Development of Spinal Geometry Corridors for Upright and Reclined Seated Postures

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I. INTRODUCTION

Virtual testing (VT) using Human Body Models (HBMs) is planned to be introduced, primarily in Euro NCAP and C-NCAP, to ensure robustness in crash safety testing. However, since all HBMs are developed based on individual CT data, unlike physical crash test dummies, many of their aspects are not standardized. Therefore, to ensure fairness in VT, both initial geometry and the response under loading must be defined. For the latter, requirements have already been established such as CP550 [1], focusing on conformity with post-mortem human subject (PMHS) corridors. But, no such requirements currently exist for the former, and initial geometry varies significantly among models. In particular, spinal initial geometry has been shown to have a significant influence on occupant kinematics and injury outcomes during collisions [2-5], making it a critical factor. We reported the results of the analysis of individual variability in spinal alignment across different postures in volunteers corresponding to 50M and 5F body sizes [6]. Based on this dataset, the objective of this study is to develop spinal geometry corridors corresponding to each body size and posture.

II. METHODS

X-ray imaging in upright and reclined seating postures was performed using an original X-ray facility equipped with an automotive seat [7]. All procedures were approved by the university's ethical review committee (Approval No. 2024-112). Measurements were obtained from 19 males and 10 females whose heights (H) and weights (W) corresponded to ±1.65σ of those defined for the Hybrid III AM50 and AF05 dummies (Fig. 1). For each subject, the coordinates of the four corners of each vertebral body from L5 to T7 were measured, and the centroids of the superior and inferior endplates of each vertebra were calculated. Using the centre of the superior surface of the sacrum as the reference point, ±1σ and ±2σ coordinates in the X and Z directions were determined from the mean values and standard deviations of the vertebral centroids. Corridor lines connecting these coordinates to the reference point were constructed.

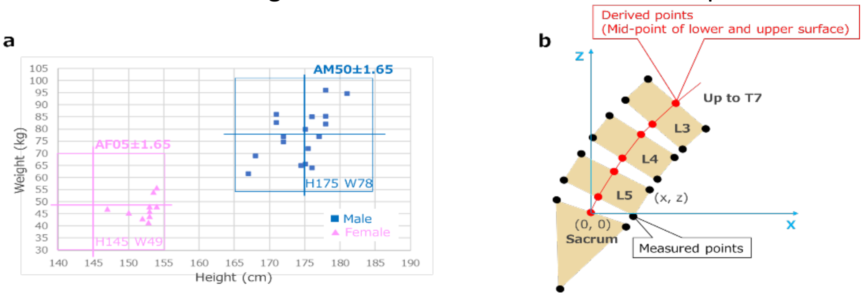

Fig. 1. **a**. Distribution of the volunteers equivalent to AM50 and AF05 [6]. **b**. Details of the measurement methods for the spine.

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III. INITIAL FINDINGS

The measurement results for each vertebra are shown in Fig. 2a. Considerable variability in spinal alignment was observed across all body sizes, with particularly large variability in the thoracic region. In upright, different lumbar spine types were identified, including lordosis, straight, and kyphosis, whereas the thoracic spine exhibited only kyphosis. By contrast, the lumbar spine consistently showed a lordotic curvature, while the thoracic spine tended to range from straight to slightly kyphosis in reclined posture. From upright to reclined, variability in the lumbar spine increased across all body sizes, whereas variability in the thoracic spine showed a decreasing trend. The constructed corridors are shown in Fig. 2b.

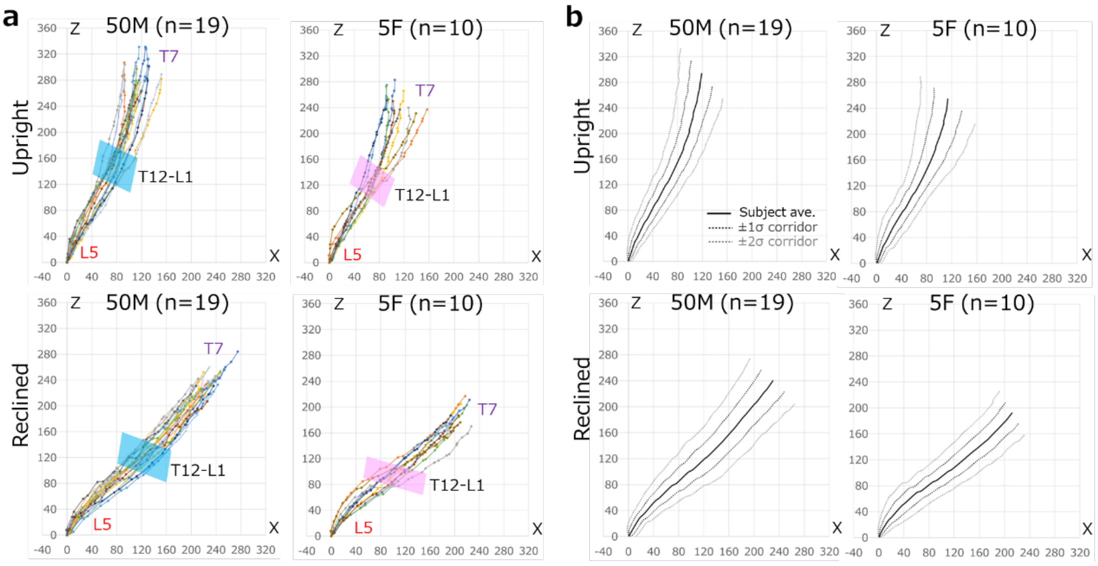

Fig. 2. **a**. The spinal alignment of all volunteers by the lines connecting the vertebral centroids. **b**. The spinal alignment corridors constructed from subject data.

IV. DISCUSSION

This study suggests that a clear and consistent definition of seated posture is critical for ensuring fair evaluations of VT using HBMs. A comparison of vertebral curvature in the L5–T7 region corresponding to 50M and 5F volunteers indicates that, as in upright, three types of lumbar alignment are present. This is presumed to be due to the relatively small influence of the seat on the lumbar spine at this seat-back angle. On the other hand, lumbar lordosis tends to be more pronounced as a result of the lumbar support in reclined posture. It was also revealed that the position of the upper body varies depending on the lumbar spine alignment type (Fig. 2a).

This study has two limitations: the volunteers were limited to Japanese individuals, only a single seat type (Mazda3 MY 2013) was used for X-ray imaging.

V. REFERENCES

[1] Euro NCAP, CP550.
[2] Draper, D., *et al., ESV,* 2019.
[3] Shibahara, T., *et al., IRCOBI,* 2021.
[4] Rieger, L., *et al., IRCOBI,* 2022.
[5] Chastain, K., *et al., Traffic Inj Prev,* 2023.
[6] Izumiyama, T., *et al., IRCOBI,* 2024.
[7] Nishida, N., *et al., PLOS ONE,* 2021.