Distribution of Anterior Iliac Wings Geometries in the Population and Comparison to Finite Element Human Body Models

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I. INTRODUCTION

The new seating options presented by automated driving have led to a growing interest in investigating reclined occupant seating positions. Optimisation of state-of-the-art restraint systems for reclined sitting positions requires an in-depth assessment of submarining, in order to reduce the risk of abdominal injuries. To this end, simulations using Finite-Element (FE) Human Body Models (HBMs) show great potential. Among other anatomic characteristics, it has been suggested that the pelvis geometry can substantially influence the occupant-belt interaction and therefore the overall occupant kinematics [1].

The available state-of-the-art FE HBM geometries are based on computed tomography (CT) scans of human individuals and are expected to show highly variable anterior iliac wing geometries. So far, their incidence in the population has not been investigated in detail. The goal of this study is to classify currently available 50th percentile FE HBM anterior iliac wing geometries within a pre-existing CT-based distribution assumed to be representative of the German population. For this, the pre-existing and already available and anonymised post-mortem (pm) CT scans were used.

II. METHODS

Study Population

Based on LMU's in-house pm CT database, a random subset of 40 female and 40 male subjects was selected for this study. Criteria included the individuals having been over 18 years of age and showing no medical history that might influence pelvis geometry. Images had to be available in high scan quality (i.e. 0.625 mm spatial resolution or higher) and without artefacts. All datasets had been anonymised before data collection. Subjects' main characteristics are shown in Table I. Assessment of HBM geometry considers 50th percentile male Total Human Body Model for Safety (THUMS) V5 and V4 and Global Human Body Model (GHBMC) V4.4 [2-4].

TABLE I

SUBJECT'S SEX, AGE AND MAIN ANTHROPOMETRIC CHARACTERISTICS (MEAN ± ONE STANDARD DEVIATION)

Sex	Body height (cm)	Body mass (kg)	BMI (kg/m^2)	Age (years)
Male	177 ± 8	79 ± 18	25 ± 5	40 ± 19
Female	164 ± 7	69 ± 14	25 ± 5	48 ± 18

3D Data Preparation and Definition of Target Values

Following cortical bone grey values, left and right ossa ilia were isolated as 3D-objects from 2D CT image stacks using image-processing software. Then, similar initial orientation was established by aligning all 3D objects and the three FE HBM iliac geometries in the anterior pelvic plane [5]. Finally, all objects' hip joint centres were translated as common local origin. The hip joint centre was defined as the midpoint of a line connecting the right and left acetabulum geometric centres. The latter was defined as the point equidistant from all nodes of the concave surface of the acetabulum geometry extracted from the FE mesh [6].

Three landmarks were defined along the anterior part of the iliac wing for the pm CT population and the HBMs in sagittal view: (1) the most anterior point of the anterior superior iliac spine (ASIS); (2) the most anterior point of the anterior inferior iliac spine (AIIS), caudal of the ASIS; (3) the most posterior point of the notch between the ASIS and AIIS. Two main target values hypothesised to be important in terms of lap-belt engagement were calculated: *ASIS_AIIS_(°)* (angle between (1), (2) and (3)); and *Depth_notch_(mm)* (length of a line dropped perpendicularly from (2) onto a direct line connecting (1) and (3)). Landmarks and measurements are schematised in Fig. 1 and Fig. 2 using THUMS V5 anterior iliac wing geometry as an example.

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III. INITIAL FINDINGS

The ASIS-AIIS angle and iliac notch depth variability across the study population are presented as boxplots in Fig. 1 and Fig. 2. The median male and female ASIS-AIIS aperture angle is 145.7 ° and 144.9 °, respectively, while the median notch depth is 7.4 mm and 7.0mm, respectively. Looking at the distributions, no significant differences between the values for males and females are apparent. Regarding the ASIS-AIIS angle, THUMS V5 iliac shape is very close to the study population median (146.0 °). The GHBMC v4.4 is located in the first quartile (137.1 °). THUMS V4 ASIS aperture angle does not occur in the study population and ranges outside the upper rim of the distribution (162.8 °). A similar observation was made regarding the anterior iliac notch depth. THUMS V5 is highly representative of 25% of the study population (7.9 mm). GHBMC's notch depth falls into the fourth quartile (8.7 mm). Again, THUMS V4's iliac shape is comparably flat and ranges outside the lower end of the distribution (3.5 mm). Few outliers occurred for individual subjects; see, for example, 83-84 in Fig. 2.

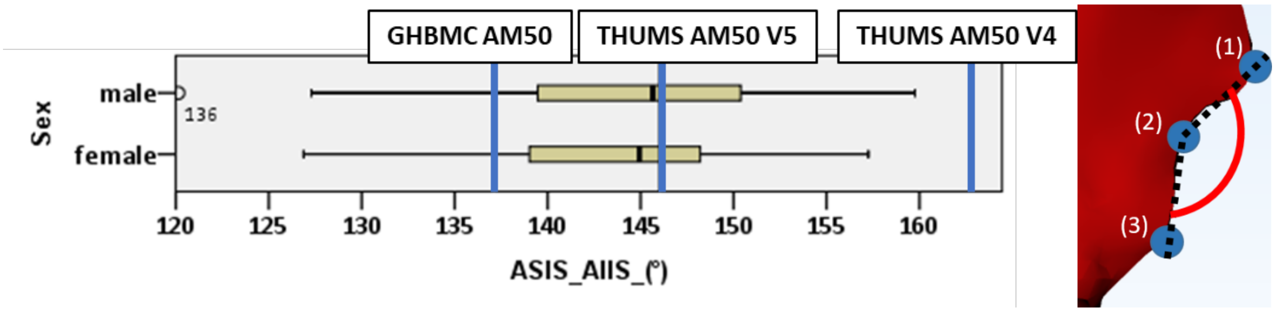

Fig. 1. ASIS-AIIS-angle (°). Left: male and female distribution (n=160); GHBMC AM50 V4.4, THUMS AM50 V4 and V5 are ranked with blue lines. Right: THUMS V5 anterior iliac wing geometry, sketch of landmarks (1)–(3) and ASIS-AIIS-angle (red).

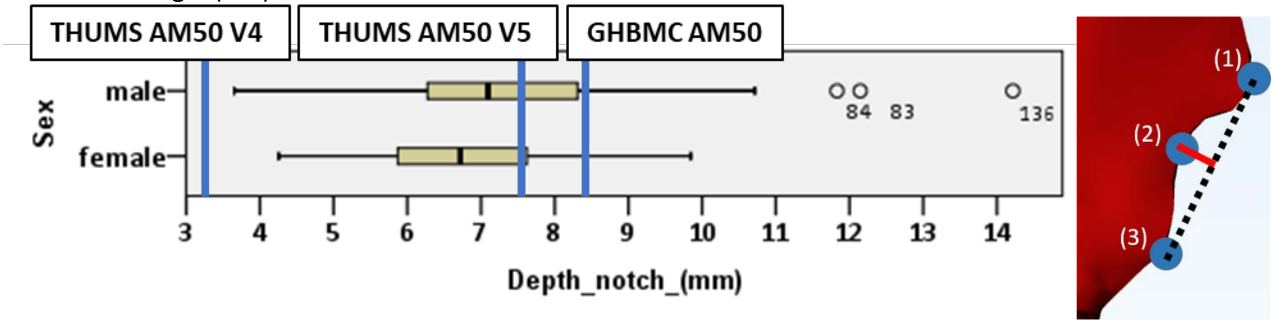

Fig. 2. Notch_depth (mm). Left: male and female distribution (n=160); GHBMC AM50 V4.4, THUMS AM50 V4 and V5 are ranked with blue lines. Right: THUMS V5 anterior iliac wing geometry, sketch of landmarks (1)–(3) and notch depth (red).

IV. DISCUSSION

This study gives an overview of the variability of the anterior iliac geometry based on 80 subjects and categorises currently available FE HBM's geometry. Neither ASIS-AIIS-angle nor iliac notch depth seem to be clearly associated with sex. Results propose THUMS V5 as the best representative for the male population's iliac geometry, while THUMS V4 appears uncommon. The latter observation is in line with the ASIS variability seen across the Japanese population [1]. The shape's contribution to lap-belt engagement and its role in submarining risk need to be investigated further in conjunction with other aspects, such as soft tissue thickness variability, initial distance and angle of the lap-belt relative to the ASIS and pelvis angle in different seated postures.

Preliminary results suggest that addressing the submarining risk with HBM geometry based on one single individual does not necessarily capture the population variability. Therefore, a selection of model geometries should be treated with caution, keeping in mind their prevalence in the population and their impact in application load cases. The available anthropometric data based on pre-existing CT-scans allow geometrical modification of existing HBMs to analyse stochastically iliac shape impact on lap-belt engagement and overall pelvis kinematics.

V. REFERENCES

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