Development of Geometric Specifications for the Pelvis of a Small Female Anthropomorphic Test Device

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I. INTRODUCTION

Despite differences between the sexes in lower extremity bone shape, the shapes of female anthropomorphic test device (ATD) skeletal components have typically been established by scaling male geometry, usually based on a characteristic length [6-7]. As a result, the bones of small female ATDs may have the appropriate size (or an appropriate correct dimension), but not a representative shape. In the pelvis, sex-specific differences in shape exist that may affect the interaction of the pelvis with vehicle belts and side structures [8]. One way to account for this would be to use a single female pelvis as the ATD design target, but such an approach does not necessarily result in a pelvis that has the typical size and shape. An approach that does result in typical pelvis geometry for a particular target body size is to use a statistical shape model that is parameterised with occupant characteristics to predict the geometry. Previous attempts have been made to develop statistical pelvis models, but the studies either do not use occupant characteristics or are not for adults [1][4-5]. This study provides geometry for the small female pelvis predicted using a new statistical pelvis model [2] that is parameterised by age, body mass index (BMI) and bispinous breadth. The resulting geometry is compared to the Hybrid III small female pelvis geometry.

II. METHODS

The steps for developing statistical models of pelvis geometry are described in [2]. Bone geometry was extracted from 58 male and 77 female clinical CT scans, and a template finite element (FE) mesh was fitted to the surface geometries. Principal component analysis was then performed on the nodal coordinates and linear regression models were developed to predict the principal component scores, in turn to predict geometry as functions of age, BMI and bispinous breadth for men and women. A complete pelvis could then be reconstructed from the principal component scores.

Target geometry for the small female pelvis was predicted using a statistical model developed from only female data, with inputs of age equal to 40 years, BMI equal to 22 kg/m^2 and bispinous breadth equal to 206 mm. The latter two parameters correspond to the Anthropometry of Motor Vehicle Occupants' (AMVO) specification for the small female [7]. An age of 40 years was developed prior to the current study as the desired target, which approximates the mean age of 37 years of a female crash-involved adult occupant in the USA based on data from the National Automotive Sampling System-Crashworthiness Data System 2001-2013. The model generated using this method is referred to as the small female pelvis model (SFPM) in the subsequent text. The SFPM was made symmetric by reflecting the left side about the midline and compared to small female pelvis dimensions from AMVO [7] and the small female (5th percentile) Hybrid III ATD.

III. INITIAL FINDINGS

The SFPM surface is shown in Fig. 1. Table I gives the Euclidean distances between the landmarks on the symmetric SFPM, the small female from the AMVO study, and the small female Hybrid III. Most SFPM and AMVO dimensions are similar, except for the distance between the right and left hip centre to ischial tuberosity, which is about 10% larger in the SFPM. More information about the SFPM can be found in [3].

Fig. 1. Small female pelvis model (SFPM) geometry.

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TABLE I

COMPARISON OF SMALL FEMALE PELVIS MODEL, AMVO AND SMALL FEMALE HYBRID III DIMENSIONS

Landmark-to-Landmark Distance	Small Female Pelvis Model (mm)	Small Female AMVO (mm)	Small Female Hybrid III (mm)
Left Hip to Right Hip	160	160	160
Left ASIS to Right ASIS*	204	206	218
Left Hip to Left ASIS*	82	80	82
Right Hip to Right ASIS*	82	80	82
Left Hip to Left Ischial Tuberosity	75	69	74
Right Hip to Right Ischial Tuberosity	75	69	74

*Anterior superior iliac spine.

Fig. 2 shows a comparison with the Hybrid III small female pelvis using a least-squares alignment based on the hip joint centres, anterior superior iliac spine (ASIS) landmarks, and the most inferior landmarks on the ischial tuberosity. Differences exist in many parts of the geometry, such as the bispinous breadth (left to right ASIS) and locations of the ischial tuberosities. The shapes of the pubic rami, anterior superior pelvis, iliac wings, ischial tuberosities, and sacrum also differ between the SFPM and the small female Hybrid III pelvis.

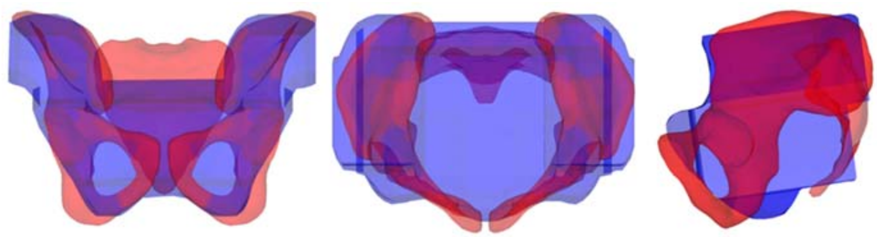

Fig. 2. Comparison of small female pelvis model (SFPM) geometry and Hybrid III geometry.

IV. DISCUSSION

Target geometry for a small female pelvis was predicted using a statistical model of pelvis shape developed from medical imaging data. The resulting surface was compared to the Hybrid III small female pelvis. The SFPM was taller than the Hybrid III pelvis, especially in the location of the ASIS landmarks. The SFPM also had different shapes for the pubic rami, ischial tuberosities, and sacrum than the Hybrid III small female pelvis, which may affect interactions with vehicle seats.

The mean age of a crash-involved adult female occupant is 37 years, based on data from the National Automotive Sampling System-Crashworthiness Data System 2001-2013. However, 40 years was used as an approximation in development of the model for this study. All landmarks for a model generated using 37 years were within 1 mm of the SFPM landmarks, indicating negligible differences.

V. ACKNOWLEDGEMENTS

This project was funded by the National Highway Traffic Safety Administration under contract number DTNH22-10-H-00288 and the National Science Foundation under award number 1300815. The authors would like to thank Humanetics for the Hybrid III small female pelvis model.

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