

Effects of Lumbar Stabilization Exercise on Postural Sway of Patients with Adolescent Idiopathic Scoliosis during Quiet Sitting

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Abstract. [Purpose] The purpose of this study was to investigate the effects of lumbar stabilization exercise on sitting balance of adolescent idiopathic scoliosis (AIS) patients. [Subjects] Eighteen patients with AIS, mean Cobb angle of 31.4°, participated in this study. [Methods] The Lumbar Trunk Muscle Endurance Test (LTMET) and the Balance Performance Monitor (BPM; SMS Healthcare, Harlow, UK.) were used to measure trunk endurance and postural sway before and after the lumbar stabilization exercise, which was performed for 40 minutes per day, 3 times per week for three weeks. [Results] Sitting balance was improved as determined by the anterior-posterior sway angle, right-left sway angle and sway area under the eyes opened and closed conditions. No correlation was found between sitting balance parameters and trunk flexor endurance after the lumbar stabilization exercise. [Conclusion] The results demonstrate that lumbar stabilization exercise effectively improves sitting balance, suggesting that lumbar stabilization exercise can be clinically used for patients with AIS to improve their postural control when seated.

Key words: Adolescent idiopathic scoliosis, Lumbar stabilization exercise, Sitting balance

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INTRODUCTION

Scoliosis is defined as a lateral curvature of the spine greater than 10° as determined by Cobb's angle on standing radiographs¹⁾. Adolescent idiopathic scoliosis (AIS) is a progressive growth disease which occurs in children aged 10 to 16 years (or to skeletal maturity) and accounts for the majority of scoliosis cases²⁾. Patients with AIS have anatomical alterations of the spine and muscular imbalance between the concave and convex sides of the spine³⁾. Furthermore, morphologic changes in AIS alter the postural orientations of the head, scapular girdle, trunk and pelvic girdle and these, in turn, affect postural control⁴⁾. Previous studies have reported the AIS patients show greater postural sway than normal excursions of the center of pressure (COP) and center of mass (COM) during quiet standing^{5, 6)}, and movement analysis studies have found that the movements of AIS patients are slower than normal during walking and side-stepping⁷⁾. Because of their ages, AIS patients spend many hours sitting while studying, watching television, or playing video games,⁸⁾ but few studies have been conducted on their postural control while sitting. Bennet et al.⁹⁾ compared sitting COP movements of AIS subjects and age-matched normal controls and found that AIS patients had symmetric sitting COP trajectories and that the magnitude of COP movement was smaller than normal. This finding is at odds with those of studies of static balance, in which patients with idiopathic scoliosis showed larger changes in ground reaction forces

and moved forward and in the opposite direction to the curve in a seated position¹⁰⁾. Furthermore, AIS patients also have less weight shift laterally on both sides and their movement of the concave side more restricted than their movement of the convex side while sitting¹¹⁾. However, no study has previously addressed therapeutic interventions aiming to improve sitting balance of AIS patients.

Recently, stabilizing therapeutic exercise for the lumbopelvic region has become popular for improving athletic performance and for treating chronic lower back pain (CLBP)^{12, 13)}. This type of exercise has been termed core lumbopelvic stabilization, core stabilization, lumbar stabilization, trunk stabilization, neutral spine control, segmental stabilization, dynamic stabilization, or muscular fusion, but as yet, has no agreed name^{14, 15)}. Lumbar stabilizing exercise is defined as exercise that improves neuromuscular control, strength, and the endurance of muscles around the lumbar spine and pelvis to maintain functional stability¹⁵⁾. Because the lumbopelvic region acts as a pivot during many activities, particularly during sports activities, the merits of strengthening the core stability are emphasized¹⁶⁾. Several studies have reported that lumbar stabilization exercise has a beneficial effect on postural control. After transient lumbar stabilizing exercise, postural sway was found to be significantly decreased in normal subjects during standing with their eyes closed. CLBP patients had poor scores in the one-legged-standing test and showed more postural sway when asked to stand on a small base with eyes closed than

Table 1. General characteristic of subjects

	N	Sex (male/female)	Major Cobb's angle (°)	Age (years)	Height (cm)	Weight (kg)
AIS	18	3/15	31.4 (7.7)	14.0 (1.8)	160.0 (8.3)	46.9 (7.1)

NOTE. Values are frequency or mean (SD)

normal controls¹⁷⁻¹⁹). After 2 weeks exercise focused on trunk strengthening, however, they developed muscle contraction reaction times similar to those of healthy subjects in response to unexpected balance challenges²⁰. Postural control during standing is affected by not only trunk stability but also by other factors, such as ankle strategy or hip strategy²¹). Excluding these factors might affect postural control, therefore we examined trunk stability in the seated position in the present study. The aims of this study were, to investigate the effect of lumbar stabilization exercise on sitting balance of AIS patients and to investigate the relation between lumbar trunk muscle endurance and postural sway while seated.

SUBJECTS AND METHODS

Eighteen AIS subjects were included in this study (Table 1). The study subjects consisted of 3 males and 15 females with major Cobb angle between 17.6° and 53.5°. The same orthopedic surgeon evaluated all stand-up radiographs to determine the location, direction and the Cobb angle of each subject's spinal curvature. The AIS subjects had a mean age of 14.0±1.8 years, a mean height of 160.1±8.3 cm, and a mean weight of 46.9±7.1 kg. The exclusion criteria were as follows: signs and symptoms of headache, numbness or weakness of one or more limbs, unsteadiness, loss of thermal sensation, dysphasia, tinnitus, vomiting, and dysarthria⁶). Informed consent was obtained from all the AIS subjects and their parents before enrollment in this study, which this study was approved by Institutional Review Board of Sahmyook University.

To evaluate muscle endurance of the trunk, the Lumbar Trunk Muscle Endurance Test (LTMET) was performed before and after the lumbar stabilization exercise. LTMET measures trunk flexor and extensor muscle endurance and is a modification of the Kraus-Weber test for flexors and the Sorensen test for extensors^{22, 23}), two of the most popular methods for measuring trunk muscle endurance. Although the Kraus-Weber and the Sorensen tests are both used clinically, they have some disadvantages because they increase lumbar lordosis and cause low-back pain in some patients^{24, 25}). On the other hand, LTMET has high reliability, and reproducibility in both healthy subjects and CLBP patients. Also, it is safe and easily performed by patients and does not need special equipment. Its test-retest correlation (*r*) with flexor endurance is 0.95 for healthy subjects and 0.91 for CLBP subjects, and for the extensor endurance test, its correlation is 0.97 for healthy subjects and 0.93 for CLBP subjects²³). To measure trunk flexor endurance, subjects were asked to adopt the supine position and to flex the hip and knee joints by 90° with arms crossed on the chest, with maximal cervical flexion and with both scapulae held off the floor. To measure trunk extensor endurance, subjects were asked to adopt the prone

position with a small pillow placed under the lower abdomen and the sternum held off the floor with maximal cervical flexion. During both endurance tests, subjects were asked to maintain the original positions with maximum flexion of the cervical spine and a neutral pelvic position for as long as possible, but not exceeding 5 minutes. Subjects were tested once for flexor and extensor endurance and no practice session was allowed. Tests were randomized and subjects had a 5-minute break between tests.

The Balance Performance Monitor (BPM; SMS Healthcare, Harlow, UK.) was used to measure postural sway in the sitting position before and after the lumbar stabilization exercise. The BPM is a portable unit with three individual moveable footplates and a seat-plate. In this study, only the seat-plate was used for data collection. The BPM provides the following data on sitting balance: mean balance, sway angle, sway area, sway path, and maximum velocity. Mean balance is calculated as the mean weight shift over a 30-second test, and is displayed as a percentage of total body weight. Left and right are used to indicate the greatest weight shifts in percentages. Only left shift is used as a parameter of mean balance. Sway angle is measured from the normal vertical to the patient's center of gravity. It is displayed in degrees (°), and is shown as the maximum angle of anterior-posterior tilt from the starting point as well as right-left tilt. The anterior-posterior angle and right-left angle are used as parameters of sway angle. The sway area is the area of the ellipse that encompasses the maximum anterior, posterior, left and right values of the sway path of the subject's center of gravity over 30 seconds, is expressed in millimeters squared (mm²). The sway path is the distance subject's center of gravity moves during 30 seconds. The sway path length is expressed in millimeters (mm). The maximum velocity of the subject's center of gravity is expressed in mm/s, and is the maximum value detected during any 0.1-second period during 30 seconds of measurement. Previous studies have reported on the excellent reliability and concurrent validity of the BPM system for measuring postural sway measurements and weight distribution measures²⁶⁻²⁹). The seat-plate was linked to a computer running SMS Data print software (version 5.3a). When a subject was seated on the seat-plate, postural sway was represented by horizontal and vertical sets of colored lights on the display console. Green lights indicated that body weight was distributed equally, and red lights that body weight distribution was shifted in any direction unequally. Subjects sat on the seat-plate and tried to equalize their weight. For the 30 seconds static test, subjects were asked to look forward and sit as upright as possible for the duration of the test without access to the display console. Each subject performed 3 trials under two visual conditions, namely, with their eyes opened and eyes closed. After performing 3 trials under one visual condition, the subject performed 3 trials under the other visual condition. A break

Table 2. Comparison of sitting balance parameters between before and after the LSE

	Measure	Pre-test	Post-test
Eye Open	Mean balance (%)	48.3 (012.1)	48.4 (01.4)
	Anterior-posterior sway angle (°)*	1.7 (001.9)	0.7 (00.3)
	Right- left sway angle (°)	1.5 (001.6)	0.7 (00.3)
	Sway area (mm ²)*	104.9 (304.7)	16.1 (12.4)
	Sway path (mm)*	137.1 (097.3)	104.1 (32.5)
	Maximum velocity (mm/s)	20.0 (022.5)	22.2 (03.4)
Eye Closed	Mean balance (%)	47.1 (004.0)	48.9 (01.6)
	Anterior-posterior sway angle (°)*	1.3 (000.8)	0.7 (00.4)
	Right- left sway angle (°)*	1.9 (002.4)	0.7 (00.2)
	Sway area (mm ²)*	51.1 (078.4)	13.4 (08.7)
	Sway path (mm)*	134.9 (089.5)	94.6 (20.5)
	Maximum velocity (mm/s)	23.4 (009.9)	21.0 (10.0)

NOTE. Values are mean (SD). *p<0.05

of approximately 3 seconds was allowed between trials and a 1-minute break was allowed when the visual condition was changed. The first visual condition was randomized and the mean values of 3 trials under each visual condition were used for the data analysis.

The lumbar stabilization exercise (LSE) was performed for 40 minutes per day, 3 times a week, for three weeks. The LSE protocol was divided into three steps based on the level of difficulty and the size of the base support. During the first step, patients learnt how to cause local muscle contraction with normal breathing in the supine hook-lying or quadruped positions³⁰. At the beginning of the first step, muscle contraction was held for 2 or 3 seconds and the holding time was then increased to 10 seconds with 10% to 15% of maximum voluntary contraction (MVC) and 10 repetitions. The second step was performed using the same procedures in the bridging or tripod position¹⁵. For the bridging position, patients were asked to lie down in the supine hook-lying position and then lift the buttock up to the position of hip extension of 0 degrees. In the tripod position, one hand or leg is lifted off the floor. During the third step, patients were asked to lift one more leg or arm off the floor while performing the procedure of the second step³¹. At the end of the 6th week, 4 subjects had failed to perform the third step, and remained at the second step stage.

Statistical analysis was performed using SPSS, version 19.0 (SPSS Inc, Chicago, IL). Descriptive analysis was used to summarize demographic data. The Wilcoxon Matched-Pairs Signed-Rank test was used to compare differences between pre- and post-intervention sitting balance parameters and the endurance of trunk muscles. Spearman's rho test was used to investigate the relationship between sitting balance parameters and the trunk flexor endurance after exercise. Statistical significance was accepted for p values of < 0.05.

RESULTS

In the comparison of sitting balance before and after lumbar stabilization exercise under the eyes open condition,

Table 3. Comparison of pre- and post-LSE trunk flexor/extensor endurance

Measure	Pre-test	Post-test
Trunk flexor endurance*	79.4 (54.9)	115.7 (66.8)
Trunk extensor endurance	187.7 (90.5)	225.6 (80.5)

NOTE. Values are mean (SD). *p<0.05

significant decreases in anterior-posterior sway angle, sway area and sway path were found. However, no significant differences were observed between sitting balance parameters, such as, mean balance, right-left sway angle and maximum velocity. The results for the eyes closed condition showed significant reductions in anterior-posterior sway angle, right-left sway angle, sway area and sway path. However, no significant differences were found between before and after LSE in mean balance and maximum velocity (Table 2). The mean values of the lumbar trunk muscle endurance between before and after the LSE are shown in Table 3. After exercise, mean flexor endurance time increased significantly from 79.4 to 115.7 seconds, but mean extensor endurance time did not differ significantly. No significant correlation between sitting balance parameters and trunk flexor endurance after LSE was found in the eyes opened or the eyes closed conditions (Tables 4 and 5).

DISCUSSION

The main purpose of this study was to determine whether lumbar stabilization exercise improves sitting balance parameters. Our results demonstrate that several sitting balance parameters showed significance improvements after 3 weeks of exercise. The seated position was selected for this study instead of the standing position, because ankle and hip strategy influence postural control and balance. In the present study, no significant difference was found under the eyes opened or closed conditions in mean balance. Mean balance was calculated as the average weight shift over the 30 seconds test. Because patients were asked to sit on the

Table 4. Correlation between sitting balance parameters and trunk flexor endurance under the eyes opened condition

	Mean balance	Anterior-posterior sway angle	Right-left sway angle	Sway area	Sway path	Maximum velocity
TFE r^{\dagger}	0.29	-0.13	0.06	-0.08	0.02	0.12

TFE: Trunk flexor endurance. † Correlation coefficient**Table 5.** Correlation between sitting balance parameters and trunk flexor endurance under the eyes closed condition

	Mean balance	Anterior-posterior sway angle	Right-left sway angle	Sway area	Sway path	Maximum velocity
TFE r^{\dagger}	0.36	-0.21	-0.02	-0.02	0.03	-0.18

TFE: Trunk flexor endurance. † Correlation coefficient

force plate as straight as possible and make the weight distribution equal while watching the display console before the test, we could not assess habitual weight distribution while sitting. Previous studies have shown that the shifted weight on sitting is displaced toward the convex side in AIS¹¹⁾. Significant differences between pre- and post-LSE were observed in anterior-posterior sway angle, sway area, and sway path under the two eye conditions. One previous study demonstrated that trunk stabilization instruction reduces peak lumbar acceleration magnitude during upper and lower body movements³²⁾, which may explain the reduced anterior-posterior sway angle, sway area, and sway path observed in the present study. After LSE, the right-left sway angle was significantly lower under the eyes closed condition, but was not reduced under the eyes open condition. Balance control requires contributions from sensory inputs, central integration, and motor response⁶⁾, and sensory inputs can be divided into visual, vestibular, and somatosensory inputs. Simoneau et al.³³⁾ suggested that AIS patients rely much more on proprioception than on vision to control the amplitude of balance control commands. The third step of the LSE mainly consisted of a closed kinetic chain and symmetric motion of the extremities, which might have improved proprioceptive input around the lumbar and pelvic regions, especially the right-left sway angle, resulting in better sitting balance. We investigated the correlations between sitting balance parameters and trunk flexor endurance after exercise, because trunk flexor endurance significantly increased after LSE, however, we did not find any relation. In previous studies, CLBP patients had poor trunk postural control during sitting on a balance board and they had delayed muscle response times to sudden loading compared with healthy subjects³⁴⁾. Idiopathic scoliotic patients also have abnormal electromyographic responses in trunk muscles during postural perturbation. They show a first muscle activation which is delayed about 30 ms during standing on an unstable platform, and their muscle contractions are significantly higher on the convex side than on the concave side³⁵⁾. After LSE for CLBP, the abdominal muscles were recruited earlier and the reaction times of trunk extensor muscles improved to become similar to those of the control group during trunk perturbations³⁶⁾. In spite of this result, it is difficult to find a study of scoliosis which has investigated the correlation between LSE and balance because most studies have focused on improvement of spinal curvature. Our LSE based on the same maneuver used for CLBP consists of facilitating the proper timing of muscle

contractions in the lumbopelvic region and symmetric motion of the right and left extremities. Improvements of sitting balance parameters might have been due to improvement in the recruitment of trunk flexor muscles as well as a change in body symmetry. The limitations of this study were that the number of AIS patients enrolled study was small and only static sitting balance and trunk muscle endurance were evaluated. Accordingly, additional larger scale studies using other morphologic evaluations and electromyographic data are needed to expand and confirm the effects of lumbar stabilization exercise found in the present study.

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