Comparison of Spinal Curvature Characteristics among Korean Population from 3D Body Scan Data

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ABSTRACT

Objective: The purpose of this paper is to investigate the difference in the horizontal distance between C7 (cervical vertebra prominens or seventh cervical vertebra) to posterior waist based on body mass index (BMI). **Background:** The analysis of the changes of spinal curvature and anthropometrical properties is very important, especially in young age. The research on human spinal shape and its characteristics are continuously increasing. Assessment of spinal curvature is generally evaluated in radiography using the Cobb method. Although radiography is the golden standard in orthopaedic practice, it carries health risk for exposure to ionizing radiation. With the technological advancement in Photonics, it is now possible to make fast and contact-free measurement by using a 3D body scanner. **Method:** 85 normal high school students (male) were participated from Gyeongi-do and Seoul in South Korea. The participants were grouped based on BMI as: underweight, normal, obese, overweight, and clinically obese. 3D whole-body scanner (Artec L™ 3D) was used to capture 3D body shapes and analyzed for the spinal curvature. From the 3D whole body scanned data, the spinal curvature measurements were extracted using the Rapidform (3D Systems Korea Corporation) software. **Results:** ANOVA on the data revealed that there were significant ($p < 0.05$) difference in the horizontal distance between C7 to posterior waist distance based on BMI. The horizontal distance between C7 to posterior waist decreased significantly ($p<0.05$) with increased BMI. **Conclusion and Application:** The decreased C7 to posterior waist distance represents increased lumbar lordosis i.e., lumbar hyperlordosis, which lead to low back pain and related disorders. The data collected from this study can provide a great help to: industries (mattress, chair, and car seat), traction therapist, researchers, digital human model construction, and so on. Also using this study's methodology it is possible to extract many human spinal characteristics which could be used for the different applications.

Keywords: Spinal curvature, cervical vertebra to posterior waist distance, 3D scanner

1. Introduction

Human spinal curvature is one the most significant spine parameters (Stokes, 1994; Vrtovec et al., 2009). The analysis of the changes of spinal curvature and anthropometrical properties, especially in young age (children and adolescents), is very vital because is affected by complex interactions between anatomical, muscular, psychological factors and this change take place very fast (Tizabi et al., 2012).

With the increasing trend of globalization, the concept of mass customization in product design is becoming an important issue. The human body measurements are necessary for designers for the development of well-fitted products such as clothing, chair, seat, bed, etc.

Assessment of spinal curvature is generally evaluated using the Cobb method. Also spinal deformity, especially adolescent idiopathic scoliosis is widely performed radiologically. Although radiography is the golden standard in orthopaedic practice, it carries health risk for exposure to ionizing radiation (Doody et al., 2000). Therefore, various non-invasive spinal curvature assessment have been developed (Krejci et al., 2012). However, these methods have not gained widespread use

in clinical practice due to the relatively low correlation between measurements (Patias et al., 2010). Traditionally, human-body dimensions are measured manually by trained personnel using dedicated instruments namely tapes, stadiometers, calipers, etc. (Norton and Olds, 2001). In the clinical setting, the goniometer is employed as a manual method to the protractor in estimating the angle of a spinal curvature (Didia et al., 2011). However, the procedure is time-consuming and requires direct contact with human subjects.

With the technological advancement in Photonics, it is now possible to make fast and contact-free measurement by using a 3D body scanner. The CAESAR (Civilian American and European Surface Anthropometry Resource) survey was the first large-scale three-dimensional (3D) anthropometric survey of civilians in the United States, Netherlands, and Italy. Nowadays, a number of 3D scanners are available on the market (example of 3D scanners Cyberware, Hamamastsu, Human Solutions), which can be adapted to a human body dimension measurement.

The research on human spinal shape and its characteristics are continuously increasing. Nicolopouios et al., (1985) and Stokes and Windisch, (2006) reported that annual spinal growth is about 15 mm per year at age 11 year and about 5 mm per year at age 16 years. Few studies have analysed these variables (age, height, weight, body mass index, gender, and spine curvature) in homogeneous sample populations during growth (Youdas et al., 2006; Kargarfard et al., 2010; Tizabi et al., 2012; Maicami et al., 2014). The purpose of this study is to construct the 3D whole-body database of Korean population for conducting a national sizing survey. The purpose of this paper was to test the horizontal distance between C7 (cervical vertebra prominens or seventh cervical vertebra) to posterior waist will differ based on body mass index (BMI).

2. Method

2.1 Subjects

In this study, 85 normal high school students (male) were participated. They were selected from Gyeongi-do and Seoul in South Korea. The participants were grouped based on BMI as: underweight, normal, obese, overweight, and clinically obese (Table 1). The participants that were investigated had no spinal column surgical history or scoliosis disorder.

Table 1. Number of participants based on BMI

	Under weight	Normal	Obese	Over weight	Clinically Obese
N=85	25	25	25	5	5

2.2 Measurement

A total of four 3D whole-body scanner (Artec L™ 3D) were used to capture 3D body shapes and analyzed for the spinal curvature. The scanner used in this study is shown in Fig. 1. The specification of the scanner is: 3D resolution (max) – 1.0 mm; 3D point accuracy (max) – 0.2 mm; dimension (H x D x W) – 353 x 114 x 70 mm. From the 3D whole body scanned data, the spinal curvature measurements were extracted using the Rapidform (3D Systems Korea Corporation) software (Fig. 2).

Figure 1. 3D whole body scanner (Artec L™)

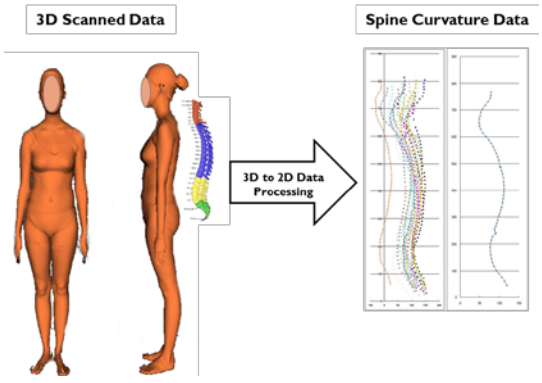

Figure 2. Spine curvature data extraction procedure

2.3 Design

ANOVA were used to investigate the main and interaction effects of the independent variables (type of BMI) on the dependent variable (spine horizontal distance). Multiple comparisons of means were performed using post hoc analysis; LSD correction was also applied. Statistical analyses were performed using SPSS (release 18, SPSS Inc., Chicago).

3. Results and Discussion

3.1 Spinal shape based on BMI

The shape of the spine shown in Fig. 3 based on different BMI. The result that the horizontal distance between C7 to posterior waist decreased significantly (p<0.05) with increased BMI. Compared with normal subjects, the obese, overweight and clinically obese subjects' horizontal distance between C7 to posterior waist were significantly (p<0.05) decreased. The decreased distance represents increased lumbar lordosis i.e., lumbar hyperlordosis, which lead to low back pain and related disorders. The LSD post-hoc test was performed to compare the C7 to posterior waist distance based on BMI as shown in Table 2.

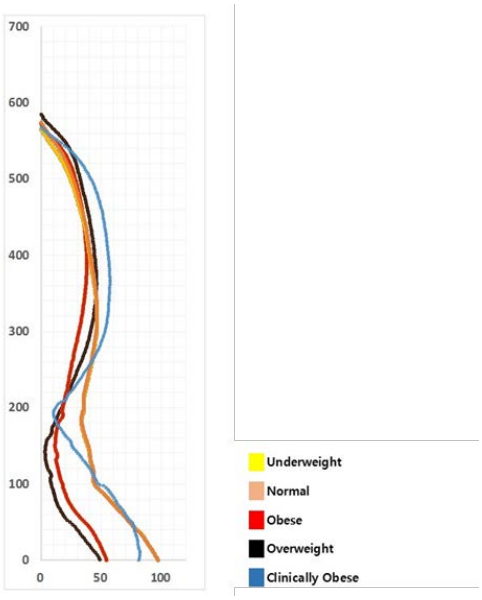

Figure 3. Spine curvature grouped based on different BMI

The present study extracted only the horizontal distance between C7 to posterior waist. In future, other spinal curvature characteristics could be extracted using the adopted methodology.

Table 2. Comparison of C7 to posterior waist distance between BMI groups using LSD post-hoc test

		Mean Difference (I-J)	Std. Error	P-value
Obese	Overweight	18.150*	6.123	.040**
	Underweight	-3.823	9.171	.017**
	Normal	-11.849	8.631	.018**
	Clinically Obese	3.493	5.286	.525
Overweight	Underweight	-21.973*	9.353	.016**
	Normal	-29.999*	9.841	.014**
	Clinically Obese	-14.657*	6.110	.043**
Underweight	Normal	-8.026	9.375	.414
	Clinically Obese	7.316	8.815	.000***
Normal	Clinically Obese	15.342	7.354	.000***

**p<0.05, ***p<0.01

4. Conclusion

This study captured the young high school male students' 3D body shapes and extracted 2D spine curvature characteristics. Based on the spinal shapes, it was clear that the horizontal distance between C7 to posterior waist decreased with increased BMI, which lead to low back pain related disorders. Also using this study's methodology it is possible to extract many human spinal characteristics which could be used for the different applications.

Acknowledgements

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