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ORIGINAL ARTICLE

Effects of Schroth exercises combined with orthotic treatment on balance control in adolescent idiopathic scoliosis

Burçin AKÇAY BAYRAKTAR[1], Ata ELVAN[1], Metin SELMANİ[1], Alphan ÇAKIROĞLU[1], İ Safa SATOĞLU[2], Ömer AKÇALI[2], Salih ANGIN[1], İ Engin ŞİMŞEK[1]

Purpose: We aimed to investigate the possible effects of three dimensional Schroth exercises combined with brace treatment on balance control in patients with adolescent idiopathic scoliosis (AIS).

Methods: Total of 20 volunteers participated in the study. Participants divided equally into two groups as a study group (patients with AIS) and an age-matched healthy control group that comprised of 10 participants each. Conservative treatment protocol consisted of brace treatment and Schroth exercises. The individuals in the study group wore full time rigid braces (Modified-Cheneau) 23 hours per day and performed individually designed Schroth exercises. The exercise treatment comprised 3 sessions per week with duration of 90 minutes each and a total of 18 sessions. Postural control parameters were assessed in four conditions which described as eyes opened firm, eyes opened foam, eyes closed firm and eyes closed foam, using a computerized force platform at baseline, 6th and 18th weeks.

Results: There were significant differences between groups in centre of gravity sway velocity in eyes closed foam condition and composite centre of gravity sway velocity values at baseline ($p<0.05$). Additionally study group demonstrated significant improvement in eyes open foam condition between 6th – 18th weeks and 1st – 18th week assessments ($p<0.05$). Moreover, changes in percentage of limit of stability (LOS) values indicated significant difference only between 6th – 18th week assessments ($p<0.05$).

Conclusion: Our results emphasized that Schroth exercises combined with brace treatment may provide significant improvement in certain components of postural control.

Keywords: Scoliosis; adolescent idiopathic, Schroth exercises, Orthosis, Postural balance.

Adölesan idyopatik skolyozda ortez tedavisi ile birlikte Schroth egzersizlerinin denge kontrolüne etkileri

Amaç: Çalışmamızda adölesan idyopatik skolyozu (AİS) olan hastalarda üç boyutlu Schroth egzersizlerinin ortez tedavisi ile birlikte denge kontrolüne olan muhtemel etkilerinin araştırılması amaçladı.

Yöntem: Çalışmaya toplam 20 gönüllü katıldı. Gönüllüler her grupta 10 katılımcı olmak üzere çalışma grubu (AİS'li hastalar) ve aynı yaştaki sağlıklı kontrol grubu olarak iki gruba ayrıldı. Konservatif tedavi protokolü ortez tedavisi ve Schroth egzersizlerinden oluşmaktaydı. Çalışma grubundaki katılımcılara kişiye özel tasarlanmış Schroth egzersizleri ve aynı zamanda tam zamanlı rijit ortez (Modifiye-Cheneau) verildi. Egzersiz tedavisi haftada 3 seans ve her seans 90 dakika olmak üzere toplam 18 seans olarak dizayn edildi. Postüral kontrol parametreleri başlangıçta, 6. ve 18. haftalarda gözler açık sert zemin, gözler açık yumuşak zemin, gözler kapalı sert zemin ve gözler kapalı yumuşak zemin olarak tanımlanan dört durumda bilgisayarlı bir kuvvet platformu kullanılarak değerlendirildi.

Bulgular: Gözler kapalı yumuşak zemin koşulunda ve toplam değerlerde vücut ağırlık merkezi salınım hızı tedavi öncesi başlangıç değerlerinde gruplar arasında fark bulundu ($p<0.05$). Buna ek olarak çalışma grubu, 6-18. haftalar ve 1-18. haftalar arası değerlendirmelerde gözler açık yumuşak zemin üzerinde anlamlı gelişim gösterdi ($p<0.05$). Ayrıca, LOS (Limit of Stability) değerlerinin yüzdesindeki değişiklikler sadece 6-18. haftalar arasında fark gösterdi ($p<0.05$).

Sonuç: Sonuçlarımız ortez tedavisi ile yapılan Schroth egzersizlerinin postüral kontrolün bazı bileşenlerinde anlamlı gelişme sağlayabileceğini vurgulamaktadır.

Anahtar kelimeler: Skolyoz; adölesan idyopatik, Schroth egzersizleri, Ortez, Postüral denge

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1: Dokuz Eylül University, School of Physical Therapy and Rehabilitation, İzmir, Türkiye.
2: Dokuz Eylül University, Faculty of Medicine, Department of Orthopedics and Traumatology, İzmir, Türkiye.
Corresponding Author: Burçin Akçay Bayraktar: akcayburcin@gmail.com
ORCID ID: 0000-0003-0883-0311
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Scoliosis is defined as a complex three-dimensional structural spinal deformity which involves lateral deviation of the spinal column more than 10° in the frontal plane, an axial (vertebral) rotation in the horizontal plane and a change in physiological curvatures in the sagittal plane (kyphosis and/or lordosis).[1-3] Idiopathic scoliosis is named as adolescent after 10 years old and progresses during skeletal growth period. Although the etiology of adolescent idiopathic scoliosis (AIS) is unknown, it is accepted as a multi-etiological condition.[2,4]

Accurate balance control requires central integration of sensory information and motor responses. Sensory information is provided by somatosensory, visual and vestibular systems to initiate accurate motor responses including alignment of the body segments and eye movements (vestibulo-ocular reflexes).[5,6] Postural changes related to AIS may be various including problems in central and peripheral balance regulation systems. Many studies which investigate central nervous system, showed vestibulo-ocular reflex differences, dysgenesis of semi-circular canals and presence of nystagmus in patients with AIS.[7-9] Catanzariti et al. emphasized that unilateral and isolated vestibular damage may cause AIS. One of the hypothesis regarding the development of AIS is considered as sensory compensation and inaccurate postural adaptation with excessive tilt of the longitudinal axis of the body that is not aligned parallel to the vertical axis of earth during spinal growth.[10] Also thinning of the cerebral cortex, asymmetric cortical hyper-excitability and volumetric differences observed in 22 brain regions compared to healthy controls have been shown in previous brain studies in AIS.[11-13]

Poor balance and impaired postural control accompanied with increased centre of gravity sway velocity have been reported in patients with AIS.[6,14,15] Kuo et al. found that dynamic balance control was sustained by increased lumbar multifidus and gluteus medius activities for compensation.[15] Guo et al. reported somatosensory evoked potentials differences between right and left limbs which effect somatosensory function related to balance control.[14] In addition, Chu et al. indicated that inadequate somato-sensorial evoked potentials and progressive spinal deformity could be the result of improper postural alignment during rapid adolescent development, with prolonged delay and problems in the control of the cerebellar tonsils, and other intracranial structural abnormalities.[16]

Common treatment approaches to scoliosis are surgical and conservative that are used in order to overcome the related signs and symptoms.[17] Studies regarding the treatment in AIS aiming to enhance to postural control are scarce. Two different studies which imply that surgical correction does not have an effect on the sway velocity of the centre of pressure, thus sensorimotor defects in AIS might explain alterations in balance control more than biomechanical factors.[18,19] Gür et al. and Paolucci et al. assessed in-brace postural dynamics, using sensory organization tests concluding that brace wear improved postural stability in patients with AIS.[20,21] Another study have reported that brace treatment did not lead any improvement on balance parameters at the end of 4 months of usage.[22] Gür et al. also have demonstrated that brace and core stabilization exercise treatments led improvements in postural stability of patients with AIS.[23] In the literature, the influence of different scoliosis treatments on the development of balance control is still confusing and contradictory to each other. Thus, the aim of this current research was to determine the possible effects of three dimensional Schroth exercises combined with orthotic treatment on balance control in patients with AIS.

METHODS

Individuals diagnosed as AIS who were referred to the School of Physical Therapy and Rehabilitation, Department of Orthotics and Prosthetics, Dokuz Eylül University, between August 2014 and May 2017 were included in the study. Ethical approval was obtained from the Non-invasive Research Ethics Board of Dokuz Eylül University with the decision number 1217-GOA 2013/16-9. The informed consents were signed by both the volunteers and one of their legal representatives.

The inclusion criteria were as follows; having a diagnosis of AIS, being between 10-16

years old of age, having a Cobb angle of 20° to 50° and a Risser sign determined to be 0-3, having no other treatment which might affect scoliosis, having no chronic diseases requiring any drug usage. The exclusion criteria were determined as; previous spinal operation, accompanying mental problems, presence of other neurologic, muscular or rheumatic diseases, and having non-idiopathic scoliosis.

Study design

The study included 10 patients with AIS, and 10 age-matched healthy individuals (control group). Conservative treatment protocol consisted of brace treatment and Schroth exercises. The individuals in the study group wore full time rigid braces (Modified-Cheneau asymmetric braces) 23 hours per day and performed individually designed Schroth exercises. The exercise treatment consisted of 18 sessions, 3 days per week with session duration of 90 minutes each. Also the study group performed aforementioned exercises daily as home exercise program.

Intervention

Study group performed Schroth exercises under the supervision of a certified Schroth therapist. Schroth exercises are patient-specific asymmetric exercises with rotational breathing techniques applied for three-dimensional correction.[24] These exercises aim to provide and facilitate improved postural control by using asymmetrical standing postural exercises which are specifically designed to restore body balance and mobility. Aid pads (with the help of a towel) were used during ground exercises to create pressure for the correction of costal protrusions and/or trunk asymmetry. To help patients to maintain their posture, visual feedback was provided with the help of a wheeled portable mirror during sessions. Postural correction was also facilitated by rotational breathing exercises. While sustaining the contraction of the convex side, the subjects were asked to breathe in focusing on the concave side of the thorax, extending the costal space of the concave side and mobilizing the soft tissues. The main goal of the exercises was to provide postural correction with the help of dynamic passive forces (manual support of the physiotherapist), static passive forces (aid pads) and selective conscious use of trunk muscles. Postural correction principles of the Schroth method (axial elongation, deflection, de-rotation, facilitation, stabilization) were used during the treatment sessions.[24] All of the exercises were recorded as video that is provided to the volunteers to help them remember their exercises, which were also used as home program.

In this study, custom-made, modified-Cheneau (rigid, patient-specific and asymmetric) braces were designed for each AIS patient in order to ensure three-dimensional corrections. The brace treatment protocol comprised of 23 hours brace wears daily and 1 hour of removal for personal care.

Assessments

Before the intervention, each patient underwent A-P x-ray in relaxed standing position. The Cobb method was used to measure the degree of scoliosis.[25] The Risser sign was assessed on the x-ray as the closure of the growth plates of iliac wings. Completion grade between 0-5 was recorded which is expressed as percent: Grade 1 ≤ 25%, Grade 2 26-50%, Grade 3 51-75%, Grade 4 75-100%. When combined with epiphyseal ilium as a single structure, it is defined as Grade 5.[26] The clinical angle of trunk rotation (ATR) was measured using a Scoliometer® and the maximum angle of trunk rotation degree was recorded during forward bending position.[27]

Balance assessments:

Postural control parameters were evaluated under four conditions, as explained below, using a computerized force platform (Balance Master System, NeuroCom International Inc., Clackamas, OR, USA. 8.1).

Modified Clinical Test of Sensory Interaction on Balance (mCTSIB):

mCTSIB evaluate the sensory system (somato-sensorial, visual and vestibular), which plays an important role in maintaining balance and postural control. Average centre of gravity (CoG) rate (measured as degrees/second) were recorded for three times (at baseline, at the 6th and 18th week for the study group but only once for the control group at baseline). Software package provided three measurements of CoG: 1) the mean sway velocity (degrees/second) for each test condition as well as an average of the mean sway velocity across all four tests, 2) the limits of stability (LOS) across all four test conditions, and 3) the CoG alignment.

mCTSIB test consists of four conditions

related to standing as; eyes open condition on a firm surface (firm EO), eyes closed on a firm surface (firm EC), eyes open on a foam surface (foam EO), eyes closed on a foam surface (foam EC). Each test was repeated 3 times with duration of 10 seconds each. All of the results were compared to values of control group.

Balance assessments for the study group were made at baseline, at 6th week, which corresponds to the end of the exercises treatment and at 18th week that 3 months after the end of the exercises treatment.

Statistical analysis

The Statistical Package for Social Sciences (SPSS) 20.0 software was used for statistical analysis. The level of significance (p) was determined as <0.05. The normality test was conducted by Shapiro-Wilks test. Since only demographic data were normally distributed, Independent t test was conducted to identify whether there were significant differences in the baseline demographics between the groups. Non-parametric tests were used in the analysis of balance and angle of trunk rotation data since data other than demographic data did not show normal distribution. The baseline mCTSIB and angle of trunk rotation parameters at baseline, 6th and 18th weeks were also compared. The difference between three assessment intervals was tested using Friedman test and the observed difference was retested by using Wilcoxon sign rank test in order to determine the difference between the assessment intervals. Differences between study and control groups were compared using Mann Whitney-U test.

RESULTS

The comparison of the demographic and clinical characteristics of the groups with the repeated measurement results are shown in Table 1. When the main characteristics were evaluated, there was no significant difference between the two groups in terms of demographic features. The initial clinical features, such as the Cobb angle within brace and without brace, the angle of the trunk rotation also were given Table 1. All patients wore a brace.

Angle of trunk rotation changes were statistically significant different 1st - 6th week (baseline to 6th week) and 1st - 18th week assessments in AIS group (p<0.05).

There were no statistically significant differences between AIS group and control group in CoG sway velocity in Firm EO, Firm EC and Foam EO conditions at the end of different assessment sessions (p>0.05) (Table 2).

Statistically significant differences were observed between CoG sway velocity in Foam EC condition and composite CoG sway velocity parameters among the two groups at initial assessment (p<0.05). After the treatment aforementioned values (Foam EC CoG and Composite CoG sway velocity) decreased compared to control group in 6th week and 18th week assessments, but there were no statistically significant differences (p>0.05) (Table 2).

When the intra-group assessment parameters were taken into account, the statistically significant differences were found only in CoG sway velocity under foam EC condition and in composite parameter (p<0.05). When the paired comparisons were conducted separately for AIS group between the 1st - 6th weeks (from baseline to 6th week), 6th -18th weeks and 1st - 18th weeks, there were no statistically significant differences for Firm EO and Firm EC conditions (p>0.05). AIS group showed statistically significant improvement under Foam EC condition between 6th - 18th week and 1st - 18th week assessments (p<0.05). We observed changes in composite sway velocity in AIS group only between 1st - 6th weeks. Also in percentage of LOS changes demonstrated a statistically significant difference only between 6th - 18th week assessments (p<0.05) (Table 3).

DISCUSSION

The aim of this study was to provide an insight, presenting the effects of three dimensional Schroth exercises accompanied with brace treatment on balance control in individuals with AIS. The hypothetical questions were comprised of whether individuals with AIS would perform better balance tests after conservative treatment, and if scoliosis specific exercises with brace treatment have any effects on balance control.

Table 1. Baseline characteristics and measurement results at the end of 6th, 18th weeks.

	Study Group (N=10) Mean±SD	Control Group (N=10) Mean±SD	p
Gender (Female/Male (n))	8/2	8/2	0.242
Age (years)	13.3±1.2	13.8±1.4	0.858
Height (cm)	163.0±8.0	165.0±6.7	0.730
Body weight (kg)	50.4±10.2	53.4±10.0	0.945
Body mass index (kg/cm^2)	18.9±3.1	19.46±2.6	0.552
Risser Sign (median (range))	2 (1-3)	-	-
Cobb Angle (°)	32.9±5.0	-	-
Cobb Angle in-brace (°)	18.5±9.2	-	-
In-brace Correction (%)	45.5±21.1	-	-
Angle of Trunk Rotation (°)			
Baseline	8.1±2.5	-	-
6th week	5.6±2.3	-	-
18th week	5.1±1.9	-	-

Table 2. Outcome measures of balance parameters between Study Group (N=10) and Control Group (N=10).

		Study Group Mean±SD	Control Group Mean±SD	p
Angle of trunk rotation (degree)	Baseline	8.1±2.5	-	-
	6th week	5.6±2.3	-	-
	18th week	5.1±1.9	-	-
Firm eyes open sway velocity (degree/sec)	Baseline	0.74±0.33	0.58±0.16	0.094
	6th week	0.52±0.14	0.58±0.16	0.853
	18th week	0.54±0.17	0.58±0.16	0.989
Firm eyes closed sway velocity (degree/sec)	Baseline	0.50±0.15	0.49±0.22	0.710
	6th week	0.54±0.19	0.49±0.22	0.441
	18th week	0.51±0.17	0.49±0.22	0.683
Foam eyes open sway velocity (degree/sec)	Baseline	0.91±0.43	0.62±0.31	0.111
	6th week	0.79±0.24	0.62±0.31	0.213
	18th week	0.75±0.26	0.62±0.31	0.368
Foam eyes closed sway velocity (degree/sec)	Baseline	1.40±0.39	0.89±0.44	0.010*
	6th week	1.26±0.54	0.89±0.44	0.091
	18th week	0.98±0.37	0.89±0.44	0.537
Composite sway velocity (degree/sec)	Baseline	0.88±0.25	0.68±0.23	0.041*
	6th week	0.81±0.24	0.68±0.23	0.126
	18th week	0.71±0.22	0.68±0.23	0.500
Limit of stability (%)	Baseline	28.0±9.6	24.0±6.8	0.534
	6th week	30.0±13.8	24.0±6.8	0.415
	18th week	32.9±10.1	24.0±6.8	0.102

*: $p < 0.05$.

Table 3. Outcome measures of Study Group (N=10) for different time parameters.

	p value		z	p
Angle of trunk rotation (degree)	0.001*	Baseline	-2.814[a]	0.004*
		6th week	-0.852[a]	0.393
		18th week	-2.808[a]	0.004*
Firm eyes open sway velocity (degree/sec)	0.500	Baseline	-1.682[a]	0.092
		6th week	-0.178[b]	0.858
		18th week	-1.329[a]	0.183
Firm eyes closed sway velocity (degree/sec)	0.886	Baseline	-0.773[b]	0.522
		6th week	-0.140[a]	0.888
		18th week	-0.140[a]	0.888
Foam eyes open sway velocity (degree/sec)	0.217	Baseline	-1.130[a]	0.258
		6th week	-0.776[a]	0.437
		18th week	-1.608[a]	0.107
Foam eyes closed sway velocity (degree/sec)	0.001*	Baseline	-1.482[a]	0.138
		6th week	-2.532[a]	0.011*
		18th week	-2.814[a]	0.004*
Composite sway velocity (degree/sec)	0.048*	Baseline	-1.929[a]	0.053
		6th week	-0.059[a]	0.952
		18th week	-0.511[b]	0.609
Limit of stability (%)	0.717	Baseline	-1.123[b]	0.261
		6th week	-0.511[b]	0.004*
		18th week	-1.123[b]	0.393

*: p<0.05. a: Based on positive ranks. b: Based on negative ranks.

Therefore, related balance and postural control parameters were assesses using mCTSIB tests which provide information about the sensory system in order to identify 1) differences between patients with AIS and healthy individuals, and 2) differences in patients with AIS between their various assessment results.

To determine the corrective effect of the brace, a rating system was developed based on the percent change in Cobb angle resulting from the in-brace x-ray following brace construction. The improvement in the brace is less than 20%, which means that the progression of the curve may not be stopped, and a recovery of more than 40% indicates that success may be achieved after brace use is stopped.[31] In our study, radiograph taken after brace application showed corrective effect of brace almost. In our study, improvement of over 50% (excellent) was achieved in 7 of 10 AIS patients while improvement of 20-29% (moderate) in 2 was achieved and only 1 patient improvement was achieved fewer than 20% (poor). When we look at the average of the in-brace correction percentages of patients with AIS in our study, it was 45.47±21.11, which indicates that the success of the corset is good. It states that the corrective effect of brace can be regarded as an effective method to decide brace quality, but it requires more and longer follow-up studies without deciding on the prognosis of the curve.[3]

Our study indicated that individuals with AIS have shown a higher mean of CoG sway velocity, which provides information about somato-sensorial, visual and vestibular systems, than control group, as CoG sway velocity changes across different test conditions (Firm EO, Firm EC, Foam EO and Foam EC). Several studies have shown an increase in sway area and lateral sway excursions in patients with AIS.[8,28,29] Postural stability

defined as the act of keeping the centre of gravity of the body within a given base of support during any posture or activity.[30,31] The postural sway refers to changes in the CoG.[32] Our findings have shown that patients with AIS had difficulties with keeping centre of gravity within the base of support in different conditions compared to healthy individuals. Although there were increased mean sway velocity values in AIS patients compared to the healthy individuals, we did not observe any statistically significant differences in Firm EO, Firm EC, Foam EO conditions. There were significant differences in composite sway velocity and CoG sway velocity in Foam EC condition. Our findings have supported that inadequate postural control mechanisms in patients with AIS may be related to dysfunctions in somato-sensorial and vestibular systems. It is clear that patients with AIS might need an extra effort to achieve postural control without any visual clue. Gue et al. indicated that individuals with abnormal somatosensory evoked potentials values have increased antero-posterior centre of pressure sway, although, they concluded that sensory inputs may compensate the problems in balance control very well in patients with AIS.[14] Our study indicated that vestibular system could be affected in AIS due to unknown reasons that are still obscure; however, it is obvious that visual feedback may compensate inadequate postural control better than somato-sensorial and vestibular systems do.

Conservative treatment approaches in patients with AIS include physiotherapy and bracing. There are different types of scoliosis specific exercise techniques including the Schroth method. Hawes emphasizes that specific exercises for scoliosis generally reduce pain, stabilize the curve, reduce physiological distress, improve cardiopulmonary function and chest expansion.[17] However, studies, which focuses on the effects of Schroth exercises, are quite limited.[33] Also there are not enough studies regarding the aforementioned treatment approaches, which may have an effect on postural control, in patients with AIS. Due to these reasons; we have investigated the effects of Schroth exercises combined with brace treatment on balance control in patients with AIS. According to our results conservative treatment seem to improve postural control. In addition, it is also determined that following combined brace and exercise treatment individuals with AIS needed fewer visual clues in order to maintain balance and postural control. It could be that limiting visual clues may have led to the development of a new compensatory mechanism comprised of sensory and vestibular data processing in the central nervous system that regulates postural control.

Two studies implied that surgical correction did not affect CoG sway velocities in AIS. Thus it may be that other factors than biomechanical may have a superior dominance over postural control alterations.[18,19] Gür et al. and Paolucci et al. mentioned that postural stability may improve in-brace but, Khanal et al. reported that there are no improvements on balance parameters following 4 months of brace treatment.[20-22] In this current study biomechanical correction has been maintained with brace then the correction effect has been tried to be stabilized by repetitive muscle activities using Schroth exercises. Brace treatment combined with exercise treatment may be recommended to patients with AIS in order to improve balance control.

Firm EO is a "basic" situation in which three sensory systems, somato-sensory, visual and vestibular, are evaluated. According to our results on the Firm EO condition values were similar in patients with AIS and healthy individuals at baseline and in AIS patients at the end of different assessment sessions. These results indicate that somato-sensory, visual, and vestibular information is available and that when used in conjunction, the CoG sway velocity is not affected in patients with AIS and there is no improvement with treatment. In the Firm EC condition does not have visual information, somato-sensory and vestibular information is used. To be stable, the individual will have to rely heavily on somato-sensory inputs and secondary vestibular inputs. In our study, the CoG sway velocity was similar between patients with AIS and at the condition of Firm EC, and no significant improvement was obtained as a result of the treatments. The results suggest that the treatment of patients with AIS does not increase the contribution of somato-sensory and vestibular system to postural control. In the Foam EO condition, somato-sensory

information is available, but not correct, as it gives the soft-ground musculoskeletal system an additional challenge. Visual and vestibular information is used. In order to remain in balance, the individual will have to rely heavily on visual input and secondary vestibular inputs. In our study, CoG sway velocity was similar between patients with AIS and healthy individuals in the condition of Foam EO, and no significant improvement was obtained as a result of the treatments. The results suggest that the treatment of patients with AIS does not increase the contribution of visual and vestibular system to postural control. Foam EC is a condition in which somato-sensory information is misrepresented as it adds an additional difficulty to the musculoskeletal system due to the inability to use visual information and softness. Only the vestibuler system is trying to balance in the direction of the information. Schroth exercises with brace treatment significantly improved the results of CoG sway velocity in Foam EC condition both between 6^{th} - 18^{th} weeks and between 1^{st} - 18^{th} weeks. It suggests that the inadequate vestibular system in patients with AİS may develop with Schroth exercises with brace treatment.

We have also observed improvement in composite sway velocity values in AIS group however this time only between 1^{st} - 6^{th} weeks. This improvement was detected following the treatment; however it became insignificant as values declined and became similar to the values of the control group. Schroth exercises combined with brace treatment may ensure improvement in static balance control tests. This implied that effects of treatment or adaptation mechanism on static balance tests may be seen at the end of treatment; however we were able to see the effect of adaptation only in Foam EC condition and at the end of 18 weeks of treatment. It may not imply any cut-off point about balance control changes but, it may be valuable information for future clinical studies.

Although percent LOS values were initially higher in AIS group, these values were not observed as statistically significant. In AIS group, t was observed that CoG was able to sway in a larger area within the LOS while composite sway velocity (cumulative sway velocity value of every condition) decreased. This means that within a larger area, CoG is able to move with higher control. Unfortunately, the direction of this pattern in the LOS has not been identified realistically due to non-standardized confounding factors (side of curvature, pelvis asymmetry / tilt and initial cumulative weight transfer directions).

Limitations

However limitations of our study should also be taken into consideration. Sample size in our study was rather small and follow-up measurements may not reflect long-term results. The number of patients is limited to 10 due to the fact that our study is the first to publish the results of a doctoral study. Thus, further randomized controlled studies are needed to cover a larger sample size with longer follow-up durations. The last but not the least, more research is needed focusing on standardizing the confounding factors such as; side of curvature, pelvis asymmetry/tilt and cumulative weight transfer directions.

Conclusion

The results of our study showed that the Schroth exercises combined with brace treatment may provide significant improvements in certain components of postural control. In future studies, the effectiveness of different scoliosis specific exercises should be focused on in patients with different spinal curve patterns and degrees of scoliosis.

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REFERENCES

1. Grivas TB, de Mauroy JC, Negrini S, et al. Terminology-glossary including acronyms and quotations in use for the conservative spinal deformities treatment: 8 th SOSORT consensus paper. Scoliosis. 2010;5:23.
2. Altaf F, Gibson A, Dannawi Z, et al. Adolescent idiopathic scoliosis. BMJ. 2013;346:f2508.
3. Negrini S, Aulisa AG, Aulisa L, et al. 2011 SOSORT guidelines: orthopaedic and

rehabilitation treatment of idiopathic scoliosis during growth. Scoliosis. 2012;7:3.
4. James J. Idiopathic scoliosis; the prognosis, diagnosis, and operative indications related to curve patterns and the age at onset. J Bone Joint Surg Br. 1954;36-B:36-49.
5. Massion J. Postural control systems in developmental perspective. Neurosci Biobehav Rev. 1998;22:465-472.
6. Haumont T, Gauchard GC, Lascombes P, et al. Postural instability in early-stage idiopathic scoliosis in adolescent girls. Spine. 2011;36:E847-E854.
7. Lion A, Haumont T, Gauchard GC, et al. Visuo-oculomotor deficiency at early-stage idiopathic scoliosis in adolescent girls. Spine. 2013;38:238-244.
8. Simoneau M, Lamothe V, Hutin E, et al. Evidence for cognitive vestibular integration impairment in idiopathic scoliosis patients. BMC Neurosci. 2009;10:102.
9. Rousie DL, Deroubaix JP, Joly O, et al. Abnormal connection between lateral and posterior semicircular canal revealed by a new modeling process. Ann N Y Acad Sci. 2009;1164:455-457.
10. Catanzariti JF, Agnani O, Guyot MA, et al. Does adolescent idiopathic scoliosis relate to vestibular disorders? A systematic review. Ann Phys Rehabil Med. 2014;57:465-479.
11. Wang D, Shi L, Chu WC, et al. Abnormal cerebral cortical thinning pattern in adolescent girls with idiopathic scoliosis. Neuroimage. 2012;59:935-42.
12. Domenech J, Tormos JM, Barrios C, et al. Motor cortical hyperexcitability in idiopathic scoliosis: could focal dystonia be a subclinical etiological factor? Eur Spine J. 2010;19:223-230.
13. Liu T, Chu WC, Young G, et al. MR analysis of regional brain volume in adolescent idiopathic scoliosis: neurological manifestation of a systemic disease. J Magn Reson Imaging. 2008;27:732-736.
14. Guo X, Chau WW, Hui-Chan CW, et al. Balance control in adolescents with idiopathic scoliosis and disturbed somatosensory function. Spine. 2006;31:E437-E440.
15. Kuo F-C, Wang N-H, Hong C-Z. Impact of visual and somatosensory deprivation on dynamic balance in adolescent idiopathic scoliosis. Spine. 2010;35:2084-2090.
16. Chu WC, Man GC, Lam WW, et al. A detailed morphologic and functional magnetic resonance imaging study of the craniocervical junction in adolescent idiopathic scoliosis. Spine. 2007;32:1667-1674.
17. Hawes MC. The use of exercises in the treatment of scoliosis: an evidence-based critical review of the literature. Pediatr Rehabil. 2003;6:171-182.
18. de Abreu DCC, Gomes MM, de Santiago HAR, et al. What is the influence of surgical treatment of adolescent idiopathic scoliosis on postural control? Gait Posture. 2012;36:586-590.
19. de Santiago HA, Reis JG, Gomes MM, et al. The influence of vision and support base on balance during quiet standing in patients with adolescent idiopathic scoliosis before and after posterior spinal fusion. Spine J. 2013;13:1470-1476.
20. Gür G, Dilek B, Ayhan C, et al. Effect of a spinal brace on postural control in different sensory conditions in adolescent idiopathic scoliosis: a preliminary analysis. Gait Posture. 2015;41:93-99.
21. Paolucci T, Morone G, Di Cesare A, et al. Effect of Chêneau brace on postural balance in adolescent idiopathic scoliosis: a pilot study. Eur J Phys Rehabil Med. 2013;49:649-657.
22. Khanal M, Arazpour M, Bahramizadeh M, et al. The influence of thermoplastic thoraco lumbo sacral orthoses on standing balance in subjects with idiopathic scoliosis. Prosthet Orthot Int. 2016;40:460-466.
23. Gür G, Yakut Y. Does conservative treatment affect postural stablity in adolescent idiopathic scoliosis? SOSORT 2017 Book of Abstracts. 2017(031.27):64-65.
24. Weiss H-R. The method of Katharina Schroth-history, principles and current development. Scoliosis. 2011;6:17.
25. Morrissy R, Goldsmith G, Hall E, et al. Measurement of the Cobb angle on radiographs of patients who have. J Bone Joint Surg Am. 1990;72:320-327.
26. Reem J, Carney J, Stanley M, et al. Risser sign inter-rater and intra-rater agreement: is the Risser sign reliable? Skeletal Radiol. 2009;38:371-375.
27. Amendt LE, Ause-Ellias KL, Eybers JL, et al. Validity and reliability testing of the Scoliometer®. Phys Ther. 1990;70:108-117.
28. Simoneau M, Richer N, Mercier P, et al. Sensory deprivation and balance control in idiopathic scoliosis adolescent. Exp Brain Res. 2006;170:576-582.
29. Chen PQ, Wang JL, Tsuang YH, et al. The postural stability control and gait pattern of idiopathic scoliotic adolescents. Clin Biomech. 1998;13:S52-S58.
30. Pickerill ML, Harter RA. Validity and reliability of limits-of-stability testing: a comparison of 2 postural stability evaluation devices. J Athl Train. 2011;46:600-606.
31. Pollock AS, Durward BR, Rowe PJ, et al. What is balance? Clin Rehabil. 2000;14:402-406.
32. Palmieri RM, Ingersoll CD, Stone MB, et al. Center-of-pressure parameters used in the

assessment of postural control. J Sport Rehabil. 2002;11:51-66.
33. Romano M, Minozzi S, Zaina F, et al. Exercises for adolescent idiopathic scoliosis: a Cochrane systematic review. Spine. 2013;38:E883-E893.