Review Article

# The Effectiveness of Schroth vs SEAS Exercise Methods for Correcting Idiopathic Scoliosis in Adolescents: A Systematic Review

**Arash Khaledi[1], Hooman Minoonejad[2*], Hassan Daneshmandi[3], Mahdieh Akoochakian[1], Mehdi Gheitasi[4]**

*1. Department of Sport Sciences, Kish International Campus, University of Tehran, Kish, Iran.*
*2. Department of Health and Sports Medicine, Faculty of Physical Education and Sport Sciences, University of Tehran, Tehran, Iran.*
*3. Department of Sport Injuries and Corrective Exercise, Faculty of Physical Education and Sport Sciences, University of Guilan, Rasht, Iran.*
*4. Department of Health and Sport Rehabilitation, Faculty of Sport Science and Health, Shahid Beheshti University, Tehran, Iran.*

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## ABSTRACT

**Purpose:** Adolescent Idiopathic Scoliosis (AIS) is the most common type of scoliosis and the most complex deformity of the spine. The promising results of Schroth and Scientific Exercise Approach to Scoliosis (SEAS), among other methods of exercise therapy, have attracted the attention of many researchers and therapists. However, there is still vague evidence of their effectiveness and their superiority. Therefore, this review aimed to evaluate and compare the effects of Schroth and SEAS exercises on correcting AIS.

**Methods:** Searching was conducted in databases, including Cochrane, MEDLINE, PubMed, Scopus, and Google Scholar from 2005 to December 2021 using keywords related to AIS. Inclusion criteria were the papers using Schroth and SEAS exercises as an intervention. The PEDro scale was used for evaluating the quality of the papers.

**Results:** Ten papers with an average PEDro score of 6.2 were licensed to enter the study. Five Randomized Controlled Trials (RCT) and one Clinical Controlled Trial (CCT) reported a significant reduction in Cobb Angle (CA) (greater than 5°) using the Schroth method (moderate). Moreover, two CCTs and one RCT indicated a significant reduction in CA (greater than 5°) using the SEAS method (limited). However, no paper was found for choosing superiority between Schroth and SEAS (no evidence).

**Conclusion:** Although there is limited to moderate evidence in the studies, it seems that both Schroth and SEAS exercises were effective in improving AIS, which was more prominent in the study of the Schroth method. Nevertheless, accessing high-quality papers is necessary for achieving more accurate results in the future.

*** Corresponding Author:**
*Hooman Minoonejad, PhD.*
***Address:*** *Department of Health and Sports Medicine, Faculty of Physical Education and Sport Sciences, University of Tehran, Tehran, Iran.*
***Phone:*** *+98 (912) 3487425*
***E-mail:*** *h.minoonejad@ut.ac.ir*

## Highlights

- There is limited evidence that SEAS exercises can be effective in improving Adolescent Idiopathic Scoliosis (AIS).
- The moderate evidence suggests that the Schroth exercise can be effective in correcting AIS.
- There is no strong evidence to make a definitive choice between the SEAS and Schroth exercises.

## Plain Language Summary

Adolescent Idiopathic Scoliosis (AIS) is one of the most complex and harmful deformities in the musculoskeletal structure of the body, which causes many problems for these patients, especially during the growth spurt. SEAS and Schroth exercises seem to be more prominent among other therapeutic exercises. The most important advantage of the SEAS method is that it is easy to do at home and with family members; however, it takes a long time to correct scoliosis, which is one of its disadvantages. On the other hand, due to the complex exercises of the Schroth method, it requires the presence of adolescents in the clinic, but one of the most important benefits of this method is the correction of scoliosis in a short time. Thus, although the limited to moderate evidence suggests the effectiveness of both Schroth and SEAS in treating AIS, in general, the Schroth method is more prominent.

## 1. Introduction

Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional deformity considered to be the lateral deviation, rotation of vertebrae, and even changes in the sagittal curvature of the spine including about 80% of all types of scoliosis [1, 2]. The prevalence of this deformity has been reported at approximately 0.47%-5.2% in various studies [2].

Scoliosis can occur and develop in different areas of the spine with the different numberss of arches (1-4), which are known as C and S-shaped deflections [3]. A defective cycle caused by scoliosis can have side effects, such as trunk asymmetry, muscle imbalance [4], respiratory disorders [5], psychiatric disorders [6], undesirable Quality of Life (QoL) [7], and even pain for the affected person [4].

The amount of lateral deflection of the spine is known as the Cobb Angle (CA), which is considered the main criterion for measuring the severity of scoliosis. The gold standard for determining this curvature is radiography of the anterior-posterior view [8]. The degree of spinal rotation and Angle of Trunk Rotation (ATR), which are the most important secondary complications of scoliosis, are usually evaluated using Adam's forward bend test in the standing and sitting positions as a clinical test or using a scoliometer [9]. A person is identified as a patient with scoliosis and is considered a candidate for receiving the correctional and medical services, when the CA in the frontal plane is equal to or more than 10 degrees [1].

Due to the progressive nature of this deformity, especially at the age of growth spurts [10], various strategies have been designed for preventing, managing, and modifying it [11]. In general, researchers have recommended the use of Corrective Exercises (CE), brace with CEs, and surgery for deflections of 10-25, 25-45, and above 45 degrees, respectively [12]. The side effects of surgery and the fear created in the person with scoliosis caused the use of a brace and CEs [13, 14], which are the most widely used non-invasive method among researchers, families, and patients [15]. However, prolonged administration of brace without CEs causes a weakness in the muscle groups of the spine [11, 16]. Therefore, the weakness caused by the inactivity of the muscles of the affected areas leads to a recurrence of an increase in the degree of deflection [16]. Physical activity in the form of games and sports is the nature of adolescence, which causes less tendency for using braces compared to the adults [17, 18].

All the above-mentioned points have indicated the important application of CEs in managing and correcting this deformity. Therefore, famous researchers in this field around the world, especially in Europe, designed CE methods as Physiography Scoliosis Specific Exercises (PSSE) in 2011, which was supported by the International Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) [19]. The methods include Lyon, Dobo-Med, Side-shift, Schroth, Barcelona Scoliosis Physical Therapy School (BSPTS), the Scientific Exercise Approach to Scoliosis (SEAS), and Functional Individual Therapy of Scoliosis (FITS), each of which has been used with a specific purpose and provided to the experts and

researchers of this field [15, 20]. Among them, SEAS and Schroth have become very prominent and received much attention of many therapists and researchers [21, 22].

Katrina Schroth designed the Schroth method in Germany [23]. Schroth exercises are performed by strengthening and stretching in asymmetric areas through breathing pattern exercises [12]. A specialist trains and assists the patients to identify herself/himself and use the mirror and other equipment, such as wood, wall bars, and soft pads for doing the exercises [23]. The body is divided into five parts, and then these parts are guided to the correct position by applying various active and passive forces, such as lateral shift, compression, and rotation [19]. The patient is first trained about the correct position of the pelvis in a sitting and standing position. Finally, the person is required to modify her/his daily activities for reducing the loads caused by asymmetry on the vertebrae [23]. Making the person aware of her/his physical posture and performing the exercises in the presence of a specialist is the main key of the Schroth method [22].

SEAS was developed by Negrini et al. in Italy, which is considered a scoliosis-specific active self-correction method conducted without any external help and included in functional exercises [24]. Enhancing posture control, rehabilitating the posture, developing stability and balance, as well as spinal stability, muscular endurance, and self-correction are considered the main aims of the SEAS [19]. Unlike the Schroth method, SEAS treatments are mostly conducted at home [22]. Furthermore, a teamwork approach, including family members and clinicians (physiotherapist, orthotist, and physician) was used for achieving successful results for the patients [24].

Nevertheless, there are still some questions. Q1. Will the SEAS and Schroth exercises improve AIS and adjust other adverse effects? Q2. Which of them is more effective in managing or correcting this deformity? and Q3. What are the advantages and disadvantages of the two methods?

Although extensive review studies have been conducted in this field, no accurate evidence is available for determining the effectiveness of these two methods in general and the superiority of one in particular [19, 20, 22, 25]. In the final review studies published in 2019 and 2020, in addition to providing the limited evidence of the effectiveness of the SEAS and Schroth exercises among other PSSEs, no convincing evidence was observed for determining the superiority of one of them, which caused the suggestion for further studies with more details [20, 22]. In addition, in all previous review studies, either the effectiveness of only one exercise method was evaluated [21, 26] or several exercise methods were compared with each other [11, 19, 20, 22, 25, 27]. Based on our knowledge, no review study that purposefully compared only Schroth and SEAS exercises were available, making this review necessary for us.

Therefore, this review aimed to evaluate and compare the effects of SEAS and Schroth methods on correcting the CA and other adverse factors caused by AIS. This will ensure that physicians and specialists have access to the best available evidence and can more confidently choose one of these methods to help manage and correct idiopathic scoliosis in adolescents. We hypothesized that both of them can have the same positive effects.

## 2. Materials and Methods

This study is a systematic review, which was performed by searching the information in the databases, including Cochrane, MEDLINE, PubMed, Scopus, and Google Scholar from 2005 to December 2021, limited to studies published in the Persian and English languages. The keywords, such as “AIS” or “adolescent”, or “Juvenile”, and “idiopathic scoliosis”, and “corrective exercise”, or “physiotherapy”, or “general exercise”, or “scoliosis specific exercise”, or “Schroth”, or “SEAS”, and “Cobb angle” or “trunk rotation” were used in this study.

### Selection of studies

Selection criteria were applied independently by two reviewers (AR and MA), the first reviewer (AR) searched the papers each year, collected only the papers using the SEAS and Schroth methods, and shared them with the second reviewer (MA). A large number of the papers were removed by the second reviewer. The removed papers included the papers, the population of which were not in the age range of adolescence. Moreover, the papers, which used other methods, such as myofascial techniques, Kinesio tape, electrotherapy, and even exercise in water along with SEAS and Schroth methods, and the papers with illegible and vague exercise methods. Any ambiguities existing among the first and second reviewers were shared with the third reviewer (HM). The most important difference between the first and second reviewers was removing the papers, which used the brace along with the exercise. The third reviewer resolved the disagreement by considering no restriction on the use of braces and exercises in the included papers. Finally, the papers, the primary variable of which was Cobb angle, were selected and entered into the study after re-reviewing the papers by the fourth

(MG) and fifth (HD) reviewers and re-consulting with the first-third reviewers.

In order to answer the questions proposed in the present review, the first and second reviewers evaluated the papers and examined the role of the SEAS method. The third and fourth reviewers investigated the papers for analyzing the role of the Schroth method. The fifth reviewer was responsible for reviewing the papers to select one of the SEAS and Schroth methods.

### Inclusion criteria

Inclusion criteria were limited to the following PICOS items: population (adolescents aged 10-18 years with idiopathic scoliosis); interventions (existence of one of the SAES or Schroth methods); comparison (an exercise group with its own before and after data, an exercise group with a control group, an exercise group with another exercise group and more groups); outcome (primary variable: CA, and secondary variable: ATR, etc.); and study design (Randomized Controlled Trial [RCT] and Clinical Controlled Trial [CCT]). It should be noted that no restrictions were considered in the angle of curvature, the number of arches, and the length of the period of exercise interventions.

### Exclusion criteria

The papers, in which the population had pathological disorders or other deformities, such as kyphosis, lordosis, etc., or used other interventions, such as surgery, Kinesio tape, massage, etc. with the exception of brace and exercise were excluded from the study.

### Level of evidence and quality assessment

The level of evidence was determined based on the van Tulder et al. [28] by two reviewers independently (AR and MG) and classified into five levels. Level 1 (strong) is given when two or more high-quality RCTs report similar findings (PEDro ≥8). Level 2a (moderate) indicates the existence of a high-quality RCT (PEDro ≥8) and several fair-quality RCTs (PEDro: 5-7). Level 2b (limited) shows the presence of a high-quality RCT (PEDro ≥8) and several fair-quality CCTs (PEDro: 5-7). Level 3 (weak) presents the existence of a poor-quality RCT or CCT (PEDro ≤4). Level 4 (conflicting) demonstrates the presence of several poor-quality RCTs or CCTs with inconsistent findings (PEDro ≤4). Level 5 (no evidence) is considered in the absence of papers. The quality of the papers was evaluated by using the PEDro scale [29]. This scale consists of 11 items, in which one score is considered for the positive answer of each item. No score belongs to the answer to the first question. The highest and lowest scores are between 0 and 10 (high: 8-10), (fair: 5-7), and (poor: 0-4) [22, 29].

## 3. Results

A total of 85 papers were found in the first search using the above-mentioned keywords, among which 22 papers were selected. Five papers were excluded due to non-compliance with the age of the population. Further, two and five papers were excluded due to duplication and unclear exercise protocols, respectively. Finally, ten selected papers with 734 subjects obtained permission to enter the present review study (Figure 1). Conducting the meta-analysis was not possible since none of the papers had similar conditions based on the study type, statistical methods, evaluation methods, and personal characteristics of the populations.

### Level of evidence and appraisal quality

Among the included papers, three, six, and one papers obtained the strong [4, 13, 17], moderate [30-35], and low [36] qualities, respectively, based on the PEDro scale assessment. Moreover, six and four papers were found in the second [4, 13, 17, 31, 32, 34] and third [30, 33, 35, 36] evidence levels, respectively. Six and four papers were performed with RCTs [4, 13, 31, 32, 34, 35] and CCTs [17, 30, 33, 36] study design, respectively. Additionally, assessor and subject blinding were conducted in four papers [4, 13, 31, 35] (Table 1).

### Characteristics of the included studies

Among the approved papers, six papers used the Schroth [13, 30-32, 34, 35], among which two RCTs were compared with Schroth at home [34] and core stability groups [31]; four RCTs were compared with the control group [13, 32, 34, 35]; one CCT used only a combination of Schroth and Pilates group [30].

Moreover, four papers obtained permission to enter the study for evaluating the SEAS [4, 17, 33, 36]. One CCT was compared with its own data [33], two CCTs were compared with the physiotherapy group [17, 36], one RCT was compared with the core stability group [4], and one CCT was compared with the control group [17].

Five papers used braces along with CEs [4, 13, 30, 33, 35] and the rest of the papers were conducted without using braces [17, 31, 32, 34, 36]. Different CE periods were observed among the papers, including more than

one year [17, 33, 36], between three and six months [4, 13, 20, 34], and less than three months [31, 32, 35], which were between two and six months for Schroth and four months to three years for SEAS (Table 2).

The CA was calculated by using radiography in all the papers [4, 13, 17, 30-36]. ATR was measured by using a Scoliometer in eight papers [4, 17, 30, 31, 33-36]. Five papers evaluated the QoL by using the Scoliosis Research Society (SRS) questionnaire [4, 30, 31, 34, 35]. Other variables, including trunk symmetry (Posterior Trunk Asymmetry Index), Hump height (Waist elbow distance) [34], trunk appearance (Walter Reed Visual Assessment Scale), spine mobility (Spinal Mouse), trunk muscle strength (Biodex System 4-Pro) [31], flexibility (Sit and Reach), and functional capacity (6-minute walk test) [32] were investigated (Table 2).

### Proposed questions

#### Can the Schroth method be effective in correcting AIS?

In response to this question, six papers (five RCTs and one CCT) were permitted to include in the study (average PEDro: 6.3). These studies reported significant positive changes in CA (greater than 5°) [13, 30-32, 34, 35], ATR, QoL [30, 31, 34, 35], and other evaluated factors (Tables 1 and 2).

In this regard, the available evidence indicates level 2a due to the existence of one high-quality RCT (PEDro: 8) [13] and five fair-quality RCTs [31, 32, 34, 35] and CCT (PEDro: 5-7) [30]. Therefore, there is moderate evidence to suggest that Schroth exercises can be effective in correcting AIS.

#### Can the SEAS method be effective in correcting AIS?

In response to this question, four papers (one RCT and three CCTs) were permitted to include in the study (average PEDro: 6). Significant changes were observed in three papers for improving the CA (greater than 5°), ATR [4, 33, 36], QoL [4], and other negative factors caused by AIS. Moreover, no significant change was observed in one paper despite decreasing the CA (less than 5°) and ATR [17] (Tables 1 and 2).

Based on the above-mentioned results and the existence of one RCT with high quality (PEDro: 8) [4] and two CCTs with poor to fair quality (PEDro: 4-5) [33, 36], which were effective in treating AIS, the available evidence to answer this question is at level 2b. Therefore, there is limited evidence to suggest correcting AIS using SEAS exercises.

#### Which of the Schroth and SEAS methods is effective in correcting AIS?

Based on the results, there is moderate to limited evidence that Schroth (level 2a) and SEAS (level 2b) exercises can be effective in treating this deformity. Although the results indicated the relative superiority of the Schroth compared to the SEAS, unfortunately, no paper, which evaluated purposefully these two methods, was found. Hence, no evidence was observed (no evidence).

## 4. Discussion

This study was conducted with two general objectives: first, evaluating the effectiveness of Schroth and SEAS exercises, and second, for the first time, comparing only these two methods to improve the Cobb Angle (CA) and other negative factors caused by AIS.

The effect of Schroth exercises on correcting AIS was evaluated in the first question. As shown in Table 2, a significant reduction of CA (more than 5°) compared to the control group and even other exercise groups was reported in all the Schroth articles [13, 30-32, 34, 35]. Saki et al. indicated that changes occurred in CA (from 15.2° to 10.2°), flexibility, and functional capacity after ten weeks of Schroth exercises compared to the control group [32]. Kwan et al. reported that Schroth exercises during bracing decreased the CA and ATR and improved the QoL compared to the control group [35]. Further, Kuru et al. evaluated the Schroth exercises in the clinic and at home, which indicated a further reduction in the severity of scoliosis due to the exercises in the clinic after six months [34]. The lack of direct supervision of experts on the populations is one of the most important reasons for the weakness of the Schroth at home. Therefore, it is necessary to perform this style of exercise in the presence of a specialist due to the complex nature of scoliosis deformity and the correct execution of exercises [19, 22].

Determining the effect of the Schroth exercises with other intervention is difficult since the application of this method without using braces were considered in only three papers [31, 32, 34]. Overall, in order to better identify the benefits of exercise therapy, it is necessary to review more articles without combining braces with CEs. However, a review study indicated the greater effectiveness of the Schroth method at angles less than

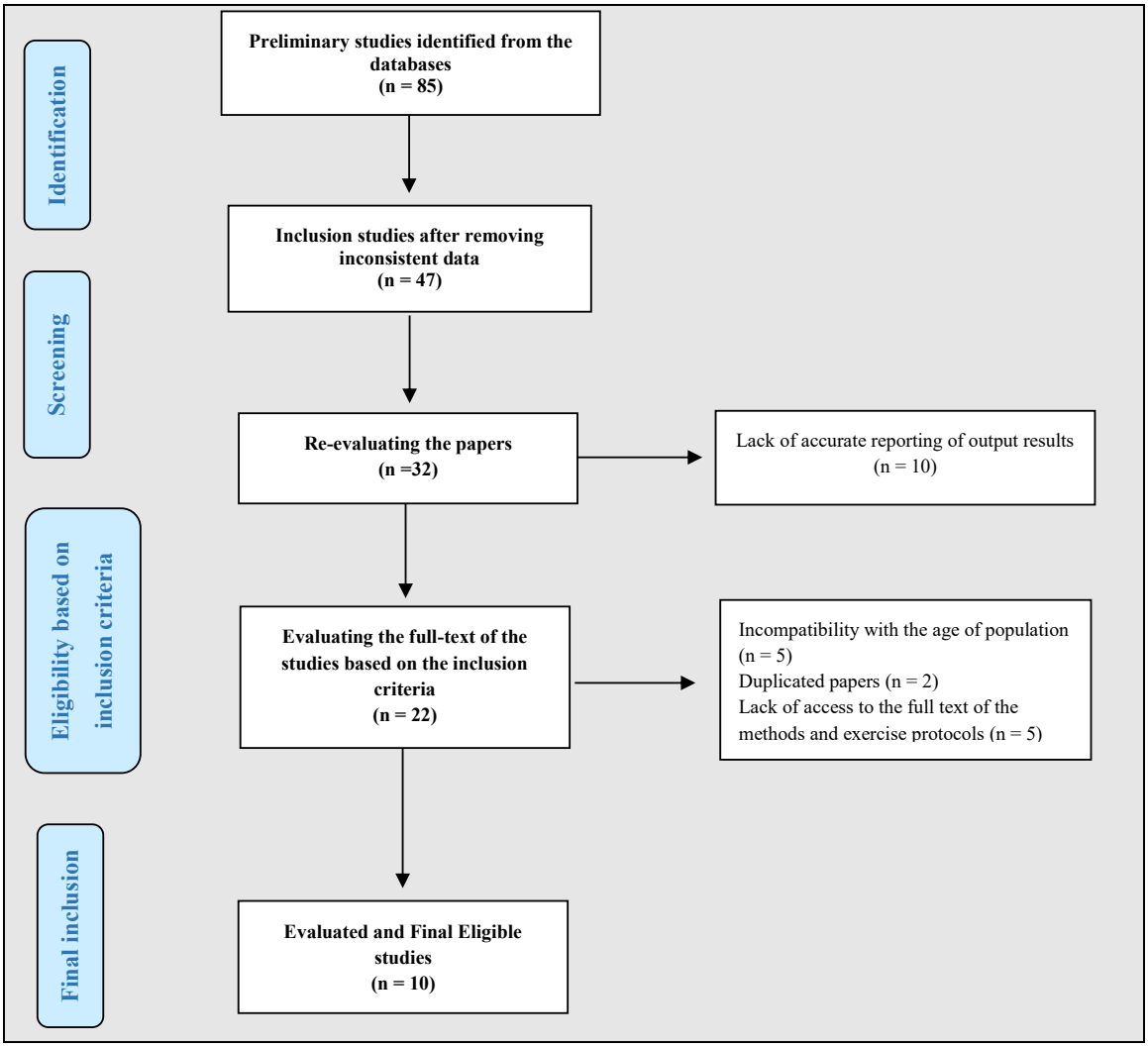


**Figure 1.** The systematic process of the review study

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30º without using a brace [37], while another review study demonstrated the positive effects of this method using a brace and without considering the differences in deflections [21]. The results of our study, related to the effective therapeutic benefits of the Schroth method, are consistent with the mentioned studies and another review study [21, 37, 38] and are inconsistent with the two review papers published in 2019 and 2020 [20, 22].

Although there is no strong evidence for the positive effects of the Schroth method, it can be considered effective with moderate confidence in improving the CA and some negative factors resulting from scoliosis (moderate evidence). In general, an average score of 6.3 was recorded based on the PEDro scale for Schroth, which indicated the fair quality of papers.

On other hand, the results of the papers showed the therapeutic benefits of the SEAS exercises in improving the CA (more than 5°) and secondary factors caused by AIS when the second question was evaluated. Among four papers, which had used the SEAS, three papers were compared with other methods [4, 17, 36] and one paper was compared with its own before and after data [33]. Negrini et al. used this method compared to traditional physiotherapy for preventing the possible risks of increasing the angles in the thoracic and lumbar regions and eliminating the use of braces in patients with mild scoliosis (10-29º). Based on the results, using the SEAS method after one year of follow-up not only prevented the worsening of deformity but also improved 23.5% of populations. However, slight changes were observed in the physiotherapy exercise group [36].

In another study, Negrini et al. evaluated the effect of SEAS as a preventative measure for surgery on AIS with moderate deflection angles (25-45º) with a brace, and more significant results of decreasing the CA and ATR

**Table 1.** Assessing the quality level of the studies based on PEDro scale and level of evidence

| Articles | Exercise Method | Score | Quality | Evidence Level | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Negrini et al. (2008) [36] | SEAS | 4 | Poor | III | Yes | No | Yes | No | No | No | No | Yes | No | Yes |
| Negrini et al. (2014) [33] | SEAS | 5 | Fair | III | Yes | No | Yes | Yes | No | No | No | Yes | Yes | No |
| Kuru et al. (2016) [34] | Schroth | 6 | Fair | II | Yes | Yes | Yes | Yes | No | No | No | Yes | No | Yes |
| Schreiber et al. (2016) [13] | Schroth | 8 | High | II | Yes | Yes | Yes | Yes | No | No | Yes | Yes | Yes | Yes |
| Kwan et al. (2017) [35] | Schroth | 5 | Fair | III | Yes | No | No | Yes | No | No | Yes | Yes | No | Yes |
| Yagci and Yakut (2019) [4] | SEAS | 8 | High | II | Yes | Yes | Yes | Yes | No | No | Yes | Yes | Yes | Yes |
| Negrini et al. (2019) [17] | SEAS | 7 | Fair | II | Yes | Yes | Yes | Yes | No | No | No | Yes | Yes | Yes |
| Rrecaj-Malaj et al. (2020) [30] | Schroth | 6 | Fair | III | Yes | Yes | Yes | Yes | No | No | No | Yes | No | Yes |
| Kocaman et al. (2021) [31] | Schroth | 7 | Fair | II | Yes | Yes | Yes | Yes | No | No | Yes | Yes | No | Yes |
| Saki et al. (2021) [32] | Schroth | 6 | Fair | II | Yes | Yes | Yes | Yes | No | No | No | Yes | No | Yes |

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and increasing the sagittal height of the spine were observed after a period of about three years [33]. In order to obtain more accurate results and eliminate the effects of a brace, Negrini et al. again examined the effect of SEAS exercises on CA and ATR with mild curvature and compared to the two physiotherapy and control groups for about two years. Based on the results, slight effectiveness (less than 5º) was obtained compared to the physiotherapy group and even the control group [17].

An overview of the SEAS papers indicated that the scores were between 4 and 8 based on the PEDro quality scale. Therefore, the existence of four papers with high [4] to poor quality [17, 33, 36], one of which showed no significant results [17], led to relying on the results of the SEAS with less confidence compared to the Schroth (limited evidence). Based on the limited evidence obtained from the positive effect of the SEAS, the results of our study are consistent with three review studies [22, 25, 39] and inconsistent with another review study [40].

The SEAS was compared with Schroth for evaluating the third question, which is the main purpose of the present review study. Unfortunately, no paper was found, which compared these methods purposefully (no evidence). Nevertheless, apart from the limited available evidence of SEAS versus moderate evidence of Schroth exercises, some differences were observed in the outcomes of the studies as well as the technique of performing these exercise methods, which can convince us that Schroth exercises are relatively superior.

For example, Yagci and Yakut could not indicate a significant difference between the effects of SEAS and core stability exercises [4], while Kocaman et al. observed the superiority of the Schroth over core stability exercises [31], with the exception that adolescents with the SEAS had moderate deviation [4] and the Schroth with mild scoliosis [31].

From another point of view, the Schroth exercises were designed for exercise periods less than two [31, 32, 35]

**Table 2.** Studies' characteristics

| Articles | Using Brace | Study Design | Treatment Length (Days) | Gender and Average AIS Age and Cobb Angle | Comparison Group | Outcomes Measured | Results |
|---|---|---|---|---|---|---|---|
| Negrini et al. (2008) [36] | No | CCT | 365 | Female<br>Age (12.4)<br>CA (15°) | SEAS (n=35)<br>Physiotherapy (n=39) | CA<br>ATR | The CA: In the SEAS group, 23.5% of AIS improved and 11.8% worsened, while in the physiotherapy group, 11.1% improved and 13.9% worsened. |
| Negrini et al. (2014) [33] | Yes | CCT | 4500 | Male and female<br>Age (12.8)<br>CA (34.4°) | SEAS (n=73) | CA<br>ATR<br>plumb line distance (mm) | Overall, 52.3% improved. 9.6% worsened, one of which progressed more than 45° and was fused. |
| Kuru et al. (2016) [34] | No | RCT | 168 | Male and female<br>Age (12.9)<br>CA (10-60°) | Schroth in the clinic (n=15)<br>Schroth at home (n=15)<br>Control (n=15) | CA<br>ATR<br>Waist asymmetry (waist – elbow distance)<br>Maximum hump<br>QoL (SRS) | The CA (-2.53°; P=0.003) was significantly reduced in the clinical exercise group compared to other groups. |
| Schreiber et al. (2016) [13] | Yes | RCT | 180 | Male and female<br>Age (13.3)<br>CA (10-45°) | Schroth added to standard of care (n=25)<br>Standard of care (Control) (n=25) | CA | In general, the CA was significantly reduced in the Schroth group compared to the control group (P=0.006). |
| Kwan et al. (2017) [35] | Yes | RCT | 56 | Male and female<br>Age (12.3)<br>CA (25-40°) | Schroth (n=24)<br>Control (n=24) | CA<br>ATR<br>QoL (SRS) | The CA in the Schroth group improved, increased, and remained unchanged by 17%, 21%, and 62%, respectively, while the mean of these numbers in the control group was 4%, 50%, and 46%, respectively. |
| Yagci and Yakut (2019) [4] | Yes | RCT | 120 | Male and female<br>Age (14.1)<br>CA (20-45°) | SEAS (n=15)<br>Core stability (n=15) | CA<br>ATR<br>Trunk asymmetry (POTSI)<br>Cosmetic trunk deformity (WRVAS)<br>QoL (SRS) | The CA changed significantly from 27.65° to 21.9° in the SEAS group and from 27.45° to 22.05° in the core stability group. |
| Negrini et al. (2019) [17] | No | CCT | 365 | Male and female<br>Age (9)<br>CA (10-20°) | SEAS (n=145)<br>Physiotherapy (n=95)<br>Control (n=53) | CA<br>ATR<br>Hump height<br>Aesthetic (TRACE)<br>plumb line distance (mm) | The CA decreased in both exercise groups. However, it was more prominent in the SEAS group (CA <5°). |
| Rrecaj-Malaj et al. (2020) [30] | Yes | CCT | 168 | Male and female<br>Age (13.6)<br>CA (10-45°) | Schroth and Pilates (n=69) | CA<br>ATR<br>Chest expansion<br>Trunk flexion (cm, distance between C7 to S2 with measuring tape)<br>QoL (SRS) | Significant improvements (P<0.05) were found in both groups of AIS wearing and not wearing a brace for CA (from 21.97° to 18.11°; from 14.19° to 11.66°), respectively. |
| Kocaman et al. (2021) [31] | No | RCT | 70 | Male and female<br>Age (14.1)<br>CA (10-26°) | Schroth (n=14)<br>Core stability (n=14) | CA<br>ATR<br>Cosmetic trunk deformity (WRVAS)<br>Spinal mobility (Spinal Mouse)<br>Peripheral muscle strength (Biodex System 4-Pro)<br>QoL (SRS) | The CA in the Schroth group changed significantly from 16.72° to 9.55°. However, no significant changes were observed in the core group (from 16.23° to 12.95°) (P<0.05). |
| Saki et al. (2021) [32] | No | RCT | 70 | Male and female<br>Age (13.1)<br>CA (10-20°) | Schroth (n=12)<br>Control (n=12) | CA<br>Flexibility (Sit and Reach)<br>Functional Capacity (6-MWT) | The CA significantly reduced from 15.2° to 10.3° compared to the control group (P<0.05). |

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Abbreviations: ATR: Angle of Trunk Rotation; CA: Cobb Angle; SEAS: Scientific Exercise Approach to Scoliosis; SRS: Scoliosis Research Society Questionnaire; QoL: Quality of Life; TRACE: Trunk Aesthetic Clinical Evaluation; WRVAS: Walter Reed Visual Assessment Scale; POTSI: Posterior Trunk Symmetry Index; 6-MWT: Six Minute Walk Test; RCT: Randomized Controlled Trial; CCT: Clinical Controlled Trial

to six months [13, 30], while the SEAS exercises were generally conducted for the periods of more than one year [17, 33, 36], which can be considered as one of the weaknesses of the SEAS. Furthermore, most researchers of the SEAS conducted the research projects based on the cohort prospective and retrospective study and performed less RCT research.

Therefore, although no paper was found for determining the superiority of one of the Schroth and SEAS methods, there is limited to moderate evidence that these two methods are effective in treating AIS, which is more promising in Schroth exercises. However, further research is needed in the future to exact choosing the superior method.

## 5. Conclusion

There is moderate evidence to suggest that the Schroth method can effectively improve AIS (level 2a). There is limited evidence that the SEAS method is effective in treating these patients (level 2b), while there was no opportunity to compare Schroth and SEAS exercises (no evidence). Therefore, the Schroth exercises can be more confidently suggested as a suitable non-invasive solution for preventing, managing, and treating AIS.

Because of the limited and moderate evidence for these two methods' efficacy, we suggest that therapists and specialists benefit from general complementary exercises, such as core stability, Pilates, yoga, etc., to help achieve better results.

Several limitations caused the problem in making the decision for the present review study and affected the presentation of the results, including limited access to the papers with high quality, separation of the effect of braces and CEs, lack of RCT design, especially based on the specific number of curves (one to four curves) as well as its severity (mild, moderate and severe scoliosis) in the spine, and also lack of access to comparative papers between SEAS and Schroth exercises and other languages except for Persian and English.

Thus, we suggest that the SEAS and Schroth exercises be compared with each other in the future original studies, especially in terms of the degree of curvature and severity of scoliosis, and the use of braces be avoided as much as possible to determine the effects of each exercise method exactly.

## Ethical Considerations

### Compliance with ethical guidelines

The Research Ethics Committee of the Sports Science Research Institute approved the current research (Code: IR.SSRC.REC.1400.108).

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### Authors' contributions

Conceptualization: All authors; Methodology: Arash Khaledi and Mehdi Gheitasi; Investigation: All authors; Writing original draft: Arash Khaledi; Writing, reviewing, and editing: Mahdieh Akoochakian and Hooman Minoonejad; Funding acquisition: All authors; Resources: All authors; Supervision: Hooman Minoonejad and Hassan Daneshmandi.

### Conflict of interest

The authors declared no conflict of interest.

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