REVIEW ARTICLE

Effects of Schroth method and core stabilization exercises on idiopathic scoliosis: a systematic review and meta-analysis

Vanja Dimitrijević[1] · Dejan Viduka[2] · Tijana Šćepanović[1] · Nebojša Maksimović[1] · Valerio Giustino[3] · Antonino Bianco[3] · Patrik Drid[1]

Abstract

Purpose Conservative approaches such as Schroth exercises and core stabilization exercises showed effective results in the treatment of idiopathic scoliosis. This study aimed to critically evaluate the magnitude effect of Schroth and core stabilization exercises using a systematic review and meta-analysis.

Methods This study has been developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement. The following three databases were searched for articles collection: Web of Science, PubMed, and Google Scholar. The key search terms were: Schroth exercise, core exercise, idiopathic scoliosis, Cobb angle, angle of trunk rotation, and quality of life. The articles included in our study was limited to original articles written only in English that met the following inclusion criteria: (1) Participants with idiopathic scoliosis; (2) Schroth exercises and core stabilization exercises used as interventions; (3) Cobb angle or angle of trunk rotation or quality of life used as outcome measures.

Results Thirteen studies were included. Depending on the outcome measured, the magnitude effect of Schroth and core stabilization exercises ranged from small to almost large as follows: Cobb angle (SMD $=-0.376$, $p < 0.001$); angle of trunk rotation (SMD $=-0.268$, $p = 0.104$); quality of life (SMD $=0.774$, $p = 0.002$). By subgroup analysis, Schroth method showed a larger effect size than core stabilization exercises.

Conclusion The current systematic review and meta-analysis indicates that both Schroth method and core stabilization exercises have a positive effect in subjects with idiopathic scoliosis. Subgroup analysis showed that the Schroth method had a larger effect size than the core stabilization exercises.

Keywords Schroth exercise · Core exercise · Idiopathic scoliosis · Physical exercise · Body posture

Introduction

Idiopathic scoliosis (IS) is a rare three-dimensional deformity of the spine that occurs in children without a known cause [1]. It can occur in different periods of childhood and adolescence characterized as periods of growth spurt. The first of these periods is between 6 and 24 months, then between 5 and 8 years, and finally between 11 and 14 years [2].

In about 20% of cases, scoliosis is secondary to another pathology, while for 80% it is idiopathic and is more frequent in female than male children [2].

IS can negatively affect physical and psychosocial health and can limit normal life functioning [1, 3]. Prevention of scoliosis is achieved through regular medical checkups, educational conversations about posture, sports practice, constant attendance of physical education classes, and the use of protective positions [4].

For scoliosis treatment can be distinguished conservative and non-conservative approaches. Non-conservative treatments usually include spine surgery and are not without risks [5]. Conservative treatments include physical

✉ Valerio Giustino
valerio.giustino@unipa.it

1 Faculty of Sports and Physical Education, University of Novi Sad, Novi Sad, Serbia

2 Faculty of Applied Management, Economics and Finance in Belgrade, University of Business Academy, Novi Sad, Serbia

3 Sport and Exercise Sciences Research Unit, Department of Psychology, Educational Science and Human Movement, University of Palermo, Via Giovanni Pascoli, 6, 90144 Palermo, Italy

therapy, physical exercise, and wearing a brace. The choice of treatment to be adopted depends on the severity of the scoliotic curve [1]. The International Society on Scoliosis Orthopaedic and Rehabilitation Treatment (SOSORT) was launched in Europe in 2004 to meet the need for the most effective treatment of subjects with scoliosis [6]. According to the most recent SOSORT guidelines, the general goals of conservative treatment of scoliosis include stopping or reducing the progression of the curve, reducing or treating respiratory dysfunctions, reducing or treating spinal pain syndromes, and improving the subject's aesthetics by correcting posture [2]. These goals ultimately prevent the need for surgery [2, 7, 8].

Among the conservative treatments, there are several approaches of physical therapy and physical exercise such as the Schroth method, and more recently, the core stabilization exercises [1, 4, 9].

The Schroth method is a three-dimensional program of exercises developed in Germany in the 1920s by Katharina Schroth [10]. Further progress of the method was made by her daughter, Christa Lehnert-Schroth [4]. This treatment is an individualized program, and it is based on kinesthetic and sensorimotor principles including postural corrective exercises, postural self-corrective exercises, and postural home-exercises and it is conducted through a mirror and adopting the exercises repetition [11]. The method uses rotational breathing techniques, i.e., exercises in which respiratory thoracic movements are performed toward the opposite side of the trunk torsion to reduce it, and a combination of stretching and strengthening exercises, based on the muscle groups imbalance [5, 10, 12].

Core stabilization is an exercise approach involving trunk muscles, i.e., the musculature of the spine, pelvis, and abdomen regions, recently used in order to improve body balance and reduce postural asymmetries [13, 14]. Indeed, core stabilization exercises recruit spinal stabilizer muscles, which improve the ability to straighten the spine [9]. The core muscles limit the forces of compression, distortion, and rotation of the spine [15]. Although core stabilization exercises would appear to be effective to increase muscle strength of the lumbar region and improve neuromuscular imbalance, which represent the causes of IS, few studies have investigated the beneficial effects of core stabilization exercises in subjects with IS [16].

Before and during of any treatment are performed different scoliosis measurements such as radiography of the spine and scoliometry. In order to monitor the status of IS during its treatment, the most commonly used parameter is the Cobb angle which is measured by radiographs in standing position [17, 18]. Among the other parameters, the angle of trunk rotation (ATR) is a measure of trunk deformity, and it is evaluated through a scoliometer [19].

The aim of this systematic review and meta-analysis is to examine the overall effect of Schroth and core stabilization exercises in subjects with IS, and also, if possible, to compare the mutual magnitudes of the effect to assess which of these treatments is better. The overall magnitude of the effect, using these two methods, was analyzed by meta-analysis, to find out whether there was a reduction in Cobb angle and in ATR and moreover, an improvement in quality of life (QoL) in subjects with IS.

Methods

Study design

This study has been developed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement [20].

Data sources and search strategy

The databases searched to identify all relevant studies were Web of Science, PubMed, and Google Scholar databases. The search strategy included the combinations of subject titles "Schroth exercise", "core exercise", "idiopathic scoliosis", "Cobb angle", "angle of trunk rotation", and "quality of life".

The search strategy is shown in Fig. 1. We also manually searched citations of identified critiques and selected original articles to download the full-text.

Study selection

PICOS (Population, Interventions, Comparators, Outcomes, Study Designs) eligibility criteria described in PRISMA were adopted for inclusion/exclusion of the studies [20]. To be included in our study, the articles had to meet the following inclusion criteria: (1) Participants with idiopathic scoliosis; (2) Schroth exercises and core stabilization exercises used as interventions; and (3) Cobb angle or angle of trunk rotation (ATR) or quality of life (QoL) used as the outcome measures. The inclusion of articles in our study was limited to original articles written only in English. The inclusion/exclusion of studies was carried out by two investigators by consultation and consensus.

Data extraction and quality assessment

After selecting studies based on the inclusion and exclusion criteria, two investigators independently conducted data extraction. The following information was extracted and inserted into a pre-formatted table: authors, year of publication, type of exercise program, characteristics of the sample
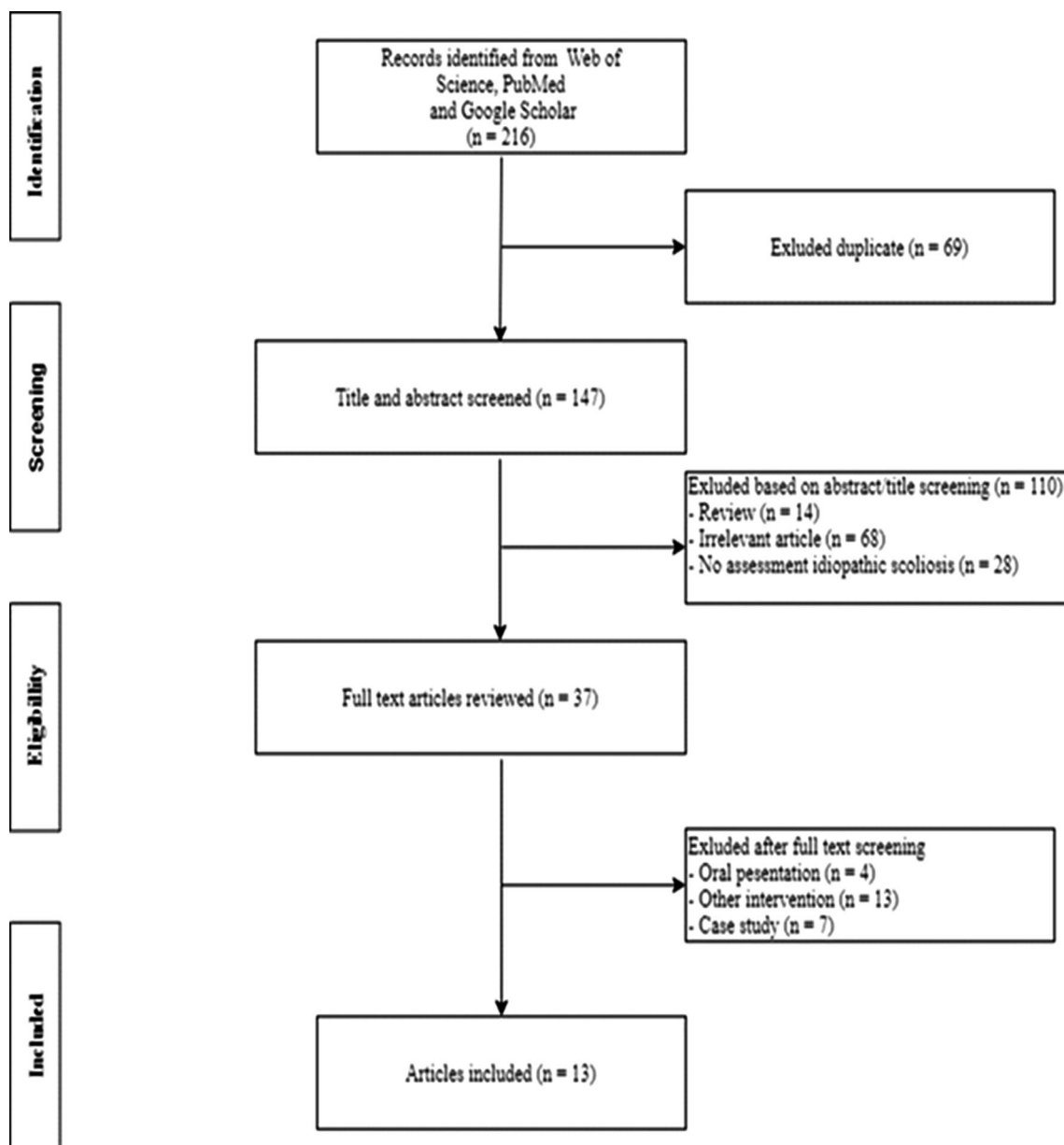
Fig. 1 Flow diagram of the process of study selection

(number of participants, age), outcomes, Cobb angle size, exercise time per day, duration of the exercise program, and whether the studies had a control group. All studies included had data available.

The categorization of the studies was assessed using the National Health and Medical Research Council (NHMRC) hierarchy of records [21].

Two investigators independently assessed the quality of the studies involved. Risk of bias was assessed for each study using the Cochrane Risk of Bias Tool (Fig. 2), which included seven sources of bias, including randomization process, allocation concealment, blinding of participants

and personnel, blinding of outcome assessment, missing outcome data, selective outcome reporting, and other potential bias [22]. Each study was examined based on the above seven aspects and subsequently assessed as at low risk of bias, high risk of bias, or unclear risk.

Data synthesis and analysis

Meta-analysis and statistical analysis were performed using Meta-Analyst software (Brown University). For all outcomes measured by at least two studies, the magnitude of the effect was estimated. For each study, standardized mean

Fig. 2 Risk of bias graph: review authors' judgments about each risk of bias item
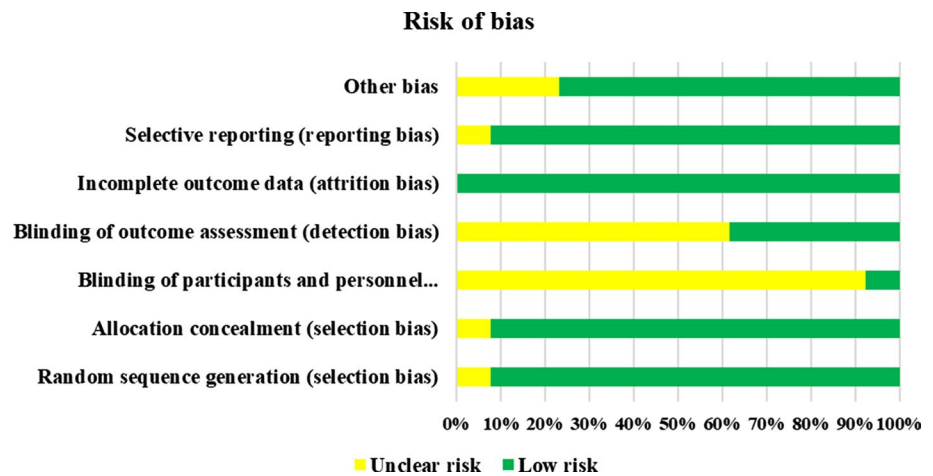
difference (SMD) and 95% confidence interval (CI) were calculated for continuous outcomes with a random model. For Cobb angle, ATR, and QoL, the overall effect size for the Schroth method and for the core stabilization exercises was measured post- minus pre-intervention in the experimental and control groups. According to the Cohen's guide, values of $\geq 0.2, \geq 0.5$, and ≥ 0.8 show small, medium, and large effect sizes, respectively [23]. After that, the analysis of subgroups for Cobb angle, ATR, and QoL outcomes was performed in order to separately assess the size of the effect and to solve the presence of increased heterogeneity. We also calculated the magnitude of the effect only in the experimental group (Schroth and core group), as post-minus pre-intervention. Statistical significance was set at $p < 0.05$. Heterogeneity between studies was assessed using the Higgins I^2 test and p values. For the meta-analysis, the interpretation of heterogeneity across randomized trials was as follows: from 0 to 40%: might not be important; from 30 to 60%: may represent moderate heterogeneity; from 50 to 90%: may represent substantial heterogeneity; from 75 to 100%: considerable heterogeneity.

Results

Study selection and characteristics

Based on the search strategy, a total of 216 studies were selected from the initial database search. After the removal of 69 studies, 147 studies were selected for further analysis. After screening of titles and abstracts, 110 studies were excluded since they did not meet the inclusion criteria. The remaining 37 studies were completely reviewed. After the review of the full-text articles, 24 studies were excluded. The remaining 13 studies, shown in Table 1, were included in this review. The flowchart of the study selection process is shown in Fig. 1.

Table 1 shows the main characteristics of the included studies. A total of 412 subjects with scoliosis participated in the thirteen included studies. The sample size of the included studies ranged from 15 to 51, including 137 subjects in the Schroth method and 123 subjects in the core stabilization exercises. Schreiber [16, 24] used the same cohort reporting different outcomes in the two studies [3, 24]. The age of the respondents ranged between 10 and 23 years. The duration of the daily treatment ranged from 50 min up to 120 min. The total duration of the treatment ranged from 6 weeks to 6 months. As comparators, groups without treatment were used, standard of care of subjects who attended only initial and final measurements, Pilates exercises, respiratory muscle exercises performed using SpiroTiger, traditional rehabilitation which included breathing exercises, spine flexibility exercises, stretching exercises for muscles involved (especially for concave sides of the curve), and general strengthening exercises for the main muscle groups of the torso, pelvis, and shoulder girdle muscles (especially on the convex sides curve), manual massage, scientific exercises approach to scoliosis (SEAS), brace, and some studies have used Schroth exercises and core stabilization exercises in the control groups (Table 1).

Of the 13 included studies, according to the National Health and Medical Research Council (NHMRC) hierarchy of evidence [21], the study of Ko and Kang [16] was assessed as level III, while the other studies were assessed as level II.

Risk of bias

Figures 2 and 3 present the summary of the risk of bias for each included study. For the item of random sequence generation, twelve studies were randomized controlled trials, while one study did not report information regarding the randomization process [16] as shown in Risk of bias (Fig. 3). The item concerning the allocation concealment to the group

Table 1 Characteristics of the studies included

Study (First author, year)	Study design	Type of exercise program	Sample N	Age	Outcomes	Cobb angle size	Exercise time per day	Exercise program duration	Control group
Duang-keaw [31]	RCT	Schroth 3D exercises vs. Kinesio tape + Schroth exercises	16 (6 vs. 10)	10–18 (14.67±2.34 vs. 17.00±1.63)	ATR Inspiratory muscle strength Expiratory muscle strength Back muscle endurance General vertebral mobility	N/A	120 min	6 weeks	Yes
HwangBo [28]	RCT	Schroth exercises vs. Pilates exercises	16 (8 vs. 8)	18.14±1.6 vs. 18.88±1.55	Cobb angle Psychological factors	>20° (22.07°±6.81° vs. 21.20°±3.95°)	60 min	12 weeks	Yes
Kim [18]	RCT	Pilates exercises vs. Schroth exercises	24 (12 vs. 12)	15.6±1.1 vs. 15.3±0.8	Cobb angle Body weight distribution	>20° (23.63°±1.5° vs. 24°±2.6°)	60 min	12 weeks	Yes
Kim [29]	RCT	Schroth 3D exercises vs. Respiratory muscle exercises (SERME)	15 (7 vs. 8)	17.75±4.71 vs. 15.57±2.70	Cobb angle Pulmonary function Functional movement screen	>10° 27.16°±12.44° vs. 24.49°±8.32°	60 min	8 weeks	Yes
Kocaman [25]	RCT	Schroth exercises vs. core stabilization exercises	28 (14 vs. 14)	10–18 (14.07±2.37 vs. 14.21±2.19)	Cobb angle ATR Cosmetic trunk deformity Spinal mobility QoL Peripheral muscle strength	10°–30° (Cobb angle of thoracic 17.64°±4.01 vs. 17.29°±3.45°) (Cobb angle of lumbar 15.80°±3.42° vs. 15.17°±4.02°)	90 min	10 weeks	Yes
Kuru [27]	RCT	Supervised Schroth 3D exercises vs. Home based Schroth 3D exercises vs. Control (No treatment)	45 (15 vs. 15 vs. 15)	10–18 (12.9±1.4 vs. 13.1±1.7 vs. 12.8±1.2)	Cobb angle ATR Waist asymmetry Maximum hump height QoL	10°–60° (33.4°±8.9° vs. 30.3°±7.6° vs. 30.3°±6.6°)	90 min	6 weeks 6 months	Yes
Schreiber [24]	RCT	Supervised Schroth exercises + Standard of care vs. Standard of care	50 (25 vs. 25)	10–18 (12.7–14.2 vs. 12.7–13.9)	QoL Back extensor strength back muscles endurance patients' perception deformity	10°–45°	60 min + 30–45 min home	3 months 6 months	Yes

Table 1 (continued)

Study (First author, year)	Study design	Type of exercise program	Sample N	Age	Outcomes	Cobb angle size	Exercise time per day	Exercise program duration	Control group
Schreiber [3]	RCT	Schroth exercise vs. Standard of care	50 (25 vs. 25)	10–18 (12.7–14.2 vs. 12.7–13.9)	Cobb angle Sum of curves	10°–45° Cobb angle of thoracic	60 min + 30–45 min home	6 months	Yes
Gür [9]	RCT	Core stabilization exercises vs. Control (Traditional rehabilitation)	25 (12 vs. 13)	10–16 (14.2 ± 1.8 vs. 14 ± 1.6)	Cobb angle Apical vertebral rotation QoL Trunk asymmetry Cosmetic trunk deformity	35° ± 11.82° vs. 31.42° ± 6.97° Cobb angle of lumbar 29° ± 8.35° vs. 34.33° ± 9.2° Cobb total angle 56.75° ± 25.70° vs. 60.69° ± 17.75°	60 min	10 weeks	Yes
Ko [16]	CCT	Core stabilization exercises vs. Control (No treatment)	29 (14 vs. 15)	12.71 ± 0.72 vs. 12.80 ± 0.86	Cobb angle Flexibility Lumbar flexion muscle Lumbar extension muscle lumbar muscle strength	10°–20° (Cobb angle of thoracic14.46° ± 2.07° vs. 13.93° ± 1.96°) (Cobb angle of lumbar 15.95° ± 1.84° vs. 15.36° ± 2.07°)	60 min	12 weeks	Yes
Park [26]	RCT	Supervised core exercises (Community group-based) vs. core exercises (home based)	51 (28 vs. 23)	20 ± 2 vs. 20.6 ± 1.8	Cobb angle Back muscle strength	10°–20° (4.5° ± 3.4° vs. 2.0° ± 2.8°)	50 min	10 weeks	Yes
Park [15]	RCT	Core stabilization exercises vs. Control (Manual massage)	33 (17 vs. 16)	≥ 20 (14 ± 1.3)	Cobb angle Static and dynamic Balance	10°–25° (15.76° ± 2.72° vs. 17.81° ± 2.99°)	50 min	8 weeks	Yes
Yagci [30]	RCT	Core stabilization exercises + Brace vs. Scientific exercises approach to scoliosis (SEAS) + Brace	30 (15 vs. 15)	≥ 12 (14.0 ± 1.3 vs. 14.2 ± 1.5)	Cobb angle ATR Trunk asymmetry cosmetic trunk deformity QoL	20°–45° (Cobb angle of thoracic 30.0° ± 9.3° vs. 27.6° ± 8.0°) (Cobb angle of lumbar 24.9° ± 9.0° vs. 25.9° ± 8.0°)	40 min + 20 min home	4 months	Yes

N Number of participants, *ATR* Angle of trunk rotation, *QoL* Quality of life, *N/A* Not answered, *RCT* Randomized controlled tria, *CCT* Clinical controlled trial

Fig. 3 Risk of bias for each study. Legend. Yellow, unclear risk; green, low risk

was unclear in one study [18]. Because of the nature of the intervention, participants and investigators could not be blinded to the treatment, but one study reports that it used blinding [9]. For outcome blinding, four studies adopted a single-blind method to evaluate the intervention measures [3, 24–26]. All studies had low risk in incomplete outcome data. One study had unclear risk in selective reporting, while

12 studies had low risk. Because of objective outcome measures, outcome data were considered at low risk in 12 studies [27].

Meta-analysis

Cobb angle

A total of 11 studies measured the outcome of Cobb angle [3, 9, 15, 16, 18, 25–30]: 6 studies using the Schroth method and 5 studies using the core stabilization exercises. After data pooling, SMD between post- and pre-intervention (Schroth or core stabilization) in the experimental group and the control group, statistical significance was reached: SMD = − 0.376; 95% CI = − 0.565, − 0.187, $p < 0.001$; heterogeneity ($I^2 = 0\%$, $p = 0.823$) (Fig. 4). Subsequently, a subgroup analysis for Cobb angle outcome was performed for both the Schroth method and the core stabilization exercises. Subgroup Schroth method showed the following results: SMD = − 0.417; 95% CI = − 0.705, − 0.129, $p = 0.005$; heterogeneity $I^2 = 0\%$, $p = 0.831$. Subgroup core stabilization exercises showed the following results: SMD = − 0.345; 95% CI = − 0.596, − 0.94, $p = 0.007$; heterogeneity $I^2 = 0\%$, $p = 0.521$) (Fig. 5).

The overall results from post- minus pre-intervention in the experimental group were: SMD = − 0.821; 95% CI = − 1.189, − 0.454, $p = 0.104$; heterogeneity $I^2 = 70.06\%$, $p = 0.000$. Subgroup Schroth method showed the following results: SMD = − 0.996; 95% CI = − 1.662, − 0.331, $p = 0.003$; heterogeneity $I^2 = 77.22\%$, $p = 0.000$. Subgroup core stabilization exercises showed the following results: SMD = − 0.700; 95% CI = − 1.143, − 0.256, $p = 0.002$; heterogeneity $I^2 = 65.5\%$, $p = 0.005$ (supplementary materials).
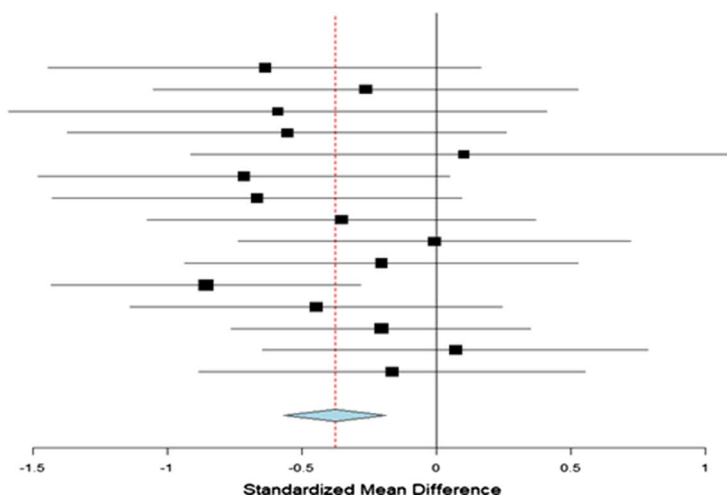

Fig. 4 Standardized mean difference (SMD) of the Cobb angle outcome. Legend. Squares represent the SMD for each trial. Diamonds represent the pooled SMD across trials
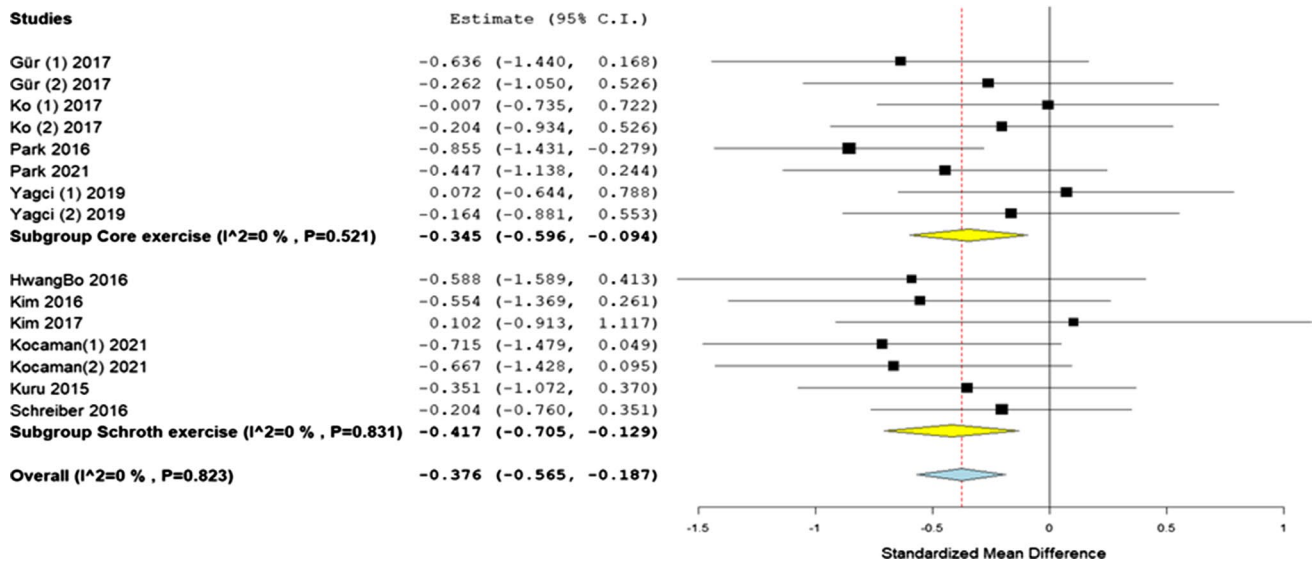
Fig. 5 Standardized mean difference (SMD) of the Cobb angle outcome, subgroup analysis. Legend. Squares represent the SMD for each trial. Diamonds represent the pooled SMD across trials
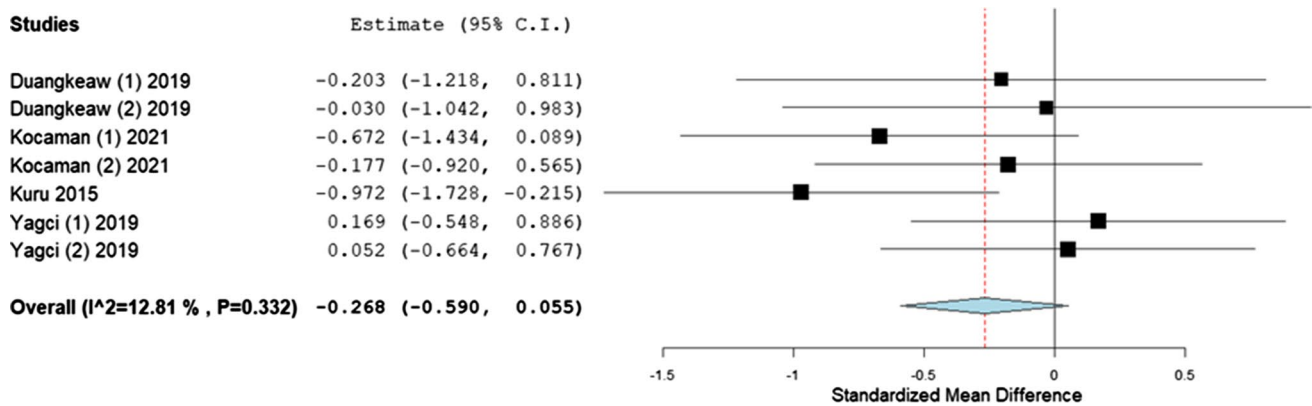

Fig. 6 Standardized mean difference (SMD) of the angle of trunk rotation (ATR) outcome. Legend. Squares represent the SMD for each trial. Diamonds represent the pooled SMD across trials

ATR

A total of 4 studies measured the outcome of ATR [25, 27, 30, 31]: 3 studies using the Schroth method and 1 study using the core stabilization exercises. There was no statistical significance in the total effect size of Schroth method and core stabilization exercises on ATR outcome when the final results of the measurement in the experimental and control group were compared with the initial results in the experimental and control group (SMD = − 0.268; 95% CI = − 0.590, − 0.055, p = 0.104), heterogeneity ($I^2 = 12.81\%$, p = 0.332) (Fig. 6). Subsequently, a subgroup analysis for ATR outcome was performed for both the Schroth method and the core stabilization exercises. Subgroup Schroth method showed

the following results: SMD = − 0.471, 95% CI = − 0.842, − 0.099, p = 0.013; heterogeneity $I^2 = 0\%$, p = 0.471. Subgroup core stabilization exercises showed the following results: SMD = 0.110, 95% CI = − 0.396, 0.617, p = 0.670; heterogeneity $I^2 = 0\%$, p = 0.820) (Fig. 7).

The overall results from post- minus pre-intervention in the experimental group were: SMD = − 0.992; 95% CI = − 1.472, − 0.513, p < 0.001; heterogeneity $I^2 = 52.53\%$, p = 0.049. Subgroup Schroth method showed the following results: SMD = − 1.064; 95% CI = − 1.678, − 0.451, p < 0.001; heterogeneity $I^2 = 53.58\%$, p = 0.071. Subgroup core stabilization exercises showed the following results: SMD = − 0.848; 95% CI = − 1.845, 0.149, p = 0.095; heterogeneity $I^2 = 71.03\%$, p = 0.063 (supplementary materials).
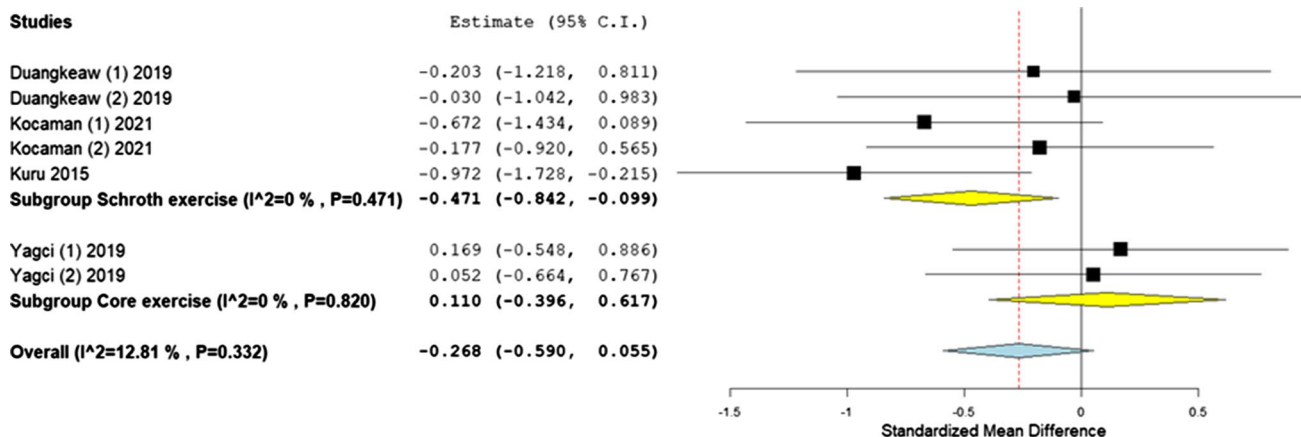
Fig. 7 Standardized mean difference (SMD) of the angle of trunk rotation (ATR) outcome, subgroup analysis. Legend. Squares represent the SMD for each trial. Diamonds represent the pooled SMD across trials
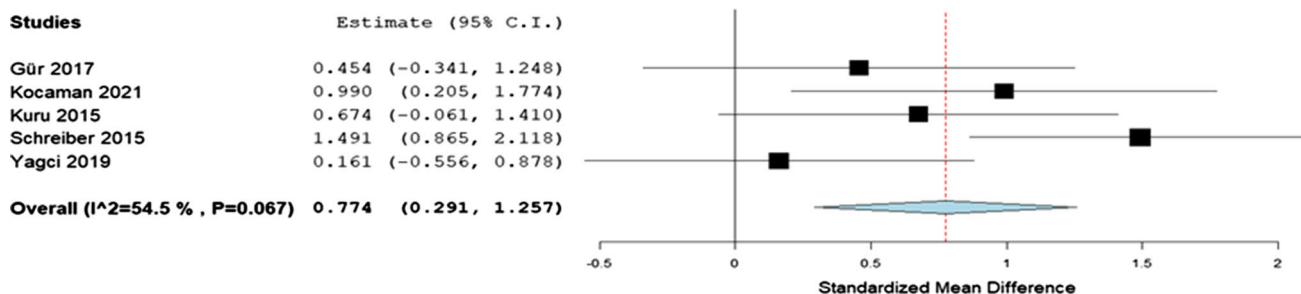

Fig. 8 Standardized mean difference (SMD) of the quality of life outcome. Legend. Squares represent the SMD for each trial. Diamonds represent the pooled SMD across trials

QoL

A total of 5 studies measured the outcome of QoL [9, 24, 25, 27, 30]: 3 studies using the Schroth method and 2 studies using the core stabilization exercises. The total effect size for all five studies when the final results of the measurement in the experimental and control group were compared with the initial results in the experimental and control groups was: SMD = 0.774; 95% CI = 0.291, 1.257, $p = 0.002$; heterogeneity $I^2 = 54.5\%$, $p = 0.067$) (Fig. 8). Subsequently, a subgroup analysis for QoL outcome was performed for both the Schroth method and the core stabilization exercises. Subgroup Schroth method showed the following results: SMD = 1.087, 95% CI = 0.597, 1.578, $p < 0.001$; heterogeneity $I^2 = 30.06\%$, $p = 0.239$. Subgroup core stabilization exercises showed the following results: SMD = 0.292, 95% CI = – 0.240, 0.825, $p = 0.282$; heterogeneity $I^2 = 0\%$, $p = 0.592$) (Fig. 9).

The overall results from post- minus pre-intervention in the experimental group for the outcome QoL are not presented due to high heterogeneity ($I^2 = 92.41\%$, $p = 0.000$).

Discussion

In this systematic review and meta-analysis, we combined the results of 13 studies in order to calculate the magnitude effect of Schroth method and core stabilization exercises in subjects with idiopathic scoliosis in a total of 412 participants.

In the thirteen studies considered, there were three outcomes measured by at least two studies, and we estimated the magnitude effect of them. In addition, a subgroup analysis of Cobb angle, ATR, and QoL outcomes was performed to compare the two approaches by effect size.

Cobb angle, the most reference value for determining the size of scoliotic deformities, was significantly reduced by applying Schroth method and core stabilization exercises. In our meta-analysis, we calculated the effect size for all three outcomes, and we presented the results comparing post- minus pre-intervention in the experimental and the control group.

By analyzing the outcome of Cobb angle for the total effect size of Schroth method and core stabilization exercises,
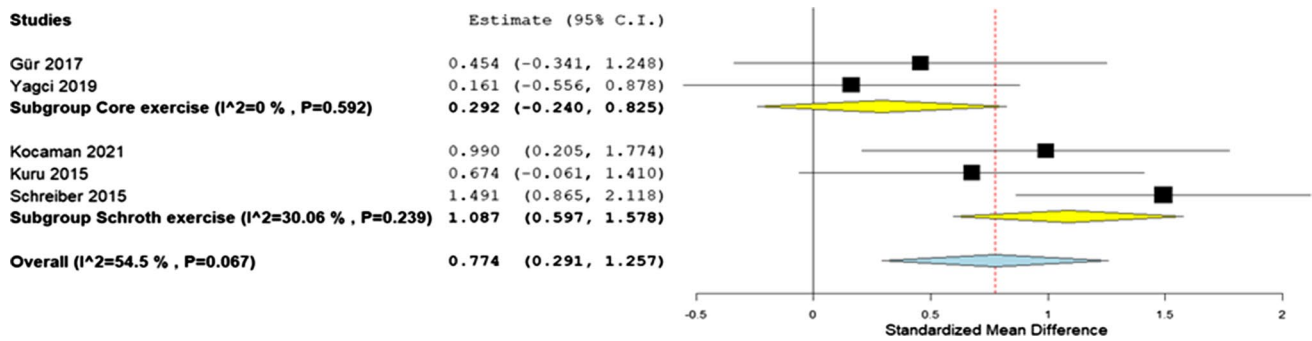
Studies	Estimate (95% C.I.)
Gür 2017	0.454 (−0.341, 1.248)
Yagci 2019	0.161 (−0.556, 0.878)
Subgroup Core exercise (I^2=0 % , P=0.592)	0.292 (−0.240, 0.825)
Kocaman 2021	0.990 (0.205, 1.774)
Kuru 2015	0.674 (−0.061, 1.410)
Schreiber 2015	1.491 (0.865, 2.118)
Subgroup Schroth exercise (I^2=30.06 % , P=0.239)	1.087 (0.597, 1.578)
Overall (I^2=54.5 % , P=0.067)	0.774 (0.291, 1.257)

Fig. 9 Standardized mean difference (SMD) of the quality of life outcome, subgroup analysis. Legend. Squares represent the SMD for each trial. Diamonds represent the pooled SMD across trials

statistical significance was achieved (SMD $=-0.376$), according to the Cohen's criterion for small effect size (Fig. 4). When subgroup analysis was subsequently performed, it showed that Schroth method had a larger effect size than core stabilization exercises (subgroup Schroth method: SMD $=-0.417$; subgroup core stabilization exercises: SMD $=-0.345$). From both analyzes, it was determined that there was no occurrence of heterogeneity among the included studies (Fig. 5).

By analyzing the outcome of ATR, negligible heterogeneity appeared, and there was no statistical significance of the effect size (SMD $=-0.268$), according to the Cohen's criterions for small effect size (Fig. 6). Analysis of subgroup for ATR outcome showed that Schroth method had a larger effect size than core stabilization exercises (subgroup Schroth method: SMD $=-0.471$; subgroup core stabilization exercises: SMD $=0.110$) (Fig. 7).

By analyzing the outcomes of QoL, the results showed an almost large effect size (SMD $=0.774$), according to the Cohen's criterions for large effect size, and moderate heterogeneity appears ($I^2=54.5\%$) (Fig. 8). Analysis of subgroup for the outcome of QoL showed that Schroth method had a larger effect size than core stabilization exercises (subgroup Schroth method: SMD $=1.087$; subgroup core stabilization exercises: SMD $=0.292$) (Fig. 9). Analysis of subgroup for QoL also solved the problem of heterogeneity that did not occur in the subgroup core stabilization exercises and occurred in the subgroup Schroth method ($I^2=30.06\%$) (Fig. 9).

The results of the effect size analysis for the Cobb angle outcome only in the experimental group (Schroth and core) show a large effect size (SMD $=-0.821$), but with the presence of substantial heterogeneity ($I^2=70.06\%$), which also occurs in the Schroth group ($I^2=77.22\%$) and in the core group ($I^2=65.5\%$) (supplementary materials). The results of the effect size analysis for the ATR outcome only in the experimental group (Schroth and core) show a large effect size (SMD $=-0.992$), but with the presence of

moderate heterogeneity ($I^2=52.53\%$), which also occurs in the Schroth group ($I^2=53.58\%$) and in the core group ($I^2=71.03\%$) (supplementary materials). The results of the effect size analysis for the QoL outcome only in the experimental group (Schroth and core) show considerable heterogeneity ($I^2=92.41\%$) and are not even shown.

Twelve included studies had low risk of bias, while the study of Kim [18] the only one had unclear risk of bias. The study of Ko et al. [16] is the only one not reporting whether it used the randomization process. The study of Kuru et al. presented the results of the final measurement for Cobb angle and QoL outcomes as Median (min–max) and not as Mean $\pm$ SD, which is a problem during the meta-analysis. This problem has been addressed according to recommendations [22].

Our meta-analysis is the only one so far that has assessed the magnitude effect of these two approaches and, through subgroup analysis, has compared which of these two treatments revealed better results for subjects with IS. A meta-analysis evaluated various conservative methods for treating IS, and some of them used the Schroth and core stabilization exercises [32]. In this meta-analysis, the magnitude effect, in terms of standardized mean difference, was 0.42 for the outcome of Cobb angle with no heterogeneity. Only one meta-analysis [12] examined the effect size for the Schroth method (SMD $=0.724$) with high heterogeneity ($I^2=75.67\%$, $p=0.000$), while no meta-analysis examined the effect size of the core stabilization exercises. In the study by Park et al., the magnitude of the effect for the Cobb angle outcome was (SMD $=0.65$), with no report of heterogeneity. The magnitude of the effect for the ATR outcome was (SMD $=0.53$), with no report of heterogeneity. The magnitude of the effect for the QoL outcome was (SMD $=0.76$), also without reports of heterogeneity.

The Schroth method has long been used in the treatment of subjects with IS. Unlike the Schroth method, the core stabilization exercises has recently been used in the treatment of IS. In addition to these two approaches, we have other

conservative methods used for these respondents. Many of the studies listed here record statistically significant results on both the impact of Schroth method and the impact of core stabilization exercises [9, 15, 18, 25, 26, 28]. Indeed, these two methods are not mutually exclusive, so they can be used together in the coming period to get better results in the treatment of IS. The various studies included in this meta-analysis provided evidence that conservative approaches as Schroth method and core stabilization exercises have a positive effect on individual outcomes through which the condition of subjects with IS is assessed [3, 9, 15, 16, 18, 24–31].

This study has several limitations. First, despite a comprehensive search, our study included only those written in English. Second, despite a detailed search, the number of studies found that would have common outcomes, except for Cobb angle, is relatively small.

Conclusion

This study addressed two conservative methods used in the treatment of subjects with IS. The current meta-analysis indicates that Schroth method and core stabilization exercises have a positive effect on subjects with IS. Depending on the outcome, the magnitude of the effect ranged from small to almost large. Subgroup analysis showed that the Schroth method had a larger effect size than the core stabilization exercises. Of the four outcomes we used in our meta-analysis, the most representative result is an estimate of the effect size for Cobb angle, as 11 studies participated in the analysis. We believe that our meta-analysis would be a good tool for specialist in physical activity, physiotherapists, and clinicians in solving IS-related problems, as well as an incentive for further work and future research.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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