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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 e[illegible]t of the Schroth method added to the Ger[illegible] brace for six months on Cobb's angle, axia[illegible]a-tion of the trunk, and pulmonary function in[illegible]- lescent idiopathic scoliosis.

PATIENTS AND METHODS: The study f[illegible] lowed a prospective, single-[illegible] randon[illegible] ized controlled trial design [illegible]wi[illegible]e CON-SORT guidelines. The stu[illegible]was co[illegible]cted in Health and Rehabilitatio[illegible]tre. 42[illegible]aged 10-18 years old, diagn[illegible]se[illegible]h [illegible] iopathic scoliosis ([illegible] with[illegible]s of 35-40°, were recruited and [illegible]were al[illegible]d into three groups: Group A[illegible]p B, and Gr[illegible]

RESULTS: S[illegible]mprovemen[illegible]< 0.001) in Cobb's an[illegible]e and [illegible]xial rotation of the trunk (ART[illegible]ere noted a[illegible]e treatment in the three gr[illegible]s, while pulmon[illegible]nction showed better[illegible]ults in Group A (p <[illegible].001) when compar[illegible] the t[illegible]her groups $p \geq 0.000$).

C[illegible]LUS[illegible]S: Six[illegible]onths of Schroth method ad[illegible]ensin[illegible]Brace demonstrate fa-[illegible]ble [illegible]s in [illegible]b's angle, thoracic trunk [illegible]n an[illegible]ulmonary function in adoles[illegible]t idiopa[illegible]coliosis.

K[illegible] [illegible]dolesc[illegible] Scoliosis, Schroth method, Gensingen [illegible]ace.

Abbreviations

Adolescent Idiopathic Scoliosis: AIS; Schroth Method: SC; Gensingen brace: GB; Activities of daily living: ADL; [illegible]rthopedic and Rehabilitation Treatment: SOSORT; Posterior Anterior: PA; Forced expiratory [illegible]volume in one second: FEV_1; Forced vital capacity: [illegible]imum voluntary ventilation: MVV.

Introduction

Idiopathic scoliosis is a type of spinal deformity that commonly occurs in adolescents[1], with no significant identifiable causes in a child who is considerably healthy[2]. It is further referred to as the three-dimensional deformity, where the spine naturally bends[3]. Patients with idiopathic scoliosis outcomes are enhanced by early detection and treatment[4]. Adolescent idiopathic scoliosis (AIS) is the most common form of scoliosis, affecting approximately 2% to 4% of adolescents[5]. Weinstein[6] 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[7] 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

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by Carfi et al[8] 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[9] that AIS has a long-standing described 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[10] 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[10]. It further initiates the development of restrictive lung disease with decreased lung volumes[11]. 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 ind[illegible]ly, causing an increase in the work of bre[illegible] The associated respiratory muscle weaknes[illegible]y lead to chronic respiratory failure[3].

Clinically, the analysis of the problem is h[illegible] through Cobb's angle analysis [illegible] where e[illegible] aminations related to the size [illegible] bending are undertaken radiographi[illegible]. The o[illegible]rvations held through this metho[illegible] depe[illegible] Cobb's angle, such as [illegible]osis, [illegible] Cobb's angle is less [illegible] 20° and [illegible]ated through periodic observ[illegible] whereas [illegible]sis with Cobb's angle [illegible]s treated by [illegible]aring an orthosis resulting in res[illegible]g the progress. However, in c[illegible] where Cobb[illegible]gle is greater than 40°, su[illegible] is recommended [illegible] Schroth Method (S[illegible] anoth[illegible]onservative technique that impr[illegible]atien[illegible] awareness of their deformity and promo[illegible] correcti[illegible]n a three-dimensional [illegible]oach [illegible]nsists [illegible]ensorimotor, postural, and [illegible]tory [illegible] purposed at the realignment of [illegible]al post[illegible] static/dynamic control of postu[illegible]stability of the spine[12].

[illegible] and Yousef[13], in their randomized [illegible]ntrolled study, declare that a significant decrease [illegible]obb's angle and right total static plantar pressure w[illegible] 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[13].

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 appropri[illegible] alignment in the sagittal plane. Beside[illegible] brace method promises a reduced i[illegible]ment t[illegible] quality of life in patients sufferin[illegible]n scoliosis, especially AIS[14]. It is stated that G[illegible]vides an acceptable correction of mor[illegible]an 50[illegible] ini-tial Cobb's angle[15].

Many studies[16-18] ha[illegible]ocused[illegible]n the [illegible] tiveness of SC and G[illegible]ngen b[illegible], but none of them have focused [illegible]n t[illegible]d effe[illegible] both methods in treat[illegible]patien[illegible]n AIS[illegible]refore, research is re[illegible]ed to dete[illegible] effectiveness and pr[illegible]f bracing i[illegible]aging adult scoliosis p[illegible]ents, [illegible]icularly those with thoracolumbar curves suc[illegible]o objective criteria or clea[illegible]tions conce[illegible] the prescription of th[illegible]pes of braces, daily w[illegible]aring time, and dura-[illegible] of the interve[illegible]ion for adult scoliosis[19].

[illegible]he study ai[illegible]o draw out the combined effe[illegible]f SC and G[illegible]singen brace on Cobb's angle and [illegible]ictions in AIS patients.

Hypothesis

[illegible]d on the study, the following hypothesis te[illegible] the combination of Schroth exercise and Gensingen brace is effective in decreasing Cobb's angle and improving pulmonary function (VC, FVC, FEV_1, FEV_1/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 1.

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

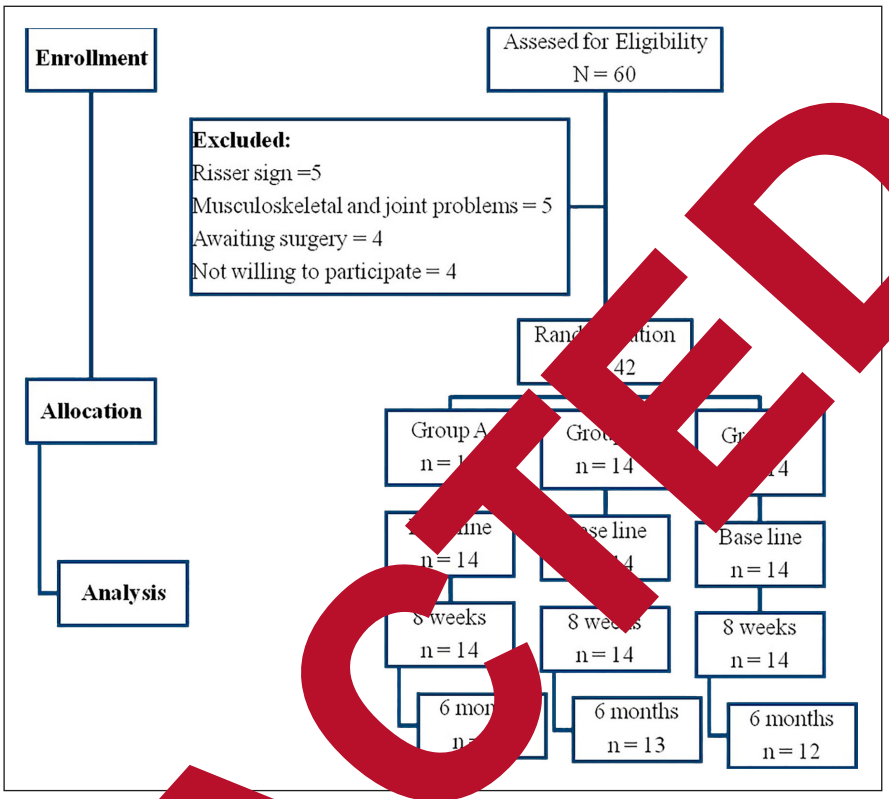

Figure 1. Flow Chart showing the study details.

participants was based on the inclusion and e… sion criteria, which involved male adolescents w… idiopathic scoliosis (AIS) diagno… orthop… dician, aged between 10 and 1… starting Cobb's angle between 35 °… no his… of any orthotics application, no p… us spi… surgeries and consent… pa… the … The participants wi… iser si… r more than four weeks, cong… defects, me… diseases, neuromuscular… trauma, an… willing to participate w… e exc…

Interv… ons

P… ipants … Group A were treated with Sc… Met… and Gensingen brace. In the first i… ey w… sked to follow certain …cises … h inc… d a series of training and …ised … for a period of six months. The …erventi… egan with one hour of personal tr… for the initial two weeks every day fol… d by … eekly training of an hour. The exer…ses were given in a three-dimensional approach …h consisted of the elongation of the spine, a… ent 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.

…et 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 55º 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 group[21]. In the study conducted by Weiss et al[22], during the treatment of scoliosis, no significant side effects or risks have been noted. conservative treatment such as active physical rehabilitation techniques specific to scoliotic patterns.

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, it can be indicated as the right or left side. To obtain this angle we draw a parallel line respectively at the upper and lower vertebra endplate lines and a vertical line from the parallel line that makes Cobb's angle. This method of measurement has good intra-rater and inter-rater reliability[23].

Scoliometer

The axial rotation of the trunk (ATR) was measured with a scoliometer (Ockendon Partnership, Newsbury, UK) in idiopathic scoliosis. The participants were asked to stand in 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 scoliosis[23].

Pulmonary function test

The pulmonary values such as Forced vital capacity (FVC), forced expiratory volume (FEV_1), FRC/TLC, and Maximum voluntary ventilation (MVV) were measured by using the device PFT (COSMED, Germany) . The patient was asked to sit in a comfortable position and the mouthpiece was connected firmly to inspire air and maximum effort and then expire it with maximum strength. The maneuver was repeated 10-15 times and the mean of the best three values was considered for analysis[24]. No changes happened throughout 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 alpha of 0.05 and a power of 80%, 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 were 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

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

S. No.	Variable	Group A	Group B	Group C	*p*-value
1	Age (y)	13.5 ± 1.2	13.8 ± 1.5	14.1 ± 1.2	0.485*
2	Height (m)	1.48 ± 0.14	1.47 ± 0.16	1.49 ± 0.15	0.9
3	Weight (kg)	42.2 ± 1.8	41.8 ± 1.7	42.8 ± 1.9	
4	BMI (kg/m^2)	16.4 ± 0.8	15.9 ± 0.7	16.2 ± 0.7	06*

*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 ($p \geq 0.05$) 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 r ogical mages o deformation. The ba e data Cobb's angle was collected by sin anteri -ray scores among G s A, C. Wh no statistical differe ($p \geq 0.05$ cted. The intra-group at various ons showed significan ange Group A and Group B ($p < 0.001$) after diffe xercise training. Over eigh of differen ing (Schroth Method, ensingen brace, and ome-based exercise)

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

S. No	Variable	Duration	Group	Grou	Group C	*p*-value
1	Cobb's angle (degree)	Base li	36.3 ± 2.4	.3	36.2 ± 2.3	0.465*
		8 wee	.2	33.8 ± 2.3	34.8 ± 2.3	0.001**
		6 mont		30.3 ± 2.1	32.3 ± 1.9	0.001**
		p-value	0	0.001**	0.00**	
2	Axial Rotation of Trunk (Scoliometer)	Base line	1.4	5.2 ± 1.3	4.9 ± 1.3	0.388*
		weeks	8 ± 2.2	7.6 ± 1.9	5.8 ± 1.5	0.001**
		nths	± 2.2	9.3 ± 1.8	6.3 ± 1.6	0.001**
		ue	01**	0.001**	0.001**	
3	Pulmonary Funct TLC (% predi va		86.3 ± 5.4	87.2 ± 5.3	86.7 ± 5.1	0.902*
		wee	91.8 ± 3.7	89.8 ± 3.9	87.8 ± 4.1	0.034**
		6 months	95.8 ± 4.2	92.3 ± 4.3	88.3 ± 3.3	0.001**
		alue	0.001**	0.018**	0.596**	
	FVC values)	line	76.3 ± 5.4	77.2 ± 5.3	76.8 ± 5.1	0.902*
		8 weeks	82.8 ± 4.1	81.8 ± 4.2	78.8 ± 4.3	0.042**
		6 months	90.6 ± 4.8	84.3 ± 4.3	79.4 ± 4.1	0.001**
		p-value	0.001**	0.001**	0.292**	
	FEV, edicted values)	Base line	78.8 ± 7.8	79.4 ± 6.9	76.2 ± 7.3	0.478*
		8 weeks	85.8 ± 6.1	82.6 ± 6.17	79.8 ± 6.2	0.042**
		6 months	96.5 ± 7.2	88.8 ± 7.3	82.3 ± 7.3	0.001**
		p-value	0.001**	0.002**	0.078**	
	F %)	Base line	44.3 ± 4.3	45.8 ± 4.6	46.2 ± 5.3	0.542*
		8 weeks	56.2 ± 5.4	48.3 ± 4.7	47.8 ± 4.8	0.001**
		6 months	61.3 ± 6.3	52.6 ± 5.4	48.2 ± 4.9	0.001**
		p-value	0.001**	0.001**	0.540**	
	MVV (l/min)	Base line	125.2 ± 9.8	124.9 ± 9.7	126.2 ± 9.3	0.932*
		8 weeks	136.8 ± 9.5	128.6 ± 9.4	126.8 ± 9.4	0.017**
		6 months	142.5 ± 9.2	135.4 ±10.3	128.3 ± 9.6	0.001**
		p-value	0.001**	0.006**	0.832**	

*Non-Significant, **Significant, TLC; total lung capacity, FVC; forced vital capacity, FEV_1; forcrd expiratory volume in one second, MVV; Maximum voluntary ventilation

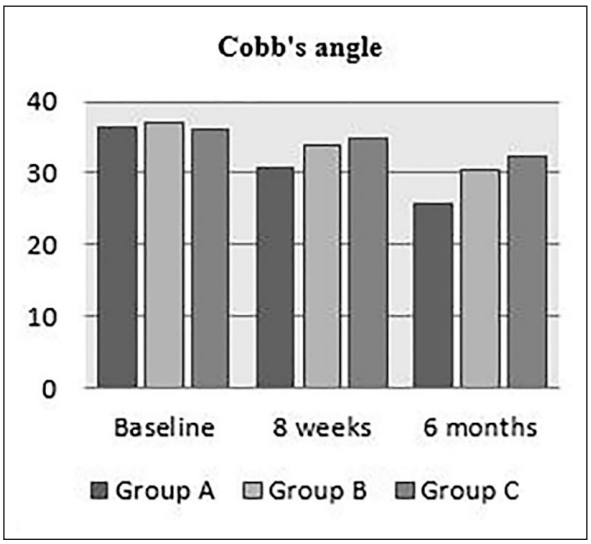

Figure 2. Mean values of Cobb's angle of Group A, B and C.

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 Group A in comparison with Groups B and C (Figure

Scoliometer

The baseline data on an axial rotation of trunk by using scoliometer scor g Group A, B, and C showed no stati ence ($p \geq 0.05$). The intra-group a is at d rent durations showed significa nges A and Group B ($p < 0.0$ a nt exe e training. Over eigh eeks o rent training (Schroth Metho singen bra nd 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 repres n showed more percentage of improvem rotation of the trunk in Group A tha Groups B and C (Figure 3).

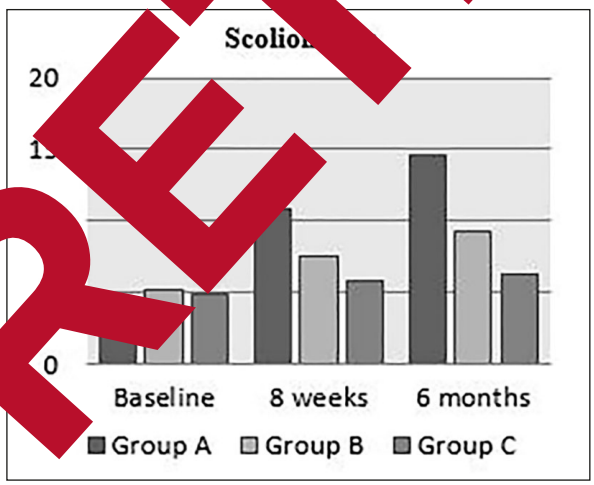

Figure 3. Scoliometer Scores of Group A, B and C.

Pulmonary Function (PF

The baseline data o lmonary (VC, FEV_1, FRC/TLC MVV) cores a Groups A, B, and C wed tatistical d ference ($p \geq 0.05$) O eeks ffer ent training (Sch Me Gensi brace, and home-ba exercise) p a signifi cant impro in pulmona ction (VC, FEV_1, FR LC VV) among groups ($p < 0.001$) at eight week six months follow-up was d (Table II). graphical represen ta showed more perce tage of improvement ulmonary fu tion (VC, FEV_1, FRC/TLC & V) in Group han in Groups B and C (Fig u The whol alysis shows a little tendency tow in towards Group A than the other t ps.

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) among 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

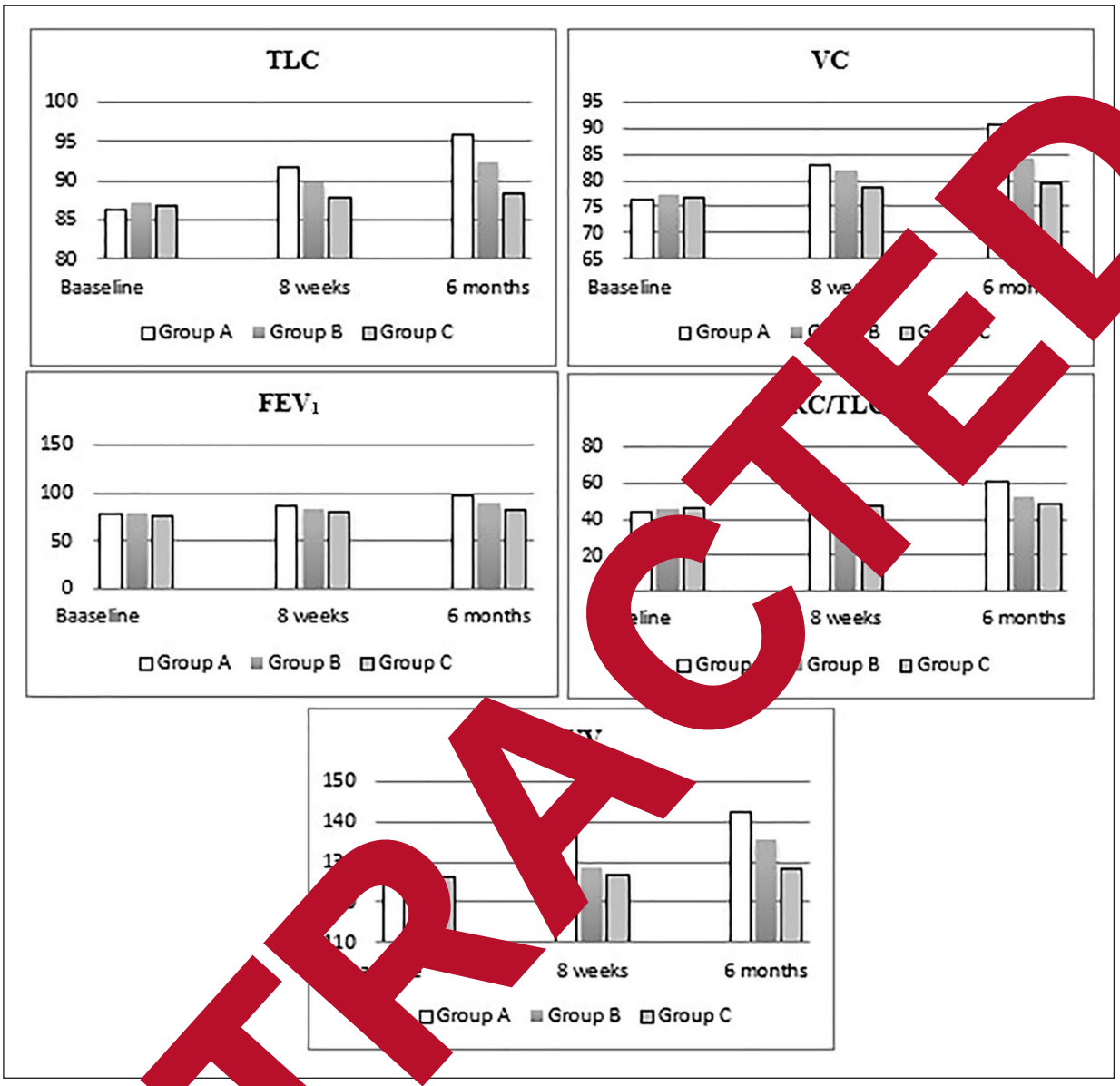

Figure 4. values of To capacity (TLC), vital capacity (VC), forced expiratory volume in one second (FEV_1), functional ual capacity/total acity (FRC/TLC) & maximal voluntary ventilation (MVV) of Group A, B and C.

sugge or ado nt idiopathic scoliosis S) su urgi eatment, bracing, electri- mulat physical activities[25], bracing for S, is pr ed to enhance specificity con- sid the adolescent curve pattern and keep- a p sagittal reposition of the deformed ine[26]. Another important reason for bracing is oid the curve progression, minimizing the s l 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°[27]. In one study[28] 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[29]. 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 9[30].

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 physiotherapy[31]. Otman et al[32] 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 Borysov[33] 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 angl[illegible]d longitudinal axial rotation of the apical ve[illegible] the higher Cobb's angle, the greater the ro[illegible]n angles[34]. Additionally, the trunk rotation angl[illegible] minished when the acromion of the rib was turn[illegible] to the opposite side by 3D rot[illegible] breathin[illegible] during the Schroth exercise[illegible]tational breathing permitted the ex[illegible]e to be[illegible]he more 3-dimensional, which e[illegible]ded th[illegible]d thoracic cage[35]. The [illegible]rel[illegible] showed s-nificant improveme[illegible]n the a[illegible]tation of the trunk in all grou[illegible]gure 4). AIS[illegible]nts suffer from respirato[illegible]y[illegible]tion as a re[illegible] of chest wall abnorma[illegible]es. Th[illegible] rigidity and size are also affec[illegible]y the abnor[illegible]nfiguration of the ribs[36]. A[illegible]ese abnormalitie[illegible]ld impair respirator[illegible]echani[illegible] The effectiveness of Schroth ex[illegible]s is [illegible]ficant here, as it increases rib move[illegible]d vital[illegible]acity while improving [illegible]flat b[illegible]y inc[illegible]ng the sagittal breathing [illegible]e[27]. [illegible]t study showed significant enh[illegible]ement i[illegible]spiratory function for the first gr[illegible]ifically.

[illegible]holars[36] exhibited positive results of [illegible]hroth exercises on breathing function, curve [illegible]ression, and surgical need. Recently, Soumag[illegible]t al[21], 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 a[illegible]ix months' study period. Another study b[illegible] Hwangbo[3] proposed similar findin[illegible]here pa[illegible]tients did Schroth exercises for tw[illegible]eeks three times a week. Significant improvem[illegible]ere observed in terms of improve[illegible]trunk [illegible]tion, Cobb's angle, and vital c[illegible]ty. These [illegible] are in agreement with t[illegible]sults p[illegible]posed i[illegible] current study.

With regard to the [illegible]St[illegible] the G[illegible]agen brace, significan[illegible]ositiv[illegible]lts we[illegible]tained in this study w[illegible]used in co[illegible]at[illegible] with other exercises[illegible]ck et al[37] c[illegible]ed that 3D whole-bo[illegible] scan[illegible]an be applied for tests, which are used for tr[illegible]easurement in preparation[illegible]ace, which i[illegible]ewest development. W[illegible] using these scanners for suitable measured [illegible]es, clinical p[illegible]gress monitoring can be con-[illegible]ed at the sa[illegible]time that the patient's measu[illegible]ents are o[illegible]ned for providing a brace. In the [illegible]sp[illegible]st practices will offer to monitor pa[illegible]rface topography with spinal deformities and its multifunction[37].

[illegible]lar et al[38] in their study examined the ef-[illegible]ctiv[illegible]ss 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 al[35] 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 wi[th] relevant guidelines and regulations. All experimental p[ro]tocols were approved by a named institutional and/or licensing committee. This study was approved by the Research Ethics Committee at Prince Sattam b[in] Abdulaziz University (No. RHPT019/42.) in accordance with the guidelines of the Helsinki Declaration for [hu]man medical research involving human subjects.

Informed Consent

Informed written consent was obtained from all participants.

Availability of Data and Materials

The data used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' Contributions

Conception and design: SAM, GN, AEE, SMH, SEBE, FAM, NAA, HAA. Analysis and interpretation of data: GN, AEE, SMH, SEBE, FAM, NAA, HAA. Drafting: SMH, SEBE, FAM, NAA. Supervision: SAM, FAM, HAA. Validation and final approval of the version of the article to be published: SAM, GN, AEE, SMH, SEBE, FAM, NAA, HAA.

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References

1) Moe JH, Bradford DS, Lonstein JE, Winter RB, Ogilvie JW. Moe's textbook of scoliosis and other spinal deformities. Saunders, 1995.
2) Asher MA, Burton DC. Adolescent idiopathic scoliosis: natural history and long term treatment effects. Scoliosis 2006; 1: 1-10.
3) Kim KT, Hwang JN. Effects of the Schroth exercise on Cobb angle and vital capacity of patients with idiopathic scoliosis that is an operative indication. J Phys Ther Sci 2016; 28: 923-926.
4) Moramarco K, Borysov M. A Modern Historical Perspective on Schroth Scoliosis Rehabilitation and Corrective Bracing Techniques for Idiopathic Scoliosis. Open J Orthop 2017; 11: 1452.
5) Souza PA, Ferreira RB, Labres D, Elias R, Sousa AP, Pereira RE. Epidemiology of adolescent idiopathic scoliosis in students of the public schools of Goiânia-GO. Acta Ortop Bras 2013; 21: 223-225.
6) Weinstein SL. Natural history. Spine 1999; 24: 2592-2600.
7) Weiss HR, Lehnert-Schroth C, Moramarco M, Moramarco K. Schroth therapy advancements in conservative scoliosis treatment. B P International (3rd Edition) 2022; 23: 1-83.
8) Carfì A, Liperoti R, Fusco D, Giovannini S, Brandi V, Vetrano DL, Meloni E, Mascia D, Villani ER, Manes Gravina E, Bernabei R. Bone mineral density in adults with Down syndrome. Osteoporos Int 2017; 28: 2929-2934.
9) Weiss HR. Schroth therapy: Advances in conservative scoliosis treatment. LAP LAMBERT Academic Publishing, 2015.
10) Chik, SKT. Classification and terminology, in Moramarco M, Borysov M, Ng SY, Weiss HR. Schroth's textbook of scoliosis and other spinal deformities. Cambridge Scholars Publishing, 2020; 150-158.
11) Rigo M, Quera-Salvá G, Villagrasa M, Ferrer M, Casas A, Corbella C, Urrutia A, Martínez S, Puigdevall N. Scoliosis intensive out-patient rehabilitation based on Schroth method. Stud Health Technol Info 2008; 135: 208-227.
12) Negrini S, Antonini G, Carabalona R, Minozzi S. Physical exercises as a treatment for adolescent idiopathic scoliosis. A systematic review. Pediatr Rehabil 2003; 6: 227-235.

13) Mohamed RA, Yousef AM. Impact of Schroth three-dimensional vs. proprioceptive neuromuscular facilitation techniques in adolescent idiopathic scoliosis: a randomized controlled study. Eur Rev Med Pharmacol Sci 2021; 25: 7717-7725.

14) Bettany Saltikov J, Parent E, Romano M, Villagrasa M, Negrini S. Physiotherapeutic scoliosis-specific exercises for adolescents with idiopathic scoliosis. Eur J Phys Rehabil Med 2014; 50: 111-121.

15) Białek M. Conservative treatment of idiopathic scoliosis according to FITS concept: presentation of the method and preliminary, short-term radiological and clinical results based on SOSORT and SRS criteria. Scoliosis 2011; 6: 1-9.

16) Moramarco M, Moramarco K, Fadzan M. Suppl-9, M4: Cobb Angle Reduction in a Nearly Skeletally Mature Adolescent (Risser 4) After Pattern-Specific Scoliosis Rehabilitation (PSSR). Open J Orthop 2017; 11: 1490.

17) Weiss HR, Werkmann M. "Brace Technology" Thematic Series-The ScoliOlogiC® Chêneau light™ brace in the treatment of scoliosis. Scoliosis 2010; 5: 1-4.

18) Pruijs JE, Hageman MA, Keessen W, Van Der Meer R, Van Wieringen JC. Variation in Cobb angle measurements in scoliosis. Skelet Radiol 1994; 23: 517-520.

19) Ng SY, Lung TH, Cheng LY, Ng YL. Bra scription for Adult Scoliosis-Literature Open J Orthop 2022; 16.

20) Bonagamba GH, Coelho DM, Oliveira AS. and intra-rater reliability of the scoliometer. Bras Fisioter 2010; 14: 432-43

21) Soumagne T, Guillien A, R , La e JJ, Botebol M, Laurent L, Roch Dalphin Degano B. Quantitative and q ve eva f spirometry for COPD s ree Respir Med Res 2 77:

22) Weiss HR, La Best-Gitten ramarco M, Jimeranez M vative treatm scoliosis patient afte he eries in early ildhood–A case repor Afr J H er 2021; 77: 1588.

23) Płasz M, Bettany ov J. Non-surgical int tions for adolescen h idiopathic scoli an ov iew of syste atic reviews. PloS 2014 10254.

24) G, Lied A, Lack W. Scoliosis and its vative tr ent possibilities. Wien Med Woch 19 44: 593-604.

25) nssinc glink AC, Berger MY, Bierma-Ze- tra SM, kerk K, Verhagen AP. Effect of and other conservative interventions in ent of idiopathic scoliosis in adolescents: a systematic review of clinical trials. Phys Ther 2005; 85: 1329-1339.

hanasopoulos S, Paxinos T, Tsafantakis E, achariou K, Chatziconstantinou S. The effect of aerobic training in girls with idiopathic scoliosis. Scand J Med Sci Sports 1999; 9: 36-40.

27) Berdishevsky H, Lebel VA, Bettany-Saltikov J, Rigo M, Lebel A, Hennes A, Romano M, Białek M, M'hango A, Betts T, de Mauroy JC. Ph py scoliosis-specific exercises–a co review of seven major schools. S sis Spina Disord 2016; 11: 1-52.

28) Noshchenko A, Hoffecker L, Lin M, Burger EL, Cain CM, Patel V Bradf Predictors of spine deform progressi ad olescent idiopathic s sis: A systema view with meta-ana World Orthop. Aug 18;6(7):537-5 10.5 wjo. v6 i7.537. PMID: 26301183 PM 539477

29) Dereli EE, G S, Çola Turnb Guidelines for th nservative nnaire for a spinal deformities consensus. S Afr 2021; 77: 158

30) Kuru T, Yeldan I, li EE, Özdinçler AR, Dikici lak I. The of three-dimensional exercises in ad cent idiopathic scoliosis: a randomized controlled clinical trial. Clin Rehabil 2016; 30 81-190.

Koumbourlis Scoliosis and the respiratory stem. Paed Respir Rev 2006; 7: 152-160.

32) S e N, Yakut Y. The efficacy of s imensional exercise therapy in the treatment of adolescent idiopathic scoliosis in Turkey. Neurosciences 2005; 10: 277-283

ov M, Borysov A. Scoliosis short-term rehabilitati (SSTR) according to'Best Practice'standards-are the results repeatable? Scoliosis 2012; 7: 1.

34) Jung JY, Heo M, Kim JJ. Effects of a personalized exercise rehabilitation device on dynamic postural balance for scoliotic patients: A feasibility study. Electronics 2020; 9: 2100.

35) Weinstein SL, Dolan LA, Wright JG, Dobbs MB. Effects of bracing in adolescents with idiopathic scoliosis. N Engl J Med 2013; 369: 1512-1521.

36) Schreiber S, Parent EC, Khodayari Moez E, Hedden DM, Hill DL, Moreau M, Lou E, Watkins EM, Southon SC. Schroth physiotherapeutic scoliosis-specific exercises added to the standard of care lead to better Cobb angle outcomes in adolescents with idiopathic scoliosis–an assessor and statistician blinded randomized controlled trial. PLos One 2016; 11: e0168746.

37) Rothstock S, Weiss HR, Krueger D, Kleban V, Paul L. Innovative decision support for scoliosis brace therapy based on statistical modeling of markerless 3D trunk surface data. Comput Methods Biomech Biomed Engin 2020; 23: 923-933.

38) Karalar S, Bayram S, Altan M, Ozdemir MA, Akgul T. Effectiveness of Gensingen brace treatment for adolescent idiopathic scoliosis: a prospective cohort study. J Turk Spinal Surg 2020; 31: 130.