Clinical Rehabilitation

Corrective exercise-based therapy for adolescent idiopathic scoliosis: Systematic review and meta-analysis.

Journal:	*Clinical Rehabilitation*
Manuscript ID	CRE-2021-11652.R1
Manuscript Type:	Original Research Article
Date Submitted by the Author:	29-Nov-2021
Complete List of Authors:	Gámiz-Bermúdez, Francisca; Andalusian Health Service, Poniente de Almería Health District Obrero-Gaitán, Esteban; University of Jaén, Health Sciences Zagalaz-Anula, Noelia; University of Jaén, Health Sciences Lomas-Vega, Rafael; University of Jaén, Health Sciences
Keywords:	Scoliosis, exercise therapy, exercise movement techniques, meta-analysis

Abstract

Objective: to analyse the efficacy of Corrective exercise-based therapy in the improvement of deformity and quality of life in adolescent idiopathic scoliosis.

Data Sources: PubMed Medline, Scopus, Web of Science, Physiotherapy Evidence Database, CINAHL Complete and SciELO, until June 2021.

Review methods: Randomized controlled trials was selected, including participants diagnosed with adolescent idiopathic scoliosis, in which the experimental group received Corrective exercise-based therapy. Two authors independently searched the scientific literature in the data sources, extracted the data and assessed the risk of bias. A pairwise meta-analysis using the random-effects model was performed.

Results: Eight randomized controlled trials providing data from 279 adolescent idiopathic scoliosis patients were included. Seven randomized controlled trials including 236 patients showed moderate-quality evidence for a medium effect (SMD=-0.52, 95% CI -0.96 to -0.1), favouring corrective exercise-based therapy for spinal deformity reduction. Corrective exercise-based therapy was better than no intervention (SMD=-0.59, 95% CI -1.18 to -0.01) but similar to other intervention (SMD=-0.2, 95% CI -0.67 to 0.27), and a medium effect was found (SMD=-0.51, 95% CI -0.89 to -0.13) when corrective exercise-based therapy was used with other therapies. Four studies including 151 patients showed low-quality evidence of a large effect of Corrective exercise-based therapy on Scoliosis Research Society measurement (SRS-22) total score improvement (SMD=1.16, 95% CI 0.36 to 1.95).

Conclusion: In mild and moderate adolescent idiopathic scoliosis patients, corrective

exercise-based therapy could be used to reduce spinal deformity and to improve quality of life as isolated treatment or as coadjuvant treatment combined with other therapeutic resources.

Corrective exercise-based therapy for adolescent idiopathic scoliosis: Systematic review and meta-analysis.

Francisca Gámiz-Bermúdez, MSc[1], Esteban Obrero-Gaitán, PhD[2], Noelia Zagalaz-Anula, PhD[2,*], Rafael Lomas-Vega, PhD[2]

Affiliations: [1]Poniente de Almería Health District. Andalusian Health Service, (Adra) Spain. [2]Department of Health Sciences, University of Jaén, Jaén, Spain

Corresponding author: [*]Noelia Zagalaz-Anula, Department of Health Sciences (Building B3, Office 214). University of Jaén. Campus Las Lagunillas s/n, 23071 Jaén, Spain. E-mail: nzagalaz@ujaen.es

Abstract

Objective: to analyse the efficacy of Corrective exercise-based therapy in the improvement of deformity and quality of life in adolescent idiopathic scoliosis.

Data Sources: PubMed Medline, Scopus, Web of Science, Physiotherapy Evidence Database, CINAHL Complete and SciELO, until June 2021.

Review methods: Randomized controlled trials was selected, including participants diagnosed with adolescent idiopathic scoliosis, in which the experimental group received Corrective exercise-based therapy. Two authors independently searched the scientific literature in the data sources, extracted the data and assessed the risk of bias. A pairwise meta-analysis using the random-effects model was performed.

Results: Eight randomized controlled trials providing data from 279 adolescent idiopathic scoliosis patients were included. Seven randomized controlled trials including 236 patients showed moderate-quality evidence for a medium effect (SMD=-0.52, 95% CI -0.96 to -0.1), favouring corrective exercise-based therapy for spinal deformity reduction. Corrective exercise-based therapy was better than no intervention (SMD=-0.59, 95% CI -1.18 to -0.01) but similar to other intervention (SMD=-0.2, 95% CI -0.67 to 0.27), and a medium effect was found (SMD=-0.51, 95% CI -0.89 to -0.13) when corrective exercise-based therapy was used with other therapies. Four studies including 151 patients showed low-quality evidence of a large effect of Corrective exercise-based therapy on Scoliosis Research Society measurement (SRS-22) total score improvement (SMD=1.16, 95% CI 0.36 to 1.95).

Conclusion: In mild and moderate adolescent idiopathic scoliosis patients, corrective exercise-based therapy could be used to reduce spinal deformity and to improve quality of life as isolated treatment or as coadjuvant treatment combined with other therapeutic resources.

INTRODUCTION

Corrective exercise-based therapy is a common therapeutic resource that has been recommended by the guidelines developed in 2011 by the International Scientific Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT).[1] The exercises used to treat adolescent idiopathic scoliosis are usually called physiotherapy scoliosis-specific exercises and are derived from schools, such as the Scientific Exercises Approach to Scoliosis or the Catharina Schroth methods.[2] Corrective exercise-based therapy has been recommended as the first step to treat adolescent idiopathic scoliosis to prevent or limit progression of the deformity, whereas the use of braces has been recommended in patients with evolutive idiopathic scoliosis above 25° during growth.[3] However, these recommendations are not based on strong evidence, and the research has focused on knowing the effect of corrective exercise-based therapy to improve the main outcome variables (spinal deformity and quality of life) when compared with observation or with other conservative treatments, such as spinal orthosis (brace) or spinal tractions, or when combined with these other options.

The profusion of studies of varying quality and therapeutic approaches has led some to locate the available evidence and synthesize it in different systematic reviews.[4–6] However, the reviews often lack quantitative synthesis, and some meta-analyses have focused on the effect of specific treatment methods, introducing a large number of studies of dubious quality, which challenges the validity of their conclusions. Currently, the number of randomised clinical trials available may be appropriate to globally synthesize the effect of corrective exercise-based therapy on trials of sufficient quality to reach valid results.

Therefore, the research question for this systematic review was:

1. Does corrective exercise-based therapy improve spinal deformity and quality of life compared with other interventions or no intervention in patients with adolescent idiopathic scoliosis?

METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[7] was used to carry out this systematic review with meta-analysis, which was previously registered in the PROSPERO International Prospective Register of Systematic Reviews (identification number CRD42020197164).[8]

Two authors (Francisca Gámiz-Bermúdez and Noelia Zagalaz-Anula) independently searched the scientific literature in the PubMed Medline, Scopus, Web of Science (WOS), PEDro (Physiotherapy Evidence Database), CINAHL Complete and SciELO databases until June 6, 2021. In addition, reference lists from retrieved full-text studies, guidelines, expert documents and previous reviews were consulted in this literature search. According to the Cochrane Library recommendations, the PICOS tool[9] was used to identify potential studies with our search strategy. No filters related to language and publication date were established. A third author (Esteban Obrero-Gaitán) was consulted about doubts related to the bibliographic search. In Supplementary Table 1, the search strategy employed in each database is shown.

Two authors (Francisca Gámiz-Bermúdez and Noelia Zagalaz-Anula) independently screened the potential studies by title/abstract. A study was examined in detail if an author selected it during the initial screening. Disagreements were resolved by consultation with a third author (Rafael Lomas-Vega).

The inclusion criteria were as follows: (1) studies including participants diagnosed with adolescent idiopathic scoliosis aged between 10 years and skeletal maturity; (2) studies in which the experimental group received corrective exercise; (3) studies in which the control group received other therapies, such as bracing or observation only or no intervention; (4) studies assessing the effect on the Cobb angle or quality of life of participants after applying the exercise programs; and (5) studies following the experimental design of randomized controlled trials or controlled clinical trials; (6) quantitative data available to carry out the meta-analysis. The proposed exclusion criteria are listed as follows: (1) studies in which the sample did not comprise only participants with adolescent idiopathic scoliosis; (2) studies without valid comparison groups that did not undergo exercise therapy; and (3) studies that did not provide sufficient data for inclusion in the quantitative synthesis of this review (mean, standard deviation).

Two independent reviewers (Francisca Gámiz-Bermúdez and Noelia Zagalaz-Anula) extracted data from the included studies using a standardized Excel data-collection form. A third author (Rafael Lomas-Vega) was consulted to resolve the issues that arose. Data extracted from each selected study were authorship and publication date, study design, sample characteristics of the experimental and control groups (sample size, age, gender ratio and initial Cobb angle) and characteristics of the experimental and control intervention (type of intervention and duration of the protocol therapy in weeks, number of sessions per week and minutes per session). Finally, we extracted data related to the outcomes (Cobb angle and Quality of life) following validation procedures.[9,10]

The main outcome measure was spine deformity (primary outcome), measured with the Cobb angle, which is considered the gold standard measure to evaluate the degrees of deformation of the spine curvature in adolescent idiopathic scoliosis.[11] The secondary outcome was Quality of life measured with instruments as the Scoliosis Research Society[12] measurement (SRS-22) and its different dimensions[13] or other Quality of life instruments.

The methodological quality of the included studies was assessed with the Cochrane Collaboration Risk of Bias Tool[14] by two authors (Francisca Gámiz-Bermúdez and Noelia Zagalaz-Anula) independently, and disagreements were resolved by a third author (Rafael Lomas-Vega). Also, the quality of evidence of the meta-analysis findings was assessed using The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) assessment.[15]

One author (Esteban Obrero-Gaitán) performed the meta-analysis using *Comprehensive Meta-Analysis version 3.0* software (Biostat, Englewood, NJ, USA).[16] The suggestions of Cooper et al. (2009)[17] presented in the *Handbook of Research Synthesis and Meta-Analysis* and Higgins and Green (2011)[9] in the Cochrane Handbook for Systematic Reviews of Interventions were taken into account to develop the meta-analysis. Meta-analysis was carried out only if at least two studies provided outcome data. Pooled effects were calculated using Cohen's standardized mean difference (SMD)[18] and its 95% confidence interval (95% CI) in a random-effects model proposed by DerSimonian and Laird with the aim of generalizing our findings. Cohen's SMD is interpreted as small (SMD 0.2), medium (SMD 0.5) and large (SMD > 0.8).[19] In addition, we calculated the mean difference (MD) in a random-effects model. Forest plots were used to display the findings in each meta-analysis.[20]

The risk of publication bias was estimated by visualizing the funnel plot (symmetry indicates low risk and asymmetry indicates high risk),[21] with Egger's test (*p-value* < 0.1 indicates risk of publication bias)[22] and with the trim-and-fill method. We used the trim-and-fill method to estimate the adjusted pooled effect (adjusted SMD), taking into account any possible risk of publication bias.[23] When the adjusted SMD varied more than 10% with respect to the original and raw pooled effects, the quality level of evidence was downgraded one level, although the funnel plot was slightly asymmetrical.[24]

The leave-one-out method (or one study removed) was used in the sensitivity analysis. - This method involves performing a meta-analysis on each subset of the studies obtained by leaving out exactly one study.[17] It shows how each individual study affects the overall estimate of the rest of the studies assessing the contribution of each study to the pooled effect in each meta-analysis.[17]

After assessing the effect of corrective exercise-based therapy (with or without other interventions) versus other interventions or no intervention on Cobb angle and quality of life (overall meta-analysis), subgroup analyses were conducted to assess possible differences in the effect according to the use alone or combined with corrective exercise-based therapy in comparison to other therapies.

RESULTS

A total of 324 records were identified from the initial database search. After excluding duplicates using Mendeley v 1.19.8, 180 references were screened by title/abstract. One hundred fifty-one references were excluded for not being relevant or not meeting the inclusion criteria. Finally, 8 randomized controlled trials[25–32] were included in this review. Figure 1 shows the PRISMA flow chart depicting the bibliographic search reports and the study selection process.

Eight randomized controlled trials[25–32] provided 23 independent comparisons and reporting data of 279 adolescents with adolescent idiopathic scoliosis with a mean age of 12.7 ± 1.22 years old and a mean initial Cobb angle of 33.87 ± 13.18 degrees. Of the total participants, approximately 86.4% were girls (approximation using data provided only by seven studies).[26–32] One hundred forty-five participants comprised the experimental intervention group and 134 the comparison control group. Experimental interventions duration in weeks was from 1 to 52 weeks; performed between 1 and 7 sessions per week; and with a duration in minutes from 10 to 120 min. The specific comparisons identified were: (1) corrective exercise-based therapy versus observation or no intervention; (2) corrective exercise-based therapy versus orthotic intervention; and (3) corrective exercise-based therapy in combination with other interventions versus others. The spinal deformation using the Cobb angle was obtained from seven studies.[25–28,30–32] Second, we obtained the effect of corrective exercise-based therapy on quality of life, assessed with the Scoliosis Research Society 22 measurement (SRS-22) from four studies.[27–29,32] On quality of life, we also obtained the effect of corrective exercise-based therapy on different domains of the Scoliosis Research Society 22 measurement (SRS-22), such as pain,[27,29,32] function,[27,29,32] self-perceived image[27,29,32] and mental health.[27,32] Table 1 shows the main characteristics of the studies included in the review.

The Cochrane Collaboration Risk of Bias Tool[14] (Supplementary Table 2) indicated risk of bias mainly in the sections of Concealment of Randomization Sequence, Blinding of Participants and Blinding of Outcomes Assessors.

Seven studies[25–28,30–32] with seven independent comparisons provided data from 236 participants with a mean age of 12.68 ± 1.37 years and an initial mean Cobb angle of 32.52 ± 10.41 degrees. Moderate-quality evidence of a medium effect of corrective exercise-based therapy on Cobb angle (SMD -0.526; 95% CI -0.96 to -0.1; *p* 0.018) was reported favoring corrective exercise-based therapy in comparison to other therapies or simple observations (Figure 2, Table 2). Experimental intervention (corrective exercise-based therapy) reduced the Cobb angle by -2.15 degrees (CI 95% -3.92 to -0.36; *p* 0.018) compared to other therapies or no intervention. The funnel plot was slightly symmetric, and trim-and-fill estimation did not report effect variation with respect to the original SMD (Supplementary Figure 1). The sensitivity analysis yielded pooled estimates that varied by 31% (SMD -0.354), excluding Vieira-Toledo, PC et al. 2011.[31]

The subgroup analyses reported very low-quality evidence of a medium effect of corrective exercise-based therapy versus simple observation[28,31] (SMD -0.59; 95% CI -1.18 to -0.01; *p* 0.049), reducing the Cobb angle by -4.33 degrees (95% CI -6.77 to -1.9; p < 0.001). In addition, low-quality evidence of a medium effect of corrective exercise-based therapy [26,27,30] (SMD -0.51; 95% CI -0.89 to -0.13; *p* 0.008) combined with other therapies in comparison with others showed that a reduction in Cobb angle degrees favoring corrective exercise-based therapy of -2.33 (95% CI -3.91 to -0.74; *p* 0.004) (Table 2). However, no statistically significant differences were found between corrective exercise-based therapy and orthotic intervention[25,32] (SMD -0.2; 95% CI, -0.67 to 0.27; *p* 0.41). A funnel plot with subgroup analysis is shown in Supplementary Figure 2.

Four studies[27–29,32] with four independent comparisons provided data from 151 participants (mean age 13.17 ± 0.7 years old and initial mean Cobb angle of 36.58 ± 10.52 degrees). Low-quality evidence of a large effect of corrective exercise-based therapy on Quality of life (SMD 1.16; 95% CI 0.36 to 1.95; *p* 0.004) was found to favor corrective exercise-based therapy in comparison to other therapies or no intervention (Figure 3, Table 2). In addition, an increase of 1.14 points (95% CI 0.38 to 1.9; *p* 0.004) on the Scoliosis Research Society 22 measurement (SRS-22) was produced by corrective exercise-based therapy in contrast to other therapies or no intervention. The asymmetric funnel plot and the trim-and-fill estimation (SMD adjusted 1.29 and 13% of variation with respect to the original SMD) showed a possible risk of publication bias (Supplementary Figure 3). No heterogeneity was present (Table 2), and the precision level was low (37.8 participants per study). The sensitivity analysis (leave-one-out method) yielded pooled estimates that varied by 34% (SMD = 0.78) with respect to the original pooled estimate when Zheng, Y et al. 2018[32] was identified. Subgroup analyses are shown in Table 2.

Finally, a meta-analysis to assess the effect of corrective exercise-based therapy compared to others or no intervention on each dimension of the Scoliosis Research Society 22 measurement (SRS-22) (pain, function, self-perceived image and mental health) was carried out. The results are summarized in Table 2.

DISCUSSION

Our results showed moderate-quality evidence of a medium effect of corrective exercise-based therapy over the main outcome in adolescent idiopathic scoliosis, spinal deformity measured with the Cobb angle. Regarding Quality of life, our results showed low-quality evidence for a large effect of corrective exercise-based therapy intervention over the total Scoliosis Research Society 22 measurement (SRS-22) score. Although the quality evidence of the effect on the main dimensions of quality of life is limited, corrective exercise-based therapy seems to show a medium or large effect on pain, self-image and mental health but not on function.

Some reviews with meta-analyses have focused on specific exercise modalities, such as the Schroth Method. In these works, the admission of many types of studies and the incomplete analysis of the quality of the evidence have made it difficult to draw valid conclusions.[6] In reviews with more demanding eligibility criteria, the number of randomized controlled trials has been very limited, which has led to the attainment of very low-quality evidence.[33] Our work combined the pooled effect of all types of corrective exercises, showing moderate-quality evidence for the main outcome variable, spinal deformity measured with the Cobb angle.

The most complete meta-analysis on this issue developed to date is that of Thompson et al.[4] However, our results differ greatly from those of this work due to the different concepts of exercises. Whereas Thomson et al. compared the exercises included in physiotherapy scoliosis-specific exercises schools versus other exercise modalities, we considered comparisons of any type of corrective exercise with other therapies, such as observation, orthosis or usual care. Some studies that Thompson et al. included in their review have been rejected with our criteria because they compare different exercise modalities.[34–37]

The most recent systematic review analysed the effectiveness of core exercise for improving spinal deformity and quality of life in patients with adolescent idiopathic scoliosis, finding a low or very low quality of evidence for a positive effect of this exercise modality.[38] However, seven randomized controlled trials using Core, Schroth and Scientific Exercises Approach to Scoliosis (SEAS) exercises were included in this meta-analysis. With the eligibility criteria of this review, types of exercises that coincide with the concept of physiotherapy scoliosis-specific exercises with others that are usually included in "Core work" were included. We also found in this review some studies that included exercise groups in the comparison group, with which there is the same problem as in the aforementioned study.

Regarding spinal deformity measured with the Cobb angle, our results support the use of corrective exercise-based therapy as a single therapy in mild and moderate spinal curvatures. It showed a similar effect to orthopaedic techniques, such as traction or brace. Additionally, when corrective exercise-based therapy is performed alongside usual care or traditional rehabilitation, there does appear to be an additional benefit compared to performing usual care or traditional rehabilitation without exercise. Our work showed medium effect sizes for spinal deformity improvement, whereas other work has shown small effect sizes for braces when compared with only observation.[39]

Regarding the effect size of corrective exercise-based therapy on quality of life dimensions, globally, corrective exercise-based therapy offers better results than other types of management, showing a large effect on the Scoliosis Research Society 22 measurement (SRS-22). Scoliosis Research Society 22 measurement total score, with low-quality evidence. The improvement in Scoliosis Research Society 22 measurement dimensions seems to be better when using corrective exercise-based therapy compared to other options, and this occurs for all dimensions, except for the function, but with low or very low-quality evidence. Compared with other reviews, our results showed better effect sizes for quality of life improvement for corrective exercise-based therapy than those obtained with braces in the majority of the Quality of life dimensons.[39,40]

This study has several limitations. First, the low number of studies included in each meta-analysis could affect the generalizability of the results. Secondly, the inability to blind both participants and therapists identified with the Cochrane Collaboration Risk of Bias Tool may increase the risk of selection bias. Furthermore, it is important to consider the possible risk of publication bias. Thirdly, we may have failed to identify some studies not registered in the databases used. Another limitation is the low number of participants per study, which reduces the precision of our findings. Finally, in the sensitivity analysis, a variation in the original combined effect of more than 20% was found, which may affect the quality of our findings.

In light of the results of this review, clinicians should consider the use of corrective exercise alone or in combination with the use of orthoses for the treatment of mild to moderate adolescent idiopathic scoliosis. Future studies should clarify the effect of the different corrective exercise modalities as well as the most appropriate dose in terms of number and duration of therapeutic sessions.

In conclusion, there is moderate-quality evidence that corrective exercise-based therapy has a medium effect on the magnitude of the curve reduction in subjects with adolescent idiopathic scoliosis. There is very low-quality evidence that corrective exercise-based therapy is better than no intervention but no better than orthotic management, and there is low-quality evidence that the joint use of exercises combined with usual care is better than usual care alone. There is low-quality evidence that corrective exercise-based therapy has a large effect on quality of life in subjects with adolescent idiopathic scoliosis when compared to other options. There is very low-quality evidence of a medium effect of corrective exercise-based therapy when combined with other options for improving quality of life. Corrective exercise-based therapy is probably better than other options to improve the pain, self-perceived image and mental health quality of life dimensions. Due to the low quality of this evidence, more research is needed to clarify the most effective combination therapy to improve the main results in adolescent idiopathic scoliosis subject management. Additionally, the evidence is insufficient to probe whether exercise modality is more effective in improving spinal deformity and quality of life.

Clinical messages

- Corrective exercise-based therapy can decrease spinal deformity and improve quality of life in adolescent idiopathic scoliosis, whether used as single therapy or in combination with usual care.

- The quality of evidence found is moderate to low, which diminishes the strength of these recommendations and indicates the need for more research.

REFERENCES

1. Negrini S, Aulisa AG, Aulisa L, et al. 2011 SOSORT guidelines: Orthopaedic and Rehabilitation treatment of idiopathic scoliosis during growth. *Scoliosis* 2012; 7: 3.
2. Berdishevsky H, Lebel VA, Bettany-Saltikov J, et al. Physiotherapy scoliosis-specific exercises - a comprehensive review of seven major schools. *Scoliosis spinal Disord* 2016; 11: 20.
3. Negrini S, Donzelli S, Aulisa AG, et al. *2016 SOSORT guidelines: Orthopaedic and rehabilitation treatment of idiopathic scoliosis during growth*. Scoliosis and Spinal Disorders, 2018. Epub ahead of print 2018. DOI: 10.1186/s13013-017-0145-8.
4. Thompson JY, Williamson EM, Williams MA, et al. Effectiveness of scoliosis-specific exercises for adolescent idiopathic scoliosis compared with other non-surgical interventions: a systematic review and meta-analysis. *Physiotherapy (United Kingdom)*. Epub ahead of print 2019. DOI: 10.1016/j.physio.2018.10.004.
5. Anwer S, Alghadir A, Abu Shaphe M, et al. Effects of Exercise on Spinal Deformities and Quality of Life in Patients with Adolescent Idiopathic Scoliosis. *Biomed Res Int*; 2015. Epub ahead of print 2015. DOI: 10.1155/2015/123848.
6. Park JH, Jeon HS, Park HW. Effects of the Schroth exercise on idiopathic scoliosis: A meta-analysis. *Eur J Phys Rehabil Med* 2018; 54: 440–449.
7. Moher D, Liberati A, Tetzlaff J, et al. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *J Clin Epidemiol* 2009; 62: 1006–1012.
8. Obrero-Gaitán E, Lomas-Vega R, Zagalaz-Anula N, et al. Effectiveness of Specific Physical Exercise in the treatment of Structured Spine deformations in Patients with Idiopathic Scoliosis. A Systematic Review with Meta-Analysis. PROSPERO 2020 CRD42020197164.
9. Higgins JPT, Green S. *Cochrane Handbook for Systematic Reviews of Intervention Version 5.1.0 [updated March 2011]*. London, UK: The Cochrane Collaboration, 2011.
10. Hozo SP, Djulbegovic B, Hozo I. Estimating the mean and variance from the median, range, and the size of a sample. *BMC Med Res Methodol* 2005; 5: 13.
11. Coelho DM, Bonagamba GH, Oliveira AS. Scoliometer measurements of patients with idiopathic scoliosis. *Brazilian J Phys Ther* 2013; 17: 179–184.
12. Asher MA, Lai SM, Glattes RC, et al. Refinement of the SRS-22 Health-Related Quality of Life Questionnaire Function Domain. *Spine (Phila Pa 1976)* 2006; 31: 593–597.
13. Glattes RC, Burton DC, Lai SM, et al. The Reliability and Concurrent Validity of the Scoliosis Research Society-22r Patient Questionnaire Compared With the Child Health Questionnaire-CF87 Patient Questionnaire for Adolescent Spinal Deformity. *Spine (Phila Pa 1976)* 2007; 32: 1778–1784.
14. Higgins JPT, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool

for assessing risk of bias in randomised trials. *BMJ* 2011; 343: d5928.
15. Atkins D, Best D, Briss PA, et al. Grading quality of evidence and strength of recommendations. *BMJ* 2004; 328: 1490.
16. Borenstein M, Hedges L, Higgins J, et al. Comprehensive meta-analysis software version 3.
17. Cooper H, Hedges L, Valentine J. *The Handbook of Research Synthesis and Meta-Analysis*. 3rd ed. New York: Russell Sage Foundation, 2019.
18. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. New York, New York: Academic Press, 1977.
19. Faraone S V. Interpreting estimates of treatment effects: Implications for managed care. *P T* 2008; 33: 700–711.
20. Rücker G, Schwarzer G. Beyond the forest plot: The drapery plot. *Res Synth Methods*. Epub ahead of print April 2020. DOI: 10.1002/jrsm.1410.
21. Sterne JAC, Egger M. Funnel plots for detecting bias in meta-analysis: Guidelines on choice of axis. *J Clin Epidemiol* 2001; 54: 1046–1055.
22. Egger M, Smith GD, Schneider M, et al. Bias in meta-analysis detected by a simple , graphical test measures of funnel plot asymmetry. *Bmj* 1997; 315: 629–34.
23. Duval S, Tweedie R. Trim and fill: A simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics* 2000; 56: 455–463.
24. Rothman KJ, Greenland S, Lash TL. *Modern epidemiology*. Lippincott Williams & Wilkins, 2008.
25. Dickson RA, Leatherman KD. Cotrel traction, exercises, casting in the treatment of idiopathic scoliosis. A pilot study and prospective randomized controlled clinical trial. *Acta Orthop Scand* 1978; 49: 46–48.
26. Gao C, Zheng Y, Fan C, et al. Could the Clinical Effectiveness Be Improved Under the Integration of Orthotic Intervention and Scoliosis-Specific Exercise in Managing Adolescent Idiopathic Scoliosis?: A Randomized Controlled Trial Study. *Am J Phys Med Rehabil* 2019; 98: 642–648.
27. Gür G, Ayhan C, Yakut Y. The effectiveness of core stabilization exercise in adolescent idiopathic scoliosis: A randomized controlled trial. *Prosthet Orthot Int* 2017; 41: 303–310.
28. Kuru T, Yeldan İ, Dereli EE, et al. The efficacy of three-dimensional Schroth exercises in adolescent idiopathic scoliosis: a randomised controlled clinical trial. *Clin Rehabil* 2016; 30: 181–190.
29. Schreiber S, Parent EC, Moez EK, et al. The effect of Schroth exercises added to the standard of care on the quality of life and muscle endurance in adolescents with idiopathic scoliosis-an assessor and statistician blinded randomized controlled trial: 'SOSORT 2015 Award Winner'. *Scoliosis* 2015; 10: 24.
30. Schreiber S, Parent EC, Khodayari Moez E, et al. Schroth Physiotherapeutic Scoliosis-Specific Exercises Added to the Standard of Care Lead to Better Cobb Angle Outcomes in Adolescents with Idiopathic Scoliosis - an Assessor and Statistician Blinded Randomized Controlled Trial. *PLoS One* 2016; 11: e0168746.
31. Toledo PCV, Mello DB de, Araújo ME, et al. Efeitos da Reeducação Postural Global em escolares com escoliose. *Fisioter e Pesqui* 2011; 18: 329–334.
32. Zheng Y, Dang Y, Yang Y, et al. Whether Orthotic Management and Exercise are Equally Effective to the Patients With Adolescent Idiopathic Scoliosis in Mainland China?: A Randomized Controlled Trial Study. *Spine (Phila Pa 1976)*

2018; 43: E494–E503.

33. Burger M, Coetzee W, du Plessis LZ, et al. The effectiveness of Schroth exercises in adolescents with idiopathic scoliosis: A systematic review and meta-analysis. *South African J Physiother* 2019; 75: 904.
34. Monticone M, Ambrosini E, Cazzaniga D, et al. Active self-correction and task-oriented exercises reduce spinal deformity and improve quality of life in subjects with mild adolescent idiopathic scoliosis. Results of a randomised controlled trial. *Eur spine J Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc* 2014; 23: 1204–1214.
35. Diab AA. The role of forward head correction in management of adolescent idiopathic scoliotic patients: a randomized controlled trial. *Clin Rehabil* 2012; 26: 1123–1132.
36. Wan L, Wang G, Rong B. Exercise therapy in treatment of essential S-shaped scoliosis: Evaluation of Cobb angle in breast and lumbar segment through a follow-up of half a year. *Chin J Clin Rehabil* 2005; 9: 82–84.
37. Kim G, HwangBo P-N. Effects of Schroth and Pilates exercises on the Cobb angle and weight distribution of patients with scoliosis. *J Phys Ther Sci* 2016; 28: 1012–1015.
38. Li X, Shen J, Liang J, et al. Effect of core-based exercise in people with scoliosis: A systematic review and meta-analysis. *Clin Rehabil* 2021; 35: 669–680.
39. Zhang Y, Li X. Treatment of bracing for adolescent idiopathic scoliosis patients: a meta-analysis. *Eur spine J Off Publ Eur Spine Soc Eur Spinal Deform Soc Eur Sect Cerv Spine Res Soc* 2019; 28: 2012–2019.
40. Meng Z-D, Li T-P, Xie X-H, et al. Quality of life in adolescent patients with idiopathic scoliosis after brace treatment: A meta-analysis. *Medicine (Baltimore)* 2017; 96: e6828.

Table 1. Characteristics of the Studies Included in the Review

		EXPERIMENTAL GROUP								CONTROL GROUP				
		Sample Characteristics				Intervention Characteristics				Sample Characteristics				
Authorship, date and country	**K**	**N_e**	**Age mean**	**Initial CA mean**	**Female**	**Type**	**Weeks**	**Ses/ week**	**Min**	**N_c**	**Age mean**	**Initial CA mean**	**Female**	**Type Control**
Dickson, RA et al 1978 (USA)	2	10	13.6	40	NR	SSE	1.14	7	120	10	13.1	42	NR	Traction
Gao, C et al 2019 (China)	3	23	12.2 (10-14)	29.13 ± 4.32	78%	SEAS + Brace	24	7	10–15	22	12.1 (10-14)	28.64 ± 3.91	81%	Brace
Gur, G et al 2017 (Turkey)	3	12	14.2 ± 1.8	35 ± 11.82	92%	Core + Traditional	10	2	60	13	14 ± 1.6	31.4 ± 6.97	100%	Brace
Kuru, T et al 2016 (Turkey)	1	15	12.9 ± 1.4	33.4 ± 8.9	93%	Schroth	24	3	90	15	12.8 ± 1.2	30.3 ± 30.3	87%	Observation
Schreiber, S et al 2015 (Canada)	3	23	13.5 (12.7-14.2)	29.1 (25.4-32.8)	100%	Schroth + UC	24	1	60	20	13.3 (12.7-13.9)	27.9 (24.3-31.5)	100%	UC
Schreiber, S et al 2016 (Canada)	3	23	13.5 (12.7-14.2)	29.1 (25.4-32.8)	100%	Schroth + UC	24	1	60	20	13.3 (12.7-13.9)	27.9 (24.3-31.5)	100%	UC
Vieira-Toledo, PC et al 2011 (Brazil)	1	10	10	15.1 ± 2.51	45%	GPR	12	2	25–30	10	10	14.7 ± 3.77	45%	Observation
Zheng, Y et al 2018 (China)	2	29	12.4 ± 0.9	27 ± 3.6	75%	SEAS	52	1	40	24	12.3 ± 0.8	28 ± 3.6	80%	Brace

K=Number of comparisons provided. N=Total Sample Size. Ne=Experimental group sample size. CA=Cobb Angle. Ses=Sessions. Min=Minutes. N=Control group sample size. SSE=Scoliosis Specific Exercise. NR=No Reported. DHE=Daily Home Exercises. GPR=Global Postural Reeducation. SEAS=Scientific Exercise Approach to Scoliosis UC = Usual Care.

Table 2. Main Findings in Meta-Analyses

		SUMMARY OF FINDINGS								QUALITY EVIDENCE GRADE ASSESSMENT				
					EFFECT SIZE		PUBLICATION BIAS							
		K	N	N_s	SMD	95% CI	Funnel Plot	Trim-and-fill (% var)	Risk	Incons. I^2 (%)	Indirect.	Imprec.	Risk of bias	Quality
SPINAL DEFORMITY (COBB ANGLE)														
Corrective exercise-based therapy vs Others (overall)		7	236	33.7	-0.52	-0.96, -0.1	Sym	0%	No	No; 13.08%	No	Yes	Yes	Moderate
Corrective exercise-based therapy vs Simple Observation		2	50	25	-0.59	-1.18, -0.01	-	-	Prob	Yes; 80%	No	Yes	Yes	Very Low
Corrective exercise-based therapy vs Orthotic Intervention		2	73	36.5	-0.2	-0.67, 0.27	-	-	Prob	Yes; 69%	No	Yes	Yes	Very Low
Corrective exercise-based therapy + Others vs Others		3	113	37.6	-0.51	-0.89, -0.13	Sym	0%	No	No; 12%	No	Yes	Yes	Low
QUALITY OF LIFE (SRS-22)														
SRS-22 Dimension	**Comparison**													
Total Score	***(Corrective exercise-based therapy vs Others)***	4	151	37.8	1.16	0.36, 1.95	Asym	13%	Yes	No; 0.92%	No	Yes	Yes	Low
	(Corrective exercise-based therapy + Others vs Others)	2	68	34	0.76	0.29, 1.23	-	-	Prob	No; 0%	No	Yes	Yes	Very Low
Pain	***(Corrective exercise-based therapy vs Others)***	3	111	37	0.86	0.2, 1.54	Sym	0%	No	No; 7.9%	No	Yes	Yes	Low
	(Corrective exercise-based therapy + Others vs Others)	2	68	34	1.17	0.44, 1.89	-	-	Prob	No; 0%	No	Yes	Yes	Very Low
Function	***(Corrective exercise-based therapy vs Others)***	3	111	37	0.79	-0.17, 1.76	Sym	0%	No	No; 0%	No	Yes	Yes	Low
	(Corrective exercise-based therapy + Others vs Others)	2	68	34	0.30	-0.16, 0.76	-	-	Prob	No; 0%	No	Yes	Yes	Very Low
Self-Perceived Image	***(Corrective exercise-based therapy vs Others)***	3	111	37	0.44	0.08, 0.8	Asym	50%	Yes	Prob; 34%	No	Yes	Yes	Very Low
	(Corrective exercise-based therapy + Others vs Others)	2	68	34	0.188	-0.27, 0.65	-	-	Prob	No; 10%	No	Yes	Yes	Very Low
Mental Health	***(Corrective exercise-based therapy vs Others)***	2	78	39	0.88	0.4, 1.38	-	-	Prob	Yes; 82%	No	Yes	Yes	Very Low

K=Number of comparisons. N=Total Sample Size. Ns=Participants per Study. SMD=Standardized Mean Difference. 95% CI=95% Confidence Interval. % var=Percentage of variation. Incons=Inconsistency. Indirect=Indirectness. Imprec=Imprecision. Sym=Symmetric. Asym=Asymmetric.

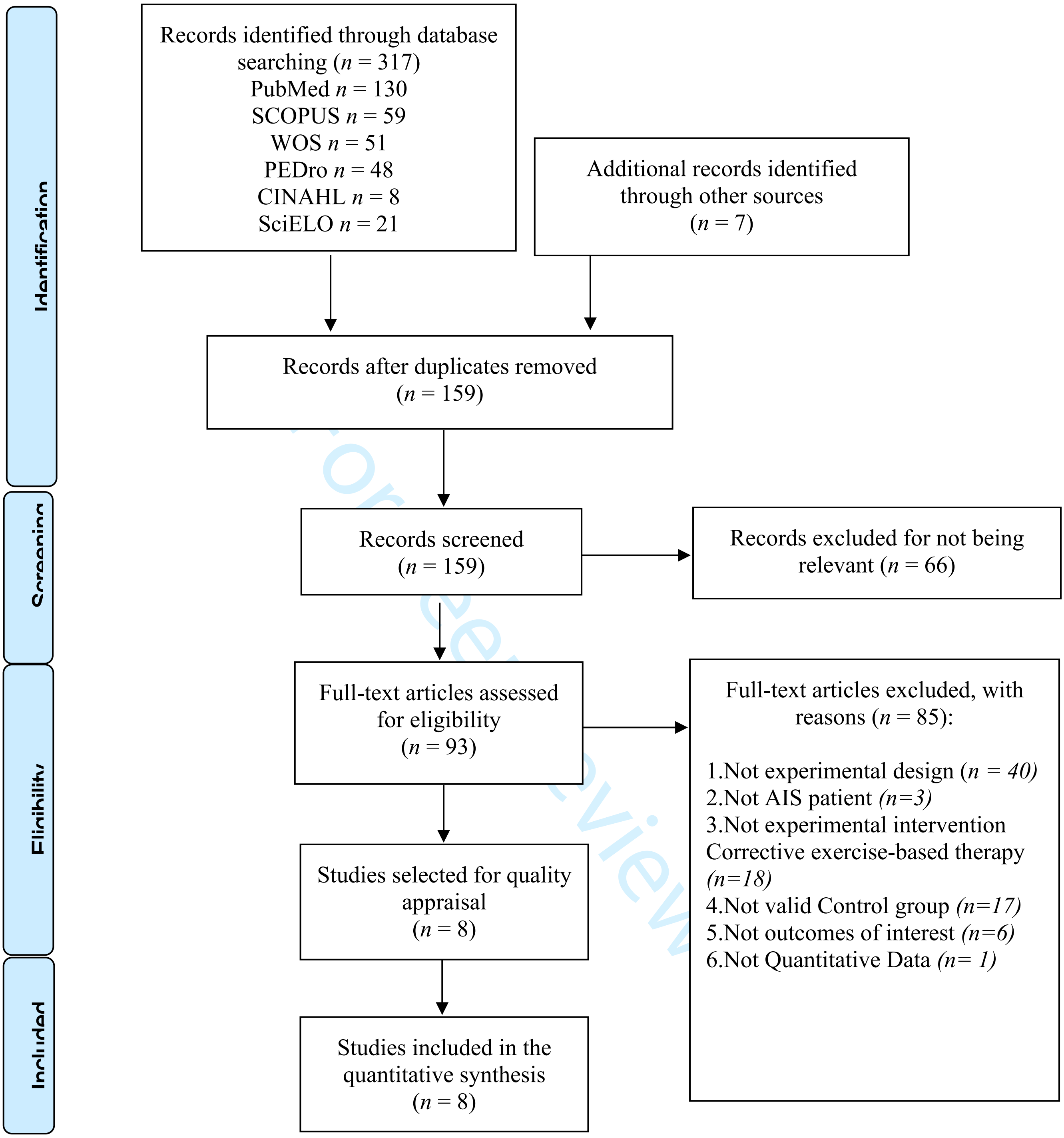


Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart for the systematic literature search and study selection process.

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Dickson, RA et al 1978	-0.940	0.471	0.222	-1.863	-0.016	-1.994	0.046
Gao, C et al 2019	-0.814	0.310	0.096	-1.422	-0.206	-2.624	0.009
Gur, G 2017	-0.592	0.409	0.167	-1.393	0.210	-1.447	0.148
Kuru, T et al 2016	0.000	0.365	0.133	-0.716	0.716	0.000	1.000
Schreiber, S et al 2016	-0.164	0.306	0.094	-0.764	0.436	-0.535	0.592
Vieira-Toledo, PC et al 2011	-1.879	0.537	0.288	-2.932	-0.827	-3.500	0.000
Zheng, Y et al 2018	0.056	0.276	0.076	-0.485	0.597	0.202	0.840
	-0.526	0.222	0.049	-0.960	-0.092	-2.374	0.018

Statistics for each study

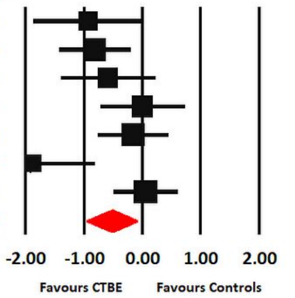


Figure 2. Forest Plot Overall Cobb Angle (SMD)

Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Gur, G 2017	0.730	0.384	0.147	-0.022	1.483	1.903	0.057
Kuru, T et al 2016	0.749	0.378	0.143	0.008	1.489	1.982	0.048
Schreiber, S et al 2015	0.781	0.313	0.098	0.168	1.395	2.495	0.013
Zheng, Y et al 2018	2.379	0.360	0.130	1.673	3.084	6.610	0.000
	1.160	0.404	0.163	0.367	1.952	2.869	0.004

Statistics for each study

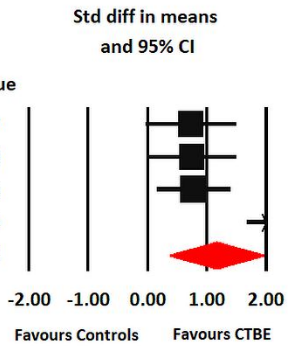


Figure 3. Forest Plot Overall Quality of Life (SMD)

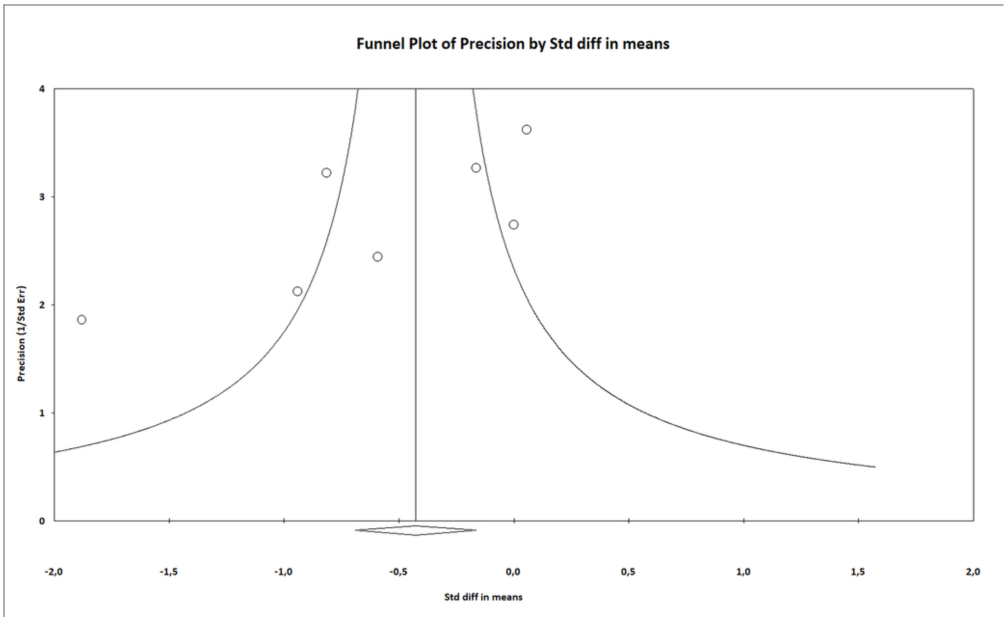
Supplementary table 1. Search Strategy Used in each Database

DATABASE	SEARCH STRATEGY
PubMed Medline	(scoliosis[mh] or scoliosis[tiab] or idiopathic scoliosis[tiab] or spinal curvatures[mh] or spinal curvatures[tiab] or kyphosis[mh] or kyphosis[tiab] or lordosis[mh] or lordosis[tiab]) AND (exercise[mh] or exercise[tiab] or exercise therapy[mh] or exercise therapy[tiab] or muscle stretching exercise[mh] or muscle stretching exercise[tiab] or resistance training[mh] or resistance training[tiab] or physical exercise[tiab] or physical activity[tiab] or exercise training[tiab] or therapeutic exercise[tiab])
SCOPUS	((TITLE-ABS-KEY ("scoliosis" or "idiopathic scoliosis" or "spinal curvatures" or "kyphosis" or "lordosis") AND TITLE-ABS-KEY(“exercise” or “exercise therapy” or “exercise training” or “muscle stretching exercise” or “resistance training” or “physical exercise” or “physical activity” or “therapeutic exercise”))
Web of Science	TOPIC:((*soliosis* OR *idiopathic scoliosis* OR *spinal curvatures*)) AND TOPIC :((*exercise* OR *exercise therapy* OR *therapeutic exercise*)) AND TOPIC:((*clinical trial*))
PEDro	idiopathic scoliosis AND exercise
CINAHL	(MH idiopatic scoliosis OR AB scoliosis OR AB spinal curvatures) AND (MH exercise OR AB therapeutic exercise OR AB exercise therapy)
SciELO	idiopathic scoliosis AND therapeutic exercise

Supplementary table 2. Analysis of the Risk of Bias in the Included Studies.

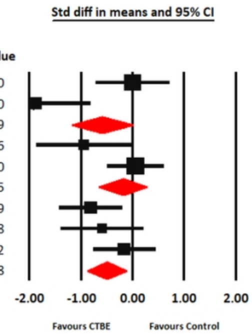
	Selection Bias		Performance Bias	Detection Bias	Attrition Bias	Reporting Bias	Other Bias
Author and Year	**Random Sequence Generation**	**Concealment of Randomization Sequence**	**Blinding of Participants**	**Blinding of Outcomes Assessors**	**Incomplete Outcome Data**	**Selective Reporting**	**Other, Ideally Prespecified**
Dickson, RA et al 1978	-	+	+	?	+	+	+
Gao, C et al 2019	-	+	+	-	-	-	-
Gur, G et al 2017	-	?	-	+	-	-	-
Kuru, T et al 2016	-	-	+	+	-	-	-
Schreiber, S et al 2015	-	-	+	-	-	-	-
Schreiber, S et al 2016	-	-	+	-	-	-	-
Vieira-Toledo, PC et al 2011	-	?	+	+	?	+	-
Zheng, Y et al 2018	-	-	+	+	-	-	-

Abbreviations: "+" = high risk of bias, "-" = low risk of bias, "?" = inadequate data for the evaluation.

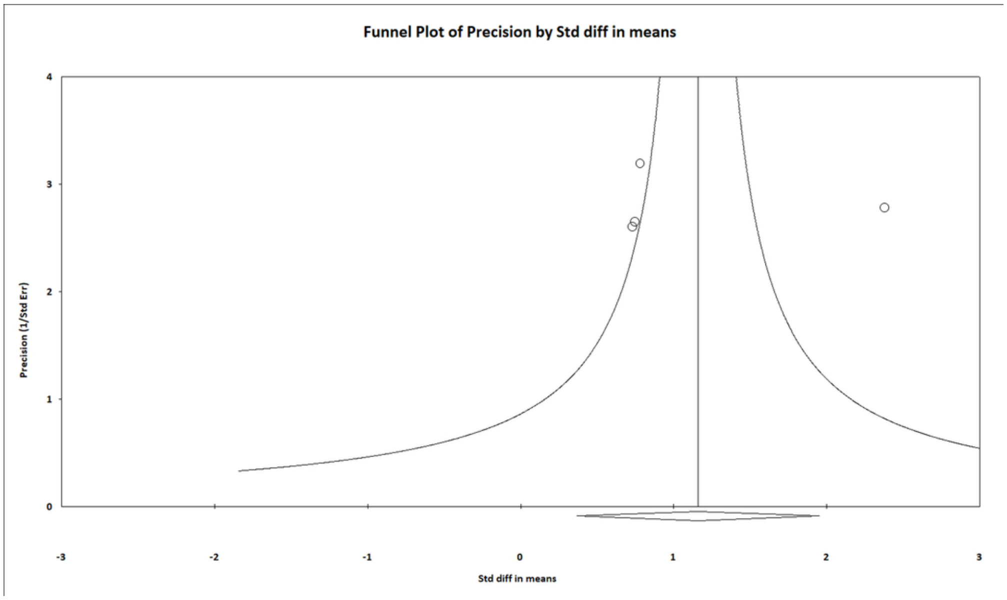


175x107mm (150 x 150 DPI)

Group by Type Exercise	Study name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
CTBE vs NI	Kuru, T et al 2016	0.000	0.365	0.133	-0.716	0.716	0.000	1.000
CTBE vs NI	Vieira-Toledo, PC et al 2011	-1.879	0.537	0.288	-2.932	-0.827	-3.500	0.000
CTBE vs NI		-0.594	0.302	0.091	-1.186	-0.003	-1.968	0.049
CTBE vs OI	Dickson, RA et al 1978	-0.940	0.471	0.222	-1.863	-0.016	-1.994	0.046
CTBE vs OI	Zheng, Y et al 2018	0.056	0.276	0.076	-0.485	0.597	0.202	0.840
CTBE vs OI		-0.199	0.238	0.057	-0.665	0.268	-0.834	0.405
CTBE + Others vs Others	Gao, C et al 2019	-0.814	0.310	0.096	-1.422	-0.206	-2.624	0.009
CTBE + Others vs Others	Gur, G 2017	-0.592	0.409	0.167	-1.393	0.210	-1.447	0.148
CTBE + Others vs Others	Schreiber, S et al 2016	-0.164	0.306	0.094	-0.764	0.436	-0.535	0.592
CTBE + Others vs Others		-0.508	0.192	0.037	-0.885	-0.131	-2.643	0.008



223x84mm (150 x 150 DPI)



176x104mm (150 x 150 DPI)

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1-2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	4
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4-5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4-5-6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supplementary table
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5-6 and figure 1
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5-6 and figure 1
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	6
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	6-7
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	6-7

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	7
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	7
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	8
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	8
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Supplementary table
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	8
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	9
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	9
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	9-11
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	11-13
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	13
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	13-14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	tittle page

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.