The Analysis of an Individual Difference using Human Skeletal Morphology in Automotive Seated Posture.

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I. INTRODUCTION

In order to figure out the injury mechanism in the crash accidents, finite element (FE) human body models (HBMs) are essential. Most of the HBMs developed so far are based on CT image data of a specific body size in a specific age or gender group. However, considering that the vertebral column is the one of the greatest influential factor on the human posture, the individual difference in vertebral column morphology due to age, gender, or body size, can lead to a different position/angle of each part of body including orientation of head/ribs and pelvic tilt. The variation of body posture may change the level of load applied to human body and cause different kinematics in the event of collision, which must be considered in the vehicle development. Furthermore, as those HBMs are based on CT image in supine posture, whether they really represent the correct skeletal morphology in seated posture is unknown. Depending on the posture based on which the model is created, the position/angle of each part of human body in seated posture may drastically vary. In this study, data of Japanese vertebral column morphology in seated posture is collected in terms of age, gender, and body size. Then, the distribution of each body factor is analysed and the representative geometry is selected as the morphing target for the HBM.

II. METHODS

Research Outline

In this study, the morphology image data of vertebral column in supine and seated postures is collected by using X-ray photography. From each image data, the angles are measured in the area from the cervical vertebra to the sacrum. Based on those measurements, individual difference is analysed from the perspectives of age, gender, height, and BMI. Normal distribution curve is drawn for each angle to grasp the variability range. Then, representative values are selected in each range and reflected into the HBM.

The X-ray Facility and a Method of X-raying

In order to reproduce the posture seated in an automotive driver seat, an X-ray device equipped with a seat of Mazda3 (MY2013-2016) has been fabricated. The seat was installed with its reclining and sliding functions. To measure under the same condition, the torso angle and seat surface angle were set at 24 degrees and 21.5 degrees respectively. Those devices were placed on a table, 1200mm in length, 600mm in width, and 500mm in

(a)X-ray facility (b)Seated posture (c)Supine posture

Figure 1. The X-ray facility and situations of X-raying

height (See Fig.1a). All procedures in this study were determined by Yamaguchi University and Mazda Motor

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Corporation and approved by the ethical committees of both Yamaguchi University Graduate of Medicine and Mazda Motor Corporation beforehand. X-ray images were taken using the SONIALVISION G4 SHIMADZU, a multi-functional universal R/F system at Department of Radiological Technology, Yamaguchi University Hospital. Subjects' bodies were scanned for seated and supine posture (See Fig.1b, c). For this study, the subjects without any medical history in the vertebral column, who give informed consent after explanation of the overview of the study, are subjected to X-ray photography. In this study, data of 135 subjects are planned to be collected in an unbiased way in terms of age, gender and body size. So far, 26 subjects have been X-rayed, thus this paper reports the results of analysis on data so far obtained.

Data Analysis and Development of FE-HBM

For the measurement of vertebral column, five parameters were used. Out of them, the angles for cervical spine, thoracic vertebrae, thoracolumbar spine and lumbar spine were measured between the line passing through the top plane of upper vertebral body and one passing through the bottom plane of lower vertebral body. For the sacrum, the angle between the line passing through the upper plane of sacrum and the horizontal line was measured. The details are provided below:

(1) Cervical curvature (CC): angle between C2 and C7 [1]
(2) Thoracic kyphosis (TK): angle between T5 and T12 [1]
(3) Thoracolumbar kyphosis (TLK): angle between T10 and L2 [2]
(4) Lumbar lordosis (LL): angle between L1 and L5 [1][3]
(5) Sacral slope (SS): angle between sacrum and the horizontal line [1][3]

For the vertebral angle, the positive values indicate lordosis of the cervical and lumbar spine, in addition to kyphosis of the thoracic vertebrae and the thoracolumbar spine.

For each angle, a normal distribution curve is drawn to define the variability range. Within that range, several angle values are selected as representative values. Then, multiple skeletal models reproducing those angle values are created. The skeletal part of the existing HBM is replaced with these skeletal models. The shape, size, and joint of peripheral tissues are modified by morphing technology.

III. INITIAL FINDINGS

Table I shows angles measured based on X–ray images of 26 subjects in seated posture.

Gender	Height [cm]	Weight [kg]	BMI	age	CC	TK	TLK	LL	SS (Seated)	SS(Supine)
Male	162	55	21	33	-2	13.1	12.8	-6.9	-20.3	30.6
Male	166.3	83.5	30.2	42	-4.6	7.7	12.2	3.3	-23	23.7
Male	167	110	39.4	25	-14.3	5	-7	2	-12.3	18.46
Male	168	69	24.4	38	1.8	27.4	18.1	3.9	-8	21.8
Male	170	57	19.7	36	-2.6	21.9	10.5	-7	-18	25
Male	170	60	20.8	55	5.3	23.2	16.85	2.3	-9.5	19
Male	171	64	21.89	66	12.8	24.7	4.8	-2.4	-20.4	22.6
Male	173	65	21.7	58	8.8	32.6	30.3	12.9	-13.2	28.3
Male	173	78	26	24	-10.8	10	13.85	-22.2	-26.3	24.9
Male	173	78	26.1	48	-16.1	20.5	18.6	2.6	-21.6	33.4
Male	175	70	22.9	25	-0.7	23.75	-1.7	-0.4	-27.5	38.4
Male	177	56	17.9	24	-25.8	25.5	21.5	17.4	-2.7	41
Male	177	79	25.2	50	6.6	26.8	12.4	6.7	-16.6	32.4
Male	187	72	20.6	50	-5.2	22.2	7.6	-0.9	-19.1	24.4
Female	145	47	22.3	57	-8.7	22.5	6.4	6.9	-17.6	36.5
Female	149	50	22.5	62	-17.6	23	19.2	-6.1	-19.7	29.1
Female	149	52	23.4	54	-6	22.8	1.88	8.8	-7.9	45.6
Female	151	54.5	23.9	61	-5.8	33.3	8.6	-5	-21.6	28.3
Female	151.5	49	21.35	60	7.4	27.5	14.2	-5.2	-20.5	28.1
Female	154	71	30	59	4.8	11.3	13.8	4.5	-16.5	42.6
Female	155	42	17.5	58	-5.7	27.4	10.3	-4.9	-27.2	20.7
Female	155	52	21.64	63	7.6	37.2	8.7	20.9	-9	36.7
Female	156	50	20.5	53	-24.5	28.5	19.1	-3	-23.2	29.4
Female	159	50.5	20	45	-14.8	22.5	18.3	2.3	-24.9	29.3
Female	160	51	19.9	57	7.4	22.3	8.9	-8.8	-23.8	20
Female	163.4	59.6	22.4	50	10	30	20.5	8.8	-18.2	32.6

Table I. Characteristics of the subjects and each angles

The analysis on data of 26 subjects revealed that vertebral column morphology can be classified into two types: one with lumber kyphosis and the other with lumbar lordosis. Fig.2 shows the average of each type. Since comparison between those two types shows difference in LL and SS angles, SS was focused in this time. Fig.3a

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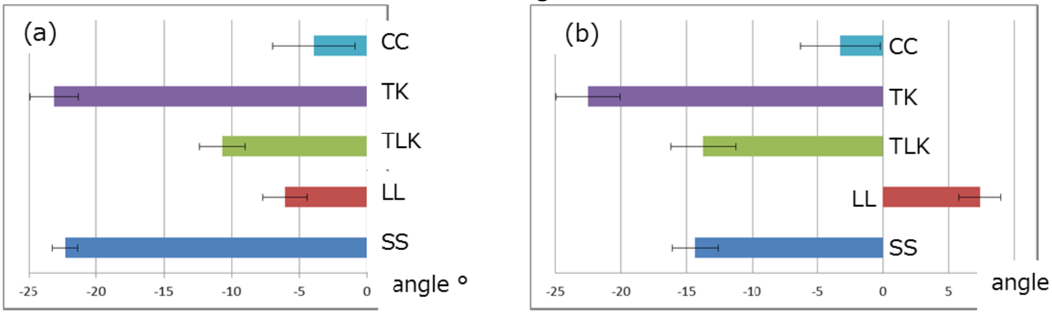
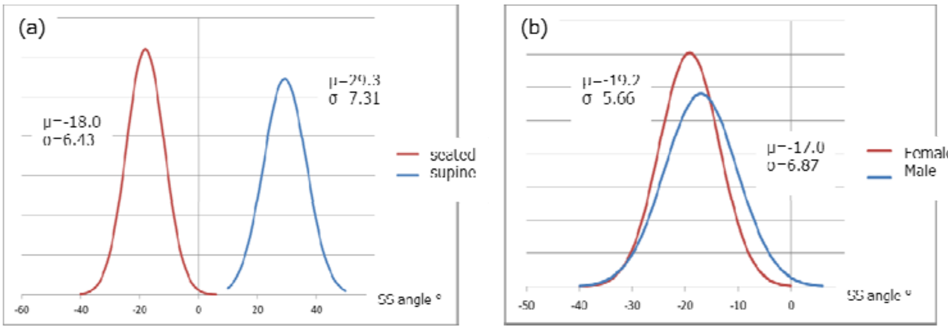
shows the normal distribution curves of SS angle in seated and supine postures. Comparison in SS angle in seated posture between male and female is shown in Fig.3b.



(a)The type of lumbar kyphosis (b)The type of lumbar lordosis

Positive angle means lordosis of the cervical and lumbar spine, kyphosis of the thoracic vertebrae and the thoracolumbar spine.

Figure 2. The average angle of two types for the vertebral column



(a)Seated and supine posture (b)Male and female

Figure 3. Normal distribution of SS angles for seated and supine posture

IV. DISCUSSION

The comparison between those two morphology types shows small difference in CC, TK, and TLK angles and significant difference in LL and SS angles (Fig.2). Thus, the morphology around lumbar region needs to be closely examined in particular, so that it will be modeled correctly. The difference in the average SS between seated and supine posture is about 50 degrees (Fig.3a). Given the fact that the morphology and angle differs depending on postures, an occupant HBM should be created based on the morphology in seated posture. On the other hand, Fig.3b shows small difference between males and females at this stage. We planned to collect more data so as to increase the accuracy and clarify the difference by age, gender and body size.

LIMITATIONS

Since this study only deals with Japanese, its relevance to other races cannot be discussed. Furthermore, since X-ray photographs are taken with subjects seated in one type of automobile seat in a short time, whether the results are applicable to long-time driving situation is not known. Out of 26 subjects, six subjects are overweight. Out of them, just three subjects are obese: at this moment of time, relevance to BMI cannot be discussed.

V. REFERENCES

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