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Characteristics of Static Balance in Patients With Adolescent Idiopathic Scoliosis

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Abstract

The purpose of this study was to compare the static balance of standing position between adolescent idiopathic scoliosis (AIS) and a normal group that were aged-matched. There were forty subjects included in this study. Twenty-seven healthy subjects (age, 13.9±1.2 yrs; height, 161.9±7.5 ㎝; weight, 52.2±7.7 ㎏) and thirteen AIS subjects (age, 14.2±2.2 yrs; height, 161.5±8.7 ㎝; weight, 48.1±8.1 ㎏) were participated in the study. The thirteen subjects in the AIS group had a major Cobb angle between 20.1° and 49°. Each group was tested with the Balance Performance Monitor (BPM). The parameters for static balance were sway area, sway path, max velocity, mean balance, anterior-posterior angle, and left-right angle of each group with their eyes opened and again with their eyes closed. Both sides of the forward reach test and the lateral reach test were also performed on each group. Results from the BPM tested showed significantly increases in all parameters of static balance with those patients with AIS under the conditions where eyes were opened and closed. In the right and left forward reach test, there was no significant difference between normal and AIS groups. However, in the lateral reach test with right and left direction, there were significant differences between normal and AIS groups. For the normal subjects, there were significant differences in the parameters with sway path and anterior-posterior sway angle between the eyes opened and closed. However, there were no significant differences in the all parameters between eyes opened and closed for the AIS subjects. These results suggest that, balance programs could be used in the rehabilitation setting for intervention of AIS and evaluation of AIS. Further study is needed to measure many patients with AIS and other functional balance scales for clinical application.

Key Words: Adolescent idopathic scoliosis; Balance control; Standing stability.

Introduction

The ability to balance requires that the body's center of gravity or mass lie over the base of support. Therefore, understanding the mechanisms involving balance impairment may lead to improvements in treatment and outcome in the rehabilitation population (Nashner, 1989). The continuous use of the information from somatosensory, proprioceptive, visual, and vestibular sources is critical for maintaining postural control in humans. This information is analyzed and integrated in the central nervous system, which then sends efferent signals to activate appropriate postural muscles (Nashner and Peters, 1990). In the presence of disease or dysfunction in the relevant parts of the nervous and musculoskeletal system the ability to control balance may be impaired (Maki and Mcllroy, 1996).

Adolescent idiopathic scoliosis (AIS) is a common disorder that occurs within families for unknown reasons (Mirovsky et al, 2006). AIS has been found in the muscular imbalance between the two sides of the spine (Ford et al, 1988). AIS sufferers have the postural alterations in the orientation of the head, shoulders, scapula, and pelvis within all three planes, and rotations of body segments in the horizontal

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plane (Le Blanc et al, 1997). Simoneau et al (2006) reported that AIS interferes with the neural mechanism that is necessary to maintain the balance commands. The remaining sensory information should come from the sole of the feet. And, AIS patients have the body imbalances that are induced by disturbances in systems such as visual, vestibular and somatosensory systems might lead to scoliosis (Wiener-Vacher and Mazda, 1998). Byl et al (1997) and Lindstrom et al (1988) were reported that AIS is associated with disorders of parameters within postural control and with an abnormal center of foot pressure position, it could be expected that this disease may leads to impaired balance control. Impairments in the structure and functioning of peripheral systems are important and might explain the balance dysfunction observed in AIS (Simoneau et al, 2006). These postural changes in body attitude associated with scoliosis could be linked with standing instabilities (Nault et al, 2002). The criteria for a successful treatment methods in the AIS should be based on several body posture parameters and the quality of standing stability (Nault et al, 2002).

Many studies have been reported on age-related physiologic decline in multiple balance-associated systems; this leads to significant balance and functional impairments in older adults (Bergin et al, 1995; Grimston et al, 1993). In addition, researches have also reported results on comparisons in decreased ability of postural control between patients with neurological disorders, normal subjects or young people and the elderly (Grealy et al, 1999; Laughton et al, 2003; Tinetti et al, 1988). To our knowledge, in Korea, few investigators have reported on the balance deficit in AIS, and many studies have not been focused on rehabilitation including balance-training programs. Therefore, the objective of this study was to investigate the characteristics of static balance in patients with AIS and the importance of providing balance-training programs during the rehabilitation process.

Methods

Subjects

Forty subjects were included in this study. Twenty-seven healthy subjects, 15 males and 12 females, volunteered as the normal group with age-matched AIS subjects. The mean age of the healthy subjects was 13.9±1.2 years, their height 161.9±7.5 ㎝, and their weight 52.2±7.7 ㎏. The thirteen subjects with AIS were grouped as 3 males and 10 females, with a major Cobb angle between 20.1° and 49°. Six subjects had single major curves, seven subjects had compensatory double curves, and four subjects′ curves were directed to the right and nine subjects′ curves were directed to the left. The same orthopedic surgeon evaluated all the stand-up radiographs to determine the location, direction and Cobb angles of each AIS subject's spinal curve. The mean age of the AIS subjects was 14.2±2.2 years, their height 161.5±8.7 ㎝, and their weight 48.1±8.1 ㎏. Subjects with scoliosis who displayed signs and symptoms of headache, numbness or weakness of one or more limbs, unsteadiness, loss of thermal sensation, diploma, dysphasia, tinnitus, vomiting, and dysarthria were excluded (Guo et al, 2006). Informed consent was obtained from all the AIS subjects and theirs parents before the data collection. No statistical difference was found between the two groups in terms of age, height, or weight (Table 1).

Table 1. Demographic data of study subjects (N=40)

Group of subjects		Normal (n_1=27)	Scoliosis (n_2=13)
Age (yrs)		13.9±1.2[a]	14.2±2.2
Height (㎝)		161.9±7.5	161.5±8.7
Weight (㎏)		52.2±7.7	48.1±8.1
Major Cobb angle (°)			31.84±7.08
Gender	Male	15	3
	Female	12	10
Number of curve	Single		6
	Double		7
Major curve direction	Right		4
	Left		9

[a]Mean±SD.

Measures

The Functional Reach Test (FRT)

The FRT test is used as a test of static balance. The subject flexed one arm to an angle of 90°, while standing with legs about shoulder width apart, subjects are asked to reach as far forward as possible along a meter stick mounted at shoulder height. The tip of the subject's middle finger in relation to the meter stick in both the starting position and ending position was evaluated. The distance between the starting and ending positions of the middle finger tip was recorded to the nearest .1 ㎝ as the magnitude of the subject's reach. The FRT has been reported to have a correlation with the center of press excursion (r=.71) and the high inter-rater and test-retest reliability (Duncan et al, 1990). It was precise (coefficient of variation=2.5%) an inexpensive and reliable and valid tool for measuring the limits of stability in the forward direction with old adults (Duncan et al, 1990; Newton, 2001). The FRT is one of the most reliable and valid measures of balance disability for post stroke patients (Tyson and Desouza, 2004). We allowed one trial on each side of the arm. No practice session was allowed.

The Lateral Reach Test (LRT)

The LRT measures lateral postural stability. The subject abducted one arm to and angle of 90°, while standing with legs about shoulder width apart, the subject's acromion is lined up with the edge of the meter stick and then reaches to the side as far as possible, while keeping both feet flat on the floor. No knee flexion was permitted and no trunk rotation or flexion was allowed (Brauer et al, 1999). The tip of the subject's middle finger in relation to the meter stick in both the starting position and ending position was evaluated. The distance between the starting and ending positions of the middle finger tip was recorded to the nearest .1 ㎝ as the magnitude of the subject's reach. A limitation is that the FRT measures only the limits of the anterior direction of the standing stability (Dewaard et al, 2002). Maki et al (1994) have shown the medial lateral postural stability was a significant factor at risk for falling in old adults. The LRT had high test-retest repeatability (r=.94) in healthy older women and a significant correlation with center of press excursion (r=.33) (Brauer et al, 1999). We allowed one trial on each side of the arm. No practice session was allowed.

Balance Performance Monitor (BPM)

The BPM[1] was used to measure postural sway of the static standing position. The BPM is a portable unit with three individual moveable footplates and one seat plate. In this study, only two footplates were used for data collection (Figure 1). The footplates were linked to a computer with SMS Dataprint software (version 5.3a). When the subject stood on the foot plates, postural sway was represented by horizontal and vertical sets of colored lights on the display console. The green lights represented that the body weight is distributed equally, the red lights represented it is unequal in the outer range of the base of support. The subject stood on the foot plates and made the weight distribution equal while watching the display console. The subject was asked to look forward and standing still for the duration of the 30 seconds static test. The display console was not in view during the recording. The subject performed 3 trials with two visual conditions, namely, eyes opened and eyes closed. After performing 3 trials with one visual condition, the subject performed 3 trials with the other visual condition. Approximately 3 seconds break was allowed between trials and a 1-minute break was allowed when the visual condition was changed. The visual condition was selected in no particular order and the mean value of 3 trials of each visual condition was used for data analysis.

The BPM provides data on standing balance for mean balance, sway angle, sway area, sway path,

1) SMS Healthcare, Harlow, UK.

and max velocity. The mean balance is calculated as the mean or average weight shift over the 30 seconds test. This is displayed as a percentage of total body weight. Left (L) or right (R) is used in indicating the greatest weight shift with percentages. The sway angle is measured from the normal vertical to the patient center of gravity. It is displayed in degrees and is shown as a maximum angle anterior, posterior and left, right as well as the total for lateral and anterior/posterior. The sway area is the area on an ellipse, which would encompass the maximum anterior, posterior, left and right values of the sway path of the subject's center of gravity during a 30 seconds. The value is expressed in millimeters squared (㎟). The sway path is the distances the subject's center of gravity moves during a 30 seconds. The sway path length is expressed in millimeters (㎜). The max velocity of the subject center of gravity is expressed in ㎜/s. This is the maximum value detected for any .1-second period of the 30 seconds.

Previous studies have reported on the excellent reliability and concurrent validity of the system in measuring postural sway measurements and weight distribution measures (Hass and Burden, 2000; Hass and Whitmarsh, 1998; Mudie et al, 2002). BPM offers visual and auditory feedback as an adjunct to therapy. After 12 weeks exercise a post study in sitting with stroke subjects 83% of the BPM training group, 38% of the task-specific reach group, 29% of the Bobath group and 0% of the untrained group were found to be distributing their weight to both sides (Mudie et al, 2002).

Data Analysis

Statistical analysis was performed using Windows SPSS version 13.0. Demographic data of subjects was summarized using descriptive analysis. The Mann-Whitney U test was used for comparing the functional balance scales, static balance parameters with eyes opened and closed while standing. The Wilcoxon Matched-Pairs Signed-Ranks test was

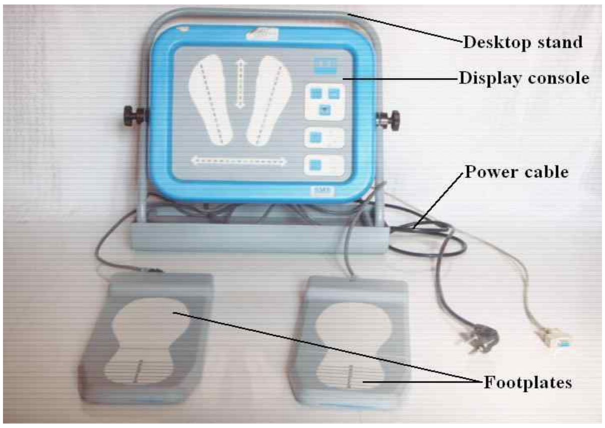

Figure 1. The Balance performance monitor.

used for comparing the static balance parameters between eyes opened and eyes closed in the patients with scoliosis. The Paired t-test was used for comparing the static balance parameters between eyes opened and eyes closed in the normal subjects. For all analyses, a significance level with an alpha less than .05 was adopted.

Results

Comparisons of balance between groups using functional balance scales

For the functional balance scales, the results of mean values and comparisons of scales between groups were shown in Table 2. In the lateral reach test with right and left direction, there were significant differences between normal and AIS groups. However, there were no significant differences between normal and AIS groups in the right and left forward reach.

Comparisons of static balance under eyes opened and eyes closed between groups

For the comparisons of static balance between groups under eyes opened with standing, there were significant increases with all parameters of standing balance in the scoliosis patients (Table 3).

Table 2. Comparisons of functional balance scales between groups (N=40)

Functional balance scales	Normal (n_1=27)	Scoliosis (n_2=13)	Z	p
Right forward reach (㎝)	33.26±8.42[a]	32.39±7.24	-.390	.697
Left forward reach (㎝)	31.08±4.73	32.40±8.35	-.939	.348
Right side reach (㎝)	23.04±5.10	18.72±4.99	-2.124	.034
Left side reach (㎝)	23.15±5.36	18.47±4.97	-2.557	.011

[a]Mean±SD.

Table 3. Comparisons of static balance parameters under eyes opened between groups (N=40)

Parameters	Normal (n_1=27)	Scoliosis (n_2=13)	Z	p
Sway area (㎟)	258.65±263.50[a]	2134.38±2066.86	-4.028	.000
Sway path (㎜)	319.49±92.07	931.36±657.87	-3.653	.000
Max velocity (㎜/s)	59.33±55.05	425.59±271.22	-3.798	.000
Mean balance[b] (%)	51.29±2.85	46.45±8.78	-2.325	.020
Anterior-posterior sway angle (°)	1.71±.51	4.37±2.41	-3.828	.000
Left-right sway angle (°)	1.28±3.40	2.11±1.35	-3.613	.000

[a]Mean±SD.
[b]Values mean the weight bearing percentage of the right foot during standing.

Table 4. Comparisons of static balance parameters under eyes closed between groups (N=40)

Parameters	Normal (n_1=27)	Scoliosis (n_2=13)	Z	p
Sway area (㎟)	284.25±215.19[a]	2113.92±1515.66	-3.971	.000
Sway path (㎜)	380.02±82.73	1138.92±542.23	-3.971	.000
Max velocity (㎜/s)	65.72±53.63	474.36±245.93	-3.871	.000
Mean balance[b] (%)	50.91±3.08	46.02±7.01	-2.440	.015
Anterior-posterior sway angle (°)	2.05±.68	4.54±1.93	-3.944	.000
Left-right sway angle (°)	.66±.25	2.95±2.53	-4.723	.000

[a]Mean±SD.
[b]Values mean the weight bearing percentage of the right foot during standing.

For the comparisons of static balance between groups under eyes closed with standing, there were significant increases with all parameters of standing balance in the scoliosis patients (Table 4).

Comparisons of static balance between eyes opened and closed in each group

For the normal subjects, there were significant differences in the parameters with sway path and anterior-posterior sway angle between eyes opened and closed. However, there were no significant differences in the all parameters between eyes opened and closed for the AIS subjects (Table 5).

Discussion

Adolescent idiopathic scoliosis (AIS) is the most common form of scoliosis and usually affects young girls (Allard et al, 2004). AIS patients have an abnormal skull position, and the spinal muscular imbalance, that might lead to vestibular asymmetry and results in difficulties in balance control (Mirovsky et al, 2006). Another hypothesis for standing instability in the patients with AIS is that of a sensory integration problem related to an organized reference body system (Allard et al, 2004). Earlier studies of standing instability in AIS have increased sway to a

Table 5. Comparisons of static balance parameters between eyes opened and closed in each group (N=40)

Parameters	Normal (n_1=27)		Scoliosis (n_2=13)	
	t	p	Z	p
Sway area	-.655	.518	-.035	.972
Sway path	-4.654	.000	-1.462	.101
Max velocity	-1.761	.090	-1.223	.221
Mean balance	1.115	.275	-.035	.972
Anterior-posterior sway angle	-3.115	.004	-.070	.944
Left-right sway angle	.997	.328	-1.084	.279

combination of vestibular, proprioception, and brainstem dysfunction, as well as mechanical imbalances (Bennett et al, 2004). In our study, we were compared the stability of standing between an AIS patient group and a normal group that were age-matched. In our testing maneuvers, there were two common methods used for evaluation of static balance and functional scale in clinical setting. Traditionally and generally, balance ability has been measured for the force plate, which is one of the objective balance measures in the clinical balance test (Hageman et al, 1995), and assessed using a functional reach test (Duncan et al, 1990). BPM has been shown high and significant inter- and intra-tester reliability (ranging from .720 to .868) in measurements of weight distribution with normal subject (Haas and Whitmarsh, 1998). We were used the parameters such as sway area, sway path, max velocity, mean balance, anterior-posterior angle, and left-right angle. The FRT is a single item test as a quick screen for balance problems. It examines the limits of stability in the forward direction. The Multi-directional reach test was developed to look at medio-lateral postural control (Brauer et al, 1999). It examines the limits of stability in a sideways direction. The test-retest reliability was quite high (ICC=.943) and was correlated with mediolateral center of pressure excursion (r=.331) (Shumway-Cook and Woollacott, 2001). Generally, postural control is essentially adultlike by 7 to 10 years of age (Shumway-Cook and Woollacott, 2001). Subjects were in two groups as patients with AIS and those without AIS. They were matched to the AIS group in their age. All the subjects in this study were over the age of ten years. No statistical difference was found between the healthy and AIS groups in terms of age, height, or weight.

The results from this study where the right and left lateral reach were showed the significant increases in the reach distance in the normal age-matched group. However, there were no significant difference in the left and right forward reach distance between AIS and the control group. These results suggest that a limitation of trunk movement related to medial-lateral direction in AIS group is more larger than it's anterior-posterior direction. The results from the BPM tested indicate there were significantly increases in all parameters of static balance with the patients with AIS under conditions where eyes were opened and closed. Nault et al (2002) was reported that the scoliosis group displayed greater deviations from normal in the postural measures than the control subject group, and was a greater increase in the sway area of the COP (44%) in the scoliosis group. They also reported that the children with scoliosis had a larger sway area of the COP compared to the normal group. The children with scoliosis also had a larger COP difference in both the anterior-posterior and medial-lateral directions as well. In our parameters of static balance we included the anterior-posterior and left-right angle. Differences in the static balance between the normal group and the patients with AIS were typically seen in the coronal plane. Therefore the risk of loss of balance may be greater in AIS subjects than the control group (Chow et al, 2006). Chen et al (1998) reported that AIS patients were poor in postural stability control because of increased sway when standing in a variety of different postures.

Balance dysfunction has been found in patients with AIS (Nault et al, 2002). Gauchard et al (2001) found that the type and position of the major curve had a significant impact on the balance. Double major curves had better balance than single major curves. In the case of a double curve, the skull retains a normal position and therefore a proper vestibular symmetry. Conversely, in the case of a single major curve, the spinal deformation induces an abnormal skull position leading to vestibular asymmetry. They also observed that the lower the curve, the worse the balance in AIS with single major curves. This can be interpreted to mean that a higher consumption of energy is required when the major curve is low to maintain posture control. Double and single curve AIS sufferers were recruited for this study. However, we did not divide them into single or double curve patients due to the small sample size of the AIS group.

Balance control requires the contribution of a 3-part system combining information provided by sensory inputs, central integration, and motor response (Guo et al, 2006). Sensory inputs divided visual, vestibular, and somatosensory inputs. For the AIS group in this study, there were no significant differences between eyes opened and closed. But, for the normal subjects, there were significant difference in sway path and anterior-posterior angle between eyes opened and closed. Simoneau et al (2006) suggest that AIS, compared to the normal subjects, relies much more on ankle proprioception to control the amplitude of the balance control commands for standing. When ankle proprioception was perturbed in AIS group, the availability of vision was not sufficient to reduce the center of pressure.

The findings from this study show that the balance-training program may provide a way of intervention in rehabilitation with AIS patients. The measurement of balance ability will be requiring the evaluation of patients with AIS. In addition, there were few patients with AIS when we conducted the tests for this study. We only evaluated the static standing balance related to proprioception and visual input. Therefore, many patients with AIS and other evaluation related to vestibular input will be needed for more objective data collecting in further studies.

Conclusion

Our study investigated the characteristics of static balance and providing the importance of the balance-training programs during the rehabilitation in patients with AIS. We used BPM and functional reach tests for measurement of static balance. Our results showed that static balance ability decreased with eyes opened and closed in individuals with AIS. Therefore, balance programs could be used in the rehabilitation setting for intervention of AIS and evaluation of AIS. Further study is needed to measure many patients with AIS and other functional balance scales for clinical application.

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