Deriving anthropometrically-correct 5th percentile female from subject-specific female CAD model

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I. INTRODUCTION

Generating an anthropometrically-correct human body model (HBM) from CAD data available in open source projects is important for comparing responses of FE human body models with dummies. The current study focuses on development of an anthropometrically-correct 5th percentile female model from a surface model. Three-dimensional surface geometry of a female was created based on MRI data of a female human cadaver with a height of 1543mm (Visible Human Project Data: NIH, USA). The techniques involved are statistical and mechanistic in approach to achieve the desired target model.

II. METHODS

Steps undertaken to achieve the anthropometrically correct model:

1. The anthropometric status of the current female model generated from MRI/CT scans was established. The model represented the 27th percentile based on a German population.
2. 44 anthropometric dimensions, derived from measurements contained in the CAESER report [1], formed the basis for generating an anthropometrically-correct female from a surface model. Initial assessment of these dimensions identified that chest circumference under the bust was 927mm (5th %ile requirement=690mm), waist circumference was 921mm (5th %ile requirement=634mm) and shoulder breadth was 402mm (5th %ile requirement=383mm)
3. Removal of excess fat (lipid) from the body was the first major step towards model correction. The gap between exterior & interior skin was measured by slicing at various levels to estimate depth of musculature in various body regions. The exterior surface of the model was reduced radially to remove excess fat in the surface model. Laurent et al. [2] discuss the mean value of epidermis-dermis thickness based on various regions.

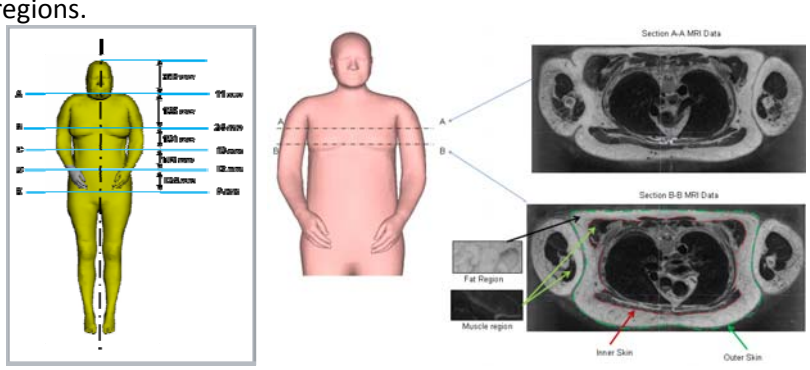

Figure 1: Distribution of fat & muscle in original CAD model

4. Movement of the shoulder complex by 40mm reduced the shoulder breadth dimensions as well as the dimensions of chest circumference below the bust. This was due to adjustment of the overall exterior surface to compensate for movement of the shoulder complex. This positioning of the shoulder complex reduced shoulder breadth to 385mm. However, the dimensions of chest circumference under the bust (843mm) & waist circumference (782mm) differed significantly from the desired requirements.

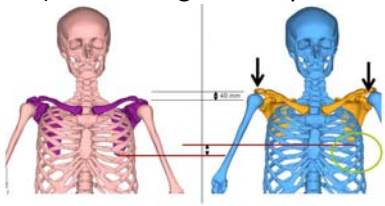

Figure 2: Shoulder complex adjustment in original CAD

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5. Further correction to the thoracic region of the model required the surface model to be aligned to a model with correct anthropometric dimensions in the thoracic region. Outer skin from RAMSIS was generated (only for the thoracic region) and was included in the THUMSD 5F model. Proper connectivity of the surface was ensured. This step ensured that the model met all anthropometric dimensions (deviation ± 2%).
6. The inner skin of THUMSD 5F was scaled (radially inwards) to meet skin thickness and musculature requirements identified in step 3. This formed the basis of linear scaling, morphing and positioning of internal organs and the ribcage. Landmarks were identified on various bones of the body, and scaling; morphing and positioning were done to ensure the same gap between internal skin and bones as in the initial surface model generated from the MRI scan.
7. The pelvic girdle is another distinct feature in the female body which was scaled due to modifications carried out in the surface model. Therefore, to ensure critical geometrical aspects were not altered, comparison was done before & after modifications with data published by Brinckmann et al. [3].

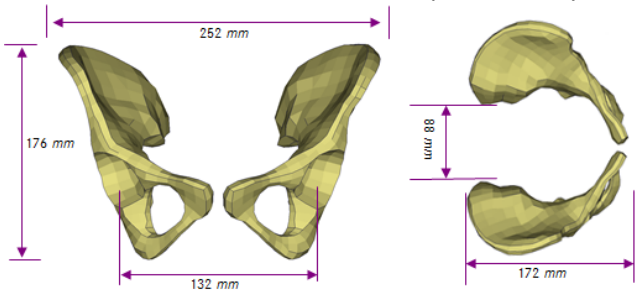
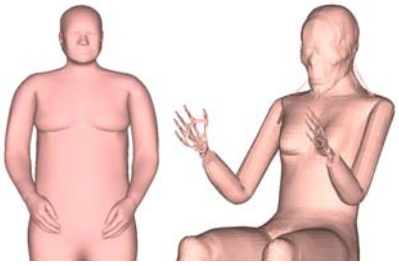


Figure 3: Scaled dimensions of original & modified pelvis

III. INITIAL FINDINGS

	Female (Before Modification)	Female (After Modification)	Brinckmann et al. (1981)
Distance between hip joints/Width of Pelvis	0.5231	0.5238	0.615
Distance between hip joints/Height of Pelvis	0.5965	0.7500	0.896
Width of Pelvis/Height of Pelvis	1.1404	1.432	1.460

Figure 4: Comparison of original & modified pelvis with parametric measurements in literature



Before After

Figure 5: Development of anthropometrically correct 5th percentile female

IV. DISCUSSION

The method addresses some aspects of conversion of data generation from a subject-specific model to a generic surface model. The positioning of skeletal parts affects geometric dimensions of the surface model. The advantage of the method is that the modified model met 44 anthropometric dimensions requirements with dimensional tolerance of ± 10%. The disadvantage of the method is that uncertainties pertaining to location of internal organs persist, but the method described above of positioning internal organs can serve as one approach in the modeling process.

V. REFERENCES

[1] Robinette et al. CAESAR Final Report. USAF, 2002.
[2] Laurent et al. *J. of Vaccine,* 2006.
[3] Brinckmann et al. *J. of Biomechanics*, 1981.