An 18-month follow-up study on the effect of a neuromuscular stabilization technique on Cobb's angle in adolescent idiopathic scoliosis: A single-blind, age-matched controlled trial

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Abstract.
BACKGROUND: The benefits of spinal realignment and stabilization in scoliosis need to be examined.
OBJECTIVE: We aimed to investigate the long-term effect of a neuromuscular stabilization technique (NST) on Cobb's angle in patients with adolescent idiopathic scoliosis.
METHODS: Twenty females recruited from two hospitals participated in this study. On the basis of convenience of location, participants were allocated to either the experimental group (EG) that underwent the NST, or the control group (CG) that received education for a home exercise program. The NST for the EG was performed for an average of 30 min per session, three times a week for six months, and consisted of spinal realignment and stabilization. Then, 12- and 18-month measurements for long-term follow-ups were conducted for the EG. The outcome measure was Cobb's angle.
RESULTS: Between-group comparison revealed a statistically significant difference at post-test ($t = -3.26$, $p < 0.01$) but not pre-test ($t = -1.36$, $p = 0.19$). Participants of the EG ($-6.20 \pm 2.49°$) showed greater differences between pre- and post-test scores compared to participants of the CG ($-1.40 \pm 0.52°$) ($p < 0.05$). Within-group comparisons showed a significant difference in both groups ($p < 0.05$). In the EG, Cobb's angle significantly changed across the follow-up sessions ($p < 0.05$), indicating more improvements by the 12-month ($8.50 \pm 4.03°$) and 18-month ($6.60 \pm 3.89°$) follow-ups.
CONCLUSION: This study shows that the NST may be a beneficial option to correct spinal alignments in patients with adolescent idiopathic scoliosis.

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1. Introduction

Idiopathic scoliosis is a typical spine disease in adolescents characterized by a three-dimensional spinal deformity [1], which results in respiratory complications, decreased functional capacity, and poor cosmetic appearance [2]. In addition, given that scoliosis is frequently developed due to poor posture, it has also been

associated with musculoskeletal trauma such as low back pain, herniation of the intervertebral disc, and sciatic nerve disease [3].

Treatments for adolescent idiopathic scoliosis aim to restore spinal mobility by correcting the alignment of the spinal segments, and optimizing the mechanical interaction in the spine and trunk to promote healing. However, the correction of misaligned spinal segments may not be the best solution to fully treat the symptoms caused by scoliosis. Further steps are needed to facilitate neuromuscular control to prevent the displacement of spinal segments to the pre-treatment positions after its correction. Therefore, exercise therapy should be performed to strengthen the deep trunk-stabilizing muscles, which helps to maintain the position of each segment after the spinal correction [3].

Because segmental instability leads to back pain and disability, it is also important to establish spinal stability [4]. Strengthening of the deep trunk-stabilizing muscles helps reduce spinal deformation and asymmetric loading on the vertebrae, thereby stabilizing the positions of spinal segments. Furthermore, it may help to enhance curve magnitude and postural symmetry, subsequently improving spinal mobility and preventing spinal disorders and their recurrence [5]. In general, physical therapy, manual therapy, exercise therapy, and postural training have been applied as therapeutic interventions to prevent these problems [3].

Traditionally, bracing and exercise therapy have been used to facilitate postural correction, prevent additional curve progression, treat spinal pain, and reduce cosmetic problems in adolescent idiopathic scoliosis [6]. However, bracing often results in undesirable impacts such as psychological stress, discomfort in daily activities, negative self-esteem [7], and impaired respiratory function [8]. Furthermore, the effectiveness of exercise therapy is still controversial, although it has been well received as a conservative management for adolescent idiopathic scoliosis [9]. While surgery can be performed to correct spinal deformities, it does not necessarily result in positive outcomes [10], and is less effective for mild scoliosis. Patients often complain of fear due to invasive surgical procedures, post-surgical pain, risk of complications, and a longer recovery time.

The restoration of a neutral position in segmental joints is necessary to facilitate neuromuscular control of the trunk, which is more likely caused by exact treatment [11]. Therefore, the treatment of adolescent idiopathic scoliosis requires a scoliosis-specific treatment course that focuses on the correction of segmental positions in the spine and the improvement of neuromuscular stabilization [12]. However, to the best of our knowledge, there has been no research interest in the integration of joint alignment correction and spinal stabilizing techniques as an optimal treatment for scoliosis, and therefore there is a lack of appropriate protocols to treat spinal deformities in patients with scoliosis. Accordingly, this study aimed to illustrate the detailed procedure of the neuromuscular stabilization technique (NST) for adolescents with idiopathic scoliosis, and to report results using Cobb's angle.

2. Methods

2.1. Participants

Twenty females with left lumbar scoliosis volunteered to participate in this study. Ten participants were allocated to the experimental group (EG) and ten were allocated to the control group (CG) (Table 1). The inclusion criteria were: (1) lateral curvature of the lumbar region (Cobb's angle > 10°) [13], (2) no other orthopedic disorders, (3) no neurological and cardiopulmonary disorders, and (4) not pregnant. Prior to the study, the experimental process and safety measures were described to the participants, and all participants provided written informed consent to participate in the study and publish its results. All procedures were based on the guidelines of good clinical practice, including participant privacy and secrecy requirements, and the principles of the Declaration of Helsinki.

2.2. Study design

This study was a single-blind, age-matched controlled trial, in which the assessors who performed the data collection were unaware of the group allocations. We compared the results of two hospitals that offered different treatment methods. Two hospitals that agreed to participate in our research program were chosen from different regions. One hospital was selected for the EG, in which 10 patients underwent our intervention. In addition, 10 age-matched participants were recruited from another hospital for the CG. Participants of the CG were paired within three years for the average age of the group. Participants of the EG underwent the NST for six months for correcting spinal alignments. Participants of the CG received education for a corrective exercise program in the first visit. All participants in both groups completed the pre- and post-tests, and additional follow-up measurements (12- and 18-month) were performed only for participants of the EG (Fig. 1).
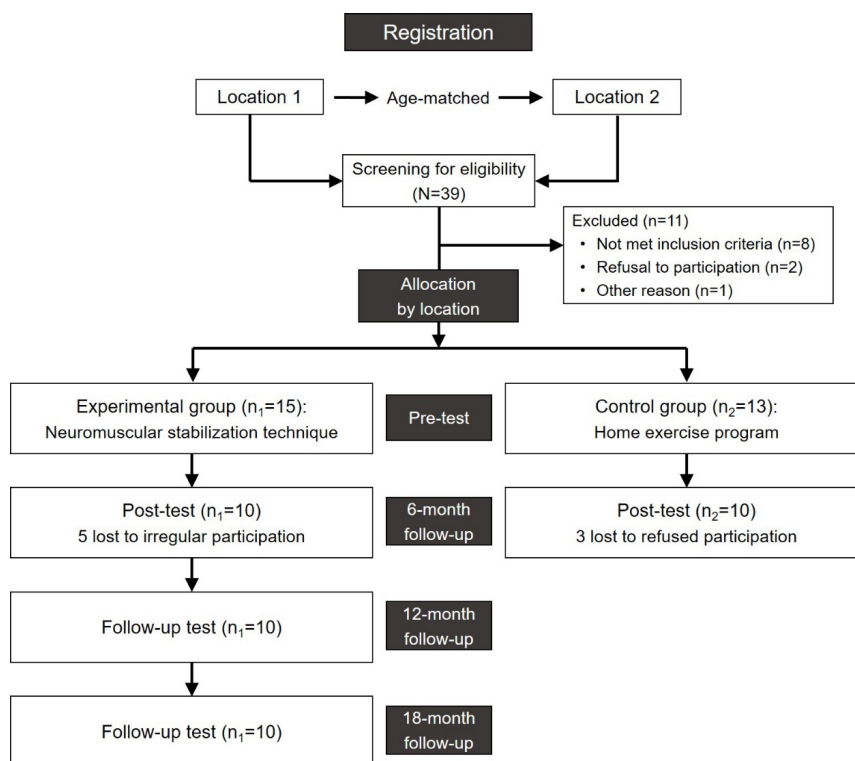
Fig. 1. Study diagram.

2.3. Outcome measures

The intervention effect was measured using Cobb's angle, which is a common measurement for identifying the extent of scoliosis. Cobb's angle was defined as the angle between lines parallel to the superior margin of the upper vertebral body and the inferior margin of the lower vertebra of the lateral curvature of the spine [14]. Intra- and inter-rater reliabilities were reported with intra-class correlation coefficients of 0.970 and 0.969, respectively [15].

2.4. Procedures

X-ray examinations were performed to screen participants, which included anteroposterior views of the whole spine in the standing position with upright and bending of the trunk to both sides. In cases of a double major type of scoliosis, spinal alignment was tested by using views with side bending of the trunk in order to identify the major lumbar curvature. Based on the examination of the side-bending views, the lumbar type of scoliosis was determined when spinal alignment was not corrected in the lumbar region [16].

The NST for participants of the EG consisted of four steps: (1) manual contact, (2) correction of spinal alignment, (3) segmental stabilization, and (4) sensory-motor training (Fig. 2). The technique was performed with participants seated on a chair without arm and back rests. After manual contact on the transverse process (TP) of the convex side, the therapist often used joint mobilization of grade II or III in the second step to correct the spinal alignment as needed to facilitate segmental mobility. In the steps for active segmental stabilization, the therapist also offered minimal guidance using tactile stimulation to encourage the participants for segmental stabilization. The technique was then maintained during the sensory-motor training, which uses trunk perturbation to create more challenging conditions. The NST was performed for a period of 30 minutes on average, including rest intervals between the techniques, three times a week for six months. Follow-up measurement sessions for participants of the EG were carried out at 12 and 18 months. Moreover, participants of the EG underwent the NST once a week for a period of follow-ups. The first author with a 20-year long career as a physiotherapist was in charge of the whole NST process. Detailed information of the NST can be found in Table 1.

Table 1
Details of the neuromuscular stabilization technique

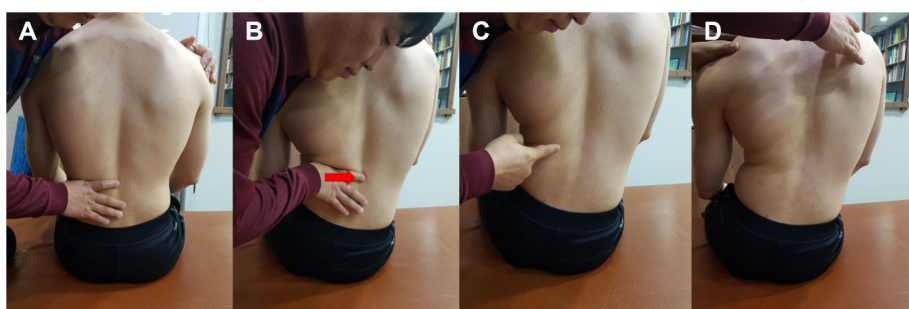| Steps	Details
Manual contact	Manual contact is made by touch using the palmar side of the proximal phalangeal base of the index finger against the prominent transverse process of the apex vertebra on the convex side.
Correction of spinal alignment	While the participant straightens their trunk, the therapist applied a force towards the midline of the trunk by pushing the transverse process using a hand in contact for further correction, and the participant's shoulders were anchored using the other arm and hand.
	Repetitions: twenty repetitions with a 10 second hold.
Segmental stabilization	The participants contract their spinal muscles of each segment on the convex side to maintain the corrected spinal alignment.
	Repetitions: twenty repetitions with a 10 second hold.
Sensory-motor training	The participants hold this posture while slightly pushing the upper part of their trunk back and forth.
	Repetitions: application of a 10 second resistance towards each direction. Repetitions: five series of ten repetitions for each direction.

Fig. 2. The neuromuscular stabilization technique steps. (A) manual contact, (B) correction of spinal alignment, (C) segmental stabilization, and (4) sensory-motor training.

The corrective exercise program for CG participants comprised of pelvic tilt, alternate arm-leg raising on the floor, back extension, trunk side-bending on the convex side, cow pose exercise (neck and trunk extension with anterior pelvic tilting), and abdominal press [17], which were taught to patients during their first visit to the hospital. A flyer and check sheets with detailed information of the exercise program for regular performance at home were offered to improve compliance at home. A physical therapist confirmed the check sheets during patients' regular visits to the hospital (once a month).

2.5. Data analysis

Cobb's angles collected from the participants of the EG and CG were analyzed by using the Statistical Package for the Social Sciences version 24.0 (SPSS Inc., Chicago, IL, USA). Data collected from the groups appeared to be normally distributed in the Shapiro-Wilk test (EG: $w = 0.920$ and $p = 0.357$; and CG: $w = 0.928$ and $p = 0.429$). The data were represented as mean $\pm$ SD. Differences in general features (age, weight, and height) of the participants were analyzed using the independent t-test. Between- and within-group com-

parisons were performed using the independent t-test and paired t-test, respectively. Furthermore, a one-way repeated ANOVA was used to analyze the changes in Cobb's angles across the follow-up sessions in the EG. For multiple pairwise comparisons, a post-hoc test with Bonferroni correction was used when $p < 0.05$.

3. Results

3.1. General characteristics of the participants

The age, height, and weight of the participants were not significantly different between the EG and CG ($p > 0.05$) (Table 2).

3.2. Comparison of pre- and post-test on Cobb's angles between the groups

The results of the comparison of the pre- and post-test data between the EG and CG are shown in Table 2, and changes in Cobb's angles across the follow-up sessions in the EG are shown in Fig. 2. Between-group comparison revealed a statistically significant difference at post-

Table 2
General characteristics of the participants

	EG ($nz_1 = 10$)	CG ($n_2 = 10$)	$t(p)$
Age (years)	14.50 ± 2.50[a]	15.90 ± 2.69	$-1.205\ (0.244)$
Height (cm)	153.50 ± 11.77	156.60 ± 13.13	$-0.574\ (0.573)$
Weight (kg)	49.20 ± 6.89	48.30 ± 11.26	$-0.216\ (0.832)$
Risser grade[b] (1/2/3/4)	5/3/1/1	4/4/2/0	

[a]Mean $\pm$ SD, [b]American version. EG: Experimental group, CG: Control group.

Table 3
Comparison of the pre- and post-test on Cobb's angles between the groups

	Experimental group ($n_1 = 10$)			Control group ($n_2 = 10$)			t^c
	Pre-test	Post-test	t^b	Pre-test	Post-test	t^b	
Values	16.56 ± 2.50[a]	11.00 ± 4.47	7.89^*	18.90 ± 5.24	17.50 ± 5.48	8.57^*	-5.98^*
Ranges	12–20	3–16		12–27	10–25		

[a]Mean $\pm$ SD. [b]Within-group comparison between pre- and post-test values in each parameter. [c]Between-group comparison of the change between pre- and post-test values in each parameter. $^*p < 0.05$.

test ($t = -3.26$, $p < 0.01$) but not pre-test ($t = -1.36$, $p = 0.19$). Participants of the EG ($-6.20 \pm 2.49°$) showed greater differences between pre- and post-test scores compared to participants of the CG ($-1.40 \pm 0.52°$) ($p < 0.05$). Within-group comparisons showed a significant difference in both groups ($p < 0.05$). In the EG, Cobb's angles significantly changed across the follow-up sessions (12-month follow-up, $8.50 \pm 4.03°$; and 18-month follow-up, $6.60 \pm 3.89°$) ($F = 42.846$, $p < 0.01$). The post-hoc test revealed significant differences between the pre- and post-test, pre-test and 12-month follow-up, pre-test and 18-month follow-up, and post-test and 18-month follow-up.

4. Discussion

This study showed that the NST may be favorably used to restore spinal alignment in adolescents with idiopathic scoliosis.

In these patients, the therapeutic goal is to have the patients counteract the asymmetric loading on the spine and trunk [18]; therefore, it is important to develop appropriate methods for correcting poor spinal alignment during daily life, and optimize the load transfer on the spine This can be largely achieved via a manual technique and exercise therapy, which enhance the mobility and stability of axial structures and thereby normalize the function of spinal musculatures. Based on this concept, the NST used in this study focused on restoring the neutral position of spinal joints, and then facilitated active efforts for segmental stabilization to maintain their position.

In general, Cobb's angle measured from the anterior-posterior X-ray image of the whole spine was useful to evaluate the extent of the lateral curvature in patients with scoliosis, by monitoring the stage of spinal deformity and curve progression. Curve progression in patients with scoliosis is related to their age and the extent of Cobb's angle [19]. Because adolescents have a greater growth potential than adults, it is more likely to aggravate spinal deformity during growth. Therefore, it is important to establish benefits from treatments as rapidly as possible in order to prevent unwanted effects of scoliosis. A Cobb's angle with a $\geqslant 5°$ difference has been commonly accepted as an indicator of true change [20]. In this study, the participants of the EG achieved a $\geqslant 5°$ change in the 12-month (17° to 9°) and 18-month (17° to 7°) follow-ups, which indicates an improvement in spinal alignment after our intervention. These findings suggest that our intervention was probably appropriate to prevent curve progression over time by restoring spinal alignment.

Our primary finding was the greater effects in the EG than in the CG, although significant improvement of Cobb's angle was found in both groups after intervention. In general, supervision is considered to be necessary for improved efficacy of exercise therapy, helping patients to precisely perform the exercise and facilitate its compliance [21]. Therefore, as used in the CG, an unsupervised home exercise program may have disadvantages because of the lack of supervision.

Adolescents with idiopathic scoliosis frequently complain of a significant limitation on functional performance and ventilatory capacity, which is proportional to its severity [22,23]. Furthermore, a recent study has reported that postural control strategies during activities may be correlated to the severity of scoliosis [24]. As shown in this study, the NST was beneficial for correcting spinal alignment in adolescent idiopathic
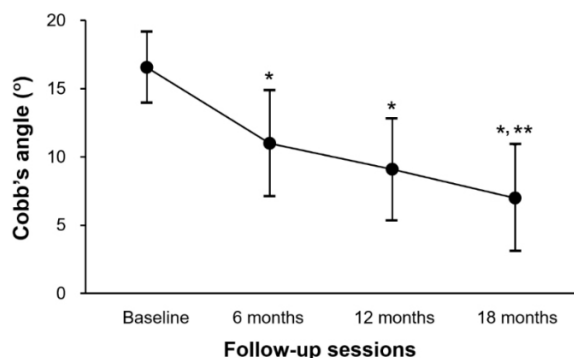
Fig. 3. Changes in Cobb's angles across the follow-up sessions in the experimental group. Bars indicate standard deviation. * indicates significant differences in comparison to the pre-test, and ** indicates significant differences in comparison to the post-test (six month follow-up).

scoliosis, with more gains after long-term use. Therefore, it may also be presumed that the enhancement of pulmonary capacity and exercise performance was obtained from our intervention, even though we did not measure these parameters.

Recent studies have shown that the integration of scoliosis-specific exercise therapy, such as the Schroth method, into standard care is superior to standard care alone to decrease curve severity in adolescent idiopathic scoliosis [6,25–27]. These studies also demonstrated auto-correction in three dimensions including postural correction and stabilization, normalization of breathing patterns, and patient education [6,28]. In addition, side-shift and hitch exercises have been demonstrated to correct spinal posture after repeatedly moving the lateral shift of the trunk to the concave side of the curve and then lifting the heel on the convex side with a straight leg to maintain the side-shifted position [29]. Although these exercises focus on regional straightening in the spine, it is difficult to recognize the exact correction of the segmental level.

In the treatment of scoliosis, patients frequently need a direct technique that aims to control segmental alignment in the spine by restoring the neutral position of spinal joints and subsequently stabilizing it prior to its integration in daily life, which may help to facilitate the rapid correction of the spine [30]. This idea is supported by a recent study demonstrating the benefits of chiropractic and exercise therapy that focused on segmental correction in the spine and strengthening spinal muscles, although it was not specific for segmental stabilization [3]. Based on this concept, our findings showed great benefits to improving the symptoms of adolescents with idiopathic scoliosis, particularly after long-

term use. Furthermore, the NST, which includes segmental correction and stabilization, might be a client-friendly approach with a relatively shorter treatment time [12]; therefore, it is suggested that the NST may be appropriate for integration into standard care, similar to that demonstrated by a brace and scoliosis-specific exercises, such as the Schroth method, at a higher level of evidence [31].

We acknowledge several limitations of this study that can be enhanced by further studies. First, our sample size was relatively small; therefore, the generality of our results may be difficult to expand beyond our sample group. However, based on our results, a power analysis (power of the study, 1-$\beta = 85\%$; effect size, $d = 1.30$; and significance level, $\alpha < 0.05$) suggested that 20 participants, 10 in each group, were needed to demonstrate intervention effects between the groups. Second, the between-group comparison was completed in the post-test. However, this comparison needs further data collected from follow-up sessions to clarify the long-term effects of our intervention. Third, this study only analyzed Cobb's angle to demonstrate the intervention effect. Although Cobb's angle is a major parameter that is indicative of the extent of scoliosis, it is probably also important to identify treatment effects using various respiratory and functional parameters in future studies. Finally, we used a research design with a hospital-based group allocation, which might not be completely free from homogeneity bias related to participants' spinal deformities (severity and progression risk) between the groups.

5. Conclusion

In adolescent idiopathic scoliosis, professional techniques that aim to restore the alignment of spinal joints and facilitate the stabilization effort for its maintenance cover the whole symptomatic spectrum related to spinal deformity. This study reports the use of the NST as a novel treatment approach for adolescent idiopathic scoliosis, and the findings suggest that the NST can make significant changes in Cobb's angle, with more gains after longer-term follow-ups. Therefore, the NST may be used as a practicable alternative to routine treatment protocols for patients with adolescent idiopathic scoliosis. Further studies with a more robust design are needed to describe optimal treatment strategies using the NST in order to demonstrate its effects on various aspects of adolescent idiopathic scoliosis.

Conflict of interest

None to report.

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