Effects of the Direction of the Curve in Adolescent Idiopathic Scoliosis on Postural Balance during Sitting

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Abstract: - Improper postural alignment and trunk stability caused by idiopathic scoliosis may affect postural balance pattern during sitting. In this study, we conducted pressure data analysis for evaluation of postural balance in patients with idiopathic scoliosis by using pressure sensor system. Subjects were divided into three groups: a control group, scoliosis with left convex side of the curve group, and scoliosis with right convex side of the curve group. Subjects were instructed to sit on pressure sensor system which was located on the unstable board for 30 seconds. Pressure distribution data were subdivided into two regions of masks and analyzed for maximum force, peak pressure, and contact area. There were significant differences in pressure distribution pattern between scoliosis patients groups according to the direction of the curve during sitting. From these results, it was concluded that idiopathic scoliosis cause postural asymmetry during sitting. Furthermore, pressure sensor system can be utilized to detect asymmetrical balance and postural change of patients with idiopathic scoliosis for individuals.

Key-Words: - Idiopathic scoliosis, postural balance, sitting, pressure sensor system, Adolescent

1 Introduction
The ability to keep balance is one of the most essential factors in activities of daily living. Human body tries to maintain its correct posture under static and dynamic conditions against gravity. However, improper postural alignment and trunk stability including asymmetrical pelvic tilt in the three different planes (frontal, sagittal, and transverse) and excessive curvature of the spine such as lordosis, kyphosis, and scoliosis can cause spinal deformities as well as influence on our balance system negatively. Previous studies discovered that abnormalities in balance function caused by progressive curve were found to be associated with...
pelvic deformities in the sagittal and frontal plane [1].

Adolescent idiopathic scoliosis (AIS) is the most common type that is present in 2 to 4 % of children between the ages of 11-17 years [2]. Initial asymmetry of the body during growth phases may affect progression of AIS. Progressive curve is related to posture asymmetry, and it can affect physical activity in adolescent. Scoliosis in adolescent has been closely associated with excessive spinal curvature, asymmetrical load on the spine, and progressive loss of both trunk and lower limb balance [3]. In biomechanics, the trunk and pelvis plays a fundamental role in the maintenance of body balance. Therefore, convexity and concavity of the spinal curve with pelvic inequality would alter the postural balance pattern in standing, sitting. The scoliosis patients group displayed increasing displacement of the center of pressure (COP) and the center of mass (COM) excursion [4]. Aggravated scoliosis with pelvic imbalance leads to increasing several trunk muscle contraction, postural instability, and asymmetrical tilting angle while standing and sitting [5].

To date, many studies related to postural balance of idiopathic scoliosis in adolescent have been conducted by utilizing various balance assessment systems [6-7]. Muscle imbalance in the lumbar or thoracolumbar area on the convex side of patients with idiopathic scoliosis was observed by measuring electromyography (EMG) signals in thoracic, lumbar, and abdominal trunk muscles [8]. More reduced step length, pelvis, hip, and shoulder frontal motion, hip transversal motion, knee sagittal motion of scoliosis patients than normal subjects was observed by using three-dimensional motion analysis equipment [9]. However, pressure distribution data have been rarely used to analyze asymmetrical postural pattern of scoliotic patients in the literature. It is crucial to assess the pressure distribution pattern for patients with idiopathic scoliosis because adolescent students spend most of time sitting with the increase in sedentary activities such as studying, watching television, and playing computer game in recent years.

The purpose of this study was to measure the effects of the direction of the curve in idiopathic scoliosis on postural balance during sitting by utilizing pressure sensor system based on capacitive sensors.

2 Pressure Sensor System
Pressure sensors are commonly used in various medical fields to provide the information about postural balance of patients by converting electric signal into physical output. There are many pressure measurement methods including resistive, inductive, capacitive, and piezoelectric for measuring pressure between two contacting surfaces. Especially, capacitive sensors are more suitable than other sensors for assessing interface pressure due to its advantage of high sensitivity and linear characteristics. Capacitance mapping system was used to analyze the effect of the body asymmetry, trunk mobility, and postural change caused by prolonged sitting in working conditions on spinal deformity [10].

Sitting balance was assessed by using Pliance seat sensor system (Novel Gmbh, Munich, Germany), as shown in Fig. 1. It is consists of a flexible 256 capacitive sensors with an individual sensor area of 1.5 cm² in a matrix configuration for measuring weight distribution of the body during sitting. The dimensions of the sensor mat were 150 mm × 100 mm × 40 mm with a sampling frequency of 100 Hz.

3 Experimental method
3.1 Subjects
Eighteen adolescents were recruited from the Department of Rehabilitation Medicine of Chungnam National University Hospital in Daejeon, Republic of Korea. Subjects were consisted of three groups. The control group (CG) consisted of 6 adolescents without spinal deformation and previous history of injury. The scoliosis group was divided into two subgroups according to the direction of the curve in scoliosis: scoliosis group 1 (SG 1) and scoliosis group 2 (SG 2). The inclusion criteria for scoliosis patients were anteroposterior (AP) full spine standing X-ray evidence of idiopathic scoliosis with a C-shaped lumbar or thoracolumbar curve and no previous conservative or surgical treatment for the scoliosis. The SG 1 consisted of 6.
adolescents with the left convex side of the curve and SG 2 consisted of 6 adolescents with the right convex side of the curve.

All adolescents and their parents provided written informed consent prior to their voluntary participation. Characteristics of subjects about demographic data including mean angle, height, body weight, body mass index (BMI), and Cobb angle are shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Control group (mean±SD) (n=6)</th>
<th>Scoliosis patients (mean±SD)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Group 1 (n=6)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>15.17±2.04</td>
<td>14.50±2.17</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>166.17±7.78</td>
<td>159.67±10.37</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>62.51±5.40</td>
<td>52.17±5.42</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.87±2.09</td>
<td>20.66±1.53</td>
</tr>
<tr>
<td>Cobb angle (°)</td>
<td>-</td>
<td>14.63±3.48</td>
</tr>
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</table>

3.2 Procedure
Subjects were instructed to sit in the usual manner on the capacitive seat sensor system with arms crossed on contra-lateral shoulder for 30 seconds, as shown in Fig. 2. Seat sensor system was located on the unstable board (length: 335 mm, width: 305 mm, height: 36 mm). The curvature radius of the board was 320 mm. Symmetrical or asymmetrical postural pattern of patient can be detected by its unstable structure. This unstable structure has been used to assess the ability of postural control of the spine in the frontal and sagittal plane while sitting [10]. Additionally, a foot support was employed to adjust the knee and ankle at 90° to prevent leg movements.

3.3 Analysis
Pressure distribution data were subdivided into two regions of masks (left and right side) and analyzed for maximum force, peak pressure, and contact area by using Novel software (Novel Gmbh, Munich, Germany). Body weight distribution data was displayed in both 2D and 3D, and then the pressure values are shown according to the corresponding color scale.

Statistical analysis was conducted using SPSS PASW statics 18 software (SPSS Inc, Chicago, USA). A t-test was used to examine the differences in pressure distribution between left and right side, at the p < 0.05 level.

4 Results
Comparisons of body pressure distribution between the groups are presented in Fig. 3-5. Maximum force, peak pressure, and contact area of the SG 1 increased on the left side, while body pressure distribution of the SG 2 decreased on the right side during sitting. There were no significant differences in the maximum force and contact area between both sides. However, peak pressure between the left and right side of SG 2 was only different significantly (p < 0.05).

![Fig. 2. Assessment of postural balance in patients](image)

![Fig. 3. Maximum force](image)

![Fig. 4. Peak pressure](image)
Figure 6 illustrates the differences in body pressure distribution between the groups by using 2D and 3D display mode. As compared with body pressure among CG, SG 1, and SG 2, pressure distribution pattern of SG 1 and SG 2 were tilted in accordance with their direction of scoliosis curve, respectively.

5 Conclusion
In this study, postural balance pattern of patients with idiopathic scoliosis in adolescent was evaluated by using pressure measurement system based on capacitive sensors. Progressive idiopathic scoliosis would alter the postural balance pattern during sitting. Generally, scoliosis patients with C-shaped curve tend to have more severe thoracolumbar spinal imbalance than patients with S-shaped curve [11]. Accordingly, we focused on patients with C-shaped lumbar or thoracolumbar curve and classified into two groups according to direction of scoliosis curve. Scoliosis patients group with left convex side of the curve showed more tilted body pressure distribution to the left side than the right side. In contrast, body pressure of scoliosis patients group with right convex side of the curve increased on the right side. It means that direction of scoliosis curve may affect directly the asymmetrical pressure pattern during sitting. These asymmetrical patterns are connected to significant difference in the contact area and peak pressure of scoliosis patients in accordance with their characteristic of spinal curve. From the results of this study, we confirmed that AIS have influence on postural imbalance and control problem in sitting conditions.

It has been reported that unbalanced pressure distribution can cause pressure ulcers and advance deformation of the spine. Therefore, studies about postural balance in patients with AIS have been emphasized by other investigators. Measurement of balance abnormalities in adolescents with idiopathic scoliosis is very important to prevent progression of the curve and to treat pain caused by spinal deformities.

Furthermore, this paper suggested that pressure sensor system which consists of a lot of capacitive sensors with high sensitivity and linear characteristics can provide accurate information about postural balance of patients with idiopathic scoliosis and can be utilized to prevent progression of postural asymmetry caused by abnormal lateral curvature of the spine by measuring body pressure of patients during sitting. Further research is needed to evaluate the effects of pelvic tilts on postural balance of AIS patients by comparing pressure distribution during sitting.

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References:


