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Research Article

Short-Term Benefit from Core Stabilization Exercises in Adolescent Idiopathic Scoliosis: A Meta-Analysis of Randomized Controlled Trials

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Background. Idiopathic scoliosis may affect adolescents' physical development. This systematic review and meta-analysis determined the effectiveness of core stabilization exercises in improving clinical symptoms of idiopathic scoliosis in adolescents. *Methods*. We searched PubMed, the Cochrane Library, and Embase for randomized controlled studies investigating core stabilization exercise and idiopathic scoliosis. Two investigators independently extracted data based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines. The Newcastle–Ottawa Scale (NOS) was used to evaluate the quality of the selected literature and we performed a meta-analysis to assess the clinical utility of core stabilization exercise for the improvement of patients with idiopathic scoliosis. Heterogeneity was assessed with the I^2 statistic. *Results*. This systematic review and meta-analysis included 9 studies. Three of the studies revealed that core stabilization exercise improved Cobb's angle (SMD: −1.06, 95% confidence interval (CI): (−1.41, −0.72), and $P < 0.001$) in adolescents' idiopathic scoliosis, but the subgroup analysis showed no significant difference in Cobb's angle in the thoracic and lumbar segments (SMD: −0.25, 95% CI: (−0.55, 0.04), and $P = 0.89$). In the angle of trunk rotation subgroup analyses (SMD: 0.35, 95% CI: (−0.01, 0.72), and $P = 0.33$), there was no significant difference before and after core stabilization exercise treatment. *Conclusions*. The results showed a very short-term effect of core stabilization exercise on patients with idiopathic scoliosis. However, this study contains a relatively short period of research and more long-term research is needed in the future to support this conclusion.

1. Introduction

Adolescent idiopathic scoliosis (AIS), which is a spinal deformity disease caused by unknown etiological factors during the growth and development of adolescents aged 10–16 years, has become one of the common diseases endangering the pathology of adolescents [1]. Regarding age at onset, it has been reported that about 80% of the individuals with scoliosis had onset in adolescence and the deformity appears during the sudden growth period before puberty [2]. The prevalence of AIS is 0.47–5.2%, and the incidence and severity of spinal curvature are higher in girls than in boys worldwide [3]. With the development of the body, the degree of spinal deformity increases and makes the patient exhibit significant stooping and hunching of the back. AIS has a certain effect on the clavicular angle, pelvic inclination angle, and Cobb's angle and could even decrease the lung function of the patient [4]. Except in extreme cases, AIS does not usually cause health problems; however, surface deformities have a negative impact on adolescents and may lead to psychological disorders [5]. The severity of AIS is divided into mild, moderate, and severe, with mild Cobb's angle being less than 25°, moderate being between 25° and 45° Cobb's angle degrees, and severe being greater than 45°

Cobb's angle degrees [6]. The larger the Cobb's angle, the higher the functional limitations in adulthood [7]. Currently, the most effective nonsurgical treatment of AIS is bracing, exercises have an important role as an adjunct modality that can be added to the brace treatment and it only should be considered for AIS curves of less than 20°, and for curves of higher than 20°, bracing and exercise is indicated for this population [1]. Moreover, recent report has shown that bracing is also effective for curves of higher than 40° (40–60°) [8], while severe AIS tends to be treated by surgery [9] and artificial disc replacement may benefit to patients with previous long fusion for scoliosis surgery [10, 11]. Therefore, it is recommended that AIS be treated as early as possible.

Exercise is a common conservative approach to correcting the curvature of the spine for AIS. It is considered an important method of maintaining spinal function and preventing the pathogenic development of scoliosis [12, 13]. There are a variety of exercise training approaches to improving AIS, with the most studied of these being the Schroth exercise; however, the study findings are contradictory [14]. In contrast, most other exercise training studies are merely retrospective and fail to report compliance, intention-to-treat analyses, or blind evaluators [15]. Thus, there is presently a controversy regarding exercise therapy and a lack of high-quality evidence as to whether AIS can be treated with exercise therapy [6].

Core stabilization (CS) exercises have recently been used in the conservative treatment of AIS [16]. CS exercises have been reported to improve local and overall spinal stability by improving muscle imbalances, particularly between the paraspinal muscles and multiple muscle groups [17]. Increasing spinal stability is one of the main treatment goals of the CS exercises approach to scoliosis. It focuses on spinal stability and core strength, training the deep trunk muscles by controlling the trunk position during static posture and functional activities [18]. It has been found that CS exercises are more effective than traditional exercise in improving spinal stability, lowering Cobb's angle and reducing pain scores in AIS [19]. However, not much research has been performed in depth on CS exercises for adolescent scoliosis and the effectiveness is unclear. Therefore, it is necessary to verify the efficacy of CS exercises in AIS based on recently published studies and we elucidated the very-short effect of the CS exercises on AIS by a comprehensive meta-analysis.

2. Methods

This systematic review and meta-analysis was conducted in line with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [20] and targeted the following PICO question: after undergoing CS exercises, to what extent is AIS improved in AIS patients? CS exercises training consist of three stages. The first phase is to activate the core muscles to improve proprioception and muscle coordination in the spinal region, and in the second and third phases, the intensity of the exercise is increased to improve muscle stability and endurance [21].

2.1. Search Strategy. A literature search was conducted in relevant databases including PubMed, Embase, and the Cochrane Library up to September 16, 2022. We selected the Medical Subject Headings (MeSH) terms, and keywords "scoliosis" and "exercise" and their synonyms to search these databases (see Supplementary Table 1 for the complete search strategy).

2.2. Inclusion Criteria. According to predefined inclusion criteria, two investigators independently assessed the retrieved randomized controlled trials (RCTs) studies. The inclusion criteria were (1) case-control design; (2) articles written in English; (3) experimental studies using CS training; (4) inclusion of subjects with Cobb's angle greater than 10 degrees; (5) provision of sufficient information to calculate effect sizes; and (6) only nonsurgically treated idiopathic scoliosis.

2.3. Data Extraction and Quality Assessment. Two of our investigators (RC and JZ) independently retrieved the following data from each of the eligible studies: first author, year of publication, country, sample size, age, percentage of women studied, exercise type, and Cobb's angle.

Two of these investigators (RC and JZ) coded all characteristics of the selected studies separately for this meta-analysis (see Supplementary Table 2). They assessed the risk of bias independently by using Cochrane's risk of bias tool 2.0 [22], which includes randomization processes, assignment hiding, blinding, data integrity, and selective reporting. For each domain, the risk of bias was judged as being low risk or unclear (see Supplementary Figure 3). All discrepancies were resolved through discussion prior to data analysis.

2.4. Outcomes of Interest. The first primary outcome of interest is Cobb's angle; this point was chosen to account for the effect of CS exercises, which is the most used value to quantify spinal deformity [23]. The other outcomes of interest were the angle of trunk rotation (ATR), Walter Reed Visual Assessment Scale (WRVAS), and Scoliosis Research Society 22 Questionnaire (SRS-22) in order to compute effect sizes.

2.5. Statistical Analysis. The strength of the correlation between the main effect and subgroup analyses was assessed by estimating the standardized mean difference (SMD) and 95% confidence intervals (CIs) through a random effects model (DerSimonian and Laird methods). $P < 0.05$ was considered a statistically significant difference. These data were analyzed in Stata 16.0 (Stata Corp, College Station, TX, USA).

3. Results

3.1. Characteristics of the Included Studies for Meta-Analysis. The selection of eligible studies is shown in Figure 1. Our initial computer literature search identified 3926 results in all. After a thorough review of titles and abstracts, 995 of

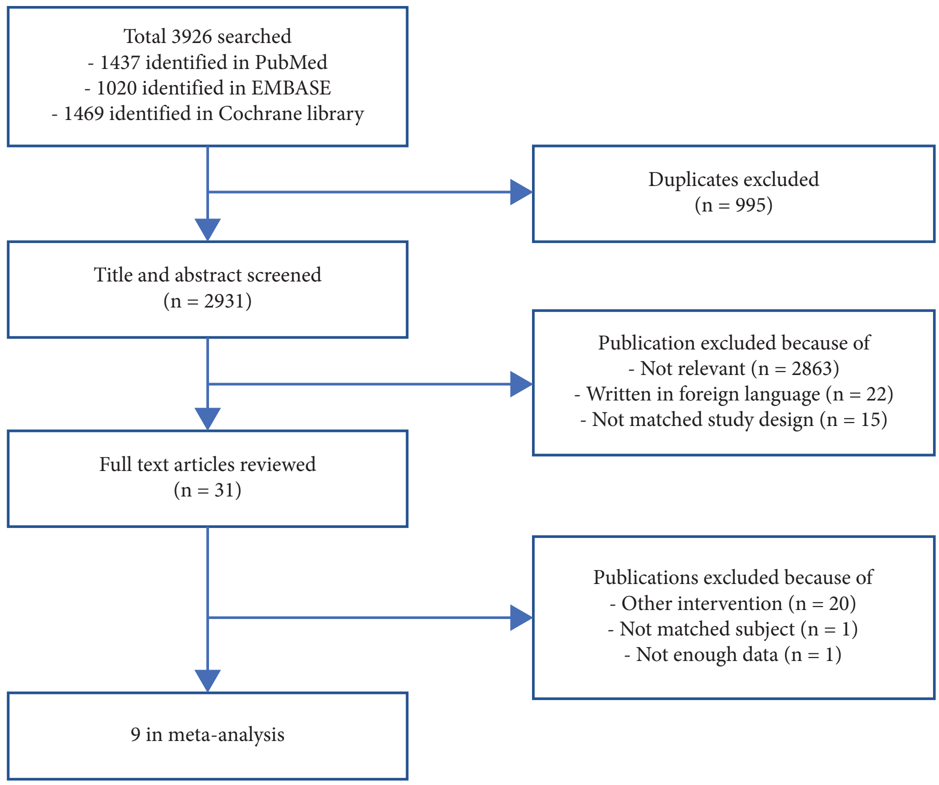

Figure 1: Preferred Reporting Items For Systematic Reviews And Meta-Analyses (PRISMA) flow diagram of the literature search and study selection process.

these records were found to be duplicates. Ultimately, we identified 9 studies for meta-analysis (Figure 1). The characteristics of these included studies are listed in Table 1. This meta-analysis investigated the effect of CS exercise training on the improvement of AIS patients, with outcome indicators including Cobb's angle and trunk rotation angle.

3.2. Meta-Analysis of CS Exercises and Cobb's Angle. In a general analysis, we found that CS exercise training could improve Cobb's angle (SMD and 95% CI: −1.06 (−1.41, −0.72) and $P < 0.001$, Figure 2) with low heterogeneity ($I^2 = 0.00\%$) in three studies; a random effects model was used for the assessment [24]. In the three other subgroup studies, however, the results showed no significant effect of CS exercise training (SMD and 95% CI: −0.25 (−0.55, 0.04) and $P = 0.89$, Figure 3) with low heterogeneity ($I^2 = 0.00\%$).

3.3. Meta-Analysis of CS Exercises and the Angle of Trunk Rotation. Two studies investigated the association between CS exercises and the thoracic ATR, and all of the reported results suggested that CS exercise training may not improve the ATR (SMD and 95% CI: 0.35 (−0.01, 0.72) and $P = 0.33$, Figure 4) with low with heterogeneity ($I^2 = 3.78\%$).

4. Discussion

Our meta-analysis found that CS exercises had a very short-term effect to reduce Cobb's angle and improve lumbar muscle strength in AIS patients compared with conventional training in three studies [7, 25, 26]; however, the subgroup analysis showed no significant improvement [16, 27, 28]. The subgroup analysis of the effects in Cobb's angle was divided into thoracic and lumbar segments. The results showed no significant difference in the improvement of Cobb's angle before and after CS exercises, possibly because there was no significant improvement in the thoracic or lumbar segments alone, presumably in relation to the degree of deformity and the duration of exercises. Two studies suggested that CS exercise training may not improve the ATR [29, 30]; another three studies showed no improvement in the WRVAS (Supplementary Figure 1) [29–31] or SRS-22 (Supplementary Figure 2) [16, 29, 30]. The most likely reason for these results is the short duration of the CS exercises. Therefore, in the present study, we investigated the effect of CS exercises on the treatment of patients with scoliosis by meta-analysis. We included nine relevant studies and found that it has a very short-term effect to improve deformity symptoms in scoliosis patients. This result implicates that CS exercises may be very short-term effective in patients of scoliosis.

To our knowledge, this is the first meta-analysis to analyze the effect of CS exercise training on the treatment of AIS. The reduction and prevention of scoliosis deformities is currently the main goal in the treatment of patients with AIS. Therefore, numerous clinicians and investigators have tried to find new ways to reduce scoliosis deformities and to elucidate the efficiency of these treatments [32]. In recent years, different exercise methods have been tried to improve

Table 1: Characteristics of the studies included in the meta-analysis.

Study	N (E/C)	Program type	Outcome type	Cobb's angle	Age	Duration
Yildirim et al. [31]	30 (15/15)	Core stabilization exercises vs. traditional scoliosis exercises	Pulmonary function, respiratory muscle strength, functional capacity, peripheral muscle strength, and WRAVS	15–40°	E: 13.8 ± 2.85 C: 15.87 ± 3.46	8 weeks
Weng and Li [7]	29 (15/14)	Core stabilization exercises vs. regular evaluation	Cobb's angle and paravertebral muscle	10–20°	E: 13.15 ± 0.47 C: 13.87 ± 0.96	12 weeks
Kamel et al. [25]	60 (30/30)	Core stabilization exercises	Cobb's angle and pain in back muscle endurance	10–25°	E: 12.91 ± 1.401 C: 13 ± 1.71	12 weeks
Kocaman et al. [29]	28 (14/14)	Core stabilization exercises *vs.* Schroth exercises	Cobb's angle, WRVAS, and ATR	10–30°	E: 14.07 ± 2.37 C: 14.21 ± 2.19	10 weeks
Yagci and Yakut [27]	30 (15/15)	Core stabilization exercises vs. traditional scoliosis exercises	Subjective visual, perception subjective, postural perception, and subjective haptic	15–45°	E: 14.0 ± 1.3 C: 14.2 ± 1.5	10 weeks
Yagci et al. [30]	22 (11/11)	Core stabilization exercises	Cobb's angle, WRVAS, ATR, and SRS-22	20–45°	E: 13.7 ± 1.6 C: 13.7 ± 1.3	4 months
Ko and Kang [28]	29 (14/15)	Core stabilization exercises	Cobb's angle, flexibility, lumbar flexion muscle, and lumbar extension muscle	10–20°	E: 12.71 ± 0.72 C: 12.80 ± 0.86	6 months
Gür et al. [16]	25 (12/13)	Core stabilization exercises *vs.* traditional scoliosis exercises	Cobb's angle, rotation, and posterior trunk symmetry Index SRS-22	35–50°	E: 14.2 ± 1.8 C: 14 ± 1.6	10 weeks
Park et al. [26]	51 (23/28)	Core stabilization exercises	Cobb's angle, symmetry, and muscle strength	10–15°	E: 20.0 ± 2.0 C: 20.6 ± 1.8	10 weeks

WRVAS: Walter Reed Visual Assessment Scale; ATR: angle of trunk rotation; SRS-22: Scoliosis Research Society 22 Questionnaire.

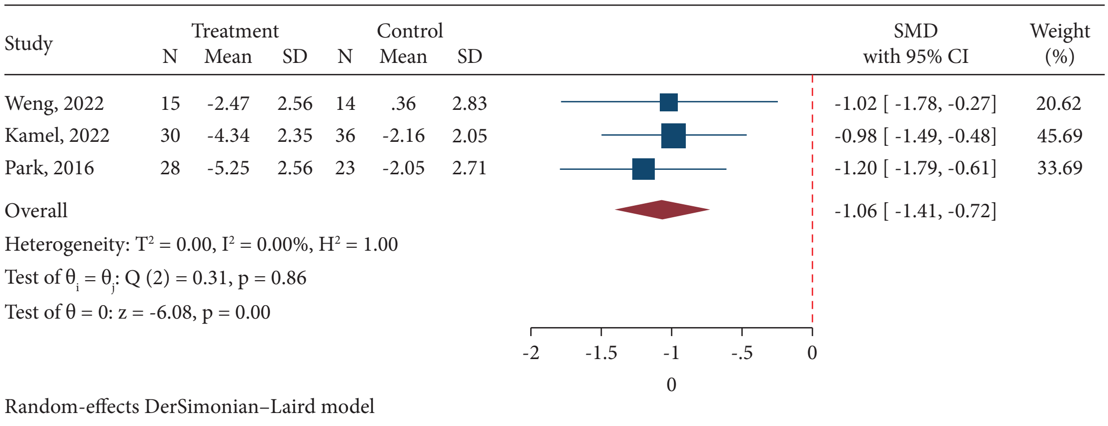

Figure 2: Meta-analysis of Cobb's and CS exercises training.

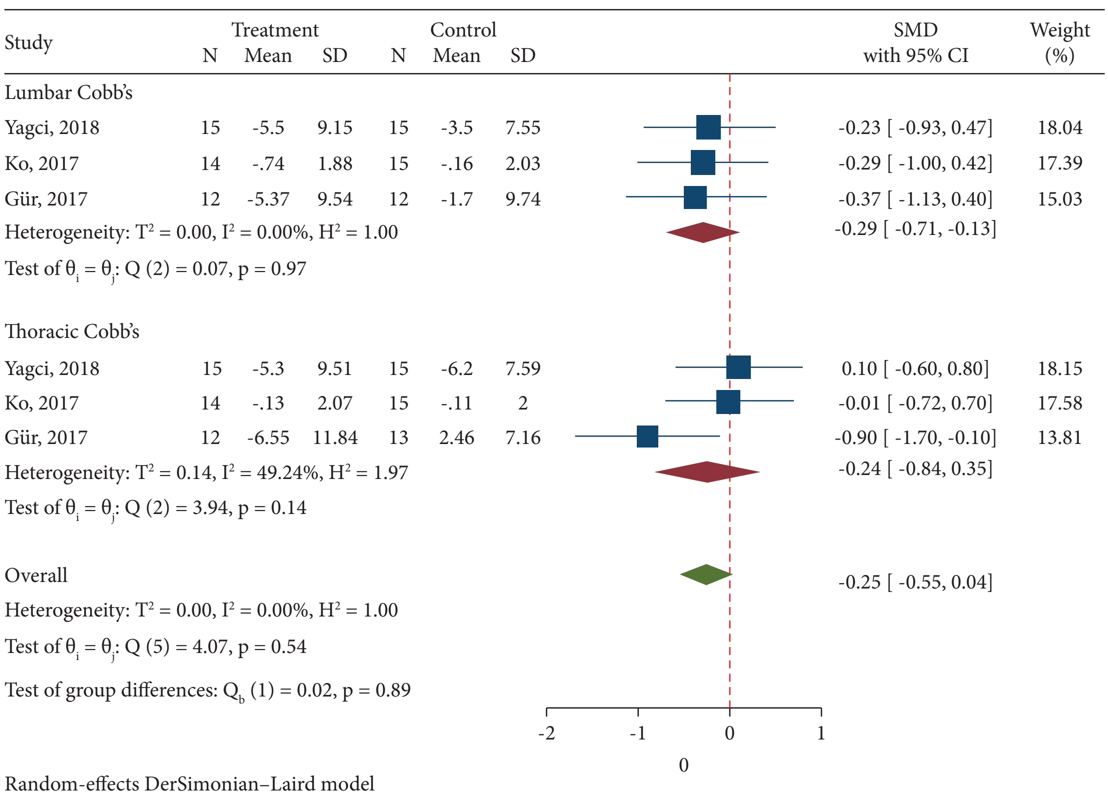

Figure 3: Meta-analysis of subgroup Cobb's and CS exercises training.

the symptoms of deformity caused by AIS and some supporting studies have been published on patients with AIS [33].

Exercise treatments for AIS include Schroth exercise, functional individualized therapy, and the Scientific Exercise Approach to Scoliosis (SEAS) [34]. Studies have found that Schroth exercise is a recommended treatment for patients with scoliosis and that it may be more beneficial to AIS patients with a Cobb's angle of 10 ~ 30° than for AIS patients with a Cobb's angle greater than 30° [16]. One of the studies found that Schroth exercises are more effective than CS exercises in the correction of scoliosis and related problems in mild adolescent idiopathic scoliosis and CS exercises are more effective than Schroth exercises in the improvement of peripheral muscle strength [29]. Our study found that CS exercises were not as effective as Schroth exercises in improving Cobb angle; however, this was the conclusion of only one single study.

However, there is limited research evidence on the efficacy of exercise training, and there is no definitive evidence on which exercise is more effective. Although some studies have confirmed that Schroth exercise training can be effective for the treatment of scoliosis, the level of evidence for this is not very high [23].

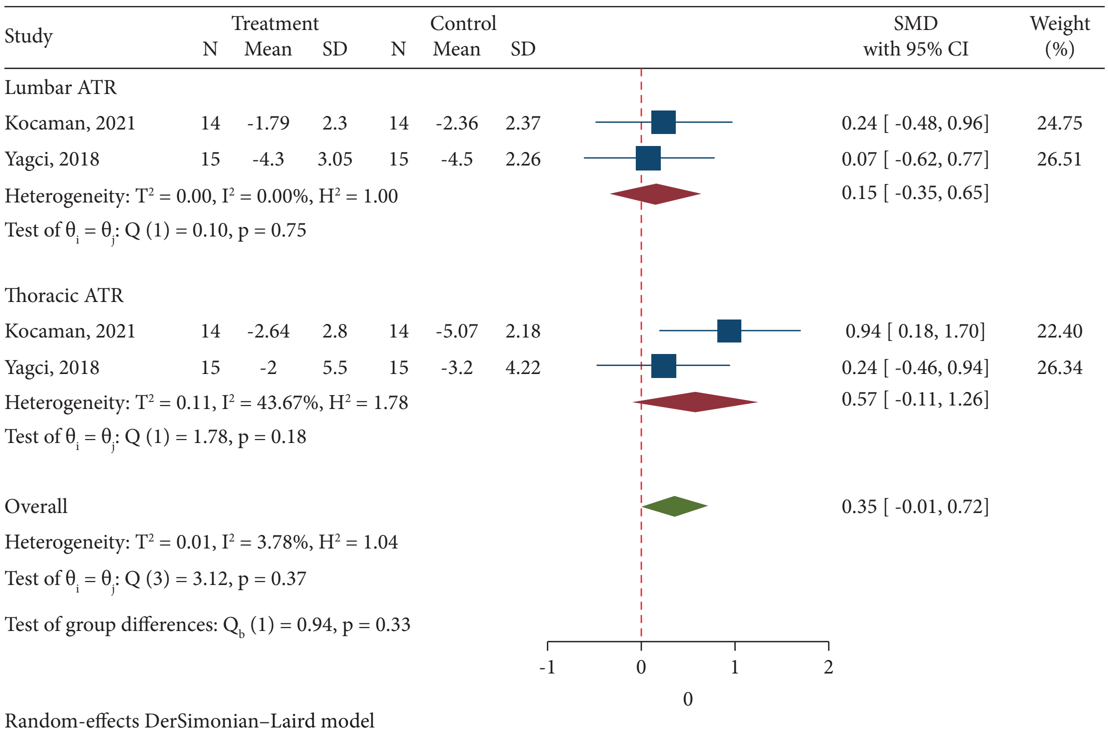

Figure 4: Meta-analysis of ATR and CS exercises training.

The improvement of Cobb's angle has been an important target for the development of goals and plans for patients with AIS. North American standards recommend that patients with a Cobb's angle of 10–25° should be observed for curve changes before deciding whether to start treatment aggressively; for patients with a Cobb's angle between 25° and 45°, conservative treatment such as bracing and exercise is recommended; bracing is a common nonsurgical technique that allows clinicians to prevent and correct malformations or injuries of a patient's spinal column, and it can be used as a conservative measure in the initial stage, as an adjunct to surgery, or as a definitive treatment [35]. One of the studies showed that CS exercises with bracing and scientific exercises approach to scoliosis with bracing had similar effects in the short-term treatment of moderate adolescent idiopathic scoliosis [27]. For other patients with a Cobb's angle greater than 45°, surgical treatment is recommended for correction [36].

CS exercises may increase the strength of spinal muscles, improve the quality of life, and relieve pain in adolescents with AIS [19] and could correct the bad posture of scoliosis patients, which may be related to the balance of the electromyographic activities (convex concave side) of paravertebral muscles in AIS patients [7]. CS exercises were more effective than traditional exercises alone in the correction of vertebral rotation and reduction of pain in adolescent idiopathic scoliosis [16]. However, the literature included in our study was not observed for a long time, so it has been suggested that exercise therapy for AIS patients should be continued for at least 6 months or longer [37] so that the effect on Cobb's angle would be greater. Among the literature included in this study were those on CS exercises to improve pulmonary function. Yildirim [24] found that after 8 weeks of CS exercises, it was possible to increase the respiratory function of the children, making no statistical difference between their respiratory function and that of healthy controls, but that after other stretching, strengthening, breathing, and core training, although there was a significant improvement in the respiratory function parameters when they increased, they did not reach the values of the healthy controls.

4.1. Limitations of the Study. Our investigation has several limitations. First, treatment of scoliosis is a long-term process that lasts approximately 2-3 years and should be followed up for at least 1 year. However, most of the studies which were included in this meta-analysis were relatively short-term, which probably makes our findings relatively weak. There is no information about the follow-up duration of the exercise because the cases of some studies were school-aged children to carry out the study without long-term follow-up and with a relatively small number of patients. More research needs to be performed diligently and should be followed up with long-term results. Second, more high-level studies are needed to conduct more robust meta-analyses in the future.

5. Conclusion

In this study, we provided the impact of CS exercises on the treatment of patients with scoliosis through a meta-analysis.

The results showed a very short-term effect of CS exercises on patients with AIS. This study is the first meta-analysis of the very short-term effect of CS exercises on patients with AIS and provides the basis for an evidence-based approach to exercise for patients with scoliosis. In conclusion, CS exercise may be a recommended treatment for patients with AIS.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Ethical Approval

Ethical review and approval were waived for this study as it is a review article and does not contain clinical studies or patient data.

Consent

Patient consent was waived for this study as it is a review article and does not contain clinical studies or patient data.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

PS and DL conceived and designed the meta-analysis. RC and JZ performed the literature search and analyzed the data. PS wrote the manuscript, and XY, JL, and WW revised it. XY and KZ polished the language. All the authors contributed to the article and approved the submitted version.

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Supplementary Materials

Supplementary Table 1: search strategy. Supplementary Table 2: data of pre-post design studies with the control group. Supplementary Figure 1: meta-analysis of WRVAS and CS exercises training. Supplementary Figure 2: meta-analysis of SRS-22 and CS exercises training. Supplementary Figure 3: risk of bias for each study. (*Supplementary Materials*)

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