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Effect of therapeutic exercises on the progression of adolescent idiopathic scoliosis: a protocol of a systematic review

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ABSTRACT

Introduction Adolescent idiopathic scoliosis (AIS) affects an estimated 200 million adolescents globally and curvatures exceeding 30° at skeletal maturity are associated with increased health risks in adulthood. The International Society for the Orthopedic and Rehabilitative Treatment of Scoliosis recommends specific therapeutic exercises to prevent the progression of AIS. However, studies have questioned the effects of specific and general therapeutic exercises on the progression of AIS. This systematic review will evaluate the effectiveness of general and specific therapeutic exercises in preventing Cobb angle progression compared with other conservative interventions.

Methods and analysis We will search MEDLINE (via PubMed), EMBASE, CENTRAL, PEDro and CINAHL from inception to 14 December 2023. Randomised clinical trials involving individuals aged 10 to 18 years with a Cobb angle above 10° will be considered. The effectiveness of therapeutic exercises will be compared with minimal intervention, other exercises and brace use, alone or in combination with exercise. The primary outcome is the Cobb angle measurement, with subgroup analyses assessing severity based on SOSORT classifications. The risk of bias will be assessed using the PEDro scale and Grading of Recommendations, Assessment, Development and Evaluation will be used to assess certainty of evidence. The Review Manager 5.4 software will be used for meta-analysis. The protocol follows the Cochrane Handbook for Preferred Reporting Items for Systematic Reviews and Meta-Analysis Protocols guidelines.

Ethics and dissemination This is a literature-based study and ethical approval is not required. The findings will be disseminated through peer-reviewed publications.

PROSPERO registration number CRD42020156639.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Reaches across five databases and trial registries, ensuring a comprehensive search. The inclusion and exclusion criteria are robust, enhancing methodological transparency.
⇒ Clearly defined eligibility criteria for randomised clinical trials contribute to methodological transparency and rigour.
⇒ Rigorous evaluation of study quality using the PEDro scale for randomised trials enhances the methodological robustness of the review.
⇒ Language inclusivity may be limited, potentially impacting the representation of non-English literature.

INTRODUCTION

Idiopathic scoliosis is a complex and progressive condition causing a three-dimensional spine deformity.[1] Although its exact cause is unknown, studies suggest the association of multifactorial factors, including biological, mechanical, hormonal and genetic factors.[2 3] Adolescent idiopathic scoliosis (AIS) is the most common type of scoliosis, affecting approximately 200 million adolescents aged 10 to 17 years old worldwide.[2 4 5] The diagnosis of AIS relies on measuring the Cobb angle through X-rays, which is considered the gold standard for assessing spine curvature.[6] The measurement of the Cobb angle determines severity and tracks treatment progress. In addition to the Cobb angle, prognosis of AIS considers factors like sex, growth potential and initial curvature size.[6] Curvatures exceeding 30° at skeletal maturity carry a higher risk of health issues in adulthood, while those below 30° have a lower risk of progression after skeletal maturity.[7]

It is recommended to initiate AIS treatment during the period of bone growth for more effective results.[8] The focus of therapeutic approach for AIS includes stabilising spinal curves, preventing progression and reducing complications.[6] Conservative interventions are recommended and play an important

role in avoiding or delaying surgery.[9] The main conservative interventions for AIS involve general therapeutic exercises and/or specific exercises for scoliosis, applied alone or in combination with braces.[2 10 11] The general therapeutic exercises for AIS are exercises prescribed by physiotherapists, such as muscle strengthening on the convex side of the curve, stretching on the concave side of the curve, postural corrective exercises, core strengthening exercises and Pilates.[6] The International Society for Orthopaedic Treatment and Rehabilitation of Scoliosis (SOSORT) uses the term 'specific exercise' to encompass activities of daily living training, three-dimensional self-correction of posture and stabilisation of corrected posture.[12] Methods like the German Schroth method and Italian Scientific Exercise Approach to Scoliosis (SEAS) are the most common scoliosis-specific exercises cited in the literature.[13–18]

Orthopaedic braces are accepted as a conservative mechanical treatment to correct spinal alignment and reduce disease progression.[2 16 18] Bracing is most effective for moderate curves (20–40° Cobb) during periods of rapid growth[19] and the choice of brace (eg, Milwaukee, Boston, Cheneau, Lyon) depends on curve location and patient preference, with each option offering different levels of correction and comfort.[19] Treatment success is highly dependent on patient compliance, with brace-wearing duration and psychological factors, such as stigmatisation and willingness to adhere to the treatment, significantly influencing overall effectiveness.[19] Literature suggests that combining general therapeutic exercises, such as core strengthening, stretching and Pilates, or specific therapeutic exercises like the Schroth method and SEAS, which focus on three-dimensional self-correction and postural stabilisation, along with bracing, can enhance muscle flexibility and strength, reduce the Cobb angle and reduce back pain in patients with AIS.[13 14 16 20–22]

There are uncertainties regarding the impact of general or specific therapeutic exercises on curvature progression in AIS, with systematic reviews highlighting concerns about low-quality evidence. Romano et al.[23] found that 38% of participants in the general exercise group experienced scoliosis progression above 5° Cobb, compared with only 7% in the AIS-specific exercises group. However, there was no significant difference in reducing the Cobb angle between the two groups (mean difference of 3.0°, 95% CI −8.2 to 2.1), based on very low-certainty evidence. Thompson *et al*[22] reported that scoliosis-specific exercises improved some measures of spinal deformity, including Cobb angle, compared with general exercises or standard care, but also with very low-quality evidence.[22] Both reviews emphasise the uncertainty regarding the additional benefits of combining therapeutic exercises, whether general or scoliosis-specific, with bracing, as the current evidence is insufficient to draw definitive conclusions.[22 23]

To date, there is no consensus on the effectiveness of general and specific therapeutic exercises for AIS, and no systematic reviews have comprehensively addressed this topic while considering varying levels of curve severity or distinguishing between short- and long-term treatment durations. A comprehensive systematic review is needed to assess high-quality studies and inform treatment effectiveness. This systematic review will aim to evaluate the effectiveness of general and specific therapeutic exercises in preventing Cobb angle progression compared with other conservative interventions in individuals with AIS. Specifically, the first objective will be to evaluate therapeutic exercise in comparison to minimal intervention or clinical observation. The second objective will be to determine if one type of therapeutic exercise is more effective than another. The third objective will be to assess whether therapeutic exercise is as effective as the use of braces. The fourth objective will be to examine the additional benefits of incorporating therapeutic exercises in patients using braces to prevent Cobb angle progression in AIS individuals.

METHODS AND ANALYSIS

This protocol follows the Preferred Reporting Items for Systematic Review and Meta-analysis Protocol 2015 statement.[24] This systematic review has been registered on PROSPERO (CRD42020156639) platform. When reporting the findings, we will follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement.[25]

Eligibility criteria

Randomised clinical trials published in peer-reviewed journals will be considered for inclusion. Non-randomised experimental studies, case control and case series were not included in this review. No language or publication time limits will be applied. However, duplicate studies or secondary analyses of randomised clinical trials (RCTs) not planned will be excluded.

Participants (P)

We will include studies that evaluate individuals over 10 years of age until bone maturity (ie, 18 years) diagnosed with AIS with a Cobb angle above 10°. Exclusion criteria will involve studies that: (1) include patients with contraindications to therapeutic exercise; (2) have a heterogeneous age sample; (3) include patients who underwent previous surgical treatment; (4) analyse patients with a history of specific diseases; (5) assess patients with spinal tumours; and (6) involve patients with other spine-related diseases.

Interventions (I)

We will include studies that feature experimental interventions using general or specific therapeutic exercises for AIS to prevent scoliosis progression. The exercises can be done individually, in groups, at the outpatient clinics, or at home. Studies involving general exercises like swimming, muscle-building, yoga, as well as exclusive breathing exercises, will be excluded.

General exercises for AIS should be prescribed by the physiotherapists and may encompass spinal mobilisation, Pilates, a conventional physiotherapeutic programme, that is, muscle strengthening exercises on the convex side of the curve and stretching exercises on the concave side, postural corrective exercises when applied alone, and core strengthening exercises. Specific exercises for AIS also should be prescribed by the physiotherapists and should combine daily life training activities, three-dimensional self-correction of posture and stabilisation of corrected posture.

Comparison (C)

In the comparator group, we will include studies that compare any conservative treatment with therapeutic exercises. These comparisons will be stratified as follows:

1. Therapeutic exercise compared with clinical observation or minimal intervention.
2. Therapeutic exercise compared with another therapeutic exercise.
3. Therapeutic exercise compared with brace.
4. Therapeutic exercise in conjunction with brace compared with brace alone.

Type of outcomes (O)

We will include studies that use the Cobb angle as an outcome measure. The selected measurement for the Cobb angle will be the greatest curvature, whether thoracic or lumbar. Studies without pretreatment and post-treatment Cobb angle measurements or those presenting only the sum of Cobb angle measurements (larger curve added to the smaller curve) will be excluded.

Time frame of outcome evaluation (T)

We will assess the included studies before and after treatment. If the treatment duration is 26 weeks or less (≤6 months), we will classify it as short-term; if it is greater than 26 weeks, it will be considered long-term. This duration aligns with common clinical practice and treatment timelines in scoliosis management, allowing us to differentiate between immediate and sustained effects of therapeutic exercises. Moreover, evaluating the Cobb angle every 6 months is recommended to minimise the patient's exposure to radiation from X-rays, making it the shortest ethical interval for assessment.[6]

Data sources and search strategy

This review will consider articles published from the beginning until 14 December 2023. We will conduct systematic searches in five databases:

- MEDLINE via PubMed (from January 1966 to December 2023).
- EMBASE (from 1947 to December 2023).
- CENTRAL (The Cochrane Library and the Cochrane Back Review Group Trials Register, 2011, number 2).
- PEDro (from January 1929 to December 2023).
- CINAHL (from January 1982 to December 2023).

We will also analyse the reference lists of eligible studies and check clinical trial registration websites, including the Australian and New Zealand Clinical Trials Register, National Research Register, ClinicalTrials.gov, metaRegister of Controlled Trials, Brazilian Clinical Trials Registry and the WHO International Clinical Trials Registry Platform (WHO ICTRP). The search strategy for MEDLINE via PubMed is given in online supplemental file 1.

Study selection

We will conduct all stages of article screening using Rayyan software.[26] The article selection process includes two stages. Two review authors (RMA and MECF) will independently screen the titles and abstracts of the articles retrieved by the electronic search for relevance and assess the full-text versions of those identified as being potentially eligible. Disagreements will be resolved by discussion between the reviewers, if agreement cannot be achieved, a third reviewer (HDK) will arbitrate.

Data extraction

Data extraction will be conducted using a pre-structured Excel spreadsheet. Two reviewers (RMA and MECF) will independently extract study data, with discrepancies resolved through discussion or with a third reviewer (HDK). The following information will be collected:

- Publication data: author, year of publication and country of publication.
- Study characteristics and interventions: study design, duration, sample description (criteria for age, Risser classification and Cobb angle variation included), sample size and number of boys included; exercise type, dose, frequency and use of other interventions like general exercises and bracing. The exercise regimen will be defined by frequency (number of sessions per week) and duration (weeks, months or years).
- Outcome measure: Cobb angle (mean, SD).

Data related to trial registration, funding and indication of a primary outcome will also be extracted. These items were selected from the Consolidated Standards of Reporting Trials statement for improved transparency and methodological quality.[27–29]

Dealing with missing data

We will initiate contact with study authors via email, making three attempts within 1 month, to request data when the main outcome information is missing or unclear. When studies present data as a median and IQR, we will treat the median as similar to the mean, and the IQR width as 1.35 times the SD. If the SD is unavailable, we will calculate it from the CI or SE, when provided by the study.[30] In cases where no variability measure is available, we will estimate the SD based on the most similar trial in the review, considering factors like the study population, sample size and risk of bias.[31]

Risk of bias assessment

The methodological quality of the RCTs will be assessed by two reviewers (RMA and MECF) using the PEDro scale, known for its validity and reliability.[32–34] The PEDro

scale evaluates the risk of bias and statistical reporting in randomised clinical trials with 11 items, but the first item does not receive a score as it measures external validity. The PEDro scale total score ranges from 0 to 10 points and higher scores mean high methodological quality. We will use the score available on the PEDro database website since all trials listed there have been assessed by two independent raters. If the score is not available on the website, the two review authors (RMA and MECF) will evaluate the risk of bias using the PEDro score.

Statistical analysis

Data synthesis will be performed with individual representation of each study. Study and participant characteristics will be presented descriptively with narrative and descriptive statistics (absolute and relative frequency, mean and SD, or median and IQR).

The assessment of the effectiveness of therapeutic exercises compared with other conservative interventions will be conducted by measuring the Cobb angle, measured in degrees and presented as a continuous outcome. The data used will be from the largest Cobb angle and SD. In cases where the primary study did not report a specific variable such as the 'largest curve' but reported stratified cervical, thoracic and lumbar curvature, only the largest curve, regardless of location, will be included for analysis. The baseline and post-treatment Cobb angle measurements will be reported using descriptive statistics, including means and SD. Studies that provide mean differences pre- and post-intervention, along with their respective SDs, will also be summarised descriptively. For studies that do not report this difference, it will be calculated.

For meta-analysis, we will use the post-treatment Cobb angle and their respective SD We will use effect sizes and 95% CIs as measures of the treatment effect. Grouped analyses will be conducted using random-effects models. Meta-analysis will be conducted using the Review Manager 5.4 for all analyses.

Heterogeneity will be assessed through visual examination, χ^2 test, and I^2 statistics. Data synthesis will require clinical homogeneity in interventions, comparisons and outcomes. We will use the I^2 statistic to quantify inconsistency among the trials in each analysis. We will also use a p value (from the χ^2 test) ≤ 0.10 to be indicative of statistical heterogeneity. We will use the following thresholds for I^2 values to interpret statistical heterogeneity: 0%–40% might not be important; 30%–60% may represent moderate heterogeneity; 50%–90% may represent substantial heterogeneity; 75%–100% represents considerable heterogeneity. The observed value of I^2 will depend on the magnitude and direction of effects, as well as the strength of evidence. This strength is gauged by factors such as the P value from the χ^2 test or CI for the I^2 statistic. Notably, when the number of studies is small, there is substantial uncertainty in the value of the I^2 statistic. In case of substantial heterogeneity, a detailed report and exploration of possible causes by conducting subgroup and sensitivity analyses will follow the recommendations in section 10.10 of the Cochrane Handbook for Systematic Reviews of Interventions.

For result interpretation, curve stability will be considered maintained with a Cobb angle change between −5° and 4°. An improvement exceeding 4° will be regarded as an exceptional benefit, demonstrating a significant impact of therapeutic exercises.[35]

Subgroup analysis

Subgroup analyses will be conducted to assess the severity of scoliosis based on the Scoliosis Research Society and the SOSORT classifications, which will use the same grading system for the severity of scoliotic curvature in degrees.[12] The classification will be based on the Cobb angle, which is an angular measure of spinal curvature observed in X-rays. Curvatures will be categorised as mild, with a Cobb angle of up to 24°; moderate, with an angle between 25° and 44°; severe, with an angle between 45° and 59°; and very severe scoliosis with a Cobb angle of 60° or more.

Certainty of evidence

We will employ the Grades of Recommendation, Assessment, Development, and Evaluation to assess the overall certainty of evidence and strength of recommendations.[36] The certainty of evidence will be evaluated by the same two review authors (RMA and MECF), with any disagreements resolved through discussion. In cases of disagreement, a third reviewer (HDK) will serve as an arbitrator. The certainty of evidence for each outcome will be based on the five domains (risk of bias, inconsistency, indirectness, imprecision and publication bias), following these categories[37 38] :

- High: we have strong confidence that the actual effect closely matches the estimated effect.
- Moderate: we are moderately confident in the effect estimate; the true effect is likely close to the estimate, but there is some possibility of substantial difference.
- Low: our confidence in the effect estimate is limited, and the true effect may significantly differ from the estimate.
- Very low: we have minimal confidence in the effect estimate, and the true effect is likely substantially different from the estimate.

The certainty level may be reduced in five domains:[37 38]

- Study design and risk of bias (eg, RCT design): downgrade by one level if more than 25% of participants come from studies with a high risk of bias (PEDro score < 6) and by two levels if more than 50% come from such studies. If there were significant limitations in trials but the PEDro score exceeded the cut-off, a one-level downgrade is applied.
- Inconsistency of results: downgrade by one level if significant heterogeneity is greater than 50%; downgraded by two levels if heterogeneity is greater than 75%. The observed I^2 value will rely on effect magnitude, direction and evidence strength (eg, χ^2 test p

value or I^2 statistic's CI), with increased uncertainty in small study numbers.

- Indirectness: downgrade by one or two levels if the participants, interventions or outcomes assessed in the studies differ substantially from the review's target population or the standard clinical practice (ie, the population of interest).
- Imprecision (eg, insufficient data): downgrade by one or two levels if the total number of participants is below the recommended threshold of 400 for continuous outcomes, or when CIs include clinically insignificant effects or span a range that suggests considerable variability in the treatment effect.
- Publication bias: downgraded if selective reporting is evident through visual inspection using funnel plots in at least 10 trials examining the same intervention comparison.

DISCUSSION

In light of these considerations, our systematic review seeks to address the existing knowledge gaps by evaluating the effectiveness of general and specific therapeutic exercises in preventing Cobb angle progression compared with other conservative interventions in AIS individuals. By conducting a rigorous analysis of high-quality studies, we aim to provide valuable insights that can guide clinical decision-making, optimise treatment outcomes and improve the long-term prognosis for patients with AIS. Additionally, this review may shed light on the synergistic effects of combining exercise and orthopaedic braces, potentially resolving the existing discrepancies in the literature and contributing to the refinement of AIS treatment protocols.

ETHICS AND DISSEMINATION

Ethics Statement

We plan to disseminate our findings through publications in peer-reviewed journals and presentations at both national and international conferences. By consolidating current knowledge, this review aims to provide valuable evidence that can guide clinical practice and potentially influence scoliosis treatment guidelines.

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Contributors RMA is the guarantor for the overall content of this manuscript. SMAJ, RMA and APR designed the study. All authors contributed to developing the protocol and will draft the manuscript. RMA, MEC, HDK, APR and SMAJ will contribute to the development of the selection criteria. RMA, APR and SMAJ will perform the risk of bias assessment and data extraction criteria. RMA, APR and SMAJ will develop the search strategy. SMAJ, NCJ, HDK and APR will provide statistical expertise. All authors reviewed, provided feedback and approved the final manuscript.

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Competing interests Andrade, Rodrigo Mantelatto is a co-owner of the Instituto Escoliose Brasil, where he prescribes specific and general exercises for scoliosis and produces orthoses for patients who require them. The remaining authors declare that they have no competing interests.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

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Supplemental material BMJ Open

The effect of therapeutic exercises on the progression of adolescent idiopathic scoliosis: a protocol of a systematic review

The search terms for this systematic review are as follows:

Database	***Search Strategy***
Medline/PubMed *Search date: 12/14/2023*	*(((scoliosis[MeSH Terms]) OR (scolioses[MeSH Terms])) OR ((((("adolescent idiopathic scoliosis"[Title/Abstract]) OR ("idiopathic scoliosis"[Title/Abstract])) OR (AIS[Title/Abstract])) OR (spinal deformity[Title/Abstract])))) AND (("exercise therapy"[MeSH Terms] OR "exercise movement techniques"[MeSH Terms] OR "muscle stretching exercises"[MeSH Terms] OR "exercise"[MeSH Terms] OR "resistance training"[MeSH Terms] OR "physical therapy exercise"[Title/Abstract]) OR ("scoliosis specific exercises"[Title/Abstract] OR "specific exercise"[Title/Abstract] OR "exercise program"[Title/Abstract] OR "physiotherapy scoliosis"[Title/Abstract] OR "task oriented exercises"[Title/Abstract] OR "Self-correction"[Title/Abstract] OR "active self correction"[Title/Abstract] OR "SEAS"[Title/Abstract] OR "SEAS exercises"[Title/Abstract] OR "schroth"[Title/Abstract] OR "schroth method"[Title/Abstract] OR "schroth exercise"[Title/Abstract] OR "lyon"[Title/Abstract] OR "dobomed"[Title/Abstract] OR "FITS"[Title/Abstract] OR "BSPTS"[Title/Abstract] OR "side-shift"[Title/Abstract] OR "PSSE"[Title/Abstract] OR "barcelona scoliosis physical therapy school"[Title/Abstract]))*

Searches will be conducted on the following databases:

MEDLINE via PubMed, Embase, CENTRAL (Cochrane), PEDro and CINAHL.