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The effect of spinal bracing on stability in patients with adolescent idiopathic scoliosis

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Abstract.
BACKGROUND: Adolescent idiopathic scoliosis (AIS) may change the physical orientation of body segments and affect balance in individuals. Spinal/trunk brace is commonly used for the management of idiopathic scoliosis. The aim of this study was to compare the standing stability of AIS patients with and without a brace, and to compare them with healthy subjects.
METHOD: Twenty subjects (10 healthy subjects and 10 AIS with thoracolumbar/lumbar curve) were recruited for the study. Stability of the scoliotic subjects was evaluated while standing with and without orthosis. A Kistler force plate was employed to estimate the mediolateral and anteroposterior displacements of center of pressure.
RESULTS: The results of this study indicated that there was no significant difference between center of pressure variables in healthy subjects and scoliotic patients. Moreover, trunk bracing only influenced the center of pressure (CoP) excursion in mediolateral direction ($p < 0.05$).
CONCLUSION: Although further research studies are needed, results showed that there was no difference between stability of scoliotic and normal subjects. Moreover, the use of orthosis did not improve their standing stability.

Keywords: Stability, scoliosis, brace, standing

1. Introduction

Adolescent idiopathic scoliosis (AIS) is a common growth related deformity of the immature spine [1] in adolescents, characterized by a lateral curvature of vertebral column greater than 10 degrees and rotation of vertebrae around a vertical axis [2,3]. The prevalence of AIS is between 1 and 4%, but the etiology of this pathology is still not well understood [4–8]. However, several possible etiological factors were introduced to this pathology such as abnormality in the central nervous system, asymmetry in paraspinal muscles activity and genetic and endocrinal factors [9–13].

Since scoliosis is a structural, lateral and rotated curvature of the spine and changes the physical orientation of body segments, it seems that this pathology can alter center of mass (COM) position and weight distribution on lower limbs. It has been shown that in a static condition the direction of ground reaction force vector should point to the location of COM which projects the center of pressure (CoP) [14]. So the estimation of center of pressure displacement in quiet standing is a proper method to evaluate the static balance of individuals. Individual balance performance and stability of upright stance in scoliotic patients is also affected by dysfunction of their visual [15], vestibular [16] and somatosensory systems [17]. This suggests that scoliotic patients show poorer stability than age-matched controls, as previous studies investigating balance performance of scoliotic patients observed that adolescent idiopathic scoliosis associated with postural control parameters disturbance [18–21] and AIS patients

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Table 1
The characteristics of scoliotic and normal subjects included in this study

Parameter	Patient group	Control group
Age (year)	13.22 ± 2.04	11.84 ± 3.52
Weight (kg)	44.22 ± 14.23	42.38 ± 8.02
Height (cm)	161.66 ± 14.94	158.36 ± 9.72

showed poorer stability than healthy subjects, in particular when visual and somatosensory systems are challenged simultaneously [22–25]. However, Wiernicka et al. showed that the control of postural stability in girls with idiopathic scoliosis was as good as in healthy girls [26].

The management of scoliosis depends on severity of scoliotic curvature and skeletal maturity of the patient and includes maintenance procedures such as physical therapy, electrical muscle stimulation, exercise, stretching, using braces and various surgical techniques. Bracing is generally recommended for scoliotic patients with a Cobb angle between 25 and 45 degrees, primarily in order to prevent curve progression and to achieve some curve correction. In previous studies that assessed the effect of bracing on postural balance of AIS patients, the results varied. In one study it has been shown that in normal condition bracing has no significant effect on balance performance of scoliotic subjects [27,28], whereas in another study it was concluded that bracing changes the balance control of idiopathic scoliosis patients [21]. Therefore, the aim of this study was to examine standing stability between normal and scoliotic patients and to examine the effect of bracing on the stability in patients with AIS.

2. Methods

Ten patients with idiopathic scoliosis (8 girls and 2 boys) participated in this study. Moreover, a group of normal subjects were matched with scoliosis subjects based on their height, weight and age. The characteristics of both groups of participants are summarized in Tables 1 and 2. Patients with leg length discrepancy more than 1 cm, with previous spinal surgery, with no ability to ambulate, with other neuromuscular and cardiovascular problems were excluded from this study. Ethical approval was obtained from the Ethics Committee at Isfahan University of Medical Sciences. A consent form was signed by the parents of each participant prior to data collection.

Procedure: Stability of the scoliotic subjects was evaluated while standing with and without orthosis. Stability was evaluated by use of a force plate (Kistler, 50*60 cm). The subjects (normal and scoliotic patients) were asked to stand on the force plate in a quiet stance for one minute. The tests were repeated to collect 5 successful trials. Data were collected with frequency of 100 Hrz and were filtered with 10 Hrz (low pass Butterworth). The first and last 15 seconds of the data were deleted to remove the effects of sudden standing on the force plate and fatigue of the muscles.

To examine the stability of the subjects, the following parameters were used. The excursion of CoP in the mediolateral and anteroposterior directions, the path length of the excursion of CoP in the mediolateral and anteroposterior directions and the velocity of CoP sway in the mediolateral and anteroposterior planes. The following equations were used to calculate the mentioned parameters.

$$\text{COPEAP (mm)} = X_{\max} - X_{\min} \quad (1)$$

$$\text{COP EML (mm)} = Y_{\max} - Y_{\min} \quad (2)$$

$$\text{PLAP (mm)} = \sum_{n-1} \sqrt{(x_{i+1} - x_i)^2} \quad (3)$$

$$\text{PLML (mm)} = \sum_{n-1} \sqrt{(y_{i+1} - y_i)^2} \quad (4)$$

$$\text{VAP (mm/min)} = \frac{\sum_{n-1} \sqrt{(x_{i+1} - x_i)^2}}{t} \quad (5)$$

$$\text{VML (mm/min)} = \frac{\sum_{n-1} \sqrt{(y_{i+1} - y_i)^2}}{t} \quad (6)$$

From the equations, COPEML represents the excursion of the CoP in mediolateral direction. COPEAP is the excursion of the center of pressure in the anteroposterior direction. PMLL represents path length in mediolateral plane and PLAP stands for path length in anteroposterior plane. While the velocities of CoP in anteroposterior and mediolateral planes are represented by VAP and VML, respectively.

Test of normality was carried out to examine the distribution of the data using the Shapiro-Wilk test which revealed that all the parameters were normally distributed. Hence, paired t test was used to examine the effect of orthosis on stability while the independent t test was carried out to determine group differences.

3. Results

The mean values of stability parameters of normal subjects and scoliotic patients while standing with and without orthosis are shown in Table 3. The mean value

Table 2
Patients' information

Subject no.	Age	Sex	Cobb angle/ side	Cobb level	Compensatory curve	Etiology	Prescribed orthotic device	Duration of orthosis use
1	14	Female	37-right	T4-T11	No	Idiopathic	Milwaukee brace	3 months (since 1392.6.25)
2	14	Female	33-left	T12-L4	No	Idiopathic	Boston brace	3 months (since 1392.5.25)
3	13	Female	24-left	T12-L4	No	Idiopathic	Boston brace	5 months (since 1392.3)
4	15	Female	45-right	T7-L1	No	Idiopathic	Boston brace	10 month (since 1392.2)
5	13	Female	37-right	T11-L3	No	idiopathic	Boston brace	3 months (since 1392.8.20)
6	15	Female	35-right	T7-T11	Yes, left T11-L3/ 47 degrees	idiopathic	Boston brace	12 months (since 1391.9)
7	12	Female	25-left	T2-T8	Yes, right T9-L3/ 35 degrees	idiopathic	Boston brace	11 months (since 1392.5.24)
8	10	Female	35-left	T3-T7	Yes, right T8-L3/ 25 degrees	Idiopathic	Milwaukee brace	5 years (62 months) (since 1389.1.17)
9	14	Male	30-left	T12-L4	No	Idiopathic	Boston brace	10 months (since 1391.10)
10	8	Male	37-left	T10-L4	No	Idiopathic	Boston brace	12 months (since 1391.9.8)

Table 3
Mean value of center of pressure parameters in normal and scoliotic patients

	Mean CoP AP excursion (mm)	Mean CoP ML excursion (mm)	Path length CoP AP (mm)	Path length CoP ML (mm)	Velocity CoP AP (mm/min)	Velocity CoP ML (mm/min)
Normal subjects	2.699 ± 1.187	4.331 ± 1.167	1593.25 ± 837.27	2213.079 ± 1387.293	3186.514 ± 1674.535	4426.159 ± 2774.585
Scoliotic patients without brace	2.347 ± 2.195	4.348 ± 1.654	1319.954 ± 770.615	2010.209 ± 1671.574	2639.91 ± 1541.23	4195.226 ± 3368.404
p-value	0.212	0.490	0.228	0.385	0.228	0.434
Scoliotic patients with brace	3.389 ± 1.480	5.514 ± 1.613	1302.79 ± 656.265	1721.723 ± 883.182	2584.915 ± 1325.528	3599.261 ± 1914.456
Scoliotic patients without brace	2.347 ± 2.195	4.348 ± 1.654	1319.954 ± 770.615	2010.209 ± 1671.574	2639.91 ± 1541.23	4195.226 ± 3368.404
p-value	0.470	0.0198	0.397	0.172	0.322	0.159

of mean CoP excursion in anteroposterior of normal subjects was 2.69 ± 1.187 mm compared to 2.34 ± 2.19 mm of scoliotic subjects ($p = 0.212$).

There was no significant difference between excursion of CoP in mediolateral direction of normal and scoliotic subjects. The path length of CoP sway of normal subjects in anteroposterior and mediolateral directions were 1593.26 ± 837.26 mm and 2213.07 ± 1387.29 mm, respectively, compared to 1319.95 ± 770.61 mm and 2010.2 ± 1671.57 mm of scoliotic subjects ($p > 0.05$).

The mean value of CoP excursion of scoliotic subjects was 3.389 ± 1.48 mm in standing without orthosis compared to 2.347 ± 2.196 mm in standing with orthosis ($p = 0.47$). It seems that the use of orthosis increased the mean value of CoP excursion in mediolateral direction. The path length of CoP in anteroposterior was 1302.79 ± 656.26 and 1319.95 ± 770.61 mm in standing with and without orthosis, respectively ($p = 0.397$). There was no significant difference between stability of scoliotic subjects in standing with and without orthosis ($p > 0.05$).

4. Discussion

Scoliosis is a three dimensional deformity of the spine which influences the abilities of subjects to stand and walk. It is controversial whether stability of subjects with idiopathic scoliosis differs from that of normal subjects or not. Moreover, it is not clear whether the use of orthosis influences standing stability. Therefore, the aim of this study was to compare stability in healthy and scoliotic patients. We furthermore aimed to examine the effect of orthosis on standing stability of scoliotic subjects.

As can be seen in Table 2, there was no difference between stability in healthy subjects and patients with AIS. The interesting point is that the excursion of CoP, path length and CoP velocity decreased in subjects with scoliosis. This is contrary to the findings of Chen et al., who observed that scoliotic subjects have some alteration in center of mass (COM) position and symmetry of weight distribution on lower limbs [29]. Shifting of COM in lateral direction causes imbalance moment in frontal plane and finally decreases standing stability. The results of the present study are similar to those observed by Chow et al. and Sadeghi et al. [30,31]. However, it should be noted that stability can be measured during quiet standing and during walking. In most of the aforementioned studies and also in the current study, stability was evaluated during quiet standing and based on force plate output. Based on the results of the current study, it can be concluded that stability of scoliotic subjects is similar to those of healthy subjects and alteration of center of mass (COM) did not influence standing stability.

The present study evaluated the effect of use of orthosis on standing stability. Based on the outcome, there was no significant difference between stability of scoliotic subjects in two conditions (with and without orthosis). The interesting point is that the mean value of CoP excursion in mediolateral direction increased following the use of orthosis. The results of the current study are in contrast with the findings of Guo et al. [32], who found that the use of orthosis improved stability of the subjects with scoliosis.

Chow claimed that use of orthosis decreased standing stability [30]. Based on the results of the present study it can be concluded that use of orthosis did not improve the standing stability especially in mediolateral direction. The reasons for observed findings are not obvious; however, they may be due to the effect of transverse loads embedded in the orthosis structure. There is no doubt that the alignment of vertebral column improved by orthosis by use of three point force systems. If the sum of forces applied on the convexity of the curve and upper and lower parts of the curve does not equal to zero, it may produce imbalance especially during standing.

The results of this study support this finding that stability of scoliotic subjects is similar to those of healthy subjects and use of orthosis did not improve stability in patients with AIS. However, it should be noted that the scoliotic subjects use orthosis especially to control progression of the curve and to improve the walking and standing performance. There are some limitations which should be acknowledged in this research study, which include small sample size limiting the generalizability of the study. Moreover, stability was evaluated only during quiet standing and it is possible that this may not reflect the overall stability in patients with scoliosis. Therefore, it is recommended that stability of scoliotic subjects is compared in standing and walking with and without orthosis in a larger sample of subjects.

5. Conclusion

The results of this study showed that there was no difference between stability of scoliotic and normal subjects. Moreover, the use of orthosis did not improve their standing stability. Clinicians are to be aware of these findings as intervention strategies other than the use of orthosis may be beneficial for patients with scoliosis to improve their stability.

Conflict of interest

None to report.

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