The Effect of Seat Back Inclination on Spinal Segmental Angles in Automotive Seated Postures

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I. INTRODUCTION

Investigations of spinal injury biomechanics in traffic accidents demonstrated that vertebral kinematics are important and influenced by both initial alignment of the cervical spine [1-2] and interaction between the thoracolumbar spine and the seat back [3]. Therefore, the whole spinal alignment of car occupants is one of the key factors in investigation of spinal injuries. In a previous study [4], the spinal alignment from C2 to the sacrum was investigated in an automotive seated posture, with image data acquired by an upright open magnetic resonance imaging (MRI) system. The study indicated that subjects with a kyphotic or straight cervical spine tended to have a less-kyphotic thoracolumbar spine, whereas subjects with a lordotic cervical spine tended to have a more pronounced kyphotic thoracolumbar spine. The purpose of this study was to investigate the effect of seat back angle and spinal segmental angles.

II. METHODS

Image data of the spinal column were scanned in an upright open MRI system, as described in [4]. All procedures were approved by the Ethical Committee of Shiga University of Medical Science, Hospital Universitario HM Montepríncipe, Japan Automobile Research Institute and Tokyo Institute of Technology in Japan.

Imaging Conditions and Human Subjects

Forward facing subjects were seated in a relaxed condition on a wooden seat installed in the MRI system. The seat was designed to correspond to a laboratory seat used in previous sled tests [5], and consisted of two flat plates with a seat back angle of 20° or 25° and a seat pan angle of 10° to exclude the influence of seat properties and ensure subjects were seated in a uniform posture. Subjects comprised 11 females and 12 males, ranging in age from 21 to 38 years (average age 27 years, Table I). All subjects were scanned in the seat with the seat back angle of 20°. To investigate the effect of the seat back inclination on spinal segmental angles, subjects in group No. 3 (Table I) were also scanned with the seat back angle of 25°.

Image Data Processing

The vertebral angle was defined as the angle of the mid-plane between the superior and inferior endplates of the vertebral body. The angle of C2 and the sacrum was obtained at the inferior and superior endplates, respectively. In this paper, initial findings of angular measurements are reported for the spinal segments according to Table II and Figure 1 (a). The positive angle is lordotic, whereas the negative angle is kyphotic.

TABLE I

TEST GROUPS AND SUBJECTS (AVERAGE AND SD)

Group ID	Seat back Ang. [deg]	Sex	No. of sbj.	Height [cm]	Weight [kg]
1 (Japanese)	20	Female	5	159.9 (5.3)	47.8 (6.1)
		Male	3	171.4 (0.7)	64.5 (4.9)
2 (European)	20	Female	3	162.3 (4.4)	58.3 (2.3)
		Male	4	175.2 (0.5)	77.7 (4.5)
3 (European)	20, 25	Female	3	162.7 (2.1)	58.3 (3.2)
		Male	5	175.8 (1.6)	78.0 (3.5)

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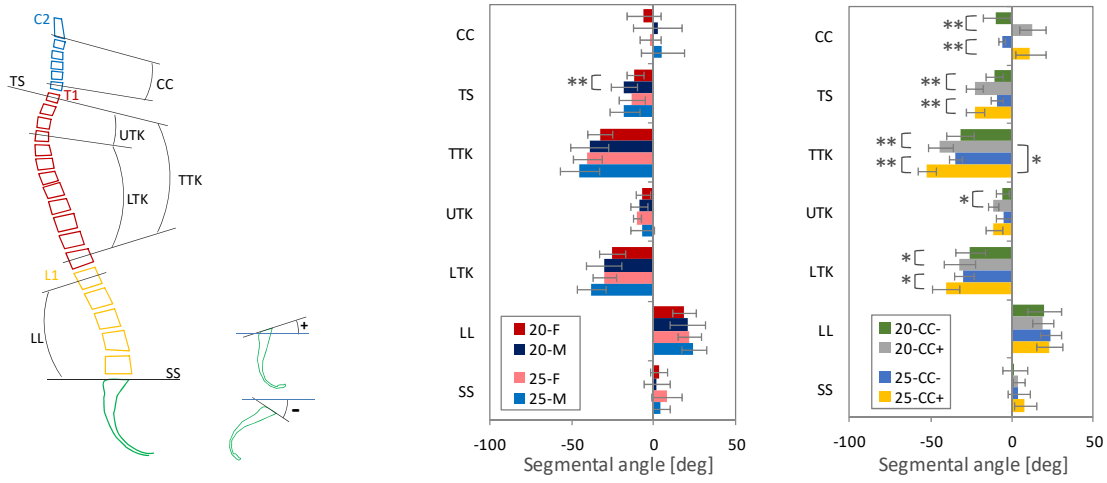
TABLE II

ANGULAR MEASUREMENTS OF THE SPINAL SEGMENTS

Angular measurements	Descriptions
Cervical curvature (CC)	Angle between C2 and C7 [6]
T1 slope (TS)	Angle of T1 from horizontal line [7-9]
Total thoracic kyphosis (TTK)	Angle between T1 and T12 [10-12]
Upper thoracic kyphosis (UTK)	Angle between T1 and T4 [10-12]
Lower thoracic kyphosis (LTK)	Angle between T4 and T12 [10-12]
Lumbar lordosis (LL)	Angle between L1 and sacrum [10-12]
Sacral slope (SS)	Angle of sacrum from the horizontal line [10-12]

III. INITIAL FINDINGS

Figure 1 illustrates a comparison of the spinal segmental angles between genders (b) and between two groups (c) classified based on the value of the cervical curvature (CC) (the cervical lordosis with a positive value of CC and the cervical kyphosis with a negative value of CC). In the comparison between genders, CC varied in both genders; negative CC (kyphotic) for nine females and six males and positive CC (lordotic) for two females and six males in the seat back angle of 20°, and negative CC for two females and two males and positive CC for one female and three males in the seat back angle of 25°. When comparing subjects with positive and negative CCs, the absolute value of the total thoracic kyphosis (TTK) with the seat back angle of 25° was significantly greater than that with the seat back angle of 20° for subjects with positive CCs. For subjects with negative CCs, the absolute value of TTK and its increment in a change of the seat back angle were smaller than for subjects with positive CCs. The T1 slope (TS) and upper thoracic kyphosis (UTK) demonstrated similar angles between the seat back angle of 20° and 25° in each group. Hence, the effect of seat back angle might be shown most largely in the lower thoracic kyphosis (LTK).



(a) (b) (c)

Fig. 1. Definitions of the angular parameters for the spinal segments (a). The average segmental angles with standard deviation in parenthesis and p-value from t-test (** < 0.05, * < 0.1), comparing male and female subjects (b) and the negative CC (CC-) and positive CC (CC+) groups (C). Figures in legends indicate the seat back angles from the vertical line.

IV. DISCUSSION

In our previous study [4], variations in the whole spinal alignment due to individual differences showed a relationship between the cervical and thoracolumbar alignment. Cervical lordosis tended to occur together with more pronounced thoracolumbar kyphosis than cervical kyphosis. Therefore, this study divided subjects to two groups based on CC values. The influence of the seat back angle on the spinal segmental angles was greater for

subjects with positive CCs than subjects with negative CCs, indicating the most prominent influence in TTK.

With negative CCs, the absolute values of TS, TTK, UTK and LTK tended to be smaller than positive CCs. This finding was consistent with previous studies [9][13-14]. Furthermore, the trends observed in a comparison between subjects with kyphotic and lordotic CC may affect differences between genders, since female subjects in this study tended to have a negative CC.

Subjects recruited in this study were selected in their twenties and thirties based on the average Japanese body sizes (159 ± 5 cm, 51 ± 6 kg for women and 172 ± 6 cm, 67± 9 kg for men) [15] for the Japanese subjects, and the mid-sized female and male in the dummy family (161.8 cm, 62.3 kg for the mid-sized female and 175.3 cm, 77.3 kg for the mid-sized male) [16] for the European subjects. All subjects were close to the average body sizes. Since the seat used in this study consisted of two flat plates, the spinal segmental angles will likely not be affected by the sitting height. Further investigations would be needed to generalize characteristics of the spine alignment in a specific group of subjects.

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