Evaluation of the dynamic trunk motion of scoliotic patients using ultrasound-based motion analysis system

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Abstract: - This study was investigated the effects of the adolescent idiopathic scoliosis on dynamic trunk motion using ultrasound-based motion analysis system. 15 subjects were participated in this study and divided into three groups according to the curve direction. Experimental procedure was divided into two sections: initial position, and left/right lateral bending position. To analyze the alteration of the trunk motion, ultrasound markers was represented the segments. There were significant differences in angle variation between left and right side during lateral bending for the scoliotic groups. In addition, angle differences between left and right side were decreased gradually according to the regions of scoliotic curvature. From these results, it was concluded that the direction and region of the abnormal lateral curvature can influence on dynamic trunk movement and postural balance. Furthermore, ultrasound-based motion analysis system can be utilized to detect asymmetrical balance and dynamic postural change of idiopathic scoliosis patients in adolescence.

Key-Words: - Adolescent idiopathic scoliosis, dynamic trunk motion, postural balance, lateral bending, ultrasound-based motion analysis system

1 Introduction

Spine plays a critical role in keeping balance and stability of the human body under both dynamic and static conditions. Irregular spinal loading distribution which is caused by deformation of the spine has been associated with excessive and progressive spinal curvature in idiopathic scoliosis. Excessive curvature of the spine in the scoliotic patients group was significantly higher than in the control group during standing and sitting [1]. Progressive curve can negatively affect physical activity in adolescent [2-3]. Curve progression of the thoracic and lumbar spine may be exacerbated caused by rapid growth during adolescence. Accordingly, numerous researches for the understanding of idiopathic scoliosis have been emphasized the importance of early detection and protection for scoliosis during adolescence [4-8]. Because, initial asymmetry due to lateral deformity of the spine leads to altered posture, asymmetrical trunk motion, and posture imbalance during standing [6], [9].

Generally, radiographic method is most widely used to assess the degree or severity of the curvature through Cobb's angle [10]. However, it provided continuous radiation exposure in patients during scoliosis measurement. In addition, standing radiography showed limitations such as inter- and intra-observer variations ranged from 3 to 9 degrees [11]. This equipment can be also only used for static posture in a fixed location. It is very important to evaluate the dynamic motion of patients with spinal deformity to identify the curve progression and provide the treatment for individual. Therefore, more accurate and reliable systems than previous x-ray system are being developed to perform long-term monitoring without radiation hazard and measurement error for evaluating and treating spinal deformity.

Especially, ultrasound-based measurement system has been used to detect movements of the upper extremities. The repeatability and reliability of this system using point marker was confirmed in pervious study [12]. Although this system is suitable for diagnosis of movement in the cervical, thoracic, and lumbar spine of patients with spine disorders [13], it has not been utilized to assess dynamic spine motion and trunk balance of patients with idiopathic scoliosis.

The purpose of this study was to investigate the effects of idiopathic scoliosis on dynamic trunk motion during lateral bending using ultrasound-based motion analysis system.

2 Method

2.1 Subjects

Fifteen adolescents were recruited from the Department of Rehabilitation Medicine of Chungnam National University Hospital in Daejeon, Republic of Korea. Subjects were divided into three sub-groups: the normal group (NG), scoliosis with left lumbar curve group (SLCG), the scoliosis with right lumbar curve group (SRCG). A posteroanterior full spine standing X-ray was conducted to calculate Cobb angle of the scoliotic patients. Subjects presenting with gait abnormalities, back pain, pelvic asymmetry greater than 1 cm, or surgical treatment for the scoliosis were excluded in this study. All participants and their parents were informed a full explanation regarding the protocol and provided written consent before their participation. The mean age, height, body weight, and Cobb angle of three groups are shown in Table 1.

Table 1. Characteristics of subjects (mean±SD)

	NG (n=5)	Scoliotic patients	
		SLCG (n=5)	SRCG (n=5)
Age (years)	15.0±1.0	13.6±1.9	14.2±2.1
Height (cm)	166.8±6.3	151.8±3.6	160.8±12.6
Body weight (kg)	63.6±6.9	44.8±6.1	53.8±17.2
BMI (kg/m^2)	23.3±1.4	19.4±1.9	20.4±3.5
Cobb angle (°)	-	17.4±3.1	13.9±8.4

2.2 Experimental setup

Dynamic trunk motion of subjects was assessed with the ultrasound-based motion analysis system CMS 20 (Zebris Medical GmbH, Isny, Germany). This system consists of 3 ultrasonic microphones (MA-XX), basic unit, and 6 ultrasonic markers (M1008), as shown in Fig. 1. Ultrasonic microphones were located behind the subject with the adjustable length, height, and angle for measuring spinal movement. These microphones are connected to the basic unit. The ultrasound markers send continuous pulses at a frequency of 40 kHz. The distance to the microphones is determined through the assessment of the running time of these pulses. Once the markers have been correctly positioned, they are then connected to the basic unit.

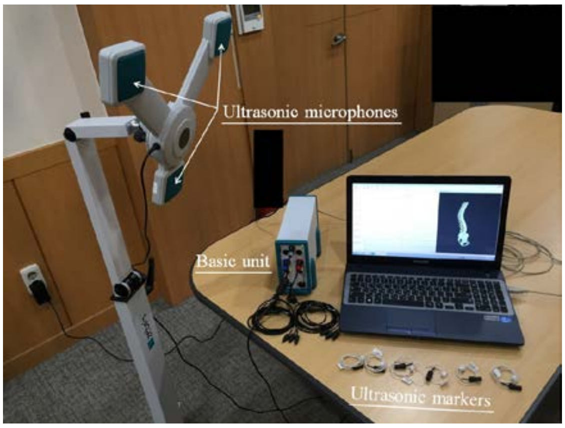

Fig. 1. Ultrasound-based motion analysis system

2.3 Procedure

Six markers were attached to the skin of the back with adhesive tape. Before attaching markers, the skin was cleaned with alcohol. Marker 1 was attached between S1 and L5 and marker 6 between C7 and T12. Following this, markers 2-5 were to be positioned at equal distance from each other, as shown in Fig. 2. For exact placement of the markers, subjects bent slightly forward when the marker was placing on. After attaching all markers, subjects were instructed to stand with upright posture. Experimental procedure was divided into two sections: initial position, and left/right lateral bending. First, in initial position, the head, shoulders, trunk, upper and lower extremities were positioned as in the standard standing position. And, second, in left/right lateral bending, subjects were asked to perform maximally left and right lateral bending of the trunk for 3 seconds, respectively. All subjects were allowed to conduct a practice all testing procedure until they become familiar with this test.

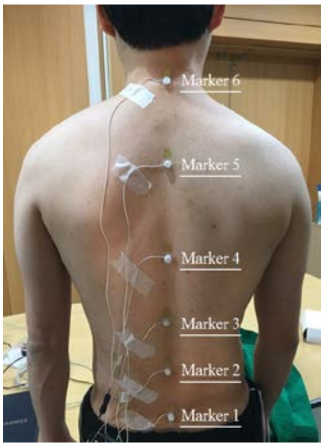

Fig. 2. Marker position

2.4 Data analysis

The alteration of the thoracic and lumbar spine alignment during lateral bending was analyzed using WinSpine software (Zebris Medical GmbH, Isny, Germany). This software calculates the angle variation according to the left and right direction during lateral movements. Angle variation was presented in lateral local mobility. It was represented the segments that are described by the markers, as shown in Fig. 3.

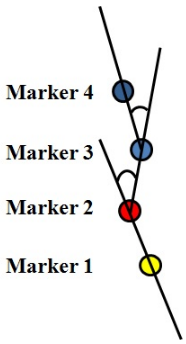

Fig. 3. Lateral local mobility calculation

Statistical analysis was performed using SPSS PASW statics 18 software (SPSS Inc, Chicago, USA). A t-test was used to examine the differences in lateral mobility between left and right side, at the $p < .05$ level.

3 Results

Differences in angle measurements between left and right side during lateral bending are presented in Fig. 4-7. As compared with lateral local mobility among NG, SLCG, and SRCG, SLCG and SRCG showed more asymmetrical lateral bending patterns than NG in all regions according to their direction of the scoliotic curve. And, angle differences of scoliotic groups between left and right side during lateral bending were decreased gradually from the region 1 to region 4. The highest measured angle on the left and right side among three groups was indicated in the region 1 for the idiopathic scoliosis group, SLCG (17.7°) and SRCG (16.7°), respectively. In addition, there were significant differences in lateral mobility between left and right lateral bending ($p < .05$). In contrast, there were no significant differences in the lateral mobility from the regions 2 to region 4.

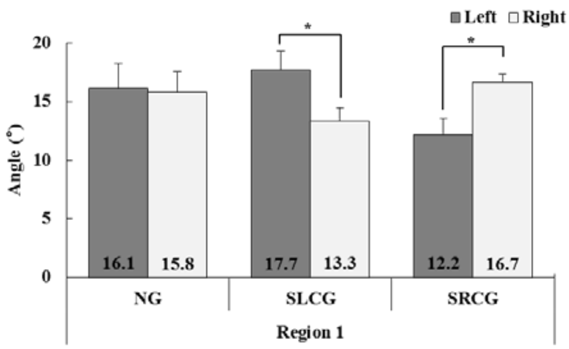

Fig. 4. Angle differences in the region 1

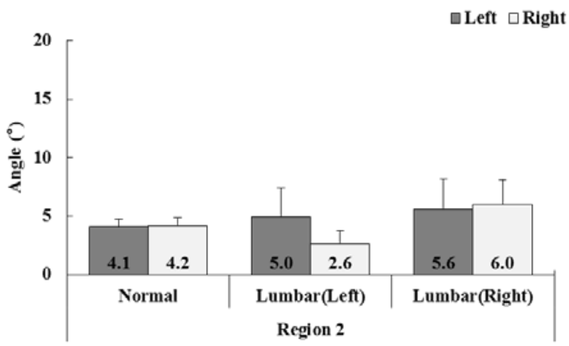

Fig. 5. Angle differences in the region 2

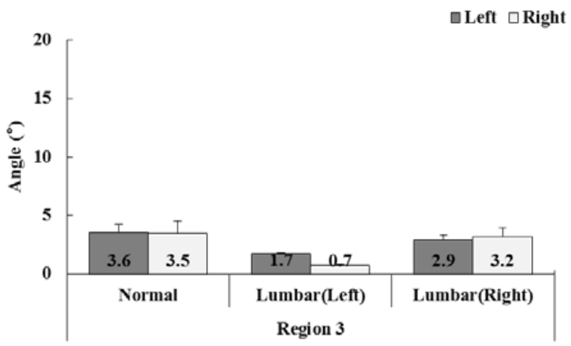

Fig. 6. Angle differences in the region 3

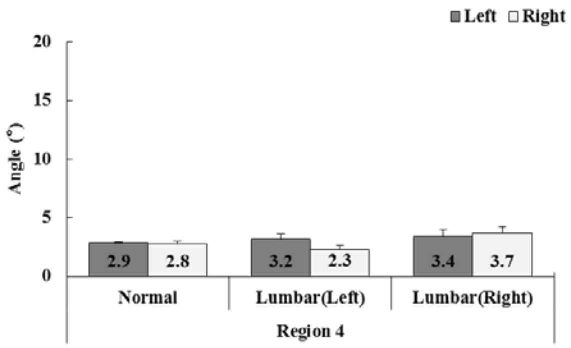

Fig. 7. Angle differences in the region 4

4 Conclusion

In this study, the effects of idiopathic scoliosis in adolescence on trunk motion during left and right lateral bending was evaluated using ultrasound-based motion analysis system.

The direction of scoliosis curve may influence directly on the postural balance of patients with idiopathic scoliosis. Previous studies reported that standing and sitting posture of the scoliotic group was more tilted asymmetrically than the control group according to the direction of the curve [14-15]. From the results of this study, we discovered tilting angle of the trunk in the scoliotic groups which were divided into two groups based on the curve direction increased with their scoliosis curve. It means that curve direction of scoliotic patients is associated with range of motion between left and right side.

Generally, scoliosis curve can occur in the thoracic spine, the lumbar spine, or both areas at the same time [16]. Accurate diagnosis for the region of scoliotic curvature is very important to evaluate the postural balance of patients and treat progression of the curve of adolescence. This study investigated the dynamic trunk motion for patients with left or right lumbar scoliosis. To evaluate the dynamic postural balance, ultrasound markers which was attached to the skin in patients with scoliosis was represented the segments, and then it was classified with 4 regions. All regions were defined as: region 1 (lumbar), region 2(thoraco/lumbar), region 3(lower thoracic), and region 4 (upper thoracic). The results showed that the highest angle difference was presented in the region 1 for the scoliosis groups compare to the normal group. In addition, angle differences between left and right side were decreased gradually from the region 1 to region 4. Subjects which were participated in this experiment have left or right lumbar curve. This indicated that the region of scoliotic curvature may affect dynamic trunk movement, and it was related to the postural balance of adolescent idiopathic scoliosis patients [17].

Furthermore, we suggested that ultrasound-based motion analysis system can be used to analyze the dynamic trunk motion for providing the information about postural balance of patients with idiopathic scoliosis.

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References:

[1] M. K. Ireneusz, P. F. Halina, S. Piotr, Z. S. Katarzyna, D. Aneta, K. Marek, R. Juozas, Analysis of the sagittal plane in standing and sitting position in girls with left lumbar idiopathic scoliosis, *Pol Ann Med*, Vol. 21, No. 1, 2013, pp. 30-34.

[2] J. W. Kouwenhoven and R. M. Castelein, The pathogenesis of adolescent idiopathic scoliosis: review of the literature, *Spine*, Vol. 33, No. 26, 2008, pp. 2898-2908.

[3] C. Fortin, D. E. Feldman, F. Cheriet, D. Gravel, F. Gauthier, H. Labelle, Reliability of a quantitative clinical posture assessment tool among persons with idiopathic scoliosis, *Physiotherapy*, Vol. 98, No. 1, 2012, pp. 64-75.

[4] S. Sahli, H. Rebai, S. Ghroubi, A. Yahia, M. Guemazi, and M. H. Elleuch, The effects of backpack load and carrying method on the balance of adolescent idiopathic scoliosis subjects, *Spine J*, Vol. 13, No. 12, 2013, pp. 1835-1842.

[5] K. S. Suk, J. H. Baek, J. O. Park, H. S. Kim, H. M. Lee, J. W. Kwon, S. H. Moon, and B. H. Lee, Postoperative quality of life in patients

with progressive neuromuscular scoliosis and their parents, *Spine J*, Vol. 15, No. 3, 2015, pp. 446-453.

[6] A. V. Bruyneel, P. Chavet, G. Bollini, and S. Mesure, Gait initiation reflects the adaptive biomechanical strategies of adolescents with idiopathic scoliosis, *Ann Phys Rehabil Med*, Vol. 53, No. 6, 2010, pp. 372-386.

[7] M. de Sèze, and E. Cugy , Pathogenesis of idiopathic scoliosis: a review, *Ann Phys Rehabil Med*, Vol. 55, No. 2, 2012, pp. 128-138.

[8] M. A. Asher, and D. C. Burton, Adolescent idiopathic scoliosis: natural history and long term treatment effects, *Scoliosis*, Vol. 1, No. 1, 2006, pp. 2.

[9] G. Gur, B. Dilek, C. Ayhan, E. Simsek, O. Aras, S. Aksoy, and Y. Yakut, Effect of spinal brace on postural control in different sensory conditions in adolescent idiopathic scoliosis: a preliminary analysis, *Gait Posture*, Vol. 41, No. 1, 2015, pp. 93-99.

[10] L. A. Stokes, and D. D. Aronsson, Computer-assisted algorithms improve reliability of King classification and Cobb angle measurement of scoliosis, *Spine*, Vol. 31, No. 6, 2006, pp. 665-670.

[11] B. S. Richards, R. M. Bernstein, C. R. D´Amato, and G. H. Thompson, Standardization of criteria for adolescent idiopathic scoliosis brace studies: SRS Committee on Bracing and Nonoperative Management, *Spine*, Vol. 30, No. 18, 2005, pp. 2068-2075.

[12] C. Fölsch, S. Schlöqel, S. Lakemeier, U. Wolf, N. Timmesfeld, and A. Skwara, “Test-retest reliability of 3D ultrasound measurements of the thoracic spine, *PM R*, Vol. 4, No. 5, 2012, pp. 335-341.

[13] S. Prange, A. Schmitz, D. Schulze-Bertelsbeck, T. Wallny, G. Schumpe, and O. Schmitt, Ultrasound topemetric measurements of thoracic kyphosis and lumbar lordosis in school children with normal and insufficient posture, *Z Orthop*, Vol. 140, No. 2, 2002, pp. 160-164.

[14] J. Y. Jung, S. K. Bok. B. O. Kim, Y. W, and J. J. Kim, Effects of the direction of the curve in adolescent idiopathic scoliosis on postural balance during sitting, *Proc. 14th Int. Conf. on Circuits, Systems, Electronics, Control & Signal Processing*, 2015, pp. 19-23.

[15] M. L. Nault, P. Allard, S. Hinse, R. Le Blanc, O. Caron, H. Labelle, and H. Sadeghi, Relationship between standing stability and body posture parameters in adolescent idiopathic scoliosis, *Spine*, Vol. 27, No. 17, 2002, pp. 1911-1917.

[16] N. M. Hebela, and P. J. Tortolani, Idiopathic scoliosis in adults: classification, indications, and treatment options, *Spine*, Vol. 21, No. 1, 2009, pp. 16-23.

[17] J. Y. Jung, E. J. Cha, K. A. Kim, Y. W, S. K. Bok, B. O. Kim, and J. J. Kim, Influence of pelvic asymmetry and idiopathic scoliosis in adolescents on postural balance during sitting, *Bio-Med Mater Eng*, Vol. 26, 2015, pp. S601-S610.