

Analysis of Individual Variabilities in the Thickness of each Intervertebral Disc and Angle between each Lumbar Vertebra for Three Body Types in a Reclined Posture

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I. INTRODUCTION

The shape of the lumbar spine not only determines the type of skeletal alignment but also serves as a significant influencing factor for the severity of lumbar injuries and the occurrence of submarining [1,2]. Skeletal alignment is greatly influenced by the thickness of the intervertebral discs and the angles formed between the vertebral bodies. We have previously analysed individual variabilities of skeletal alignment in both upright and reclined seating postures using X-ray data [3]. In order to mimic the spine with high biofidelity in HBMs, tendencies for the geometry of the lumbar spine among three body types were investigated.

II. METHODS

In this study, X-ray imaging in both standing and seating postures was performed. An automotive seating posture was reproduced using an original X-ray facility equipped with a seat from a Mazda3 (MY 2013), its seat-back inclined at 24 (upright) or 45 (reclined) degrees [4]. X-ray images were taken using the device at Yamaguchi University Hospital. All procedures were determined by Yamaguchi University Graduate School of Medicine and Mazda Motor Co. and received prior approval from the ethical committees of both institutions (Approval No. 2024-112). The anterior thickness of each intervertebral disc and the angles between each vertebra from the twelfth thoracic vertebra to the upper of the sacrum were measured (Fig. 1a). A total of 29 subjects equivalent to AF05, AM50, and AM95 defined for Hybrid III dummy were selected from 100 asymptomatic volunteers. Those within the range of $\pm 1.65\sigma$ for height (H) and weight (W) were included (Fig. 1b).

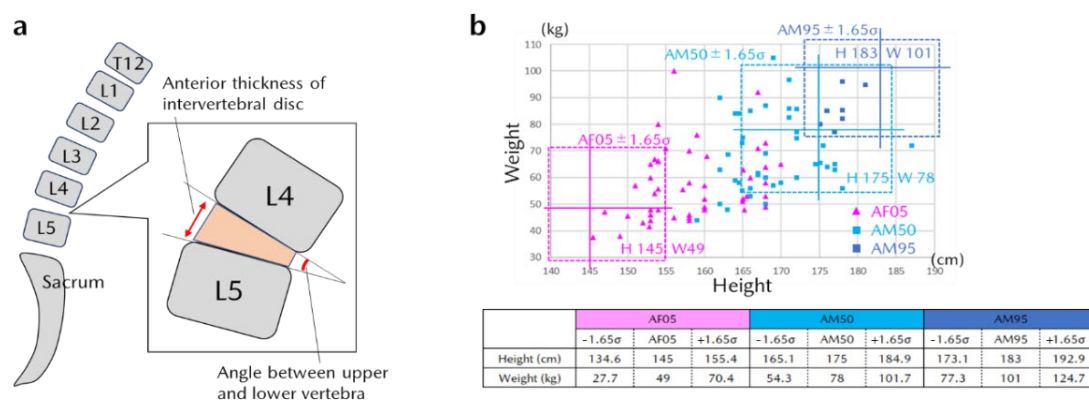


Fig. 1. a. Details of the measurement items for the lumbar spine.

b. Distribution of the subjects equivalent to AF05, AM50 and AM95 [3].

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III. INITIAL FINDINGS

The average values for anterior thickness of intervertebral discs and the angles between the upper and lower vertebrae of AF05, AM50, and AM95 subjects, are shown in Fig. 2. In AM50 and AM95, both values increased towards the lower lumbar vertebra, while the values were highest at L3-L4, showing a peak-shaped in AF05. In detail, the thickness of intervertebral disc was greatest in standing posture for all body types, decreased in upright seating posture, and showed values in reclined seating posture close to those of standing. The angles showed similar trends in both the standing and reclined postures for all body types, but the upright exhibits distinct characteristics for each as follows: the angles at L3-L4 and L5-S were largest in AF05; each angle from T12 to L5 was similar and the lowest angle (L5-S) increased sharply in AM50; the angle between L3 and L4 was smallest, showing an inverted peak-shaped in AM95.

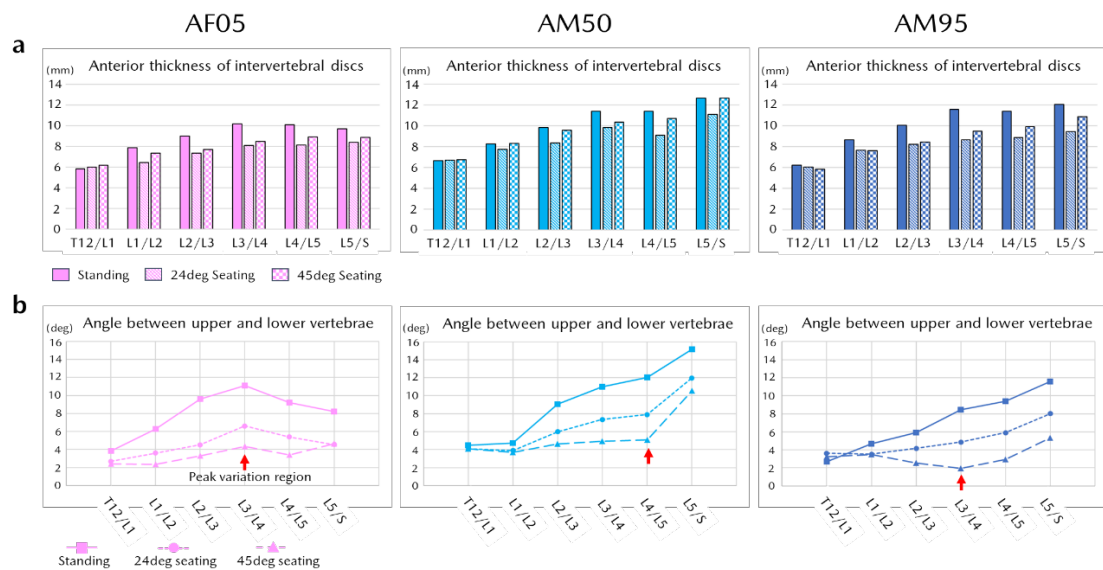


Fig. 2. **a.** The graphs of average anterior thickness of intervertebral discs for each body type. **b.** The average angles between upper and lower vertebrae from T12 to the sacrum.

IV. DISCUSSION

There have been several reports on the measurement of intervertebral disc thickness based on MRI images of M50 and analyses of individual variabilities in spinal alignment based on X-ray imaging. However, this study focused on the comparison of intervertebral disc thickness between different body types. In AF05, anterior thickness of the intervertebral discs was thinner in both standing and seating postures compared to AM50 and AM95, and the overall alignment of the lumbar spine was more compact. Previous study has reported that differences in intervertebral disc thickness and material properties affect flexion moment-angle responses of the lumbar spine [5]. The analysis results of this study suggest that difference in this thickness might be a factor causing differences in lumbar spine kinematics between body types.

Additionally, while females tended to exhibit lumbar lordosis around L3 to L4 region in all postures, a notable characteristic observed in males was a particularly pronounced lordosis from L5 to the sacrum. Since the sacrum is connected to the pelvis via the sacroiliac joints, it could be said that in males, skeletal kinematics due to posture is absorbed at the lower end of the spine.

However, it is not clear whether this phenomenon is due to differences in gender or body type, so it will be necessary to compare different body types within the same gender.

V. REFERENCES

- [1] Draper, D., *et al.*, ESV, 2019.
 [2] Shibahara, T., *et al.*, IRCOBI, 2021.
 [3] Izumiyama, T., *et al.*, IRCOBI, 2024.
 [4] Nishida, N., *et al.*, PLOS ONE, 2021.
 [5] Tushak, S., *et al.*, IRCOBI, 2024.

VI. APPENDIX

TABLE A1

THE DATA OF ANTERIOR THICKNESS OF INTERVERTEBRAL DISCS

AF05		Standing						Seating (Upright)						Seating (Reclined)					
Height	Weight	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S
147	47	5.5	6.4	8.8	9.3	8	7.4	5.2	5.8	6.1	6	4.8	6.7	6.4	6.6	7.6	7.9	6.1	8.7
150	45.5	6.6	8.3	9.5	10.2	9.3	8.9	6.7	5.8	7.3	8.4	9.8	9	6.6	7.5	7.7	9.4	10.4	11.4
152	43	5.2	7.6	9.9	10.4	12.8	10.9	7.8	8.8	9.9	10.4	11.8	8.6	7.3	8.7	9.3	9.9	11.1	9.5
152.8	41.5	6.6	8.5	7.1	10.2	7.1	7.4	5.9	7.4	7.5	8.1	6.1	5.4	7.6	7	7.4	8.8	7	6.9
153	44	6.2	7.6	8.5	11.5	11.1	11.3	6.8	6.6	5.8	7.5	9.4	10.2	5.8	6.8	7	8.2	10.7	10.2
153	46	6	8.6	8.6	8.4	9.3	9.4	5.3	6.5	7.6	8.4	8.4	9.5	5.4	8.2	8.2	9.3	11.4	8
153	48	4.2	10	10.3	8.9	6.9	9.2	6.6	7.6	8.4	8	6.6	8.9	4.2	9	7.6	7.7	3.6	4.3
153.5	54	6	7.7	9.8	10.8	11.3	11.2	5.3	6.5	7.5	10	8.3	8.4	6.6	7.3	7	8.4	9.4	8.9
154	48	5.5	6.5	7.4	10.9	12.9	10.9	5.5	4.5	7.7	7.5	8.6	8.7	6.2	6.9	8.3	8	10.9	11.2
154	55.8	6.3	7.6	9.9	10.9	11.9	10.1	4.8	4.7	5.5	6.5	7.3	8.4	5.6	5.5	6.9	7.2	8.5	9.4
Average		5.8	7.9	9.0	10.1	10.0	9.7	6.0	6.4	7.3	8.1	8.1	8.4	6.2	7.4	7.7	8.5	8.9	8.9

AM50		Standing						Seating (Upright)						Seating (Reclined)					
Height	Weight	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S
167	61.6	7.3	6.7	9	10.3	12.3	13.6	6.5	7	6.9	8.6	9.7	12.1	5.1	6.8	9.5	10.2	12.8	12.1
168	69	6.6	7.8	7.7	9.1	13.8	12.7	6.2	6.7	9.5	8.2	10.8	10.6	5.9	8.1	10.3	8.5	12.3	14.9
171	82.6	7.3	10.8	11.2	15.2	13	15.2	7.3	10.4	9.5	11	9.3	13.4	6.8	9.7	11	11.2	12.6	16.6
171	86	7.5	10.6	11.1	12.4	14.1	13.9	7.2	9.2	8.2	10	10.9	12.4	6	10.8	9.8	8.3	11.6	12.8
172	74.8	8.9	9.8	10.3	9.1	12	6.2	8.1	9.7	10.2	10.5	10.5	5.2	9.5	12.2	10.6	12.1	12.4	7.5
172	77	4.5	7.7	8.1	10	11	10.3	5.8	6.9	6.5	8.9	10.7	10.3	6.7	6.1	7.7	8.5	9	11.8
174.5	65	6.7	10.3	10.8	11.6	4.3	12.1	6.4	10.9	8.7	10.3	6.6	11	8.3	10.9	12.1	10.9	7.9	13.4
175.1	65.5	4.9	7.4	8.9	11.7	7.6	14.5	5.8	5.4	9	10.1	5.1	9.9	5.1	7.2	8.3	12	7.5	10.3
175.5	72	6.7	9	13.2	14.1	15.8	15	7	7.4	8.9	10.5	9.8	12.8	7.1	8.5	9.9	11.1	11.5	13.6
176	64	6.3	2.6	7.9	10.5	10	13.3	6.9	4	6.3	10.1	7.8	13.1	7.1	2.7	6.5	10.6	9.6	13.8
Average		6.7	8.3	9.8	11.4	11.4	12.7	6.7	7.8	8.4	9.8	9.1	11.1	6.8	8.3	9.6	10.3	10.7	12.7

AM95		Standing						Seating (Upright)						Seating (Reclined)					
Height	Weight	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S
175.1	80	5.3	7.2	9	12.3	9.5	13	6.3	7.4	7.6	8.8	9.1	9.1	5.9	7.2	6.4	10.9	7.5	10.2
176	85	6.7	8.4	10.3	11.3	13.3	13.6	6.2	8.1	8	6.3	7.3	10.3	7.3	8.6	8.3	8.3	7.9	10.5
176	85	7.2	10.9	11.4	10.2	9.2	10.6	6.9	9.1	10.1	7.1	8.1	8.5	6.7	7.9	8.5	6.9	8.8	8.8
177	77	5.1	8.1	10	11	10.3	10.7	4.6	6.8	7.2	5.5	6.4	7.5	4	6.9	6.9	8	8.3	8.1
177	77	6.7	10.8	10.8	12.6	12.1	12.3	5.3	8.5	8.3	10.9	11.4	11.4	4.8	7.8	8.5	10.3	10.7	12.7
178	82	6.8	10.8	10.9	13.6	12.5	13.2	8.5	11	10.5	14	12.1	8.8	6	11.5	9.9	12.9	13.1	12.2
178	85.2	7.6	9.6	10.9	10.9	12.5	12.5	6.7	8.2	7.7	8.8	8.6	8.8	6.7	7.3	8.8	8.6	9.9	12.8
178	96	4.4	4.6	6.5	11.5	13.2	9.2	4.3	4.7	6.2	8.2	9.4	10.5	4	4.8	6.4	9.3	13.1	12.8
181	94.7	6.3	7.3	10.7	10.6	9.9	13.2	5.7	5.1	8.4	8.3	7.3	9.9	7.1	6.4	12.1	10.1	9.8	9.9
Average		6.2	8.6	10.1	11.6	11.4	12.0	6.1	7.7	8.2	8.7	8.9	9.4	5.8	7.6	8.4	9.5	9.9	10.9

TABLE A2

THE DATA OF ANGLES BETWEEN UPPER AND LOWER VERTEBRAE

AF05		Standing						Seating (Upright)						Seating (Reclined)					
Height	Weight	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S
147	47	6.5	3.9	9.4	8.9	7	3.7	6.6	4.2	3.2	0	-1.5	5.4	7.8	6	5.3	4.9	-2.2	3.3
150	45.5	0.6	5.6	5.1	8.5	6.6	6.9	-4	1.6	2.1	4.8	5.1	1.6	-2.5	3.5	4.2	9.4	-7.9	1.4
152	43	1.3	3.5	6.6	12.3	11.9	15.3	1.4	3.8	3.5	1.6	1.9	2.8	0.5	1.6	0.4	1.4	2.6	3.4
152.8	41.5	7.1	12.1	14.4	14	11.6	3.8	4.2	5.8	9.1	17.4	8.7	4.4	3	7	10.7	14.2	9.8	5.3
153	44	0.9	0.6	2.5	8.9	9.3	11.7	2.3	2.1	0.8	-0.2	3.7	9.7	2.9	2.7	1.1	2.7	2.4	4.1
153	46	1.1	5.6	8.6	9.5	7.6	2.1	2.3	1	1.2	2.2	1.9	1.3	0.2	0.7	3.8	6.8	4.4	4.8
153	48	2.3	8.6	13.6	9.2	2.5	13.5	0.7	1.5	1.5	0.1	1.8	2.7	5.2	2.9	6.1	4.4	-4.9	5.4
153.5	54	6.9	8.9	14.4	10.3	12	12.1	2.3	2.8	7.6	10.1	8.2	2	3.1	6	6.9	8.7	11.4	5.8
154	48	5.6	5.2	9	12.1	11.7	8.4	5.2	1.4	5	3.4	2.4	11	3.6	3.9	6.2	6.5	11.4	5
154	55.8	6	8.8	12.7	17.1	11.8	4.9	3.1	-0.5	-0.9	4.1	1.7	5.5	3.2	1.9	0.5	7.2	11.3	7
Average		3.8	6.3	9.6	11.1	9.2	8.2	2.4	-0.4	3.3	4.4	3.4	4.6	2.7	3.6	4.5	6.6	5.4	4.6

AM50		Standing					Seating (Upright)					Seating (Reclined)							
Height	Weight	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S
167	61.6	4.5	4.2	11.5	7	13.9	22.7	4.9	2.4	3.7	3.3	6.5	12.8	2.1	3.9	6.1	8.2	7.5	9.7
168	69	2.3	2	5.5	11.8	17.5	15.5	3.6	1.9	2.3	5.3	8.8	14.8	3.3	1.3	0.8	7.3	10.1	20.4
171	82.6	4.7	6.2	11	17.3	16.4	13	6.4	6.9	8.6	11.8	10.2	16.5	3.2	5.8	10.1	14	15.2	14.3
171	86	2.5	6.5	7.2	10.1	9.4	18	6.9	3.8	2.1	-0.3	-0.4	3.5	2.8	5.7	5.4	3.5	4.4	9.4
172	74.8	12.3	8.3	11	9.9	12.2	12.4	7.6	8.9	7.6	7	6.6	12.6	8.2	8.8	12.9	7.7	10.5	12.3
172	77	0.1	3	5.5	9.6	10.7	15.1	-0.7	1.2	3.2	7.7	11.5	8.5	2.6	2.6	2.7	5.7	12.2	5.4
174.5	65	7.1	4.8	12	8.8	-0.5	12.6	1.8	4.7	6.2	0.7	6.8	9.2	4.7	3.2	3.9	2.3	2.1	11.9
175.1	65.5	4.6	5.4	9.3	9.7	7.6	16.1	1	5.2	5.1	5.2	-6.5	6.3	4.6	3.4	5.5	10.5	-0.5	9.8
175.5	72	3.3	5.7	12.9	15	17.8	13.9	3.8	4.6	4.4	3.8	4.6	11.1	5	5.6	5.8	7.4	8.6	12.8
176	64	3.6	1.4	4.7	10.6	15.3	12.4	5.7	-2.9	3.3	4.7	2.6	10.3	4.3	-1.4	6.8	5.9	8.8	13.7
Average		4.5	4.8	9.1	11.0	12.0	15.2	4.1	3.7	4.7	4.9	5.1	10.6	4.1	3.9	6.0	7.4	7.9	12.0

AM95		Standing					Seating (Upright)					Seating (Reclined)							
Height	Weight	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S	T12/L1	L1/2	L2/3	L3/4	L4/5	L5/S
175.1	80	3	7.7	7.7	6.3	12.7	16.2	4.5	4.3	1.8	-1.2	3.8	1.2	4.2	4.5	6.3	8.2	8.3	12.6
176	85	1.2	3.4	5.8	9	8.8	15.2	3	1.9	-0.5	-1.4	0.3	4.1	4.6	1.2	2.5	2	3	7.6
176	85	3.2	4.2	6	7.7	3.7	9.8	5.9	4.9	2.7	-0.9	2.9	5.8	4.5	5.4	4	4.9	3.1	
177	77	3.9	7.9	9.6	8.8	14	5.5	1.2	3.9	3.3	0.6	2	1.9	3.6	1.7	3.1	0.5	1.4	2.6
177	77	4.5	7.7	6.8	9.8	7.4	18.4	2.2	4.4	5.2	3.1	3.9	5.6	3.9	7.6	3.6	6.7	5.7	10.8
178	82	2.8	4.3	6	10.6	11.1	5.2	5	5.7	5.7	5.9	5.6	10.3	3.1	5.5	8	9.7	10.8	8.3
178	85	3.3	4.9	4.6	8	9	12.9	2.2	1.9	2.6	0.5	3.5	5	3.6	2.8	6.3	2.1	6.3	11.1
178	96	0.9	0.7	1.8	7.4	9.7	11.9	3.3	2.4	0.5	3.7	5.9	5.1	1.3	1.8	0.3	4.7	9.1	7.9
181	94.7	1.3	1.3	5	8.6	8.3	9.2	1.6	-2	1.9	4.1	-1.3	5.6	2.7	2	1.9	4.8	3.7	8.1
Average		2.7	4.7	5.9	8.4	9.4	11.6	3.2	3.5	2.5	1.9	3.0	5.3	3.6	3.5	4.2	4.9	5.9	8.0