Posture, Pressure, and Muscle Activation Pattern of Adolescent with Idiopathic Scoliosis in Static and Dynamic Sitting

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Abstract: - In this study, we evaluated the influence of idiopathic scoliosis on postural balance and muscle activity in static and dynamic sitting condition. Twelve adolescents with idiopathic scoliosis were included in this study. Postural balance and muscle activities of all subjects were assessed under two experimental conditions: i) static sitting, ii) dynamic sitting. In static sitting condition, subjects were instructed to sit the board for 30 seconds. In dynamic sitting condition, subjects performed pelvic anterior, posterior, left, right tilting induced by the structure of the board for 5 seconds, respectively. Inclination angle was measured by accelerometer which was attached to the center of the unstable board. Body pressure distribution pattern (contact area, maximum force, peak pressure, and mean pressure) was analyzed using capacitive seat sensor system. Also, surface electrodes were attached to the thoracic erector spinae, lumbar erector spinae, lumbar multifidus, and external oblique for assessing muscle activity. In comparison with mean inclination angle and pressure distribution between left and right side, postural balance was tilted to the posterior and left side. In addition, erector spinae muscles, especially thoracic erector spinae muscle, of subjects with AIS more increased on right side than left side in dynamic sitting condition. From these results, we confirmed that idiopathic scoliosis cause postural asymmetry, unequal balance, and muscular imbalance in static and dynamic sitting. Furthermore, postural balance measurement system in this study can be utilized to detect asymmetric sitting posture and abnormal muscle activity caused by idiopathic scoliosis.

Key-Words: - Adolescent idiopathic scoliosis, postural balance, body pressure, muscle activity, static sitting, dynamic sitting, unstable board.

1 Introduction

Scoliosis is an abnormal lateral curvature of the spine. Adolescent idiopathic scoliosis (AIS) is the most common deformity occurring 2-4% of children between the ages of 11 and 17 years of age [1, 2]. More severe curve that requires treatment is present more frequently in females than males [3].

Idiopathic scoliosis has been associated with abnormal spinal curvature, trunk balance, and muscle activity [4, 5]. Excessive curvature of the spine which is called kyphosis and lordosis in patients with left lumbar idiopathic scoliosis was significantly higher than in the control group during standing and sitting [6]. Progressive curve is related to posture asymmetry, and it can negatively affect physical activity in adolescent [7, 8]. The scoliotic group displayed increasing displacement of the center of pressure (COP) and the center of mass (COM) excursion [9]. Postural change associated with spinal deformity can lead to balance problems and further progression of unequal pressure distribution, and it could be related to lesser postural stability in standing [10]. Muscle imbalance in the lumbar or thracolumbar area on the convex side of patients with idiopathic scoliosis was observed by measuring electromyography (EMG) signals in thoracic, lumbar, and abdominal trunk muscles [11]. EMG asymmetry can occur around a scoliotic deviation and asymmetric muscle activity on the convex side is associated with increasing cob angle and kyphosis [12].

With the change of social structure and working condition, most people spend more time sitting at work [13]. Especially, sitting has become the most common posture with the increase in study time of adolescent students. Previous studies reported that patients with AIS have muscular imbalance between concave and convex side of the spine as they spend most of the time sitting while studying [14, 15].

It is very important to understand the effect of scoliosis on postural balance and muscle activity during sitting for AIS patients. Although there is evidence that how idiopathic scoliosis affect the entire skeletal system in our daily life, such as standing and walking, the correlation between posture problem and muscular imbalance caused by bilateral asymmetry with scoliosis in sitting condition has not been studied. Accordingly, we analyzed the association among tilting angle, pressure distribution, and muscle activity during static and dynamic sitting. In addition, we proposed the efficient method for evaluating the biomechanics of sitting for scoliosis using an unstable board with accelerometer to detect postural change.

2 Material and Methods

2.1 Subjects

Twelve female subjects with adolescent idiopathic scoliosis participated in this study. All subjects were recruited from the Department of Rehabilitation Medicine of Chungnam National University Hospital in Daejeon, Republic of Korea. Their mean age was 16 years (standard deviation [SD] ±2), mean height 160 cm (SD ±5), and mean body weight 50 kg (SD ±6). The inclusion criteria for patients were anteroposterior (AP) full spine standing X-ray evidence of idiopathic scoliosis with a lumbar or thoraco-lumbar curve and no previous conservative or surgical treatment for the scoliosis. The mean cob angle was 21.6 ° (range: 16° to 29°) and major curve defined by a Cobb angle was to the right (convex side) as shown in Fig. 1. Exclusion criteria were previous orthopaedic surgery, central or peripheral neurologic disorders, or other spinal disorders. All subjects were informed a full explanation regarding the protocol and written consent prior to their participation.

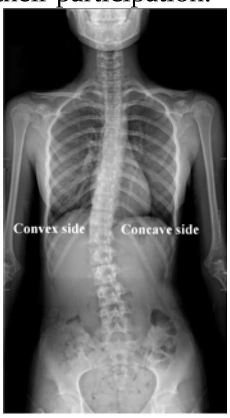

Fig.1 AIS patients with curve in right convex side

2.2 Measurement Instrument

To assess the postural balance of subjects in sitting, we used unstable board with 3-axis accelerometer which shape and appearance was hemisphere. As shown in Fig. 2, the dimensions of the unstable board were as follows: length 370 mm, width 320 mm, height 85 mm, and its curvature radius of the board was designed to incline in the sagittal (anterior-posterior, AP) and frontal (left-right, LR) plane for evaluating the postural balance of trunk and pelvis as well as muscle activity according to trunk and pelvis movement. Accelerometer which was positioned to middle bottom of the board facilitated measurement on asymmetry sitting posture [16]. Also, photo sensors (SG-23FF, Kodenshi CO., Tokyo, Japan) were attached to the surface of both sides in board to check sitting state of subjects by measuring the gap between the inner tip and plate. These sensors employed to use the energy more efficiently by operating the measurement system during sitting [13].

Fig.2 Structure of the unstable board

Pliance seat sensor system (Novel Gmbh, Munich, Germany) was used for body pressure distribution measurement while sitting. This flexible and elastic measuring mat contained 256 capacitive sensors, sampled at a rate of 50Hz, and measured data were transferred by using a Bluetooth connection and recorded on a computer.

Muscle activities were recorded using Noraxson Telemyo 2400T (Noraxson Inc., Scottsdale, USA). Wireless surface electrodes (Noraxson Inc., Socttsdale, USA) were attached to the trunk muscles: thoracic erector spinae (5-cm lateral to the T9 spinous process, TES), lumbar erector spinae (3-cm lateral to L3 spinous process, LES) [17], and lumbar multifidus (L5 level, parallel to a line connecting the posterior superior iliac spine and L1-L2 interspinous space, LM) [18], and external oblique (just below the rib cage, along a line connecting the most inferior costal margin and the contralateral public tubercle, EO) muscle [19] bilaterally as shown in Fig. 3.

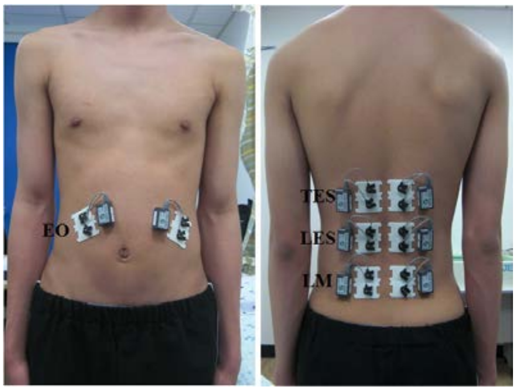

Fig.3 Position of EMG electrode

2.3 Experimental Protocol

Experimental protocol was divided into two conditions: static and dynamic sitting. First, in static sitting condition, subjects were instructed to sit in their usual manner on the board, which is located in the center of stool, with their arms crossed on contra-lateral shoulder for 30 seconds. And, lastly, in dynamic sitting condition, subjects were asked to perform pelvic anterior, posterior, left, and right tilt using curvature structure of the board, and then subjects keep the posture for 5 seconds, respectively.

From these experimental conditions, we evaluated the neutral sitting posture and correlation between association among tilting angle, body pressure, and muscle activation caused by idiopathic scoliosis. A foot support was used to prevent the influence of leg movement, and it was adjusted to support the feet by keeping knee and ankle angles at 90° [20]. Before the experiment, all subjects had enough time to adapt to instability by inducing the board. To prevent fatigue, subjects took a 5 minute rest in between experiments.

2.4 Data Analysis

Inclination angles with trunk and pelvic movement in frontal and sagittal plane under two conditions were analyzed, sampled at a rate of 100 Hz, using LabVIEW 2010 (National Instrument CO., Texas, USA).

Pressure distribution was analyzed to contact area, maximum force, peak pressure, and mean pressure. These data were divided into 2 regions of masks (left and right) and defined using Novel software (Novel Gmbh., Munich, Germany). For accurate analysis, pressure data were normalized by body weight of subjects [21].

All EMG signals from trunk muscles (TES, LES, LM, and EO) were amplified, bandpass filtered (passband 20-450 Hz), notch-filtered at 60 Hz, and then sampled at 1000 Hz. MyoResearch Master XP 1.07 (Noraxson Inc., Scottsdale, USA) was used to analyze the measured data. To normalize the difference of muscle contraction for individuals, EMG data was expressed as a percentage relative to the maximum voluntary contraction (MVC). Typically, excellent stabilization and support of all involved segments is very important to produce a maximal contraction. Thus, two MVC trails were conducted to obtain the maximal electromyography of abdominal and erector spinae muscles. As shown in Fig. 4, subjects attempted to lift the upper trunk from the floor with the maximum effort, and then hold it for five seconds. The person who assisted in measurement applied external load to the chest and scapulae of subjects according to the experimental protocol. The ankle was held by the second assistant to stabilize the position [22, 23].

Fig.4 Maximum voluntary contraction methods

Statistical analysis was performed using SPSS 18.0 software (SPSS Inc., Chicago, USA). Independent t-test was used to examine the differences in angle variation, muscle activity, and pressure distribution between AP and LR side, at p < .05 and < .01 level.

3 Results

3.1 Inclination Angle

As shown in Fig. 5, in static sitting condition, mean inclination angle in AP and LR direction was -1.58° and -1.65°, respectively. Angle variation of AIS patients in static sitting was tilted to posterior and left side.

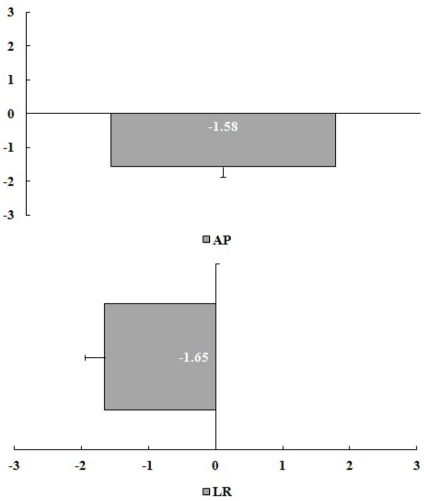

Fig.5 Inclination angle in static sitting condition

In dynamic sitting condition, mean inclination angle in AP and LR direction was presented in Fig. 6. Anterior and posterior tilting angle was 5.46° and 5.50°, respectively. In addition, left and right tilting angle was 6.73° and 3.46°, respectively. Mean inclination angle in posterior and left side was larger than anterior and right side. Especially, inclination angle in left side increased more significantly compared to that of side ($p < 0.05$).

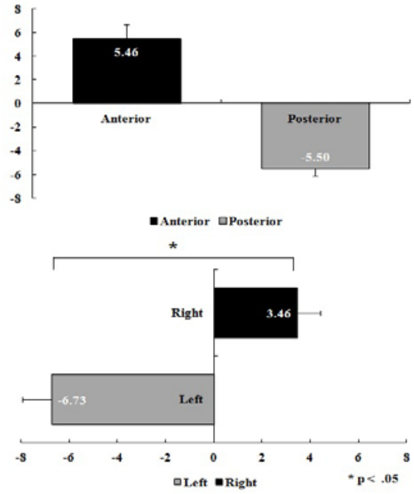

Fig.6 Inclination angle in dynamic sitting condition

3.2 Pressure distribution

The contact area, maximum force, peak pressure, and mean pressure of left and right side are presented in Fig. 7~10.

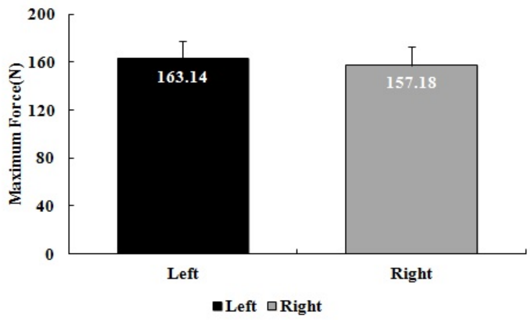

Fig.7 Maximum force

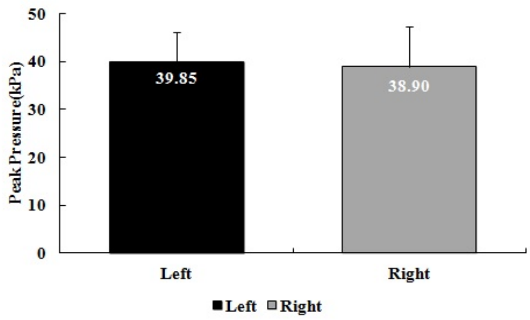

Fig.8 Peak pressure

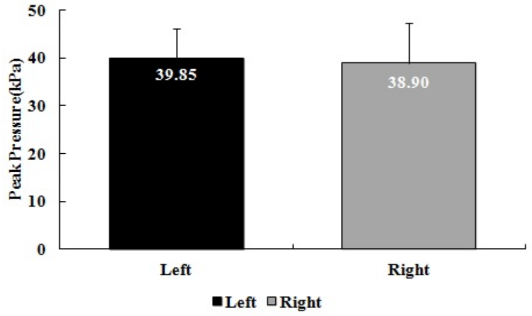

Fig.9 Peak pressure

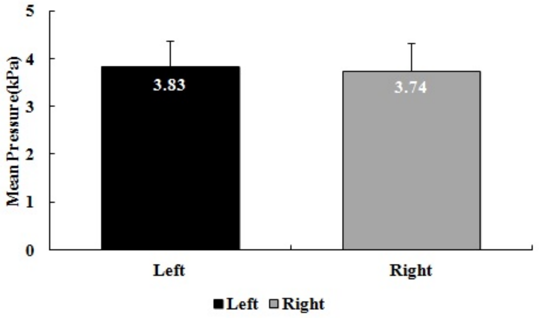

Fig.10 Mean pressure

There is no big difference in contact area between both sides. On the contrary, maximum force, peak pressure, and mean pressure of left side was higher than left side. Especially, difference in maximum force between left and right side was larger than other parameters while there is no statistical significance.

3.3 Muscle Activity

Differences in muscle activity of both sides during pelvic anterior tilting are presented in Fig. 11. External oblique, thoracic erector spinae, lumbar erector spinae muscle increased on right side while lumbar multifidus muscle was reduced on that side.

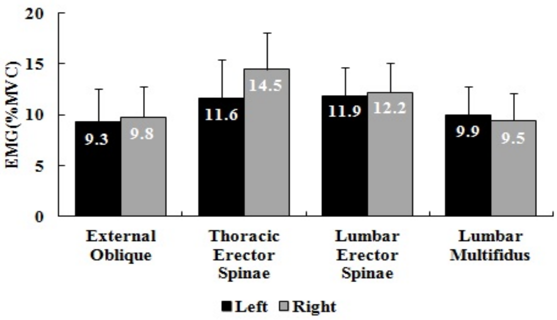

Fig.11 Muscle activity in pelvic anterior tilting

In contrast, all trunk muscles more increased on right side than left side when pelvic posterior tilting as shown in Fig. 12. Especially, differences in muscle activity of thoracic erector spinae, lumbar erector spinae, and lumbar multifidus muscle increased significantly on right side during pelvic left tilting ($p < 0.01$, $p < 0.01$, and $p < 0.01$, respectively) as shown in Fig. 13. Muscle activity of external oblique, lumbar erector spinae, and lumbar multifidus muscle increased on left side while thoracic erector spinae muscle only decreased on that side when pelvic right tilting as shown in Fig. 14.

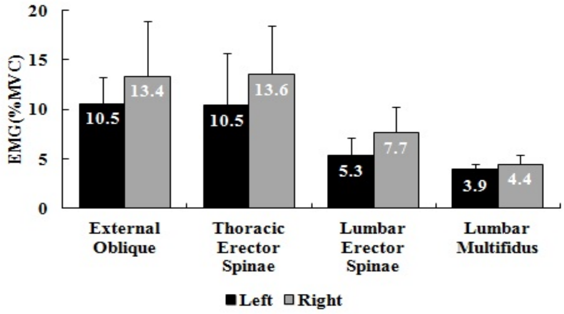

Fig.12 Muscle activity in pelvic posterior tilting

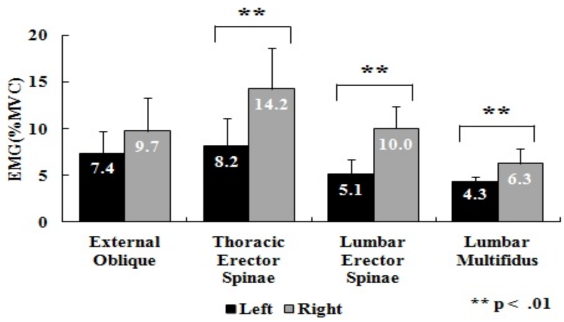

Fig.13 Muscle activity in pelvic left tilting

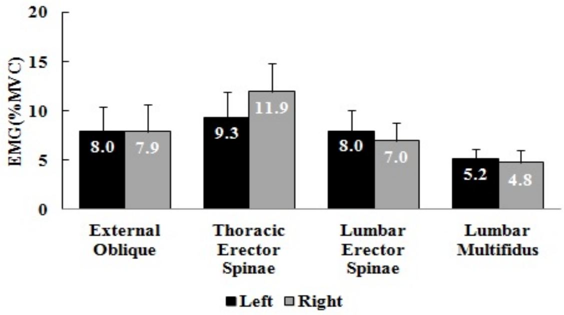

Fig.14 Muscle activity in pelvic right tilting

4 Discussion

In this study, we assessed the inclination angle, muscle activity, and pressure distribution pattern of subjects with idiopathic scoliosis in static and dynamic sitting condition.

In static sitting condition, mean inclination angle in sagittal and frontal plane was tilted to posterior and left side. Also, pressure distribution pattern of left side was higher than right side. Postural asymmetry in static sitting may affect the results of inclination angle and EMG activity in dynamic sitting condition. Differences in mean inclination angle between pelvic left and right tilting was more increased significantly than anterior and posterior tilting. Measurement of balance abnormalities in adolescents with idiopathic scoliosis is very important to prevent progression of the curve and to treat pain caused by scoliosis. From these results, we confirmed that AIS have influence on postural imbalance in frontal plane, and it cause balance control problem in standing and sitting [9].

Pressure distribution of left side more increased than right side. Unbalance sitting pressure cause pressure ulcers and continuous deformation of the spine [24]. Accordingly, postural change detection device for testing and training sitting balance consistently is needed. In this study, we used unstable board with accelerometer to detect the postural balance in sitting, and then we can ascertain the utility of this system for evaluation of postural asymmetry in patients with idiopathic scoliosis.

There was a difference in muscle activity pattern between both sides of abdominal and erector spinae muscles. Erector spinae muscles of subjects with AIS more increased on right side than left side in pelvic anterior, posterior, left tilting. Especially, thoracic erector spinae muscle on right side increased in all direction. Subjects who participated in this study has major curve defined by a Cobb angle to the right side (convex side). Previous studies demonstrated that larger muscle activity has often observed on the convex side [11, 12]. Quadrates lumborum and erector spinae muscles showed a prolonged duration of activation and the co-contraction between the spinal muscles of the convex side for stabilizing the spine [25]. AIS patients have prolonged activity of erector spine and this abnormal muscle activity cause the structural bony spinal deformity [26]. In addition, muscle activity of thoracic erector spinae, lumbar erector spinae, and lumbar multifidus muscle more increased significantly on right side than left side when pelvic posterior and left tilting. These results are associated with inclination angle and pressure distribution pattern which was tilted to posterior and left side.

5 Conclusion

We evaluated the effects of idiopathic scoliosis on postural balance, pressure distribution, and muscle activity in sitting. Inclination angle was tilted to posterior and left side in static and dynamic sitting. And, differences in mean inclination angle between pelvic left and right tilting was more increased significantly than anterior and posterior tilting. There is not big difference in pressure distribution pattern between left and right side. AIS patients showed larger muscle activity on the convex side of thoracic erector spinae, lumbar erector spinae, and lumbar multifidus muscle. And, these muscular imbalance of erector spinae muscles are associated with inclination angle and pressure distribution pattern which was tilted to posterior and left side. Consequently, we concluded idiopathic scoliosis cause postural asymmetry, unequal balance, and muscular imbalance in sitting.

This paper suggested that structure of unstable board may be utilized to assess the effect of postural and muscular imbalance caused by low back pain, scoliosis, leg length discrepancy, and pelvic asymmetry on the individual’s activities in daily life. Future research is required to compare the inclination angle and muscle activity between AIS patients and control subjects.

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