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Schroth Three-Dimensional Exercises versus Trunk Rotation Exercises on Scoliosis and Balance in Hemiplegic Cerebral Palsy

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Abstract : Objectives: The purpose of this study was to investigate and compare the effects of Schroth three-dimensional (3D) and trunk rotation exercises on scoliosis and balance in hemiplegic cerebral palsy (CP). **Methods:** Thirty children with hemiplegic CP from both sexes ranging in age from 7 to 9 years were participated in this study. They were assigned randomly using opaque envelops into two intervention groups (group A and B). Both groups underwent the same physical therapy program. In addition, group A received the Schroth 3D exercises, whereas, group B received the trunk rotation exercises. Both groups received the treatment program for 2 hour, 3 times/week, for three months. Assessment of Cobb angle and stability indices was conducted before and after three successive months of the treatment. **Results:** There was a significant decrease in Cobb's angle ($p = 0.02$) and stability indices ($p < 0.05$) of group A compared with that of group B after treatment. Moreover, a positive significant correlation was observed between Cobb's angle and stability indices ($p < 0.001$). **Conclusions**: Both Schroth 3D and trunk rotation exercises induced improvements in scoliosis and balance in hemiplegic CP, with greater effect was shown in the Schroth 3D exercises group.
Key words : Cerebral palsy, Hemiplegia, Schroth method, Scoliosis, Trunk rotation exercises.

Introduction

Cerebral palsy (CP) is a non-progressive, permanent abnormality of motor function due to injury to the developing brain[1]. It includes a heterogeneous group of conditions characterized by abnormal movement, muscle tone and posture[2]. Scoliosis is a three dimensional deformity of the spine and is characterized by rotations in all three planes of view[3]. Moreover, it is considered when the Cobb angle is more than 10 degrees[4]. It can be classified into neuromuscular scoliosis that develops secondary to a neuromuscular disorder such as CP, congenital scoliosis due to an underlying abnormality of the formation of the spine or idiopathic scoliosis with unknown cause[3, 5]. There is a strong link between CP and the development of scoliosis, as 21% to 64% of

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patients with CP develops scoliosis and is closely associated with the severity of the CP disability[6, 7]. Scoliosis may be considered one of the main causes of postural instability in these children, as in scoliosis, the system controlling balance reactions, postural reflexes and voluntary movements are disturbed because of disturbed proprioceptive sense[8]. In addition, the reaction to balance disturbance is clearly delayed, and characterized by lower impulsiveness[9].

Impaired balance, frequent falls and gait disturbances are the most common problems among children with CP, as they have deficits in postural control system that may provide a partial explanation for balance problems[10]. Balance problems in children with hemiplegic CP could be attributed to impaired coordination of movement, reduced between-limb synchronization, and less weight bearing on the affected side, which in turn can affect the ability to maintain an upright weight-bearing position[11, 12].

Numerous modalities including exercises, electrical stimulation, botulinum toxin injections and bracing have been suggested for the treatment of scoliosis in children with CP[13]. Previous studies[14-16] have proved that physiotherapy rehabilitation can reduce scoliosis by regular exercise program. Schroth three-dimensional (3D) method is considered one of the exercise techniques that was used for rehabilitation of scoliosis[17] through postural control in the sagittal plane (front-back), side-to-side displacement in frontal plane, as well as rotation in the transverse plane[18].

The Schroth 3D method is a physiotherapeutic approach that uses isometrics and other exercises to strengthen or lengthen the asymmetrical muscles. The treatment program consists of scoliotic posture correction and a breathing pattern with the help of proprioceptive, exteroceptive stimulations and mirror control[19]. Similarly, trunk rotation exercises are considered one of the programs used to correct scoliosis[20].

Previous studies have documented the effects of Schroth 3D exercise therapy in scoliosis[21-24]. Furthermore, previous studies emphasized the effect of the trunk rotation exercises in the reduction of the Cobb angle [20, 25]. However, up till now, there are no studies conducted to investigate the effects of Schroth 3D program and trunk rotation exercises on correction of scoliosis and balance in children with hemiplegic CP. Therefore, the purpose of this study was conducted to investigate and compare the effectiveness of Schroth 3D exercises and trunk rotation exercises on scoliosis and balance in children with hemiplegic CP.

Materials and Methods

Subjects

A randomized controlled trial was conducted on 30 children with hemiplegic CP from both sexes ranging in age from 7 to 9 years as spinal deformity is thought to occur before 10 years of age[26]. They were recruited from the outpatient clinic of Faculty of Physical Therapy, Cairo University, Cairo, Egypt.

Children with non-structural dorso-lumbar scoliosis with a Cobb angle 12-20 degrees (The minimum and maximum values of Cobb's angle was 12 and 20 degrees respectively) with rightward convexity (SRC) or leftward convexity (SLC), able to understand commands given to them, the degree of spasticity was 1^+ to 2 according to the Modified Ashowrth Scale[27], Gross Motor Function Classification System (GMFCS) scores I and II[28] and able to walk independently at least 10 meters without the use of walking aids were included in this study.

Children who had true leg length discrepancy, obesity, previous spinal surgery, associated pathologies that may interfere with maintaining an erect standing posture such as cerebellar or inner ear disorders, vision or hearing loss, cardiac anomalies, previous history of fracture were excluded.

After the initial evaluation, the children were assigned randomly using sealed envelopes into two intervention groups. The group A consisted of 15 children (9 boys and 6 girls) and received the designed physical therapy program in addition to the Schroth 3D exercises. The group B consisted of 15 children (8 boys and 7 girls) and received the same physical therapy program in addition to the trunk rotation exercises.

Before conducting the study, the investigators explained the procedures of evaluation and treatment, expected benefits as well as the unexpected risks of the study to the parents of all children and they signed a consent form prior to participation. The Ethical Committee of Cairo University approved this study. In addition, the procedures of this study followed the code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving human subjects.

Randomization

The investigators assessed thirty-five children for eligibility. They excluded five children, as they did not meet the inclusion criteria. After the initial evaluation of Cobb angle and balance in all children, randomization process was done via 30 closed envelopes with each envelope containing a card labeled with either group A or B. The investigators stratified the children with regard to their age and gender for equal distribution in both groups. Each child was asked to draw a closed envelope that contained weather he/ she was allocated to the group A or B. The experimental design of the study is shown as a flow diagram in Figure 1.

Procedures

Preliminary evaluations were conducted at the beginning to select the children for the study. It included evaluations of the motor functions of children that were measured by the Gross Motor Function Measure (GMFM–88)[29, 30], Leg length discrepancy[31]. In addition**,** Adam's forward bend test was conducted to determine if the scoliosis was structural or non- structural[32]. Measurement of the Cobb angle and stability indices was done before and after the three successive months of the treatment program. A familiarity session was conducted prior to the test session to all the children to ensure their comfort with the research team and to be aware of the different test steps.

Assessment of the Cobb angle

The Cobb method was used to measure the degree of scoliosis and to make decisions regarding the progression of the curve, which is necessary to verify the effectiveness of treatment[33, 34]. Assessment of the Cobb angle in children was conducted by using x-ray. The entire spinal column of each child was x-rayed in an anterior-posterior direction in a standing position. The Cobb angle was measured by tracing a line parallel to the upper boundary of the top vertebra and another line on the bottom edge of the lower vertebra, above and below the apex of the scoliotic curve, respectively. The intersection of these two lines determined the angle of deviation of the spine. Cobb angle measurements may be subjected to some limitations. Varying Cobb angles could result due to patient position and diurnal variation. In order to have a perfect comparison, patients should ideally assume identical positioning for successive x-rays and the images were taken at a similar time of the day[35].

Assessment of balance

Balance was assessed by using the Biodex Stability System (BSS; Biodex, Inc, Shirley, NY) and it is an objective assessment of balance[36]. The BSS consisted of a dynamic balance platform that allowed movements in the anterior-posterior (AP) and medial-lateral (ML) axes simultaneously. The BSS measured the degree of tilting around each axis which was reflected in calculation of an anterior-posterior stability index (APSI), medial-lateral stability index (MLSI), and overall stability index (OSI) [37]. The BSS had eight levels of stability, extending from the least stable level (level 1) to the most stable level (level 8). In this study, level 8 was used to measure the stability indices as the children had difficulty in maintaining their balance below this level during the familiarity sessions. In addition, the BSS consisted of support handles and a display screen in front of the child, which could be adjusted according to the height of each child. The screen provided visual feedback about the degree of tilting, that the child should maintain the cursor in the center of the screen to obtain a good score of balance.

Each child in both groups was asked to stand on the center of the locked platform with the two legs stance while grasping the handrails. Then the child was asked to achieve a centered position, in a slightly unstable platform, by shifting his/her feet position to keep the cursor (representing the center of the platform) centered on the screen grid while standing in a comfortable upright position. The balance measurement test was repeated 3 times and the mean was obtained for data analysis.

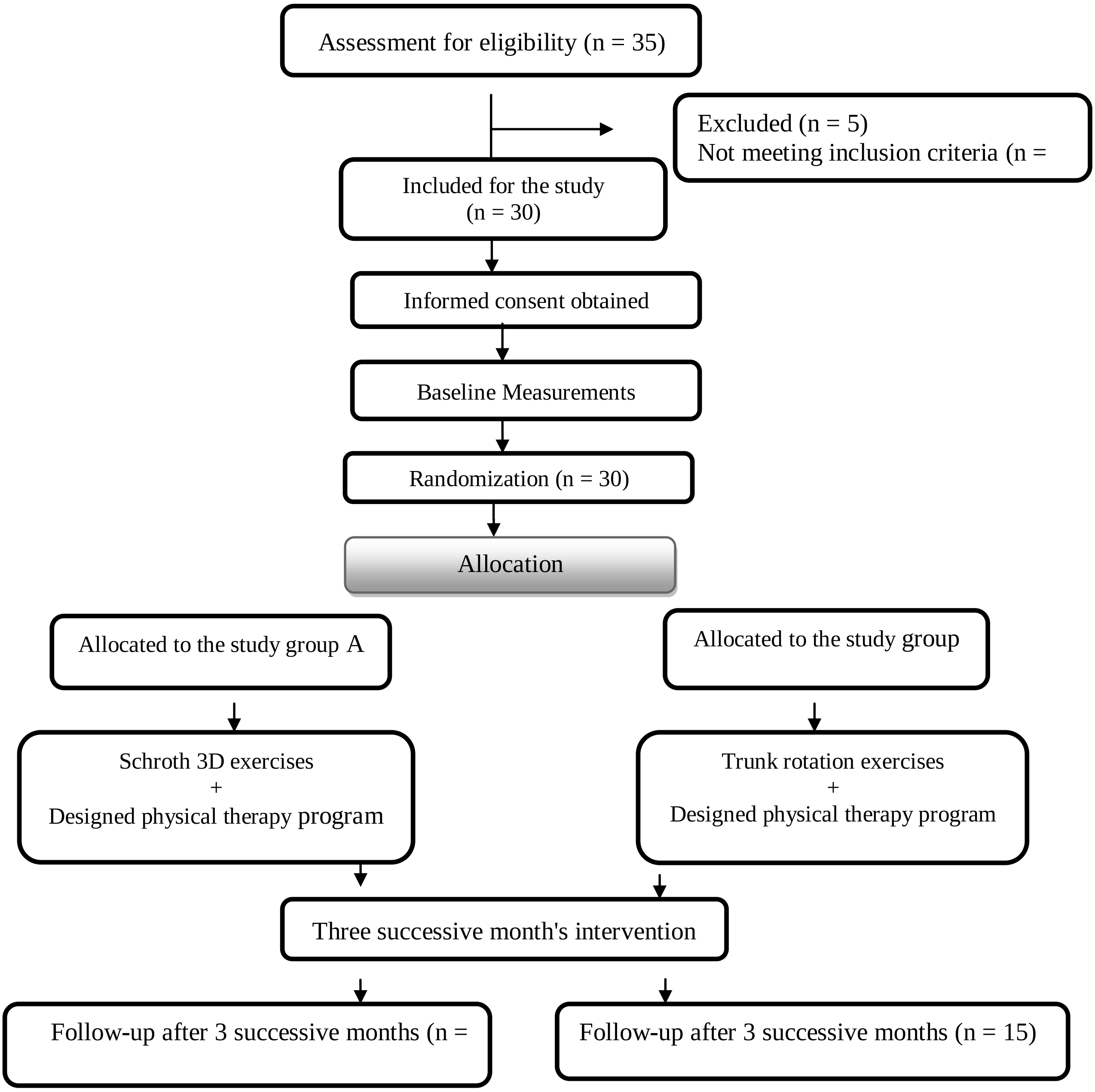

Figure 1. Flow chart showing the experimental design of the study.

Protocol of treatment

1-Schroth three-dimensional exercises

The children in the group A only received the Schroth 3D exercises for 1 hour / three times / week for three successive months. It started with a preparatory exercise or warm-up for 15 min (included conscious walking for 5 min followed by exercising on a fixed bicycle for 10 min), followed by the Schroth 3D exercises for 40 min, and ended with 5 min finishing exercise or cool down (moving ribs) [24]. The Schroth 3D exercises were conducted as shown in table 1. Each exercise was designed according to the curvature of the individuals. The self-correction exercise was given, so the patient could reconstruct the 3D spinal movement independently[7]. They included the following exercises[24]:

Conscious walking : The patient was instructed to walk at a slow pace with the physiologic gait pattern for hip, knee, ankle, and foot, prolonged single stance phase while swinging the unloaded limb for and back during normal breathing.

Stretching the lumbar part : The patient was asked to lie side lying on lumbar convex side with passive support of a towel or pillow under the apex of the curve. While holding the leg downwards, the patient was instructed to keep the waist from falling off the floor.

Stretching the thoracic part : The patient was asked to lie side lying on the thoracic convex site with passive support of a towel or pillow under the apex of the curve. While holding the arms upwards, the patient was instructed to keep the waist from falling off the floor.

Exercise in sitting : The patient sat in front of the wall bar, the arm of the concave side of the thoracic curve is abducted horizontally and held the bar of the wall at the same level of the shoulder with the elbow is semiflexed while the arm on the convex side is held at 90° flexion and held the bar above the level of shoulder with the elbow joint in semiflexed position. The patient was asked to self-correct the curve by pushing the convex side towards the concave side. After that, the subject raised the feet 3 cm from the floor to push arm side without bending of the body at this time.

Exercise in side-lying : The patient was asked to lie on the lumbar curve with chair above the head and the arm of lumbar curve site outstretched in front of the body. Upper leg extended and foot resting on a stool. Then, the patient was asked to push with the flexed elbow slight laterally in order to adjust the scapula in an abduction position

Exercise in prone : It corrects the thoracic curve using shoulder traction and shoulder counter-traction and the lumbar curve via activation of the iliopsoas muscle

Muscle cylinder : In the standing position, the patient was leaning toward the lumbar convex site, stood on the leg (knee) of the lumbar convex site, extended the leg of the thoracic convex site and placed it either on chair or on the floor. The arm of lumbar concave was in shoulder 90° abduction and external rotation. The lumbar convex site was pushed to the opposite direction by static movement.

Cool down (Moving the ribs) : The patient was lying in supine position and flexed knees in order to fix the pelvis in a posterior tilted position. Repeated forward movements with the thoraco-lumbar junction with normal breathing. The therapist gave support under the spinal processes and felt the emerging movement.

Table 1. Schroth's 3D exercises program [24]

Exercise sequence	Schroth's 3D exercises program	Frequency
Warm-up (15 min)	Conscious walking	4 set×10 m (5 min)
	Fixed bicycle	10 min
Stretching & exercise (40 min)	Stretching the lumbar part	10 sec×15 time
	Stretching the thoracic part	10 sec×15 time
	Exercise in sitting	4 set×6 rep
	Exercise in side-lying	4 set×6 rep
	exercise in prone	4 set×6 rep
	Muscle cylinder	4 set×6 rep
Cool down (5 min)	Moving the ribs	4 set×12 rep

2- Trunk rotation exercises

The children in the group B only received the trunk rotation exercises for 1 hour / three times / week for three successive months[20].

Flexion rotation exercise

This exercise was performed in supine lying position. The child was asked to hold both hands together in front of his/her body and the head rotated towards right side. Then the child was asked to rotate the trunk towards the right side until the hands reach the right knee for a right sided scoliosis and vice versa for the left scoliosis. This exercise was done for 3 sets with each set included 10 repetitions.

Extension rotation exercise

This exercise was performed in prone lying position. The child was asked to hold both hands on his/her back and the head rotated to the left side. Then, the child was asked to rotate the trunk towards the right side for a right sided scoliosis and vice versa for the left scoliosis until the chest raised from the table. This exercise was done for 3 sets with each set included 10 repetitions.

3- The designed physical therapy program

The children in both groups received the same physical therapy program for 1 hour / 3 times / week for three successive months. The physical therapy program aimed to improve biomechanical faults, correct muscle imbalances and improve functional capacity. It included the following:

- Gentle stretching exercise for the tight muscles as hip flexors, adductors, hamstrings and planter flexors.
- Facilitation for the anti-spastic muscles.
- Balance training in standing, walk standing and high step standing positions with manual titling of the child was done in different directions
- Stoop and recover exercise from standing.
- Gait training in different directions while using obstacles.

Statistical analysis

Sample size calculation was performed prior to the study using G*POWER statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) and revealed that the appropriate sample size for this study was n=30, which gave observed power equal to 0.8. Calculations were made using $\alpha=0.05$, $\beta=0.2$ and medium effect size.

Subject characteristics were compared between groups using t-test. Chi- squared test was used for comparison of sex distribution between both groups. Normal distribution of data was checked using the Shapiro-Wilk test for all variables. Levene's test for homogeneity of variances was conducted to test the homogeneity between groups. Mixed MANOVA was performed to compare within and between groups effects of treatment on Cobb's angle and stability indices between the group A and B as between group comparison, and between before and after treatment in each group as within group comparison. Partial squared eta was considered as the effect size. Post-hoc tests using the Bonferroni correction were carried out for subsequent multiple comparison. Pearson Correlation Coefficient was conducted to determine the correlation between Cobb's angle and stability indices. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 19 for windows (IBM SPSS, Chicago, IL, USA).

Results

Subject characteristics

Table 2 showed the subject characteristics of both groups. There was no significant difference between both groups in the mean age, weight and height ($p > 0.05$). In addition, there was no significant difference in sex distribution between both groups ($p > 0.5$).

Table 2. Comparison of subject characteristics between group A and B.

	Group A	**Group B**			
	$\bar{x}$±SD	**$\bar{x}$±SD**	**MD**	**t- value**	**p- value**
Age (years)	7.77 ± 0.8	8.1 ± 0.69	-0.33	-1.21	0.23
Weight (kg)	26.64 ± 1.21	26.74 ± 1.08	-0.1	-0.22	0.82
Height (cm)	117.4 ± 2.79	117.86 ± 2.5	-0.46	-0.48	0.63
Boys/girls	9/6	8/7		(χ^2 = 0.13)	0.71*

$\bar{x}$, Mean; SD, Standard deviation; MD, Mean difference; χ^2, Chi squared value; p value, Probability value; *, Non-significant.

Effect of treatment on Cobb's angle and stability indices

Mixed MANOVA revealed that there was a significant interaction of treatment and time (Wilks' Lambda = 0.13; F (4, 25) = 40.29, p = 0.001, $\eta^2 = 0.86$). There was a significant main effect of time (Wilks' Lambda = 0.02; F (4, 25) = 206.52, p = 0.0001, $\eta^2 = 0.97$). There was a significant main effect of treatment (Wilks' Lambda = 0.68; F (4, 25) = 2.94, p = 0.04, $\eta^2 = 0.32$). Table 3 and figures 2-3 showed descriptive statistics of Cobb's angle, APSI, MLSI and OSI and the significant level of comparison between groups as well as the significant level of comparison between before and after treatment in each group.

Between group comparison

There was no significant difference between the group A and B in all variables before treatment (p > 0.05). After treatment there was a significant decrease in the Cobb's angle of group A compared with that of group B (p = 0.02). In addition, there was a significant decrease in APSI, MLSI and OSI of group A compared with that of group B after treatment (p < 0.05).

Within group comparison

There was a significant decrease in the Cobb's angle, APSI, MLSI and OSI after treatment compared with that before treatment in both groups (p < 0.01).

Table 3: Mean Cobb's angle, APSI, MLSI and OSI pre and post treatment of the group A and B:

	Group A	**Group B**		
	x̄±SD	**x̄±SD**	**MD**	**p value**
Cobb's angle (degrees)				
Pre	16.53 ± 1.93	16.93 ± 2.6	-0.4	0.63*
Post	12.53 ± 2.19	14.8 ± 2.88	-2.27	0.02**
MD	4	2.13		
% of change	24.2	12.58		
	p = 0.001*	***p = 0.001****		
APSI				
Pre	1.64 ± 0.62	1.43 ± 0.49	0.21	0.31*
Post	0.91 ± 0.27	1.17 ± 0.32	-0.26	0.02**
MD	0.73	0.26		
% of change	44.51	18.18		
	p = 0.001*	***p = 0.01****		
MLSI				
Pre	1.74 ± 0.58	1.86 ± 0.51	-0.12	0.53*
Post	1.03 ± 0.39	1.67 ± 0.54	-0.64	0.001**
MD	0.71	0.19		
% of change	40.8	10.21		
	p = 0.001*	***p = 0.001****		
OSI				
Pre	2.06 ± 0.65	1.96 ± 0.4	0.1	0.64*
Post	1.17 ± 0.46	1.76 ± 0.38	-0.59	0.001**
MD	0.89	0.2		
% of change	43.2	10.2		
	p = 0.001*	***p = 0.002****		

x̄, mean; SD, standard deviation; MD, mean difference; p-value, level of significance; *, Non-significant; ** Significant.

Correlation between the Cobb's angle and stability indices

The scores pre and post treatment of Cobb's angle and stability indices were overlapped comprised 30 scores and then correlated. Table 4 showed the correlation between Cobb's angle and stability indices was positive moderate significant correlation ($p < 0.001$) with highest correlation was for MLSI.

Table 4. Correlation between the Cobb's angle, APSI, MLSI and OSI.

	Stability indices	r value	p value
Cobb's angle (degrees))	**APSI**	0.39	0.002**
	MLSI	0.51	0.001**
	OSI	0.5	0.001**

r value, correlation coefficient value; p value, probability value, ** Significant

Discussion

Scoliosis is one of the most common deformities in children with CP that could continue to progress and cause impairment in function with increased risk of poor health[7]. Physical exercises are most important, and when done correctly, worsening of the curve could be prevented[38]. Therefore, the present study was designed to investigate and compare the effects of Schroth 3D and trunk rotation exercises on scoliosis and balance in children with hemiplegic CP. The main findings suggested that both Schroth 3D and trunk rotation exercises induced improvements in scoliosis and balance in hemiplegic CP with greater improvements are shown in the group A who received the Schroth 3D exercises.

Concerning the Cobb angle, significant improvements were noted in both groups after treatment. These results are consistent with the findings of Kuru et al.[22] who investigated the short-term effect of supervised and non-supervised Schroth program and no intervention on change in the Cobb angle, trunk rotation, height of the rib hump, waist asymmetry and Scoliosis Research Society-23 domains questionnaire in 45 patients with adolescents with idiopathic scoliosis. Differences between the supervised group and the other two groups were statistically significant. The supervised Schroth intervention was also superior in improving all other measured outcomes. In addition, the 12-weeks of conservative treatment with Schroth exercise therapy was found to be effective in decreasing the Cobb angle from 42.40 ± 7.86° to 26.0 ± 3.65° after treatment for patients with growing idiopathic scoliosis, indicated to surgery[23]. In a systemic review of Negrini et al.[15] on the effect of exercises on the reduction of idiopathic scoliosis, they concluded that, exercises could be recommended for reducing scoliosis progression. Moreover, trunk rotation exercises decreased the Cobb angle among post-polio residual paralysis with scoliosis[20].

The cause of scoliosis in hemiplegic CP is muscular imbalance around the spinal axis [38, 39] with weakness in one side and more activity in the contralateral side[40]. Therefore, the improvement in the Cobb angle could be attributed to strengthening of the trunk muscles and improving of muscle balance through strengthening of the spinal muscles on the convex side and stretching of the muscles on the concave side [41, 42]. This explanation is supported by the finding of Otman et al.21 who found that muscle strength is increased significantly after 1 year of Schroth exercises. Another study that followed the Schroth principles showed an improvement in back asymmetry and spinal imbalance both in the frontal plane and in the transversal plane[43]. In a study conducted by McIntire et al.[25] to investigate the effect of a quantified trunk rotational strength training protocol on trunk strength and stability or reduction of the curve in idiopathic scoliosis (AIS) curve size. It was applied on 7 adolescents with AIS (5 female 2 male; mean 14 yrs +/- 2.6 yrs; mean Cobb 28 degrees +/- 6 degrees range 20 degrees -37 degrees) underwent four months of supervised trunk rotational strength training, and repeat strength test. Trunk strength in both directions increased significantly after training. Average Cobb angle decreased to 23 degrees +/- 11 degrees. Four individuals showed reduction (>5 degrees) in their original curve, and 3 remained the same (+/-5 degrees).

Scoliosis is caused by impairment of proprioceptive functions in CP [44] that leads to inadequate gravity control causing lateral flexion of the thorax over the relative mobile spine, thus a thoracolumbar curve [41]. Therefore, the improvement in the Cobb angle could be caused by improvement in the trunk proprioception.

Similarly, the results revealed significant improvements in the stability indices of both groups with positive correlation between improvement of stability indices and that of Cobb angle, which means that the reduction in the Cobb's angle in turn caused improvement in the standing stability. These results are consistent with Tsirikos [45] who stated that the development of trunk imbalance along with the associated pelvic obliquity could affect standing balance in ambulatory CP patients. Improvement in standing balance could be attributed to the effect of Schroth 3D and trunk rotation exercises in addition to the selected physical therapy program. Improvement in standing balance could be due to improving weight bearing on the affected side and weight distribution on both sides, which in turn improve the proprioceptive senses on both lower limbs and hence improving neuromotor control and balance reaction [46]. These results are consistent with the results of Lee et al.[16] who conducted her study on single case with idiopathic scoliosis to determine the effect of proprioceptive neuromuscular facilitation exercise programs for 6 weeks on the spinal curve and balancing abilities and concluded that the Cobb angle, static and dynamic balancing abilities were improved compared to the baseline values.

The significant improvements in group A could be attributed to the three dimensional effects of the Schroth 3D exercises[38,47], its effect of gravity[18] and its stability exercises which are emphasized rather than simple mobility exercises to correct posture and regain control of white and red muscles[48]. Numerous previous studies have shown that the Schroth exercises significantly change the Cobb's angle in comparison with the traditional exercises [14, 23, 49-50].

Small sample size which limit the generalizability of the findings and the short duration of the study to detect the long term effects of the Schroth 3D and trunk rotation exercises represent the limitations in this study. Therefore, in the future, studies with a larger sample size and extended duration should be developed further.

It is possible to validate the therapeutic effects of Schroth 3D and trunk rotation exercises on scoliosis and balance in the rehabilitation process of children with hemiplegic CP. However, there was a greater effect shown in the Schroth 3D exercises group, indicating that the Schroth 3D exercises are more effective than trunk rotation exercises in treating scoliosis and balance in children with hemiplegic CP. The authors recommended the future researches on different age groups, for long duration and measuring of trunk rotation angles. The authors are planning to follow these patients to skeletal maturity to see if in fact the exercise program did make a long-term difference in their Cobb angles and scoliosis progression.

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Authors' Contributions

R Mohamed, M Eid and S Aly conceived and designed the study. **M Eid and S Aly** were involved in participant recruitment. **R Mohamed and S Aly** were involved in data collection and data entry. **R Mohamed and M Eid** provided access to research tools and input on analysis and interpretation. **R Mohamed** accepts responsibility for integrity of the data. All authors have read and approved the manuscript.

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