Combined effect of Schroth method and Gensingen brace on Cobb's angle and pulmonary functions in adolescent idiopathic scoliosis: a prospective, single blinded randomized controlled trial

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Abstract. – OBJECTIVE: To detect the effect of the Schroth method added to the Gensingen brace for six months on Cobb’s angle, axial rotation of the trunk, and pulmonary function in adolescent idiopathic scoliosis.

PATIENTS AND METHODS: The study followed a prospective, single-blinded, randomized controlled trial design following the CONSORT guidelines. The study was conducted in the Health and Rehabilitation Sciences Department, with a sample of 42 patients aged 10-18 years old, diagnosed with adolescent idiopathic scoliosis (AIS) with curves of 35-40°, were recruited and then were allocated into three groups: Group A, Group B, and Group C.

RESULTS: Significant improvement (p < 0.001) in Cobb’s angle and axial rotation of the trunk (ART) were noted after the treatment in the three groups, while pulmonary function showed better results in Group A (p < 0.001) when compared with the other groups (p ≥ 0.000).

CONCLUSIONS: Six months of Schroth method and Gensingen brace on Cobb’s angle, thoracic trunk rotation angle, and pulmonary function in adolescent idiopathic scoliosis.

Key Words: Adolescent, Scoliosis, Schroth method, Gensingen brace.

Abbreviations
Adolescent Idiopathic Scoliosis: AIS; Schroth Method: SC; Gensingen brace: GB; Activities of daily living: ADL; Scoliosis Orthopedic and Rehabilitation Treatment: SOSORT; Posterior Anterior: PA; Forced expiratory volume in one second: FEV1; Forced vital capacity: FVC; Maximum voluntary ventilation: MVV.

Introduction
Idiopathic scoliosis is a type of spinal deformity that commonly occurs in adolescents, with no significant identifiable causes in a child who is considerably healthy. It is further referred to as the three-dimensional deformity, where the spine naturally bends. Patients with idiopathic scoliosis outcomes are enhanced by early detection and treatment. Adolescent idiopathic scoliosis (AIS) is the most common form of scoliosis, affecting approximately 2% to 4% of adolescents. Weinstein outlined that the diagnosis of scoliosis is confirmed through an X-ray of the full spine, while the patient standing in full position. It is also of utmost significance to consider the importance of bone density, especially in young patients. In one of the recent studies, Weiss et al. study explains that alteration of the neuromuscular system (neuromuscular scoliosis), alterations of soft tissue (Marfan’s syndrome and Ehlers-Danlos syndrome), alterations of the nervous system (neurofibromatosis), failure of formation of vertebrae and ribs (congenital scoliosis) is the major cause which leads to Scoliosis. In this context, a study...
by Carfi et al. evaluated the data on bone mineral density (BMD) from a large cohort of adults with Down syndrome. It was found that BMD decreased with age more quickly in these subjects than in the general population, exposing the adults with Down syndrome to an increased risk of osteoporosis and bone fracture.

It has been identified that AIS has a long-standing history of back pain patients with severe curves have a high prevalence than normal subjects and are exposed to minor disabilities. In Chik and Weiss 2020 study, the majority of scoliotic curves are called idiopathic, but the reasons are not identified yet. Scoliosis can be symptomatic or syndromic scoliosis, the curve may appear very individual, sometimes bizarre, in idiopathic scoliosis, there are certain curve patterns that regularly occur. It further initiates the development of restrictive lung disease with decreased lung volumes. The movement of the ribs is also affected by scoliosis which develops a mechanical loading on the respiratory muscles and puts various organs of the thoracic cavity out of their places. Besides, it decreases the chest wall compliance directly and the lung compliance indirectly, causing an increase in the work of breathing. The associated respiratory muscle weakness may lead to chronic respiratory failure.

Clinically, the analysis of the problem is held through Cobb's angle analysis method where examinations related to the size of the lateral bending are undertaken radiographically. The observations held through this method vary depending on the Cobb's angle, such as in minor scoliosis, where Cobb's angle is less than 20° and is treated through periodic observation, whereas scoliosis with Cobb's angle of 20°-40° is treated by wearing an orthosis resulting in restricting the progress. However, in cases where Cobb's angle is greater than 40°, surgery is recommended. The Schroth Method is an another conservative technique that improves awareness of their deformity and promotes postural correction in a three-dimensional approach of sensorimotor, postural, and ventilatory exercise purposed at the realignment of normal posture, static/dynamic control of posture, and realigning of the spine.

Mohamed and Yousef, in their randomized controlled study, declare that a significant decrease in Cobb's angle and right total static plantar pressure with a significant increase in left total static plantar pressure post-treatment was noted with a higher effect and six-minute walk test with a decrease in the angle trunk rotation in the Schroth group.

Recently, the Gensingen brace (GB), is preferred for the management of scoliosis to correct individual curves with a specific brace for each treated patient and restore an appropriate alignment in the sagittal plane. Besides, the brace method promises a reduced improvement to quality of life in patients suffering from scoliosis, especially AIS. It is stated that GB provides an acceptable correction of more than 50% in initial Cobb's angle.

Many studies have focused on the effectiveness of SC and GB in the treatment of AIS, but none of them have focused on the combined effects of both methods in treating patients with AIS. Therefore, research is needed to determine the effectiveness and most effective treatment in managing adult scoliosis patients, particularly those with thoracolumbar curves such as idiopathic scoliosis. The guidelines concern the prescription of the types of braces, daily wearing time, and duration of the intervention for adult scoliosis.

The study aims to draw out the combined effects of SC and Gensingen brace on Cobb's angle and pulmonary functions in AIS patients.

Hypothesis
Based on the study, the following hypothesis was tested: the combination of Schroth exercise and Gensingen brace is effective in decreasing Cobb's angle and improving pulmonary function (VC, FVC, FEV₁, FEV₁/FVC, and MVV) in patients with AIS.

Patients and Methods

Trial Design
This study is a prospective, single-blinded, randomized controlled trial, conducted following the CONSORT guidelines. The study was conducted in Health and Rehabilitation Centre.

Study Population and Sample
The eligible participants were selected in the physical therapy department by a trained physiotherapist according to the selection criteria. The flow chart of the participants in the study at various durations is illustrated in Figure I.

The sample of this study involved forty-two adolescents with idiopathic scoliosis, which were divided into three groups in a 1:1:1 ratio using a computer random assignment method i.e., Group A (n=14), Group B (n=14), and Group C (control group) with n=14 participants. The selection of the
participants was based on the inclusion and exclusion criteria, which involved male adolescents with idiopathic scoliosis (AIS) diagnosed by an orthopedician, aged between 10 and 18 years, with starting Cobb’s angle between 35°-40°, no history of any orthotics application, no previous spine corrective surgeries and consent to participate in the study. The participants with Risser sign for more than four weeks, congenital defects, metabolic diseases, neuromuscular disorders, trauma, and not willing to participate were excluded.

Interventions
Participants in Group A were treated with Schroth Method and Gensingen Brace. In the first method, they were asked to follow certain exercises which consisted of a series of training and supervised protocols for a period of six months. The interventions began with one hour of personal training for the initial two weeks every day followed by a weekly training of an hour. The exercises were given in a three-dimensional approach which consisted of the elongation of the spine, alignment of the pelvis, rotation of the thorax, and correction of the shoulder. The training further included different breathing patterns in lying, sitting, and standing positions.

This set of exercises also involved postural correction and modifications to obtain the ideal body alignment through their activities of daily living (ADL). The primary focus was on sensorimotor, breathing, and postural domain and the improvement of the spine stability. The protocol took special care of the movements required, the amount of passive support involved and the dosage recommended. Any compliance raised by the participant was noted in the logbook and verified weekly by a treating physiotherapist. The exercise performed each day was checked using a checklist. The attendance and performance of exercise during the course of the treatment were monitored continuously.

Participants in this group also received a Cheneau Gensingen Brace™ (Scoliosis Bracing Innovations, Gensingen, Germany) if the bracing criteria were met. It can be applied at all stages of scoliosis and provides a 3D correction effect. It helps improve the posture of the participant with a more balanced appearance. The presence of expansions at the concavities decreases further spine rotation and induces spine correction. It has an open hip design which provides free hip and pelvic motions. The application of the brace did not crush the chest region and allowed free breathing. This brace was easy to wear, take off,
breathe, eat and do other activities. Its positive effect on participants was its customized design according to the patient’s curve pattern through its 3D scanning technology. It was recommended for patients with Cobb’s angles of 45°, 50°, and more than 55° and it should be worn as indicated in the guidelines of society on scoliosis orthopedic and rehabilitation treatment (SOSORT)20.

Group B only received the Gensingen brace application, while Group C received controlled conventional scoliosis exercises. These were specific exercises that are taught to patients with scoliosis. The exercises were pelvic tilt, cat-camel, double-leg abdominal press, and single-leg stance. Initially, the exercises were demonstrated by the therapist, and the subjects practiced in the presence of the therapist, and the clarifications were rectified. These home-based exercises were printed in a hand manual in comprehensive language. The first part of the manual contains the do and don’ts during the study period. The next part of the manual contains different stretching and strengthening exercises for the back and chest muscles. They performed these exercises 10-15 reps/day for 5 days per week for 6 months. Stretching was focused on each muscle group for 3 repetitions for 15 seconds per muscle group21.

Procedures Involved

Cobb’s angle
This angle was used to measure the degree of scoliosis on the posterior-anterior (PA) spinal X-ray. Based on the convexity they can be indicated as the right or left side. To obtain this angle we drew a parallel line at the upper and lower vertebra endplate lines and a vertical line from a parallel line that makes Cobb’s angle. This method of measurement has good intra-rater and inter-rater reliability23.

Scoliometer
The axial rotation of the trunk (ATR) was measured with a scoliometer (Ockendon Partners Ltd., Shrewsbury, UK) in idiopathic scoliosis. The participants were asked to stand in a forward flexion position, while a scoliometer was placed over the spinous process, where maximum rotation of the spine occurs. It showed good to excellent reliability measurements in idiopathic scoliosis23.

Pulmonary function test
The pulmonary values such as Forced vital capacity (FVC), forced expiratory volume (FEV), FRC/TLC, and Maximum voluntary ventilation (MVV) were measured by using the device Quark PFT (COSMED, Germany). The patient was asked to sit in a comfortable position and a mouthpiece was connected firmly to inspire air at maximum effort and then expire it with maximum strength. The maneuver was repeated 10 times and the mean of the best three values was considered for analysis24. No changes happened to any of the methodology after the recruitment of the participants.

Sample Size
A pilot study was conducted to detect a 0.5% difference in the primary variable (Cobb’s angle), a study with two parallel arms and three measurement time-points, an α of 0.05 and a power of 0.8, and a sample size of 12 in each group were calculated. Assuming 10% dropouts, this implies that a total pool of 14 participants in each group was included in the study. G*Power version 3.1.2 (Heinrich Heine Universität Düsseldorf, Düsseldorf, Germany) was used for these calculations.

Blinding
The treating therapists and participants could not be blinded when providing or performing the different training protocols. However, participants were asked not to disclose their group allocation to ensure the blinding of the outcome assessor. The outcomes were measured at baseline, after six months and eight weeks. The biostatistician who conducted the data analysis was not aware of the data coding.

Statistical Analysis
All demographic characters and outcome measures were presented in form of means ± standard deviations. Changes in the variables among the three groups were assessed using ANOVA, while pre-post changes within each group were assessed using repeated measures ANOVA. p < 0.05 indicates significant changes. All data were statistically analyzed using SPSS v. 25 (IBM Corp., Armonk, NY, USA).

Results

Final Sample After Six Months
Out of 42 participants, 38 patients were considered as the final sample and were divided as follows: 13 in Groups A and B each, while 12 in Group C as only these patients have completed
Combined effect of Schroth method and Gensingen brace on Cobb’s angle

Table I. Demographic details of Group A, B and C.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Variable</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Age (y)</td>
<td>13.5 ± 1.2</td>
<td>13.8 ± 1.5</td>
<td>14.1 ± 1.2</td>
<td>0.4855</td>
</tr>
<tr>
<td>2</td>
<td>Height (m)</td>
<td>1.48 ± 0.14</td>
<td>1.47 ± 0.16</td>
<td>1.49 ± 0.15</td>
<td>0.6388</td>
</tr>
<tr>
<td>3</td>
<td>Weight (kg)</td>
<td>42.2 ± 1.8</td>
<td>41.8 ± 1.7</td>
<td>42.8 ± 1.9</td>
<td>0.1568</td>
</tr>
<tr>
<td>4</td>
<td>BMI (kg/m²)</td>
<td>16.4 ± 0.8</td>
<td>15.9 ± 0.7</td>
<td>16.2 ± 0.7</td>
<td>0.0444</td>
</tr>
</tbody>
</table>

*Non-Significant, BMI; body mass index

the treatment program within six months of follow-up. The basic demographic variables such as age, height, weight, and BMI did not show any significant difference between the groups (p ≥ 0.05) at baseline (Table I).

**Cobb’s Angle**

Patients were advised to take the brace off for a minimum of two hours before the scheduled X-ray, to allow full relaxation of the trunk in order to obtain reliable radiological images of deformation. The baseline Cobb’s angle was collected by using the anteroposterior X-ray scores among Groups A, B, and C. While, no statistical difference (p ≥ 0.05) was detected. The intra-group analysis of various durations showed significant changes in Group A and Group B (p < 0.01) after different exercise training. Over eight weeks of different training (Schroth Method, Gensingen brace, and home-based exercise)...

Table II. Pre and post analysis of Group A, B and C.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Variable</th>
<th>Duration</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cobb’s angle (degree)</td>
<td>Base line</td>
<td>36.3 ± 2.4</td>
<td>36.2 ± 2.3</td>
<td>36.3 ± 2.3</td>
<td>0.465*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 weeks</td>
<td>35.2 ± 2.2</td>
<td>36.8 ± 2.3</td>
<td>34.8 ± 2.3</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 months</td>
<td>30.3 ± 2.1</td>
<td>32.3 ± 1.9</td>
<td>32.3 ± 1.9</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p-value</td>
<td>0.001**</td>
<td>0.001**</td>
<td>0.001**</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Axial Rotation of Trunk</td>
<td>Base line</td>
<td>5.4 ± 1.3</td>
<td>4.9 ± 1.3</td>
<td>4.9 ± 1.3</td>
<td>0.388*</td>
</tr>
<tr>
<td></td>
<td>(Scoliometer)</td>
<td>8 weeks</td>
<td>5.2 ± 1.3</td>
<td>7.6 ± 1.9</td>
<td>5.8 ± 1.5</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 months</td>
<td>9.3 ± 1.8</td>
<td>6.3 ± 1.6</td>
<td>6.3 ± 1.6</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p-value</td>
<td>0.001**</td>
<td>0.001**</td>
<td>0.001**</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Pulmonary Function</td>
<td>Base line</td>
<td>56.3 ± 5.4</td>
<td>87.2 ± 5.3</td>
<td>86.7 ± 5.1</td>
<td>0.902*</td>
</tr>
<tr>
<td></td>
<td>TLC (% predicted values)</td>
<td>8 weeks</td>
<td>91.8 ± 3.7</td>
<td>89.8 ± 3.9</td>
<td>87.8 ± 4.1</td>
<td>0.034**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 months</td>
<td>95.8 ± 4.2</td>
<td>92.3 ± 4.3</td>
<td>88.3 ± 3.3</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p-value</td>
<td>0.001**</td>
<td>0.018**</td>
<td>0.596**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FEV1 (predicted values)</td>
<td>Base line</td>
<td>76.3 ± 5.4</td>
<td>77.2 ± 5.3</td>
<td>76.8 ± 5.1</td>
<td>0.902*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 weeks</td>
<td>82.8 ± 4.1</td>
<td>81.8 ± 4.2</td>
<td>78.8 ± 4.3</td>
<td>0.042**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 months</td>
<td>90.6 ± 4.8</td>
<td>84.3 ± 4.3</td>
<td>79.4 ± 4.1</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p-value</td>
<td>0.001**</td>
<td>0.001**</td>
<td>0.292**</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>FEV1 (L)</td>
<td>Base line</td>
<td>78.8 ± 7.8</td>
<td>79.4 ± 6.9</td>
<td>76.2 ± 7.3</td>
<td>0.478*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 weeks</td>
<td>85.8 ± 6.1</td>
<td>82.6 ± 6.17</td>
<td>79.8 ± 6.2</td>
<td>0.042**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 months</td>
<td>96.5 ± 7.2</td>
<td>88.8 ± 7.3</td>
<td>82.3 ± 7.3</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p-value</td>
<td>0.001**</td>
<td>0.002**</td>
<td>0.078**</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>MVV (l/min)</td>
<td>Base line</td>
<td>44.3 ± 4.3</td>
<td>45.8 ± 4.6</td>
<td>46.2 ± 5.3</td>
<td>0.542*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 weeks</td>
<td>56.2 ± 5.4</td>
<td>48.3 ± 4.7</td>
<td>47.8 ± 4.8</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6 months</td>
<td>61.3 ± 6.3</td>
<td>52.6 ± 5.4</td>
<td>48.2 ± 4.9</td>
<td>0.001**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>p-value</td>
<td>0.001**</td>
<td>0.001**</td>
<td>0.103**</td>
<td></td>
</tr>
</tbody>
</table>

*Non-Significant, **Significant, TLC; total lung capacity, FVC; forced vital capacity, FEV1; forced expiratory volume in one second, MVV; Maximum voluntary ventilation
protocols, a significant difference between Group A ($p < 0.001$), Group B, and C at eight weeks and six months follow-up (Table II) was detected. The graphical representation showed more percentage of improvement in Cobb’s angle in comparison with Groups B and C (Figure 2).

**Pulmonary Function (PFT)**

The baseline data on pulmonary function (VC, FEV$_1$, FRC/TLC, and MVV) scores among Groups A, B, and C showed no statistical difference ($p \geq 0.05$). Over eight weeks of different training (Schroth Method, Gensingen brace, and home-based exercise) protocols, a significant difference among Group A ($p < 0.001$), Group B, and C at eight weeks and six months follow-up was detected (Table II). The graphical representation showed more percentage of improvement in pulmonary function (VC, FEV$_1$, FRC/TLC, and MVV) among groups ($p < 0.001$) at eight weeks and six months of follow-up was observed (Table II). The whole analysis shows a little tendency towards Group A than the other two groups.

**Discussion**

This prospective, single-blinded, randomized controlled trial evaluated the effectiveness of the Schroth exercise in combination with the Gensingen brace on Cobb’s angle, axial rotation of the trunk, and pulmonary function (VC, FVC, FEV$_1$, FEV$_1$/FVC, and MVV) in adolescent idiopathic scoliosis. We hypothesized that Schroth exercise added to Gensingen brace could have useful effects on reducing Cobb’s angle, axial rotation of the trunk, and improving pulmonary function (VC, FVC, FEV$_1$, FEV$_1$/FVC, and MVV) in those adolescents. The study findings supported the hypothesis and showed that Schroth exercise added to the Gensingen brace decreased Cobb’s angle significantly and further improved pulmonary function (VC, FVC, FEV$_1$, FEV$_1$/FVC, and MVV) in patients with AIS.

Findings of the current study suggested significant improvements with respect to the percentages of the improvement in Cobb’s angle in Group A, which followed the combination of both techniques. A significant improvement in the pulmonary function, and axial rotations of Group A at eight weeks and six months of follow-up were also observed. Since several treatments have been
suggested for adolescent idiopathic scoliosis of such severity, such as surgical treatment, bracing, electrical stimulation, and physical activities; bracing for AIS is preferred to enhance specificity considering the adolescent curve pattern and keeping a proper sagittal reposition of the deformed spine. Another important reason for bracing is to avoid the curve progression, minimizing the surgical correction of scoliosis for better cosmetic appearance. Additionally, PAs are significant during the development to postpone or stop the need for an alternative brace as well as to keep scoliosis likely lesser than 30°. In one study, according to the Progression factor calculation, a ten-year-old girl with a 20° Cobb's angle and a Risser sign of 0 would have a progression factor of 2. The correlating chart indicates a 90% risk of progression in a fifteen-year-old girl with a 20° Cobb's angle who might typically be 2.6 years postmenarcheal and a Risser 4, whereas in some of the cases, the progression factor is 0.53 which indicates little risk for progression. It is proved that PAs have an encouraging effect on AIS by enhancing lung function, increasing strength, and
improving postural balance. Therefore, PEs could be recommended in AIS 930.

The Schroth exercise on the other hand is highly acknowledged for improving the vital capacity in adolescents with idiopathic scoliosis. The main goal of the Schroth technique is to give powerful treatment to those patients through its treatment approach which incorporates both concentrated inpatient rehabilitation and private outpatient physiotherapy31. Otman et al12 executed Schroth exercises for 30 sessions, four hours each, followed by 90 minutes of home exercise each day for 50 adolescent patients with right thoracic scoliosis and concluded a 2.65° reduction in Cobb’s angle after six weeks, 6.85° after six months, and to 8.25° after one year. Furthermore, Borysov and Borysov33 applied the Schroth exercise and evaluated Cobb’s angle by a scoliometer, which was significantly decreased to 2.4°. This comes in agreement with the current study which stated that there is an improvement in Cobb’s angle following six months of training and supervised protocols.

The magnitude of the axial rotation of the trunk significantly relies upon Cobb’s angle and longitudinal axial rotation of the apical vertebrae, the higher Cobb’s angle, the greater the rotation angles34. Additionally, the trunk rotation angle diminished when the acromion of the rib was turned to the opposite side by 3D rotational breathing during the Schroth exercise, as 3D rotational breathing permitted the exercise to become more 3-dimensional, which expanded the narrowed thoracic cage35. The current study showed significant improvements in the axial rotation of the trunk in all groups (Figure 4). AIS patients suffer from respiratory dysfunction as a result of chest wall abnormalities. Thoracic rigidity and size are also affected by the abnormal configuration of the ribs36 which impairs respiratory mechanics. The effectiveness of Schroth exercises is significant here, as it increases rib movements and vital capacity while improving flat back posture improving the sagittal breathing exercise27. The current study showed significant enhancement in respiratory function for the first group only.

Several scholars36 exhibited positive results of Schroth exercises on breathing function, curve regression, and surgical need. Recently, Soumagne et al21, concluded that after 6-month of the randomized controlled trial (RCT) that compared the viability of a supervised to non-supervised Schroth intervention in patients with AIS, the supervised Schroth exercises showed better results in reducing Cobb’s angles, scoliometer measures, waist asymmetry, and rib hump as compared to non-supervised and no-treatment groups over six months’ study period. Another study by Hoang Hwangbo3 proposed similar findings, where patients did Schroth exercises for two weeks three times a week. Significant improvements were observed in terms of improved trunk rotation, Cobb’s angle, and vital capacity. These findings are in agreement with the results proposed in the current study.

With regard to the use of the Gensingen brace, significant positive results were obtained in this study, fitted in comparison with other exercises. Rothstock et al37 examined that 3D whole-body scanners can be applied for tests, which were used for trunk measurement in preparation for a brace, which is the newest development. Using these scanners for suitable measured values, clinical progress monitoring can be conducted at the same time that the patient’s measurements are obtained for providing a brace. In the future, specialist practices will offer to monitor patients’ surface topography with spinal deformities and its multifunction37.

Karalar et al38 in their study examined the effectiveness of Gensingen brace treatment in patients with AIS. According to the findings, the overall success rate of the Gensingen brace was 48%, while no significant association was found between the patient’s age, gender, and Risser grade with the success rate of the treatment outcomes. Another study by Weinstein et al35 provided similar results, as the use of Gensingen brace in conservative brace treatment was successful in 92% of patients with AIS. The present study showed a prominent effect by adding Gensingen brace to treatment intervention for AIS in both the first and second groups.

Study Limitations

The study had a limited number of subjects with AIS and less time available for those patients to join the study because most of them were school students. In addition, the effect of treatment procedures on back pain was also not evaluated.

Conclusions

The current study focused on the treatment outcomes of Gensingen brace and Schroth Method when used in combination for patients with
AIS. The influence was majorly recorded for improving Cobb’s angle and pulmonary functions. The comparison among the three groups provided comparable results, however, better results were obtained for Group A which used Schroth Method and Gensingen brace in combination. The results were significant for observations related to pulmonary functions and the combined effect produced a favorable effect on adolescents suffering from idiopathic scoliosis.

The study findings may help clinicians in providing better treatment therapies for patients with AIS. They can be further implied in improving the quality of life of adolescents and can be used as a source of information for parents of adolescents in seeking guidance and support for the timely identification, diagnosis, and treatment of the disease. For future researchers, a study comparing the impacts of the Schroth exercise alone to detect its sole effect on scoliosis is recommended.

Conflict of Interests
The authors declare that they have no conflict of interest.

Ethics Approval
All methods were carried out in accordance with relevant guidelines and regulations. All experimental protocols were approved by a named institutional and/or ethics committee. This study was approved by the Research Ethics Committee at Prince Sattam bin Abdulaziz University (No. RHP1019/42.) in accordance with the guidelines of the Helsinki Declaration for ethical research involving human subjects.

Informed Consent
Informed written consent was obtained from all participants.

Availability of Data and Materials
The data used or analyzed during the current study are available from the corresponding author on reasonable request.

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