Upper Body Skeletal Posture of the Average Pedestrian Male from Upright High-Resolution X-ray Images – Comparison to the THUMS Pedestrian Model

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I. INTRODUCTION

Pedestrian protection in motor-vehicle accidents is a complex problem because of the multiple variables in the impact configuration that may affect the injury outcome. It is a pressing issue, however, as 22% of the fatalities worldwide are pedestrians [1]. One approach to determine pedestrian injury mechanisms, and design effective countermeasures, is to use computational human body models (CHBM), such as the Total Human Model for Safety (THUMS) [2-3]. One of the challenges for the creation of pedestrian CHBM is to determine the posture of the human body in standing position, as common medical imaging modalities require the subject to be lying down. Therefore, the goal of this study is to measure the skeletal postures of volunteer subjects imaged in standing position and to compare these postures to that of the posture of the THUMS CHBM.

II. METHODS

Creation of volunteer skeletal model

Two volunteer male subjects (V1: 1.78 m, 74 kg, 29 YO; V2: 1.76 m, 74 kg, 25 YO) were imaged with an EOS system (EOS Imaging, Paris, France) (CPP 2009-A01002-55), a low-dose X-ray imaging system that allows the acquisition of the musculoskeletal geometry of volunteer subjects in a weight-bearing posture from two high-resolution images (0.2 mm/pixel) [4]. Subject-specific models of the upper body were created by registering a statistical parametric model of the spine, of the pelvis and of the rib cage on the frontal and sagittal images obtained with EOS [5-6]. The rib cage includes the 10 most superior ribs.

THUMS pedestrian model

The pelvis, spine and rib cage meshes were extracted from the THUMS pedestrian model (V4.0, Toyota Motor Corporation, Japan) in its default posture (based on 39 YO male, scaled to 1.78 m, 74.3 kg). THUMS was created from X-ray computed tomography images.

Evaluation of the upper body posture

A qualitative assessment of the posture was performed by comparing V1, V2 and THUMS posture in the frontal and sagittal planes. A qualitative assessment was also performed by computing the antero-posterior distance between the vertical line that passes through the centre of the 5th lumbar vertebral body and the centre of the vertebral bodies in the thoracic and lumbar spine.

III. INITIAL FINDINGS

Differences could be observed between the volunteers' postures: the pelvises had different shapes, the spines were not perfectly straight in the frontal plane, and the sternums were at markedly different angles (Fig. 1). The ribs pointed downward at an angle of about 45 degrees. However, the differences between V1 and V2 were minor compared to what discriminated the volunteers' postures from THUMS posture. For THUMS, the spine was straighter, with less pronounced thoracic kyphosis and lumbar lordosis, and the ribs were more horizontal, with THUMS sternum located more superior. This results in the volunteer ribs covering a greater proportion of the spine (in V1, the anterior rib 10 ends at the level of L3, while in THUMS it ends at the level of L1). Finally, the THUMS pelvis was in retroversion (towards extended) compared to the volunteers'. The thoracic

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and lumbar spines in the volunteer subjects were indeed more 'curved' compared to THUMS (Fig. 2), and only little variations were observed between the two volunteers.

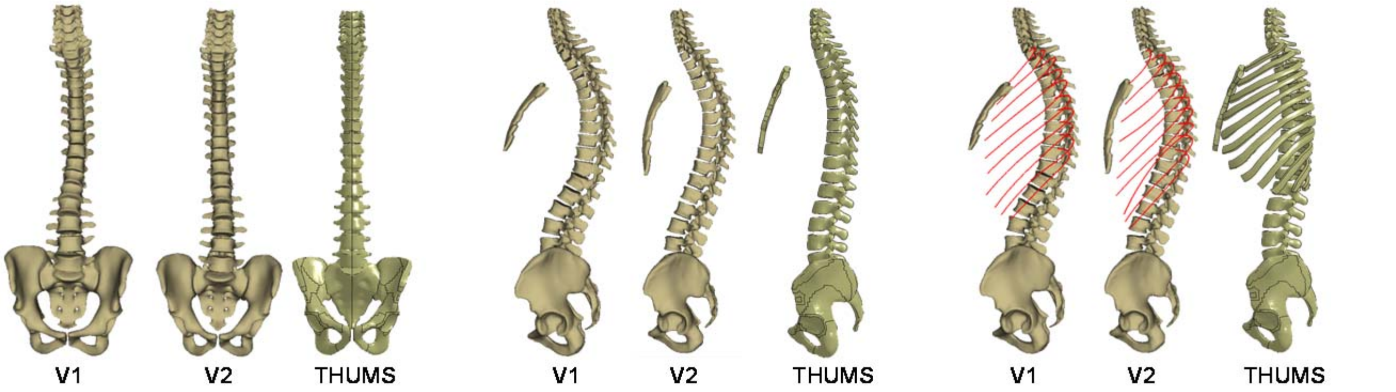

Fig. 1. Anterior and lateral views of the volunteers' and pedestrian THUMS skeleton. *Left:* anterior view, *centre*: sagittal view, and *right:* sagittal view with the ribs shown.

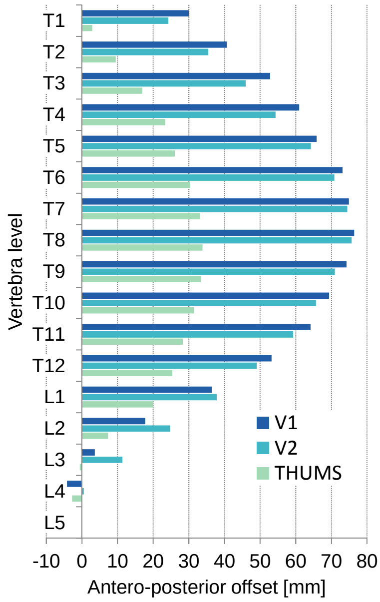

Fig. 2. Anterior-posterior offset of the thoracic and lumbar vertebrae in the volunteers and pedestrian THUMS.

IV. DISCUSSION

Large differences were found between the posture documented for the volunteers and for THUMS. However, volunteer data were collected on a very limited number of subjects, which is not sufficient to assess whether the curvature of THUMS spine is too extreme. Besides, the effect of the differences documented in this study on the pedestrian response needs to be assessed. Nevertheless, the differences in the shapes of the rib cage and the spine will likely lead to different load paths within the pedestrian upper body during an actual impact, such as the interaction of the rib cage with a vehicle hood. The next steps in the research presented here will include a more detailed evaluation of the volunteer and THUMS rib-cages geometry, as well as of the position of the lower extremity. The volunteer data presented in this communication represents a new data source for the development of human surrogates, as living subjects in a standing position can be imaged.

V. REFERENCES

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