한국전문물리치료학회지 제 14권 제 4호
PTK Vol. 14 No. 4 2007.

Characteristics of Sitting Balance and Trunk Muscle Endurance in Patients With Adolescent Idiopathic Scoliosis

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Abstract

The purpose of this study was to compare the static balance in a sitting position between a group with adolescent idiopathic scoliosis (AIS) and a normal aged-matched group. Forty-nine subjects were included in this study. Thirty-one healthy subjects and eighteen AIS subjects were participated. Each group was tested with the Lumbar Trunk Muscle Endurance Test (LTMET) and Balance Performance Monitor (BPM). The parameters for static balance were sway area, sway path, mean balance, maximum velocity, anterior-posterior angle, and left-right angle of each group with eyes opened and closed. Results from the LTMET showed significantly more increase in the normal group than in the AIS group in the flexor and extensor endurance. The BPM tested showed significantly difference beteen the groups in parameters of sitting balance such as maximum velocity and anterior-posterior sway angle. For the AIS subjects, there were no significant differences in all parameters of sitting balance between eyes opened and eyes closed. In comparisons of the groups with eyes opened there were no significant differences in all parameters of sitting balance. In comparisons of the groups with eyes closed there were significant differences in the sway area, maximum velocity, anterior-posterior sway angle and left-right sway angle. These results suggest that the AIS group relies much more on proprioception than on vision, and develops compensatory passive postures of the spine. Further study is needed to measure many AIS patients with morphologic and electromyographic data for clinical application.

Key Words: Adolescent idopathic scoliosis; Balance; Trunk muscle endurance.

Introduction

Scoliosis has been defined as a lateral curvature of the spine greater than 10° according to Cobb angle on standing radiography (Kane, 1977). Adolescent idiopathic scoliosis (AIS) is found in children aged 10 to 16 years or skeletal maturity and AIS makes up the majority of all cases of scoliosis (Weinstein, 1999). The deviation of the spine leads to change in the muscle properties. McIntire et al (2007) reported that low force arc trunk strengths on the concave side in scoliotic individuals were also significantly lower than those on the left side in healthy subjects. Mooney et al (2000) examined the trunk rotational strength asymmetry in adolescents with idiopathic scoliosis. They reported that patients with idiopathic scoliosis were weak when rotating toward their curve's concave side suggesting a relation between the strength asymmetry and progression of the spinal curvature.

Morphologic changes alter the postural orientation of the head, sacapular girdle, trunk and pelvic girdle and these postural changes are likely to be linked to standing instability (Nault et al, 2002). Additionally, AIS subjects have body imbalance induced by disturbances in systems such as the visual, vestibular and somatosensory systems which might lead to scoliosis (Wiener-Vacher and Mazda, 1998). Nault et al (2002) found that the scoliotic group had a significant

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increase of about 44% in the center of pressure (COP) sway area on standing position compared to that of able-bodied normal subjects. Another study showed that patients with AIS had increased sway when they stood in a variety of postures (Chen et al, 1998).

Sitting is a common position used as a basis for other motor activities. If there is an impairment in sitting posture and balance this may affect ability to perform the activities of daily living (Lanzetta et al, 2004). Many studies of standing posture and balance have already been undertaken but there have been few studies of sitting posture and balance (Bennett et al, 2004). Kantor et al (2001) made a comparison between COP movement in standing and sitting in normal subjects. They found that the sway area was greater in standing than sitting, but the sway path of COP was longer in seated subjects than standing ones.

Gram and Hasan (1999) found that change in spinal curve apexes in AIS subjects was shown from standing to sitting posture and this change depended on the number, location and direction of the spinal apexes. Bennet et al (2004) compared the COP movement of AIS subjects and age-matched normal subjects in sitting. They found that AIS had symmetric sitting COP trajectories and the magnitude of COP movement was more reduced than in the normal group. This result was contrary to the standing studies of static balance.

Few studies have focused on sitting balance and trunk muscle endurance of AIS in spite of the fact that most AIS subjects spend many hours of the day sitting in school or in leisure activities such as watching television or playing video games (Gram and Hasan, 1999), and prolonged sitting has been correlated with poorer back muscle endurance (O'Sullivan et al, 2006). Therefore, the objective of this study was to investigate the trunk muscle endurance, the characteristics of static sitting balance in patients with AIS and the correlation between sitting balance and trunk muscle endurance, and then show its importance in the rehabilitation of AIS.

Methods

Subjects

Forty nine subjects were included in this study. Thirty-one healthy subjects, 19 males and 12 females, volunteered as the normal group with age-matched AIS subjects. The mean age of the healthy subjects was 14.1±1.4 years, their height 163.8±8.8 ㎝, and their weight 54.5±9.5 ㎏. The eighteen subjects with AIS were grouped as 2 males and 16 females, with a major Cobb angle between 16.8° and 53.5°. Nine subjects had single major curves and nine subjects had compensatory double curves, and seven subjects' curves were directed to the right and eleven 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 14.3±2.0 years, their height 160.1±8.0 ㎝, and their weight 47.6.1±7.3 ㎏. 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 their parents before the data collection (Table 1).

Table 1. Demographic data of study subjects (N=49)

Group of subjects		Normal (n_1=31)	AIS[a] (n_2=18)
Age (yrs)		14.1±1.4[b]	14.3±2.0
Height (㎝)		163.8±8.8	160.1±8.0
Weight (㎏)		54.5±9.5	47.6±7.3
Major Cobb angle (°)			30.5±8.5
Gender	Male	19	2
	Female	12	16
Number of curve	Single		9
	Double		9
Major curve direction	Right		7
	Left		11

[a]AIS: adolescent idiopathic scoliosis.
[b]Mean±SD.

Measures

Lumbar Trunk Muscle Endurance Test (LTMET)

LTMET is the method for measuring trunk flexor and extensor muscle endurance, a modified version of the Kraus-Weber and the Sorensen tests for extensors (Ito et al, 1996; Moreau et al, 2001). Two of the most popular methods for measuring trunk muscle endurance are the Kraus-Weber test for flexors and the Sorensen test for extensors. Although both tests have been used clinically, there are some disadvantages. They may increase the lumbar lordosis and low-back pain and may need to be modified for some patients (Flanagan and Kulig, 2007; Selkowitz et al, 2006).

Ito et al (1996) reported that LTMET shows high reliability and reproducibility in both healthy subjects and chronic low back pain (CLBP) patients. LTMET is safe and easy to perform for the patient with no need for special equipment. The test-retest correlation (r) of flexor endurance was .95 and .89 for the healthy subjects, and was .91 and .85 in the CLBP subjects. In the extensor endurance test, r was .97 and .94 for the healthy and was .93 and .95 for the CLBP subjects.

For measuring trunk flexor endurance, subjects were asked to be in a supine position and to flex the hip and knee joint to 90°. The subject's crossed arms were on his or her chest with maximal cervical flexion and held both scapulae off the floor. For measuring trunk extensor endurance, subjects were asked to be in a prone position with a small pillow placed under the lower abdomen, holding the sternum off the floor with maximal cervical flexion. During both endurance tests, the subjects were asked to maintain the original positions with the maximum flexion of cervical spine and pelvic neutral position for as long as possible, not exceeding a 5-minute time limit. Subjects were tested with one trial on each flexor and extensor and no practice session was allowed. The tests were not in order and subjects had a 5-minute break time after each test.

Balance Performance Monitor for Sitting Balance

The Balance Performance Monitor (BPM)[1] was used to measure postural sway of the sitting balance. The BPM is a portable unit with three individual moveable footplates and one seat-plate. In this study, only one seat-plate was used for data collection. The seat-plate was linked to a computer with SMS Dataprint software (version 5.3a). When the subject seated on the seat-plate, postural sway in a sitting position was represented by horizontal and vertical sets of colored lights on the display console. Green lights indicated that the body weight was distributed equally, and red lights indicated an inequality in the outer range of the base of support. The subject was seated on the seat-plate and made the weight distribution equal while watching the display console. The subject was asked to look forward and sit as tall as possible for the duration of the 30 seconds static test. The display console was not in view during the recording. The subject performed 3 trials in two visual conditions, namely with eyes opened and eyes closed. After performing 3 trials in one visual condition, the subject performed 3 trials in 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 sitting balance for sway area, sway path, mean balance, maximum velocity, and sway angle. 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 second period. The value is expressed in millimeters squared (㎟). The sway path is the distance the subject's center of gravity moves during a 30 second period. The sway path length is expressed in millimeters (㎜). The mean balance is calculated as the mean or average weight shift over the 30 second

1) SMS Healthcare, Harlow, UK.

Table 2. Comparison of trunk flexor and extensor endurance between groups (N=49)

Parameters	Normal (n_1=31)	AIS[a] (n_2=18)	t	p
Flexor (s)	103.6±43.9[b]	67.4±32.9	-3.01	.004
Extensor (s)	255.8±70.2	181.3±93.0	-3.18	.003

[a]AIS: adolescent idiopathic scoliosis.
[b]Mean±SD.

Table 3. Comparisons of static sitting balance parameters between groups under eyes opened (N=49)

Parameters	Normal (n_1=31)	AIS[a] (n_2=18)	t	p
Sway area (㎟)	19.23±15.41[b]	32.21±29.36	1.74	.095
Sway path (㎜)	103.53±32.00	111.10±22.75	.88	.382
Mean balance (%)	49.07±1.65	48.40±1.76	-1.35	.184
Maximum velocity (㎜/s)	27.28±8.49	22.98±6.74	-1.83	.073
Anterior-posterior sway angle (°)	.98±.62	1.25±.86	1.27	.211
Left-right sway angle (°)	.99±.47	1.10±.48	.79	.436

[a]AIS: adolescent idiopathic scoliosis.
[b]Mean±SD.

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 maximum 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. The sway angle is measured from the normal vertical to the patient's 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. 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; Sackley et al, 2005). Mudie et al (2002) reported that BPM offers visual and auditory feedback as an adjunct to therapy. After 12 weeks exercise a post study in sitting with 83% stroke subjects 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.

Data Analysis

Statistical analysis was performed using Windows SPSS version 13.0. Demographic data of subjects was summarized using descriptive analysis. The independent t-test was used to compare the endurance of the trunk muscles and the balance parameters under eyes opened and eyes closed while seated in the two groups. The paired t-test was used to compare the static sitting balance parameters between eyes opened and eyes closed in the patients with scoliosis and the normal subjects. The Pearson test was used to investigate the relationship between the static sitting balance parameters and trunk endurance in each group. For all analyses, a significance level with an alpha less than .05 was adopted.

Results

Comparison of Trunk Muscle Endurance Between Groups

For trunk muscle endurance, the results of mean value of endurance between groups were shown in Table 2. In flexor and extensor endurance, there were significant increases in the normal group compared to the AIS group ($p<.05$).

Table 4. Comparisons of static sitting balance parameters between groups under eyes closed (N=49)

Parameters	Normal (n_1=31)	AIS[a] (n_2=18)	t	p
Sway area (㎟)	14.34±10.00[b]	32.24±26.81	2.73	.013
Sway path (㎜)	98.53±33.80	112.38±18.71	1.85	.071
Mean balance (%)	48.77±1.48	47.77±2.50	−1.55	.135
Maximum velocity (㎜/s)	24.76±7.21	20.68±4.01	−2.21	.032
Anterior-posterior sway angle (°)	.71±.33	1.12±.50	3.38	.001
Left-right sway angle (°)	.81±.29	1.14±.41	3.25	.002

[a]AIS: adolescent idiopathic scoliosis.
[b]Mean±SD.

Table 5. Comparisons of static sitting balance parameters under eyes opened and closed in each group (N=49)

Parameters	Normal (n_1=31)		AIS[a] (n_2=18)	
	t	p	t	p
Sway area (㎟)	1.94	.061	−.01	.996
Sway path (㎜)	.78	.443	−.23	.822
Mean balance (%)	1.27	.214	1.58	.132
Maximum velocity (㎜/s)	2.60	.014	1.53	.144
Anterior-posterior sway angle (°)	2.38	.024	.76	.457
Left-right sway angle (°)	1.82	.079	−.34	.737

[a]AIS: adolescent idiopathic scoliosis.

Comparisons of Sitting Balance Between Groups in Each Visual Condition

Under eyes opened condition, there were no significant differences in the parameters of sitting balance between groups ($p>.05$) (Table 3). Under eyes closed condition, there were significant differences in the parameters of sitting balance such as sway area, maximum velocity, anterior-posterior sway angle, and left-right sway angle between groups ($p<.05$). However, there were no significant differences in sway path and mean balance between groups ($p>.05$) (Table 4).

Comparisons of Sitting Balance Under Different Visual Conditions in Each Group

For the comparisons of sitting balance between eyes opened and eyes closed in the normal group, there were significant differences in parameters of sitting balance such as maximum velocity and anterior-posterior sway angle in the normal group ($p<.05$). But, in the other parameters of sitting balance, there were no significant differences between eyes opened and eyes closed in the normal group ($p>.05$). There were no significant differences in any of the parameters of sitting balance between eyes opened and eyes closed in the AIS group ($p>.05$) (Table 5).

Relationship Between Static Balance and Trunk Muscle Endurance in Each Group

For the relationship between static sitting balance parameters and trunk muscle endurance, there was no significant correlation between eyes opened and eyes closed in the normal group ($p>.05$) (Table 6). There was also no significant correlation between eyes open and eyes closed in the AIS group except the parameter of maximum velocity with eyes opened ($p<.05$) (Table 7).

Table 6. Relationship between static sitting balance parameters and trunk muscles in the normal group (N=31)

Condition			Sway area	Sway path	Mean balance	Maximum velocity	Anterior-posterior sway angle	Left-right sway angle
Eyes opened	TFE[a]	r	.020	-.071	.221	.037	-.033	-.234
	TEE[b]	r	.087	-.002	.162	.300	.077	.072
Condition			Sway area	Sway path	Mean balance	Maximum velocity	Anterior-posterior sway angle	Left-right sway angle
Eyes closed	TFE	r	.045	-.167	-.027	-.153	-.046	.095
	TEE	r	.088	.047	-.005	.253	-.038	.077

[a]TFE: trunk flexor endurance.
[b]TEE: trunk extensor endurance.

Table 7. Relationship between static sitting balance parameters and trunk muscles in the AIS group (N=18)

Condition			Sway area	Sway path	Mean balance	Maximum velocity	Anterior-posterior sway angle	Left-right sway angle
Eyes opened	TFE[a]	r	-.273	.212	-.074	-.523*	-.179	-.062
	TEE[b]	r	.095	-.042	.100	.138*	.183	-.119
Condition			Sway area	Sway path	Mean balance	Maximum velocity	Anterior-posterior sway angle	Left-right sway angle
Eyes closed	TFE	r	-.081	.184	-.209	.098	-.276	-.011
	TEE	r	.098	.079	-.102	.289	-.002	-.003

[a]TFE: trunk flexor endurance.
[b]TEE: trunk extensor endurance.
*$p<.05$.

Discussion

Muscle endurance is the ability of a muscle group to perform repeated contractions against a load and these contractions include isometric, concentric, eccentric, or combination of these types (Brody, 1999). Postural muscle endurance is necessary to maintain the balance and proper alignment of the body (Kisner and Colby, 2002). Many studies have focused on the trunk muscle strength in AIS (McIntire et al, 2007; Mooney et al, 2000). In our study, we compared the trunk muscle endurance between AIS and a normal age-matched group. Results from this study show that the trunk flexor and extensor muscle endurance were significantly higher in the normal group than in the AIS group. We suggest that AIS subjects not only have decreased muscle strength of trunk but also have decreased muscle endurance of trunk.

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 are divided into 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 differences in maximum velocity and anterior-posterior angle between eyes opened and closed. The normal subjects needed more stability without visual input. Simoneau et al (2006) suggest that AIS subjects, compared to normal subjects, rely much more on proprioception than on vision to control the amplitude of the balance control commands. Bennet et al (2004) examined the trajectory of the COP in AIS subjects sitting in a Balans style kneeling chair with arms crossed on their chest and eyes closed. They found that the magnitude of COP movement of AIS group was more reduced than in a normal group. The results suggest that a control strategy sitting posture does not change with the development of scoliosis, and decreased COP movement comes from developing compensation of passive structures. AIS seem to maintain their trunk in a stable posture by reducing the movements moments of trunk rather than increasing the muscle activation. But these strategies may decondition the trunk muscles. O'Sullivan et al (2002) reported that adopting passive postures such as slump sitting result in lower muscle activity in the transverse abdominal wall and back muscles, when compared to more upright standing and sitting postures in normal subjects. In an AIS study, Gram and Hasan (1999) found that the activation of lumbar multifidus was less in relaxed sitting than erect sitting. They also reported that electromyographic activity was greater on the convex side of the curve in both relaxed sitting and erect sitting. It may be that one of the reasons why AIS subjects showed decreased trunk muscle endurance is a result of developing compensation of passive structures. But the role of trunk muscles in postural adjustments still remains unclear (Lanzetta et al, 2004).

For the correlations between endurance of trunk muscles and static sitting balance parameters, there was only one negative correlation between trunk extensor endurance and maximum velocity in the AIS group with eyes open. The maximum velocity is the maximum value of the subject COP detected for any .1-second period of the 30 seconds. Fernie et al (1982) examined the sway velocity in an elderly group and reported that the sway velocity was significantly greater in subjects with experience of falling than in subjects without that experience. They claimed that sway velocity is a more accurate index of balance problems than the sway path. But it is not clear why trunk extensor endurance only correlated with maximum velocity in AIS group with eyes open.

The findings from this study may provide a means of intervention in rehabilitation with AIS by a program of trunk muscle endurance training, avioiding compensation of passive structures. In addition, we tested only few patients with AIS for this study and only evaluated the static sitting balance and trunk muscle endurance. Therefore, a larger group of patients with AIS will be needed and other evaluation related to morphologic and electromyographic data should be collected in further study.

Conclusion

Our study investigated the characteristics of static sitting balance and showed the importance of a balance-training program during rehabilitation of patients with AIS. We used LTMET for trunk muscle endurance and BPM for measurement of static balance. Our results showed that trunk muscle endurance decreased in individuals with AIS and static sitting balance ability was no different with eyes opened between AIS and normal subjects. But there were significant differences between the groups with eyes closed. Therefore, the AIS group relies much more on proprioception than on vision, and develops compensatory passive postures of spine. Further study is needed to measure many patients with AIS, and with morphologic and electromyographic data for findings that can be used in clinical application.

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This article was received October 10, 2007, and was accepted November 5, 2007.