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The best therapeutic exercise methods based on age, Cobb and trunk rotation angles in children and adolescent idiopathic scoliosis: A systematic review

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Abstract

Background: The promising results of idiopathic scoliosis for children and adolescent idiopathic scoliosis found in low-quality in review of literature in Iran.

Aim: The purpose of this study was to investigate the effect of various types of exercises to improve idiopathic scoliosis in terms of reducing Cobb angle and angle of trunk rotation (ATR) in different ages of children and adolescents.

Materials and Methods: Searches were conducted in databases including Cochrane, PubMed, Scopus and Google Scholar during 2005-2021. Inclusion criteria were papers using only corrective exercises (CE) or CEs with braces as an intervention. The PEDro scale was used for evaluating the quality of papers.

Results: Thirteen papers were licensed for review. The papers (PEDro: 4-9) showed the positive effect of the CEs in reducing Cobb angle (eleven papers) and ATR (eight papers) greater than 5° and 3°, respectively. Moreover, two papers (PEDro: 4-7) showed that the physiotherapy scoliosis specific exercises (PSSE) were more effective than the general exercises (GE), while no paper was found to compare one PSSE to another. Two papers (PEDro: 6-9) indicated the greater effectiveness of CEs in childhood than adolescence.

Conclusion: The relative evidence suggested the effect of CEs on improving idiopathic scoliosis, especially in children. However, it seems that the use of SEAS and Schroth methods, depending on the individual nature, can be more effective. High-quality papers are necessary to achieve more accurate results in the future.

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1. Introduction

Scoliosis is a lateral and three-dimensional deformity in the spine and trunk [1], which can cause changes in the kinetics and kinematics of other organs in the distal and proximal areas, leading to the defective cycle in the musculoskeletal system [2]. Therefore, it is followed by the secondary physical effects such as trunk asymmetry, muscle imbalance, decreased respiratory capacity, decreased quality of life (QoL) and even pain [1, 2, 3].

Scoliosis is usually divided into non-idiopathic scoliosis caused by pathophysiological disorders [4], and idiopathic scoliosis caused by physio pathological disorders [5]. The prevalence rate of scoliosis is reported around 3-5% and in some sources up to 9% in the general societies [6], approximately 70-80% of which is related to the children and adolescent idiopathic scoliosis [7].

A person is identified as the patient with scoliosis and considered as a candidate for treatment services, when the angle of deflection of the spine in the frontal plane is equal to or greater than 10° and the angle of trunk rotation (ATR) is greater than 3° [8, 9]. Scoliosis is considered as the mild, moderate, and severe when the deflection is up to 25, between 25-45, and greater than 45°, respectively [10].

Researchers proposed different strategies for preventing, managing, and correcting the scoliosis, depending on the severity of the deformity [1, 3, 11]. Invasive methods such as surgery used for severe deflections and conservative methods including corrective exercises (CE) and braces used for mild to moderate deflections were reported to be effective to treat scoliosis [12]. However, surgical methods received less attention due to the side effects, high economic costs, long recovery period, as well as fear created in the scoliosis person, especially in children and adolescents [13]. Therefore, the use of conservative methods is further considered by therapists, families, and affected persons [12, 14]. As physical activity in the form of sports and games is the nature of childhood and adolescence, they show much less tendency to use braces compared to the adults [3, 8].

All of the above-mentioned have highlighted the importance of the CEs for improving this deformity. Nevertheless, no exact evidence was presented for the effectiveness of the CEs and the superiority of one method of these exercises [1, 15, 16, 17, 18, 19]. CEs including general exercises (GE) (e.g. stability, Pilates, Yoga) and physiotherapy scoliosis specific exercises (PSSE) (scientific exercise approach to scoliosis (SEAS), Barcelona scoliosis physical therapy school (BSPTS), functional individual therapy of scoliosis (FITS), Side Shift, Lyon, Dobomed and Schroth) are the most popular solutions used by researchers [11, 20]. The difference is that the GEs are used not only to improve scoliosis [1, 9, 21, 22], but also to correct other spinal deformities such as kyphosis and lordosis [23, 24, 25]. However, the PSSEs are only used for improving the idiopathic scoliosis [20]. A survey, which was performed among the members of the scoliosis research society (SRS) to choose GEs or PSSEs, showed that both types of exercises can have the same effect in controlling and improving this deformity [7].

Some researchers reported that the PSSEs were more effective due to their specified structure [26, 27], while some indicated weak evidence of the effectiveness of these methods [7]. Additionally, the lack of separating the

population in different age groups to identify the effects of exercise in each age group more accurately is a significant point, which has received less attention. Nonetheless, some studies recommended the CEs in childhood and early adolescence [17] and some reported that the appropriate time was the final stages of adolescence [28, 29].

The last review study conducted by Fan et al. (2020), indicated insufficient evidence for the overall effectiveness of CEs and the superiority of one of these methods [30]. Further, they suggested that future studies examine factors such as age and skeletal maturity that can alter the effects of CEs on reducing Cobb and trunk rotation angles in patients with idiopathic scoliosis. So far, all of the review studies only considered the population as general and/or adolescents, while no review study investigated the child and adolescent population with idiopathic scoliosis.

Therefore, this systematic review aimed to determine the overall effect of CEs, its effects in different age periods and comparing the effect of these exercise methods in reducing Cobb angle and ATR in children and adolescents with idiopathic scoliosis. We assume that all CE methods will demonstrate objective amelioration in these patients.

2. Materials and Methods

This study is a systematic review, which was conducted by searching the studies during 2005 to August 2021 in the databases including PubMed, Cochrane, Google Scholar, and Scopus. The keywords such as “adolescent”, “children”, “idiopathic scoliosis”, “corrective exercise”, “physiotherapy”, “age”, “side-shift”, “FITS”, “SEAS”, “schroth”, “scoliosis specific exercise”, “prevention”, “rehabilitation”, “core stability”, “DoboMed”, “Pilates”, “Yoga”, and “conservative” were used in this study. Further, it was limited to the papers published in the English language.

2.1. Inclusion and exclusion criteria

Selection criteria were considered based on the population, interventions, comparisons, outcomes and study designs (PICOS). No restrictions were considered during the exercise interventions. Additionally, no restriction was considered as the angle of curvature and the number of arches.

2.2. Population

Papers including children and adolescents with idiopathic scoliosis were studied. Other papers about pathophysiological disorders or other deformities such as kyphosis or lordosis were excluded from the study.

2.3. Interventions

The papers intervened at least one exercise method were included in this study. Papers, which used surgery, kinesio tape, and massage in one of the intervention groups with the exception of brace and exercise, were excluded from the study.

2.4. Comparison groups

The number of comparison groups was not considered as a limiting factor. The groups included an exercise group with its own before and after data, an exercise group with a control (CON) group, and two exercise groups with the CON group and more groups.

2.5. Outcomes

Evaluating the Cobb angle is the main inclusion criterion. ATR variable was considered as a secondary criterion. As a third criterion, no restrictions are

considered in the other variables.

2.6. Study design

The papers entering to the study were limited to randomized controlled trial studies (RCT) and clinical controlled trial (CCT).

2.7. Quality assessment and level of evidence

The quality of the papers was assessed using the PEDro scale [31, 32]. This scale consists of 11 items, which, score 1 is considered for the positive answer of each item and score 0 is considered if there is negative answer. Moreover, no score belongs to the answer to the first question. Finally, all the scores are added up and considered as the final score; the scores are between 0-10. The scores between 8-10, 5-7, and 0-4 are considered as high, moderate, and low quality levels, respectively [31, 33].

The evidence level was determined based on the Cochrane Back Review Group [34]. Level A (strong) was given if consistent findings were observed among multiple high quality RCTs. Level B (moderate) was considered when one high-quality RCT or consistent findings existed among multiple low quality RCTs and CCTs. Level C (limited) was presented when one low quality RCT or CCT existed. Level D (conflicting) was considered when inconsistent findings were found between RCT and CCT [30]. No evidence was considered when no papers were found about trials (no RCTs or CCTs).

3. Results

208 papers were found by using the above-mentioned keywords in the first search. Among which 34 papers were selected, which were in the main framework of the study but were slightly different from the final goal of the research. Among these papers, seven papers were removed due to non-compliance with the age of the study population. Three and nine papers were removed due to duplication and unclear exercise protocols, respectively. Moreover, two papers were removed since only the abstract of which was English and another language was used in the original text (Figure 1). Finally, 13 papers with 1108 participants were included to the study, among which the lowest [28] and highest [3] number of participants were 15 and 293 cases, respectively (Table 1). Since none of the papers had similar conditions based on the study type, statistical methods, evaluation methods and personal characteristics of the populations, it was not possible to conduct the meta-analysis.

3.1. Exercise methods

In general, 39, 30, and 7% of the papers used the SEAS [3, 8, 11, 29, 35], Schroth [15, 28, 36, 37], and FITS [38] methods, respectively. Overall, 76% of included papers used PSSEs [3, 8, 11, 15, 28, 29, 35, 36, 37, 38]. Moreover, GEs were used in 38% of the papers including physiotherapy [3, 35], traditional [29, 39], breathing [36], core stability [11], Pilates [15], Plank [40], and Xinmiao [17] exercises (Figure 2).

3.2. Exercise groups

Thirty-eight percent of the papers compared the PSSEs with the GEs or the CON group [3, 11, 28, 29, 35]. 15% of all the papers compared the exercise group with the brace group [37, 38]. 23% of these papers were conducted on one group [8, 15, 36], while GEs were compared with the CON group in 15% of them [39, 40]. Finally, the brace was used in the protocol of 53% of all studies [3, 8, 11, 15, 37, 38, 40] (Table 1).

Table 1. Evaluating the protocols and results obtained from the papers

Author names	Days	Methods	Population	Dependent variables and tools	Purpose	Results
Otman et al. [36]	42, 180, 365	Schroth (N=50)	Men and women, Age (15.14) Cobb angles (26.10º)	Cobb angles (XR), Vital capacity (Inhalation and exhalation in airbags), Muscle strength (Manual muscular strength tests).	Determining the effect of Schroth method on the Cobb angles, vital capacity, and muscular strength around the trunk in AIS.	The Cobb angles decreased from 26 to 23.45, 19.25 and 17.85° after 6 weeks, 6 months and 1 year, respectively (P <0.01). Vital capacity increased from 2795 mL to 2956, 3125 and 3215, respectively (P <0.01). Muscle strength increased (P<0.01).
Negrini et al. [35]	365	SEAS (N=35) PT (N=39)	Women, age (12.14), Cobb angles (12.4°)	Cobb angles (XR), ATR (Scoliometer)	Comparing the effect of SEAS method and PT to avoid braces and prevent the progression of curvature and ATR in AIS.	The Cobb angles improved in 23.5% of patients and worsened in 11.8% of them in the SEAS group. Moreover, it improved in 11.1% of the patients and worsened in 13.9% in the PT group. The ATR improved in 9.1%, worsened in 15.1% in the SEAS group, and improved in 2.8% in the PT group. Failure in decreasing the use of the brace was reported 11.5 and 30.8% for the SEAS and PT groups, respectively.
Zaina et al. [29]	985	SEAS (N=14) GE (N=14) Discontinuous exercises (N=19 CON) No practice (N=10 CON)	Women, age (15±1), Cobb angles (22±8º)	Cobb angles (XR), ATR (Scoliometer)	Comparing the effect of SEAS and the GE on the Cobb angles and ATR in AIS.	The Cobb angles (22°) increased by 3.1° without exercise and by 3.9° in intermittent exercises.
Białek [38]	1022	FITS without brace (N=78) FITS with brace (N=37)	Men and women, age (12.17), Cobb angles (10-25º) (26-40º)	Cobb angles (XR), ATR (Scoliometer), distance plumb line (cm), Scapulae level asymmetry (Bunnell degrees).	Comparing the effect of FITS method in groups lower and higher than 25° on the Cobb angles, ATR in children and adolescents.	The Cobb angles (17º): 50,0% of patients improved, 46,2% were remained unchanged and 3,8% progressed in and single arc ATR. 50,0% of patients improved, 30,8% were stable and 19,2% progressed in double-arc ATR (without bracing).

Author names	Days	Methods	Population	Dependent variables and tools	Purpose	Results
						The Cobb angles (28.6º): 20,0% of patients improved, 80,0% were remained unchanged in single-arc, ATR. 28,1% of patients improved, 46,9% were remained unchanged and 25,0% progressed in double-arc (with bracing).
Monticone, et al. [39]	365	Self-correction and performing the right techniques (N=55) GE or CON (N=55)	Men and women, age (12.14), Cobb angles (19.3º)	Cobb angles (XR), ATR (Scoliometer), QoL (SRS).	Comparing the effect of two non-specialized self-correction and GE methods on the Cobb angles, ATR and QoL in children and adolescents.	The Cobb angles (19º): 69% of patients improved, 8% progressed, and 23% remained unchanged in the self-correction group, and 6% of patients improved, 39% progressed, and 55% remained unchanged in the CON. The ATR improved by 3.5º (exercise) and remained unchanged (CON). QoL (exercise) significantly increased, and the effect of time in both groups showed a significant increase (P <0.01). However, this effect was more in the exercise group (P <0.01).
Negrini, et al. [8]	4500	SEAS and brace (N=73)	Men and women, age (12.8), Cobb angles (34.4±4.4º)	Cobb angles (XR), ATR (Scoliometer), Plumb line (The distance of the vertical line between the C7 to L3 vertebrae).	Evaluating the effect of SEAS on the Cobb angles, ATR and overall alignment of the trunk in AIS.	The Cobb angles (34°) and ATR of 53.3% of patients improved, 9.6% remained unchanged, and only one patient progressed in the combined exercises of SEAS and brace.
Kwan et al. [37]	56	Schroth (brace) (N=34) CON (only brace) (N=24)	Men and women, age (12.3), Cobb angles (25-40º)	Cobb angles (XR). ATR (Scoliometer), QoL (SRS).	Evaluating the effect of Schroth exercises on the Cobb angles, ATR and QoL in AIS.	The Cobb angles (20-45º): 17% of patients improved, 21% progressed, and 62% remained unchanged in the Schroth group, and 4% of patients improved, 50% progressed, and 46% remained unchanged in the CON. The ATR decreased from 9.43 to 8.45º in the Schroth, which was not significant. Moreover, the ATR was not changed in the CON group. The QoL of the exercise group was significant.

Author names	Days	Methods	Population	Dependent variables and tools	Purpose	Results
Kim & Park [28]	56	Schroth and respiratory muscles (N=8) Schroth (CON) (N=7)	Men and women, age (16.66), Cobb angles (24.49º) (27.16º)	Cobb angles (XR), pulmonary function (Cardio Touch), evaluating the movement disorders (FMS).	Comparing the effect of combination exercises of Schroth and the respiratory muscles and the Schroth exercises alone on the Cobb angles, pulmonary function and assessing the functional movement screening in AIS.	The Cobb angles, pulmonary function and FMS score were significant (P<0.05) in the Schroth and respiratory muscles and the Schroth groups. Combined exercises were significantly more (P <0.05). The experimental and CON, The Cobb angles decreased from 24.49 to 20.23° and from 27.16 to 24.47°, respectively (P <0.05).
Yagci & Yakut [11]	120	SEAS (brace) (N=15) Core stability (brace) (N=15)	Men and women, age (14.1), Cobb angles (20-.45º)	Cobb angles (XR), ATR (Scoliometer), posterior trunk symmetry (POTSI), assessing the trunk deformity (WRVAS), QoL (SRS)	Comparing the effect of SEAS and core stability methods on theCobb angles, ATR, body alignment and QoL in AIS.	Both groups showed significant changes in all the studied variables. Moreover, no significant change was observed in the QoL score in the groups.
Negrini et al. [3]	365, 730	SEAS (brace) (N=145) PT (brace) (N=95) CON (brace) (N=53)	Men and women, age (9), Cobb angles (11-20º)	Cobb angles (XR), ATR (Scoliometer), assessing the body alignment (TRACE index), plumb line (The distance of the vertical line between the C7 to L3 vertebrae).	Comparing the effect of SEAS and GE methods and people without exercise on the Cobb angles, ATR and alignment of trunk in AIS.	The Cobb angles (16°) and ATR showed a difference between all the groups, which was reported less than 5º. The difference in the height of the curvature and the distance of the plumb line in the direction of the spine was reported to be insignificant. The index of assessing the body alignment increased in SEAS and the GEs, respectively, and the score of this index remained unchanged in the CON group. The SEAS group was more effective than the GE and both were more efficient compared to the CON group.
Sarkisova et al. [40]	185	Side plank (brace) (N=32) Anterior plank (brace) (CON) (N=32)	Men and women, age (13)	Cobb angles (XR)	Determining the effect of side and anterior plank exercises on the Cobb angles in AIS.	The Cobb angle (30º) and scoliometer degree were changed from 31 to 32º and from 12 to 13º, respectively, in the side plank group. No change was observed (P=0.67: side plank, P=0.53: CON), (P=0.67: side plank, P=0.22: CON).

Author names	Days	Methods	Population	Dependent variables and tools	Purpose	Results
Rrecaj-Malaj et al. [15]	168	Schroth and Pilates (with and without brace) (N=69)	Men and women, age (10-16), Cobb angles (10-45º)	Cobb angles (XR), ATR (Scoliometer), chest expansion (cm), trunk flexion (cm), QoL (SRS)	The effect of combined exercises of Schroth and Pilates on preventing and reducing the Cobb angles and ATR, and improving the flexibility, trunk alignment and QoL in AIS	The significant differences were reported in the both exercise groups with and without braces (P <0.05). Cobb angles (22°) improved from 27.91 to 18.11 and 19.14 to 11.66 with and without brace, respectively. ATR improved from 7.19 to 5.36 and 4.72 to 3.58 with and without brace, respectively. Chest expansion, trunk flexion, and QoL score improved from 2.56 to 3.46 cm, 9.55 to 14.33 cm, and 3.50 to 3.82, respectively, with brace. Further, chest expansion, trunk flexion, and QoL score improved from 2.57 to 3.52 cm, 9.82 to 13.98, and 3.42 to 3.78.cm, respectively, without brace.
Liu et al. [17]	365	Xinmiao Age (under 10 years) (N=29) Age (10-12 years) (N=24) Age (12-15 years) (N=46)	Men and women, age (11.1), Cobb angles (10-25º)	Cobb angles and Risser sign (XR).	Determining the effect of Xinmiao exercises on children and adolescents in different age groups	The significance of the three groups in the Cobb angles (15°) and growth sign was reported before and after interventions (P <0.05). The significant decrease of 6.8º (44% improvement) was observed in the first group compared to 3.1º (18% improvement) and 1.5º (9% improvement) in the second and third groups, respectively. Moreover, 45.8% (26.1%) improved, 50% (63.0%) were remained unchanged, and 4.2% (10.9%) progressed in the second group (third group).

Abbreviations: GE: General Exercise; PT: Physical Therapy; ATR: Angle of Trunk Rotation; FITS: Functional Individual Therapy of Scoliosis; SEAS: Scientific Exercise Approach to Scoliosis; QoL: Quality of Life; SRS: Scoliosis Research Society Questionnaire; TRACE: Trunk Aesthetic Clinical Evaluation; POTSI: Posterior Trunk Symmetry Index; WRVAS: Walter Reed Visual Assessment Scale; CCT: Clinical Controlled Trial; RCT: Randomized Controlled Trial; AIS: Adolescent Idiopathic Scoliosis.

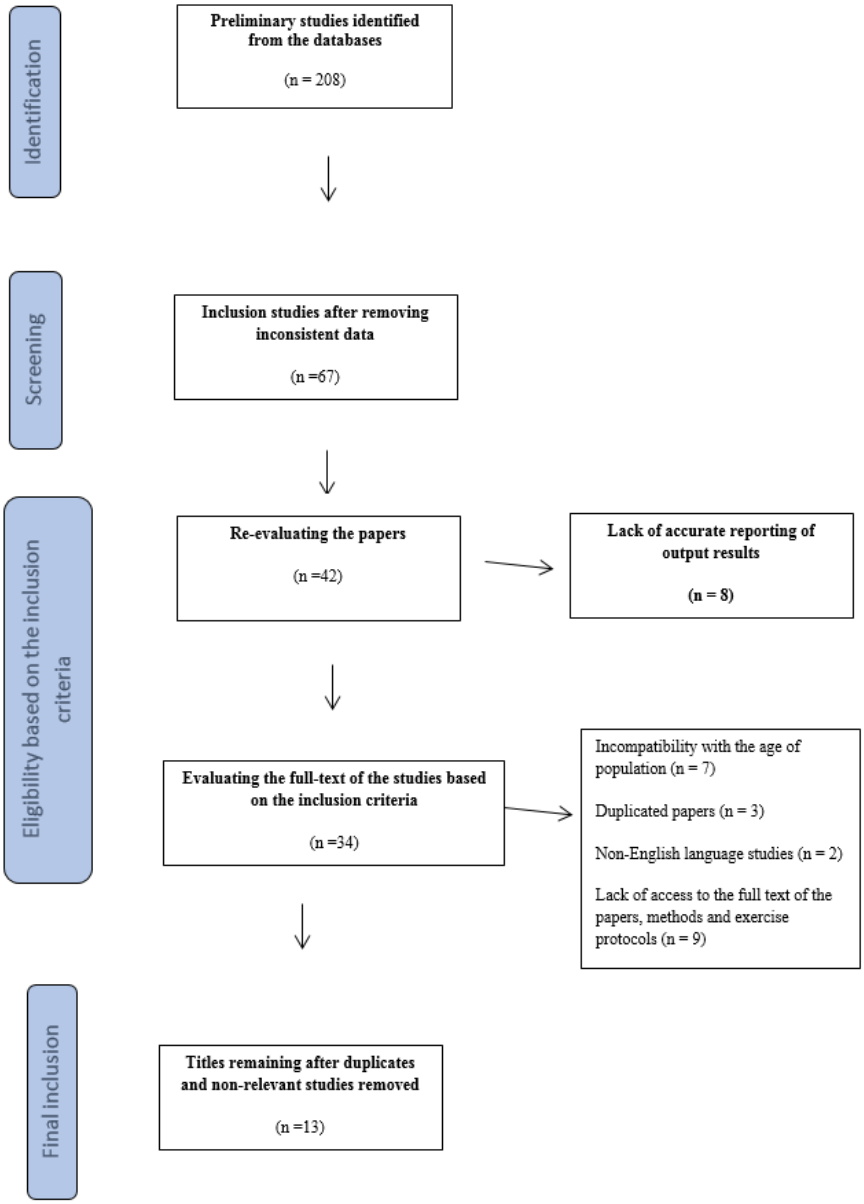

Figure 1. Systematic process of the review study

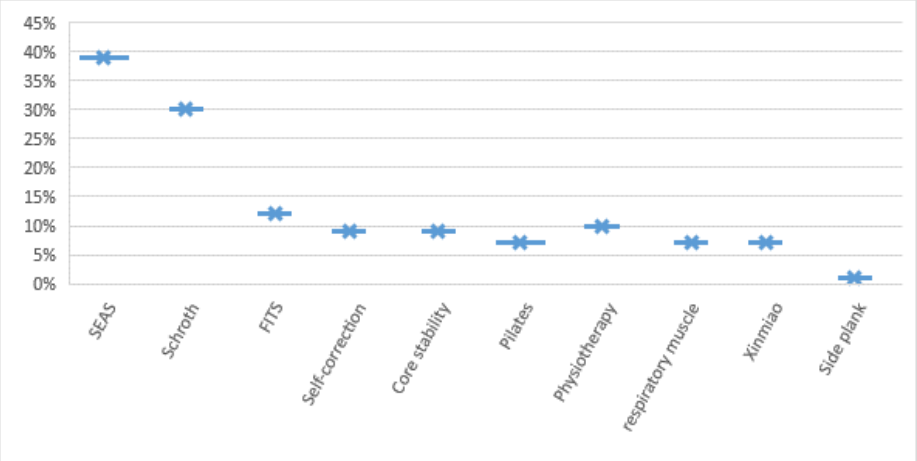

Figure 2. Comparing the average of exercise protocols used in the papers

3.3. Exercise period

Seventy-seven percent of studies used an exercise period longer than 6 months [3, 8, 15, 17, 29, 35, 36, 38, 39, 40], among which 61% was over than 1 year [3, 8, 17, 29, 35, 36, 38, 39], while 15% was less than 2 months [28, 37] (Table 1).

3.4. Dependent variables and instruments

The Cobb angles were evaluated by using radiography (XR) in all studies [3, 8, 11, 15, 17, 28, 29, 35, 36, 37, 38, 39, 40]. The ATR was evaluated by using scoliometer in 70% of the papers [3, 8, 11, 15, 29, 35, 37, 38, 39]. Trunk asymmetry used in 40% of the papers was considered as assessing the trunk alignment by using the line of gravity in the anterior and posterior views of the spine [3, 8, 11, 15, 38]. QoL was found in 30% of the papers, which was evaluated only by using the SRS questionnaire [11, 15, 37, 39]. Respiratory disorders and pulmonary function were observed in 15% of them [28, 36]. Finally, other factors assessing the muscle strength and movement patterns were evaluated by using clinical and FMS tests, which was seen in 15% of all studies [28, 36] (Table 1).

3.5. Quality assessment of included studies

As shown in Table 2, three [28, 35, 36], eight [3, 8, 15, 17, 29, 37, 38, 40], and two papers [11, 39] obtained low, moderate and high quality levels of the PEDro scale, respectively. Overall, the average scores of the PEDro scale indicate the almost moderate quality of the papers.

3.6. The effect of corrective exercises on decreasing Cobb angles and ATR

Relative improvement of Cobb angles (Cobb angle > 5°) [3, 8, 11, 15, 17, 28, 35, 36, 37, 38, 39] and ATR (ATR > 3°) [3, 8, 10, 11, 15, 35, 37, 38, 39] was reported in children and adolescents with idiopathic scoliosis in 11 papers (86%) [3, 8, 11, 15, 17, 28, 35, 36, 37, 38, 39] (Table 1). Hence, the strong level of evidence with almost moderate quality papers suggests the effectiveness of CEs in improving these two variables due to the existence of two high quality RCTs (PEDro: 8-9) [11, 39] and multiple moderate [8, 15, 17, 37, 38] and low [28, 35, 36] quality RCTs [28, 37] and CCTs (PEDro: 4-6) (Level A) (Table 2).

3.7. Determining the appropriate age for effectiveness of corrective exercises

Based on the average age reported in the papers, participants in 30, 62 and 8% were between 13-16 [11, 28, 29, 36], 9-13 [8, 15, 17, 35, 37, 38, 39, 40] and under 9 years old [3], respectively (Table 1). Only one CCT (PEDro: 6) and one RCT (PEDro: 9) examined the effect of exercise interventions based on the age groups, showing greater effectiveness of CEs in childhood [17, 39]. Thus, moderate level of evidence suggests for more effectiveness of CEs in the childhood and early adolescence (level B) [17, 39] (Table 2).

3.8. Determining the superiority of one exercise method

Four papers (30%) compared the PSSEs with the GEs, among which two CCTs (PEDro: 4-5) [3, 35] reported a higher effect of the PSSEs (Level C) and one RCT [11] and one CCT [29] (PEDro: 5-8) indicated no significant difference (Tables 1 and 2).

The results showed that the SEAS method was efficient on the Cobb angles and ATR in one RCT (7%) (PEDro: 8) [11] and two CCTs (15%) (PEDro: 4-7) (Level B) [8, 35]. Moreover, the Schroth method was effective for Cobb angles [15, 28, 36, 37] and ATR [15, 37] in two RCTs [28, 37] and two CCTs (30%) (PEDro: 4-6) (level B) [15, 36]. Finally, two papers (15%) reported

the effectiveness of core stability (RCT) and FITS (CCT) methods in improving these two variables (PEDro: 6-8) (level C) [11, 38].

Overall, Limited level of evidence suggests the superiority of PSSEs compared to the GEs (Level C) [3, 35] and this evidence suggests that SEAS and Schroth methods are superior to other methods (Level C) [3, 8, 11, 15, 28, 35, 36, 37]. In addition, moderate evidence suggests that SEAS and Schroth methods can decreasing Cobb angles and ATR [3, 11, 29, 35] (Level B), while no paper was found to compare one PSSE to another (No evidence) (Tables 1 and 2).

Table 2. Evaluating the studies based on the PEDro scale

Author names	Type of exercise	Quality	Study design	1. Eligibility	2. Random allocation	3. Concealed allocation	4. Baseline measure	5. Blind subjects	6. Blind therapist	7. Blind assessor	8. Adequate follow up	9. Intention to treat	10. Between group comparisons	11. Point Estimate of Variability	Scores
Otman et al. [36]	Schroth	I	CCT	Yes	No	Yes	Yes	No	No	No	Yes	No	No	Yes	4
Negrini et al. [35]	SEAS	I	CCT	Yes	No	Yes	Yes	No	No	No	Yes	No	Yes	No	4
Zaina et al. [29]	SEAS	II	CCT	Yes	No	No	Yes	No	No	No	Yes	Yes	Yes	Yes	5
Białek [38]	FITS	II	CCT	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	6
Monticone et al. [39]	Active self-correction	III	RCT	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	9
Negrini et al. [8]	SEAS	II	CCT	Yes	No	Yes	Yes	No	No	No	Yes	Yes	No	Yes	5
Kwan et al. [37]	Schroth	II	RCT	Yes	No	No	Yes	No	No	Yes	Yes	No	Yes	Yes	5
Kim and Park [28]	Schroth	I	RCT	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4
Yagci and Yakut [11]	SEAS Core Stability	III	RCT	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8
Negrini et al. [3]	SEAS	II	CCT	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	7
Sarkisova et al. [40]	Side Plank	II	RCT	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	No	5
Rrecaj-Malaj et al. [15]	Schroth	II	CCT	Yes	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	6
Liu et al. [17]	Xinmiao	II	CCT	Yes	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	6

4. Discussion

The objectives of this review study included determining the overall effect of CEs (PSEEs and GEs), the effect of CEs at different ages, and selection the suitable exercise method for decreasing Cobb angles and ATR at children and adolescents with idiopathic scoliosis. Based on the inclusion and exclusion criteria, this study included 13 papers with 10 different exercise

methods (Figure 2).

The results of the first hypothesis showed that the CEs could be effective for preventing, controlling, and improving children and adolescents with idiopathic scoliosis. Overall, this hypothesis can be confirmed based on the evidence presented with an average level in the papers (Level A) [3, 8, 11, 15, 17, 28, 35, 36, 37, 38, 39]. However, Sarkisova et al. (2019) indicated no change in improving process of scoliosis, even with the use of braces [40], which could be related to the lack of using the various types of exercises, especially self-correction and PSSEs [39]. Therefore, the correct use of braces without using basic exercises could not be effective in this study due to only side plank exercises were used along with the brace [40]. Our study is inconsistent with those of some review studies in terms of the positive effect of CEs [16, 19, 30, 41], while in line with some others [10, 12, 27, 42, 43].

Anwer et al. (2015) reported that the CEs not only prevented the development of curves in patients with adolescent idiopathic scoliosis, but also improved it effectively [43]. On other hand, Monticon et al. (2014) reported that improving lifestyle and daily behaviors was more effective in the posture of the subject than performing the CEs without considering lifestyle modification. They believed that performing active and passive self-correction exercises over time can be more effective than major conservative approaches [39]. This paper obtained a high quality level, which makes the results of which more confident. Due to the importance of the self-correction exercises in improving the spinal deformities, these exercises are an inseparable part of the PSSEs [7, 14, 30, 39].

A large number of papers, which purposefully focused on the effect of CEs on the specific age groups, were not found for examining the second hypothesis. Only two papers (PEDro: 6-9) reported that the exercise interventions were more effective in childhood than in adolescence [17, 39]. However, moderate levels of evidence support this hypothesis (level B).

The main belief of the treatment experts is that not paying attention to musculoskeletal disorders in childhood and adolescence can worsen the problem during the growth process and makes the effectiveness of existing treatment strategies more difficult [5, 21]. Moreover, Hueter-Volkmann's law directly confirms this issue and implies that by increasing the age, the convexity and concavity in the spine in a child with scoliosis can cause the cessation of bone growth of the vertebrae in the compressed side and the abnormal increase in the vertebrae growth in the stretched side [44]. However, some physicians did not take mild degrees seriously and recommend that the person rest or take a wait-and-see approach [17]. Thus, the effect of CEs cannot be ignored to prevent this deformity worsening in the late maturity and adulthood by considering all the above-mentioned cases. The results of the present study are consistent by Fan et al. (2020) based on the age. However, the results show ineffectiveness of the exercise are inconsistent with each other [30].

The important point, which was observed in the previous review studies, is the lack of evaluating the effect of the superiority of a particular exercise technique to improve Cobb angles and ATR of children and adolescent with idiopathic scoliosis. This made the role of the third and main hypothesis of the present study more prominent.

The initial review of the articles

indicated that the SEAS and schroth methods were the most widely choice among researchers, respectively [3, 8, 11, 29, 35]. Despite the positive changes in the Cobb angle and ATR due to these methods [8, 11, 35], the superiority of SEAS method compared to the GEs was observed in two papers. Therefore, the limited evidence suggests that the PSSEs are more effective than the GEs (level C) (PEDro: 4-7) [8, 15, 28, 36, 37, 38]. The results of the present review study based on the effects of SEAS and Schroth methods are consistent with two review studies [7, 27] and not consistent with the other two review studies [16, 30].

However, there are differences in performing SEAS and Schroth methods. The Schroth method requires the presence of a patient in the clinic and under the supervision of a specialist. The nature of these exercises is based on the principles of feedback and feed forward between the subject and the expert. Moreover, the answer to performing exercises in short intervals is considered as its strength. The SEAS method can be easily continued at home after the necessary initial training by a specialist, and there is no need for the subject to visit the clinic and the specialist directly. However, this can cause the disadvantages such as performing the wrong technique and worsening the deformity conditions [27]. Additionally, the long exercise period is another disadvantage. Since there is the limited evidence which specifically compares the exercise methods, conducting more careful study is inevitable in the future [10, 43].

Therefore, based on the evidence, the role of exercise, especially SEAS and Schroth methods, for improving idiopathic scoliosis was known as the best conservative solutions in childhood and adolescence, which suggests the greater effects of CEs in childhood.

Several main limitations, which can play a significant role in presenting the results of the papers, were observed in our review study describing as follows. The length of exercise periods and the basis of its principles of frequency, intensity, time and type were not exactly presented in the most papers. The paper which compared the two PSSE methods was not found. The papers which separated the effect of exercise and brace in the interventions or only used exercise as an intervention were limit. The high-quality papers were limited in recent years, which obtained a score above seven in the quality evaluation the PEDro scale. Moreover, access was difficult to the limited studies in the field of the influence of the factors such as age and skeletal maturity. Finally, the search was restricted to English language papers.

5. Conclusion

Evaluating the papers indicated that the CEs may be effective to improve the children and adolescent with idiopathic scoliosis in terms of reducing Cobb angles and ATR, especially in childhood. It seems that Schroth and SEAS methods could show the acceptable results compared to the other methods to improvr this deformity. However, no convincing evidence was found to choost the Schroth or SEAS methods. Overall, more choosing the SEAS method compared to the Schroth method can be justified by considering the current urban conditions and issues such as the availability of the clinic location, the necessary tools, the means of transportation and most importantly spending time. SEAS method is designed in such a way that exercises were performed with simple tools and movement patterns at home and

without the continuous supervision of an expert. However, the lack of direct supervision of specialists can cause the significant disadvantages such as improper implementation of the CE techniques. Due to the development of communication networks such as online monitoring, sending training videos and reviewing the completion of exercise checklists, this problem can be largely eliminated.

Conflict of interest

The authors declared no conflicts of interest.

Authors' contributions

All authors contributed to the original idea, study design.

Ethical considerations

The author has completely considered ethical issues, including informed consent, plagiarism, data fabrication, misconduct, and/or falsification, double publication and/or redundancy, submission, etc.

Data availability

The dataset generated and analyzed during the current study is available from the corresponding author on reasonable request.

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