5)	100	N (different outcome measure)
Watson, 2019	Osteoporotic postmenopausal females, over 60 yrs	External measurement (Inclinometer: degree of kyphosis) relaxed standing at 8 months	Specific strength and impact-loading exercises	2 times per week over 8 months	20	64 (4)	100	Low intensity general strength exercise	23	64 (5)	100	N (different outcome measure)
Watson, 2019	Osteoporotic postmenopausal females, over 60 yrs	External measurement (Flexicurve ruler: kyphosis index (%)) at 8 months	Specific strength and impact-loading exercises	2 times per week over 8 months	20	64 (4)	100	Low intensity general strength exercise	23	64 (5)	100	N (different outcome measure)
Watson, 2019	Osteoporotic postmenopausal females, over 60 yrs	External measurement (Inclinometer: degree of kyphosis) tall standing at 8 months	Specific strength and impact-loading exercises	2 times per week over 8 months	20	64 (4)	100	Low intensity general strength exercise	23	64 (5)	100	N (different outcome measure)

Key: IQR Interquartile range; SD standard deviation

Table 2: Risk of bias of included studies

Study	Selection Bias: Was the method of randomisation adequate?	Selection Bias: Was the intervention allocation concealed?	Selection Bias: Were the groups similar at baseline measurement regarding the most important prognostic	Performance Bias: Was the patient blinded to the intervention?	Performance Bias: Was the practitioner blinded to the intervention?	Detection Bias: Was the outcome assessor blinded to the intervention or using objective outcome measures?	Detection Bias: Was the primary outcome measurement tool reliable?	Attrition Bias: Was incomplete outcome data described and within reasonable limits?	Reporting Bias: Is the study free of suggestion of selective reporting?	Other bias: Is the study free of any other likely sources of bias?
Balbas-Alvarez, 2018	Y	Y	Y	N	N	Y	Y	Y	Y	Y
Barker, 2020	Y	Y	Y	N	N	Y	Y	Y	Y	Y
Bautman 2010	Y	Y	Y	N	N	Y	Y	Y	Y	Y
Benedetti 2008	N	N	Y	N	N	Y	Y	N	Y	Y
Bennell 2010	Y	Y	Y	N	N	Y	Y	Y	Y	Y
Bergstrom 2011	Y	N	Y	N	N	Y	Y	Y	N	N
Bulut, 2019	Y	N	N	N	N	N	Y	Y	Y	N
Cergel, 2019	Y	N	Y	N	N	Y	Y	Y	Y	Y
Gibbs, 2020	Y	N	Y	N	N	Y	Y	Y	Y	Y
Greendale 2009	Y	Y	Y	N	N	Y	Y	Y	Y	Y
Hosseinabadi	Y	Y	Y	N	N	Y	Y	Y	Y	Y
Itoi, 1994	N	N	Y	N	N	Y	Y	Y	Y	Y
Jaromi 2012	Y	N	Y	N	N	Y	Y	Y	Y	N
Kaijser 2019	Y	Y	N	N	N	Y	Y	Y	N	Y

Katzman Parimi 2017	Y	Y	N	N	N	Y	Y	Y	Y	Y
Katzman Vittinghoff, 2017	Y	Y	Y	N	N	Y	Y	Y	Y	Y
Muyor, 2012	Y	N	Y	N	N	Y	Y	Y	Y	Y
Naderi, 2019	N	N	Y	N	N	Y	Y	N	N	Y
Pfeifer, 2004	N	N	Y	N	N	Y	Y	Y	Y	Y
Pfeifer, 2011	N	N	Y	N	N	Y	Y	Y	Y	Y
Seidi, 2014	Y	Y	Y	N	N	Y	Y	Y	Y	Y
Seidi, 2020	Y	Y	Y	N	N	N	Y	Y	Y	Y
Senthil, 2017	Y	Y	Y	N	N	Y	Y	Y	Y	Y
Tarasi, 2019	N	N	Y	N	N	N	Y	N	Y	Y
Toprak 2015	N	N	Y	N	N	Y	Y	Y	N	Y
Toprak, 2017	Y	N	Y	N	N	Y	Y	Y	Y	Y
Vaughn, 2007	Y	N	Y	N	N	Y	Y	Y	Y	Y
Watson, 2019	Y	Y	Y	N	N	Y	Y	N	N	Y

Key: Y low risk of bias; N high risk of bias

Table 3: Results of included studies

		Intervention group				Control group					
Study	**Outcome measure and timing**	**Description**	**Sample size**	**Mean baseline kyphosis in degrees (SD)**	**Mean post-intervention kyphosis in degrees (SD)**	**Description**	**Sample size**	**Mean baseline kyphosis in degrees (SD)**	**Mean post-intervention kyphosis in degrees (SD)**	**Difference in means in degrees (95% CI)**	**Standardised difference in means (95% CI)**
Exercise interventions											
Barker, 2020	External measurement of kyphosis (Flexicurve ruler) at 4 months	Strength, balance, and flexibility exercise program	170	51.2 (34.8)	Not reported	General education session	167	49.1 (40.6)	Not reported	-1.0 (-9.6, 7.7)	-0.0 (-0.2, 0.2)
Barker, 2020	External measurement of kyphosis (Flexicurve ruler) at 12 months	Strength, balance, and flexibility exercise program	152	51.2 (34.8)	Not reported	General education session	167	49.1 (40.6)	Not reported	-4.2 (-13.4, 5.1)	-0.1 (-0.3, 0.1)
Benedetti, 2008	External measurement (Occiput to wall distance (cm)) at 3 months	Strength and flexibility exercises targeting improving a flexed posture	15	7.4cm (2.0)	6.0cm (1.9)	General postural exercises	13	8.5cm (2.6)	7.9cm (2.3)	-0.9cm (-2.9, 1.2)	-0.3 (-1.0, 0.5)
Bergstrom, 2011	External measurement (Debrunner kyphometer: degree of kyphosis) at 4 months	Strength and flexibility exercises targeting improving a flexed posture	15	38.1 (11.9)	Not reported	No treatment	13	45.7 (8.8)	Not reported	No post-intervention data reported - results stated no significant change	Not estimable

Cergel, 2019	External measurement of kyphosis (Inclinometer) at 6 weeks	Supervised group strengthening exercise program	20	46.4 (8.8)	41.3 (7.2)	No treatment	20	42.6 (6.7)	42.9 (6.6)	-5.4 (-11.9, 1.1)	-0.5 (-1.2, 0.1)
Cergel, 2019	External measurement of kyphosis (Inclinometer) at 6 weeks	Home structured strengthening exercise program	20	42.1 (7.2)	40.7 (6.1)	No treatment	20	42.6 (6.7)	42.9 (6.6)	-1.8 (-7.0, 3.5)	-0.2 (-0.8, 0.4)
Gibbs, 2020	External measurement (Occiput to wall distance (cm)) at 12 months	Individual strengthening, flexibility, and balance exercise program	71	5.3cm (4.0)	5.3cm (4.4)	Educational sessions	70	6.2cm (4.7)	6.1cm (3.9)	0.1cm (-0.7, 1.0)	0.1 (-0.3, 0.4)
Greendale, 2009	External measurement (Debrunner kyphometer: degree of kyphosis) at 6 months	Hatha yoga addressing strength, flexibility, and proprioception	55	56.2 (95%CI: 51.7, 63.7)	Not reported	Educational sessions	50	58.7 (95%CI: 49.0, 65.5)	Not reported	-1.7 (-5.3, 1.9)	-0.1 (-0.5, 0.3)
Greendale, 2009	External measurement (Flexicurve ruler: kyphosis index (%)) at 6 months	Hatha yoga addressing strength, flexibility, and proprioception	55	16% (95%CI: 14, 18)	Not reported	Educational sessions	50	16% (95%CI: 14, 19)	Not reported	0.0 (0.0, 0.0)	-0.5 (-0.9, -0.1)
Greendale, 2009	External measurement (Flexicurve ruler: degree of kyphosis) at 6 months	Hatha yoga addressing strength, flexibility, and proprioception	55	36.1 (95%CI: 31.6, 39.8)	Not reported	Educational sessions	50	36.6 (95%CI: 31.3, 41.7)	Not reported	-1.8 (-3.7, 0.2)	-0.3 (-0.6, 0.1)

Itoi, 1994	Xray measurement (Cobb angle: degree of kyphosis) at 2 years	Home strength exercises	32	34.1 (11.2)	35.7 (10.2)	No treatment	28	34.2 (8.4)	34.3 (9.2)	1.6 (-1.1, 4.3)	0.3 (-0.2, 0.8)
Jaromi, 2012	External measurement (Zebris WinSpine Pointer Posture 3D ultrasonic biomechanical movement analysis system: degree of kyphosis) at 6 weeks	Strength, flexibility, postural exercises and back school	56	Not reported	Not reported	Passive physiotherapy (TENS and heat therapy)	55	Not reported	Not reported	-28.4 (-30.7, -26.1)	-4.6 (-5.3, -3.9)
Jaromi, 2012	External measurement (Zebris WinSpine Pointer Posture 3D ultrasonic biomechanical movement analysis system: degree of kyphosis) at 6 months	Strength, flexibility, postural exercises and back school	56	Not reported	Not reported	Passive physiotherapy (TENS and heat therapy)	55	Not reported	Not reported	-28.4 (-30.7, -26.1)	-4.6 (-5.3, -3.9)

Jaromi, 2012	External measurement (Zebris WinSpine Pointer Posture 3D ultrasonic biomechanical movement analysis system: degree of kyphosis) at 1 year	Strength, flexibility, postural exercises and back school	56	Not reported	Not reported	Passive physiotherapy (TENS and heat therapy)	55	Not reported	Not reported	-27.3 (-29.9, -24.7)	-3.9 (-4.6, -3.3)
Kaijser, 2019	External measurement (Flexicurve ruler: kyphosis index (%)) at 6 months	Strength, balance and postural exercises	38	Not reported	Not reported	No treatment	37	Not reported	Not reported	No post-intervention data reported - results stated no significant change	Not estimable
Katzman Parimi, 2017	Xray measurement (Cobb angle: degree of kyphosis) at 3 months	Strength, flexibility and postural group exercises	53	57.5 (13.6)	Not reported	Waitlist	48	54.2 (10.4)	Not reported	-1.7 (-3.1, -0.3)	-0.4 (-0.8, 0.0)
Katzman Parimi, 2017	External measurement (Debrunner kyphometer: degree of kyphosis) at 3 months	Strength, flexibility and postural group exercises	53	51.4 (7.9)	Not reported	Waitlist	48	52.7 (7.0)	Not reported	-4.8 (-6.3, -3.3)	-0.9 (-1.3, -0.5)

Katzman Vittinghoff, 2017	Xray measurement (Cobb angle: degree of kyphosis) at 6 months	Strength, flexibility and postural group exercises	51	56.8 (12.2)	Not reported	Educational sessions	48	57.9 (12.9)	Not reported	-3.0 (-4.6, -1.4)	-0.5 (-0.9, -0.1)
Katzman Vittinghoff, 2017	External measurement (Debrunner kyphometer: degree of kyphosis) at 6 months	Strength, flexibility and postural group exercises	51	54.1 (8.2)	Not reported	Educational sessions	48	54.1 (9.1)	Not reported	-2.9 (-4.8, -1.0)	-0.4 (-0.8, -0.0)
Muyor, 2012	External measurement (Spinal mouse: degree of kyphosis) standing at 12 weeks	Hamstring stretches	27	31.9 (10.3)	32.6 (10.1)	No treatment	31	32.7 (9.2)	34.0 (10.1)	-0.6 (-6.0, 4.7)	-0.0 (-0.6, 0.5)
Muyor, 2012	External measurement (Spinal mouse: degree of kyphosis) in forward flexion at 12 weeks	Hamstring stretches	27	45.8 (8.5)	37.3 (8.0)	No treatment	31	43.7 (8.6)	42.9 (10.9)	-7.7 (-12.5, -2.8)	-0.6 (-1.1, -0.1)
Naderi, 2019	External measurement (Flexicurve ruler: degree of kyphosis) at 12 weeks	Strength and flexibility exercises	12	59.3 (5.3)	51.8 (4.5)	No treatment	12	57.7 (2.9)	55.7 (2.0)	-5.6 (-9.9, -1.2)	-0.8 (-1.7, 0.0)

Seidi, 2014	External measurement (Flexicurve ruler: degree of kyphosis) at 12 weeks	Local corrective strength and flexibility exercises	19	48.1 (2.0)	43.0 (2.1)	No treatment	19	46.6 (2.0)	45.9 (2.0)	-4.4 (-5.8, -3.0)	-1.6 (-2.3, -0.8)
Seidi, 2014	External measurement (Flexicurve ruler: degree of kyphosis) at 12 weeks	Comprehensive corrective strength and flexibility exercises	18	47.3 (2.1)	35.0 (2.3)	No treatment	19	46.6 (2.0)	45.9 (2.0)	-11.6 (-13.1, -10.2)	-4.0 (-5.1, -2.8)
Seidi, 2020	External measurement (Flexicurve ruler: degree of kyphosis) at 8 weeks	Comprehensive corrective strength and flexibility exercises	12	47.9 (2.6)	36.3 (1.9)	No treatment	12	46.7 (1.8)	47.3 (2.1)	-12.1 (-13.8, -10.4)	-5.4 (-7.2, -3.5)
Seidi, 2020	External measurement (Flexicurve ruler: degree of kyphosis) at 12 weeks	Comprehensive corrective strength and flexibility exercises	12	47.9 (2.6)	38.2 (1.2)	No treatment	12	46.7 (1.8)	47.2 (2.3)	-10.2 (-11.7, -8.6)	-5.0 (-6.8, -3.3)
Senthil, 2017	External measurement (Posture Pro 8 Postural Analysis photogrammetry: posture number) at 8 weeks	Sspecific strength, flexibility, and postural exercises	30	17.6 posture number (4.2)	7.7 posture number (3.8)	General, non-specific exercise	30	16.7 posture number (2.9)	12.6 posture number (2.6)	-5.7 posture number (-7.6, -3.9)	-1.2 (-1.8, -0.7)
Tarasi, 2019	External measurement of kyphosis (Flexicurve ruler) at 12 weeks	Group strengthing, flexibility, and postural exercise program	47	48.0 (3.0)	40.8 (2.3)	No treatment	50	47.7 (2.8)	48.0 (3.0)	-7.6 (-8.3, -6.9)	-4.3 (-5.1, -3.6)

Toprak, 2015	External measurement (Spinal mouse: degree of kyphosis) at 8 weeks	Group spinal stabilisation exercise and postural education	24	43.3 (2.2)	34.2 (2.1)	Postural education	24	39.5 (1.7)	Not reported	-7.0 (-10.7, -3.4)	-1.1 (-1.7, -0.5)
Toprak, 2017	External measurement (Spinal mouse: degree of kyphosis) at 8 weeks	Group spinal stabilisation exercise	28	Median (IQR): 44.5 (37.0, 48.8)	Median (IQR): 36.5 (28.3, 41.5)	No treatment	25	Median (IQR): 42.0 (34.0, 48.0)	Median (IQR): 42.0 (31.0, 48.0)	-8.0 (-10.9, -5.1)	-1.5 (-2.1, -0.9)
Vaughn, 2007	External measurement (Flexicurve ruler: degree of kyphosis) at 13 weeks	Strength and flexibility exercises	32	46.4 (8.7)	43.4 (9.6)	No treatment	39	44.6 (12.5)	45.1 (13.4)	-3.5 (-6.7, -0.4)	-0.5 (-1.0, -0.1)
Watson, 2019	Xray measurement (Cobb angle (endplate): degree of kyphosis) at 8 months	Specific strength and impact-loading exercises	20	29.6 (9.6)	29.6 (9.1)	Low intensity general strength exercise	23	31.5 (11.4)	30.8 (10.1)	0.6 (-2.1, 3.3)	0.1 (-0.5, 0.7)
Watson, 2019	Xray measurement (Cobb angle (body): degree of kyphosis) at 8 months	Specific strength and impact-loading exercises	20	32.2 (9.2)	31.1 (10.5)	Low intensity general strength exercise	23	33.4 (12.3)	33.9 (11.3)	-1.5 (-4.3, 1.3)	-0.3 (-0.9, 0.3)

Watson, 2019	External measurement (Inclinometer: degree of kyphosis) relaxed standing at 8 months	Specific strength and impact-loading exercises	20	49.6 (8.6)	44.9 (7.6)	Low intensity general strength exercise	23	44.5 (9.5)	40.3 (6.2)	-0.5 (-4.5, 3.5)	-0.1 (-0.7, 0.5)
Watson, 2019	External measurement (Flexicurve ruler: kyphosis index (%)) at 8 months	Specific strength and impact-loading exercises	20	11.0% (2.8)	8.9% (2.4)	Low intensity general strength exercise	23	10.6% (2.6)	8.7% (2.4)	-0.2% (-1.6, 1.2)	-0.1 (-0.7, 0.5)
Watson, 2019	External measurement (Inclinometer: degree of kyphosis) tall standing at 8 months	Specific strength and impact-loading exercises	20	43.1 (9.0)	37.8 (8.8)	Low intensity general strength exercise	23	35.0 (10.2)	33.0 (7.1)	-3.3 (-8.0, 1.4)	-0.4 (-1.0, 0.2)
Multimodal interventions											
Balbas-Alvarez, 2018	External measurement (Flexicurve ruler: kyphosis index (%)) at 4 weeks	Multimodal: manual therapy, exercises, and inspiratory muscle training	26	10.1% (1.7)	8.7% (1.5)	Inspiratory muscle training	25	8.9% (2.3)	8.5% (2.4)	-0.9% (-1.5, -0.3)	-0.6 (-1.2, -0.1)
Barker, 2020	External measurement of kyphosis (Flexicurve ruler) at 4 months	Manual therapy, taping and stretching exercises	173	48.6 (22.4)	Not reported	No treatment	167	49.1 (40.6)	Not reported	0.7 (-5.2, 6.9)	0.0 (-0.2, 0.2)

Barker, 2020	External measurement of kyphosis (Flexicurve ruler) at 12 months	Manual therapy, taping and stretching exercises	156	48.6 (22.4)	Not reported	No treatment	167	49.1 (40.6)	Not reported	-1.9 (-10.4, 6.6)	-0.1 (-0.3, 0.2)
Bautman, 2010	External measurement (Spinal mouse: degree of kyphosis) at 3 months	Multi modal: rehabilitation including spinal manipulation, taping, and strength and flexibility exercises	29	52.5 (2.2)	49.1 (2.0)	Wait list physiotherapy	19	52.8 (3.6)	54.8 (3.6)	-5.4 (-7.0, -3.8)	-1.4 (-2.0, -0.7)
Bennell, 2010	External measurement (Dualer electric inclinometer: degree of kyphosis) at 11 weeks	Multimodal: physiotherapy including manual therapy (massage and spinal mobilisation), taping, and strength and flexibility exercises	11	59 (9)	56 (10)	No treatment	9	58 (12)	58 (12)	-3.0 (-7.8, 1.8)	-0.6 (-1.5, 0.3)
Bracing											
Hosseinabadi, 2020	External measurement of kyphosis (Inclinometer) at 13 weeks	Spinomed brace	22	55.3 (1.1)	43.5 (1.2)	No treatment	22	54.7 (1.1)	56.7 (1.1)	-13.8 (-16.9, -10.8)	-2.7 (-3.5, -1.9)
Kaijser, 2019	External measurement (Flexicurve ruler: kyphosis index (%)) at 6 months	Spinomed brace	38	Not reported	Not reported	No treatment	37	Not reported	Not reported	No post-intervention data reported - results stated no significant change	Not estimable

Pfeifer, 2004	External measurement (3D photomorphometry: degree of kyphosis) at 6 months	Spinomed brace	31	74.2 (9.8)	Not reported	No treatment	31	70.8 (9.9)	Not reported	-6.3 (-9.0, -3.7)	-1.2 (-1.7, -0.7)
Pfeifer, 2011	External measurement (3D photomorphometry: degree of kyphosis) at 6 months	Spinomed brace	36	74.2 (9.8)	Not reported	No treatment	36	70.8 (9.9)	Not reported	-6.3 (-8.8, -3.9)	-1.2 (-1.7, -0.7)
Pfeifer, 2011	External measurement (3D photomorphometry: degree of kyphosis) at 6 months	Spinomed active brace	36	72.7 (10.2)	Not reported	No treatment	36	70.8 (9.9)	Not reported	-6.5 (-10.4, -2.6)	-0.2 (-0.6, 0.3)
Taping											
Bulut, 2019	External measurement of kyphosis (Inclinometer) at 3 weeks	Taping for 3 weeks and standard home osteoporosis exercises twice a day for 6 weeks	20	57.1 (10.3)	55.9 (9.8)	General exercise	22	56.0 (9.3)	55.1 (9.9)	-0.4 (-1.5, 0.6)	-0.3 (-0.9, 0.4)
Bulut, 2019	External measurement of kyphosis (Inclinometer) at 6 weeks	Taping for 3 weeks and standard home osteoporosis exercises twice a day for 6 weeks	20	57.1 (10.3)	56.4 (10.1)	General exercise	22	56.0 (9.3)	55.1 (9.7)	0.2 (-1.0, 1.3)	0.1 (-0.5, 0.7)
Electrical stimulation											

Toprak, 2015	External measurement (Spinal mouse: degree of kyphosis) at 8 weeks	Postural education and electrical stimulation	24	43.6 (1.6)	37.0 (2.5)	Postural education	24	39.5 (1.7)	Not reported	-4.5 (-9.3, 0.2)	-0.6 (-1.1, 0.0)
Biofeedback training											
Toprak, 2015	External measurement (Spinal mouse: degree of kyphosis) at 8 weeks	Postural education and biofeedback training	24	42.5 (2.0)	Not reported	Postural education	24	39.5 (1.7)	Not reported	-0.9 (-5.8, 3.9)	-0.1 (-0.7, 0.5)

Key: SD standard deviation; 95%CI 95% confidence interval; IQR interquartile range

Figures

Figure 1 Prisma flowchart of study selection

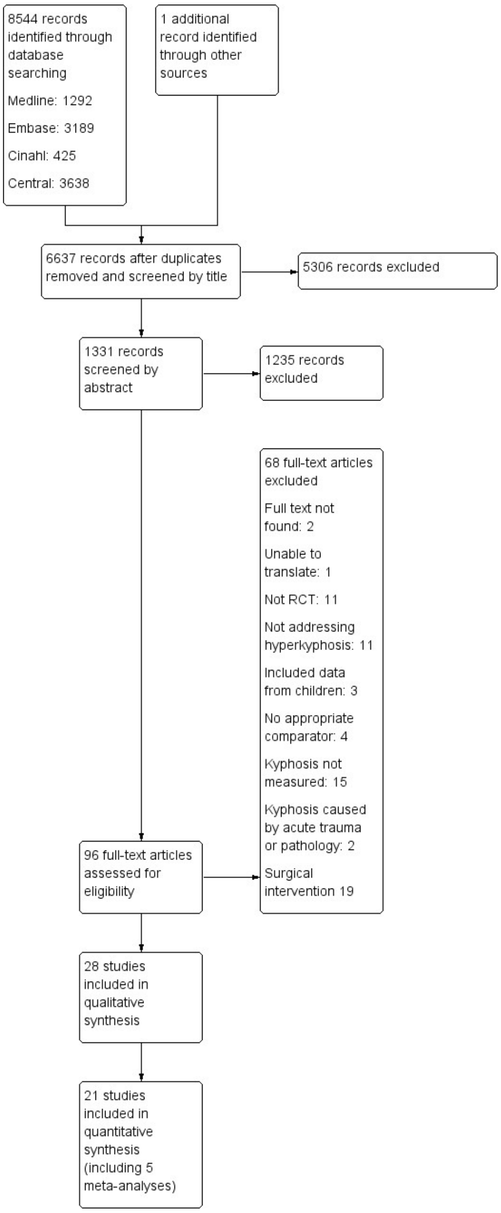

Figure 2 Forest plot of meta-analyses

Subgroup	Intervention Mean	Intervention SD	Intervention Total	Control Mean	Control SD	Control Total	Weight	Std. Mean Difference IV, Random, 95% CI
Short-term (≤3 months) exercise program in younger adults compared to no treatment								
Jaromi 2012a	−28.75	7.64	56	−0.36	4.29	55	17.1%	−4.54 [−5.25, −3.83]
Seidi 2014	−8.65	8.52	38	−0.62	2.76	19	17.3%	−1.11 [−1.69, −0.52]
Seidi 2020a	−11.56	2.97	12	0.53	0.83	12	14.1%	−5.35 [−7.19, −3.51]
Tarasi 2019	−7.24	2.04	47	0.34	1.38	50	17.0%	−4.34 [−5.08, −3.60]
Toprak 2017	−8	6.85	28	0	2.22	25	17.2%	−1.51 [−2.13, −0.90]
Vaughn 2007	−3.02	6.08	32	0.51	6.99	39	17.4%	−0.53 [−1.01, −0.05]
Subtotal (95% CI)			**213**			**200**	**100.0%**	**−2.81 [−4.32, −1.29]**
Heterogeneity: $Tau^2 = 3.38$; $Chi^2 = 147.95$, df = 5 ($P < 0.00001$); $I^2 = 97\%$								
Test for overall effect: Z = 3.63 (P = 0.0003)								
Short-term (≤3 months) exercise program in older adults compared to no treatment								
Barker 2020c	−4.21	40.63	170	−3.26	40.33	167	42.0%	−0.02 [−0.24, 0.19]
Cergel 2019a	−5.05	11	20	0.35	9.1	20	17.3%	−0.52 [−1.16, 0.11]
Katzman Parimi 2017a	−1.4	4.72	53	0.3	4.82	48	29.2%	−0.35 [−0.75, 0.04]
Naderi 2019	−7.5	6.56	12	−1.95	6.36	12	11.5%	−0.83 [−1.67, 0.01]
Subtotal (95% CI)			**255**			**247**	**100.0%**	**−0.30 [−0.62, 0.02]**
Heterogeneity: $Tau^2 = 0.05$; $Chi^2 = 6.22$, df = 3 ($P = 0.10$); $I^2 = 52\%$								
Test for overall effect: Z = 1.82 (P = 0.07)								
Long-term (>3 months) exercise program in older adults compared to no treatment								
Gibbs 2020	−0.01	2.44	71	−0.15	2.84	70	36.3%	0.05 [−0.28, 0.38]
Greendale 2009a	−3	9.88	55	−1.33	15.25	50	32.5%	−0.13 [−0.51, 0.25]
Katzman Vittinghoff 2017a	−3.3	5.69	51	−0.3	5.34	48	31.2%	−0.54 [−0.94, −0.14]
Subtotal (95% CI)			**177**			**168**	**100.0%**	**−0.19 [−0.53, 0.15]**
Heterogeneity: $Tau^2 = 0.05$; $Chi^2 = 5.03$, df = 2 ($P = 0.08$); $I^2 = 60\%$								
Test for overall effect: Z = 1.10 (P = 0.27)								
Long-term (>3 months) bracing in older adults compared to no treatment								
Pfeiffer 2004	−7.9	4.9	31	−1.6	5.5	31	37.1%	−1.19 [−1.74, −0.65]
Pfeiffer 2011	−8	8.14	72	−1.6	5.5	36	62.9%	−0.86 [−1.28, −0.44]
Subtotal (95% CI)			**103**			**67**	**100.0%**	**−0.99 [−1.32, −0.65]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.91$, df = 1 ($P = 0.34$); $I^2 = 0\%$								
Test for overall effect: Z = 5.84 (P < 0.00001)								
Short-term (≤3 months) multimodal care in older adults compared to no treatment								
Barker 2020a	−2.58	9.31	173	−3.26	40.33	167	38.1%	0.02 [−0.19, 0.24]
Bautman 2010	−3.4	2.92	29	2	4.92	19	33.0%	−1.39 [−2.03, −0.74]
Bennell 2010	−3.2	5.9	11	−0.2	3.7	9	28.9%	−0.57 [−1.47, 0.33]
Subtotal (95% CI)			**213**			**195**	**100.0%**	**−0.61 [−1.58, 0.35]**
Heterogeneity: $Tau^2 = 0.62$; $Chi^2 = 17.41$, df = 2 ($P = 0.0002$); $I^2 = 89\%$								
Test for overall effect: Z = 1.25 (P = 0.21)