Development and Validation of a 95th Percentile Male Pedestrian Finite Element Model

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Introduction

The pedestrian is one of the most vulnerable road users and comprise about 22 % of the road crash related fatalities in the world [1]. Among the road traffic deaths, the pedestrian fatalities are comprised 22% (World), 26% (Europe), and 22% (US) reported in 2015. Therefore, protection of pedestrians in car-to-pedestrian collisions (CPC) has recently generated increased attention with vehicle regulations (in Europe, Asia, and US) which involve three subsystem tests for pedestrian protection (leg, thigh, and head impact tests).

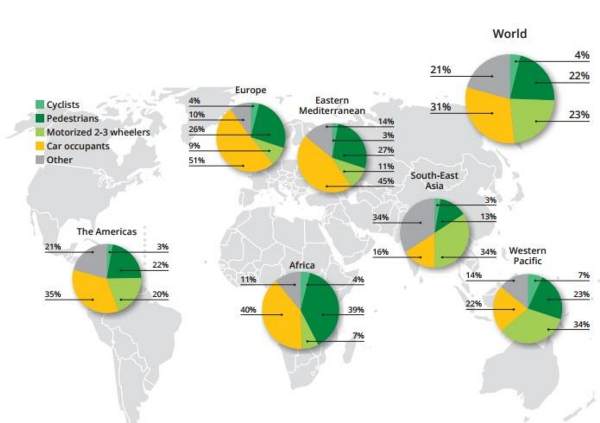

Figure 1. Road traffic deaths by type of road user

The primary goal of this study was to develop and validate a finite element model corresponding to a 95th percentile male (M95) anthropometry. This pedestrian FE model could be useful to evaluate injury biomechanics in lateral vehicle accident.

Method

A 95th percentile male pedestrian simplified (M95-PS) FE model was developed based on anthropometry of a recruited male subject (186.7 cm and 102.1 kg). The mesh of FE model was obtained by WFU-CIB group using morphing a linear scaled version of the 50th percentile male (M50) pedestrian simplified model to target geometry using a radial basis interpolation approach.

To validate the biomechanical and injury response of the M95-PS model at component level, a four-point bending test was simulated at the knee joint [2]. The upper body region of the FE model was validated under lateral and anterior-lateral blunt impact loadings at the shoulder, abdomen, thorax, and pelvis [3-4]. Then, the whole body FE model was validated in a CPC scenario (Fig. 2) [5]. All responses predicted by the M95-PS model were compared to corresponding post mortem human surrogate (PMHS) test data provided in literature.

Schematic Methodology

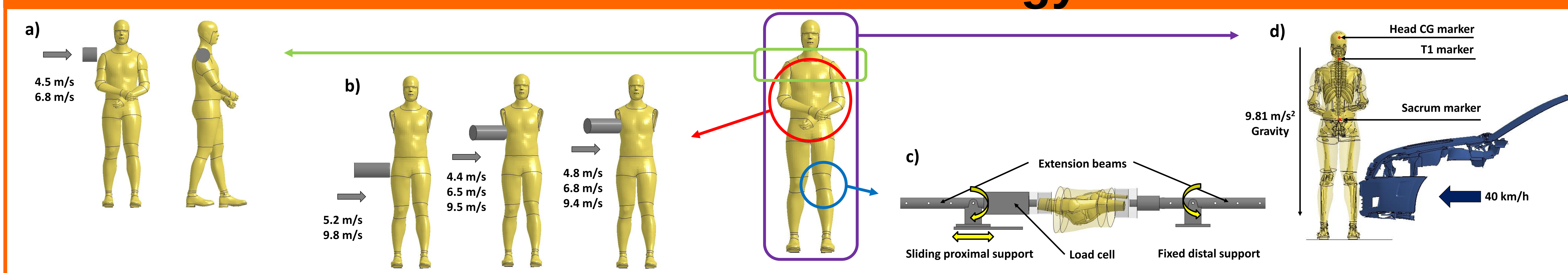

Figure 2. Schematic M95-PS model validation methods: a) Shoulder, b) upper body, c) knee joint, and d) whole body

Result

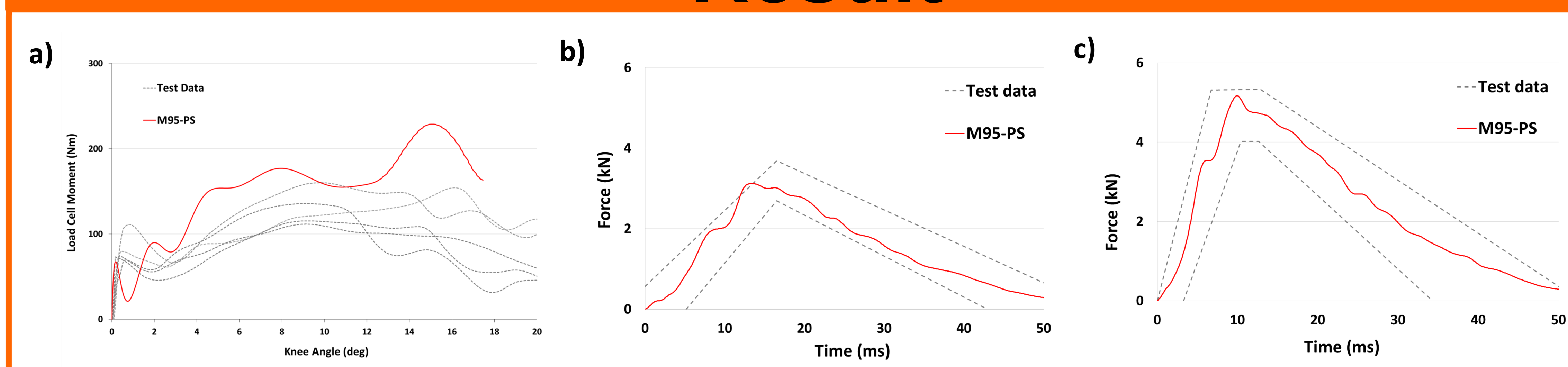

Figure 3. FE simulation vs. PMHS test: a) knee joint under bending loading, b) shoulder under lateral impact at 4.5 m/s, c) shoulder under lateral impact at 6.8 m/s

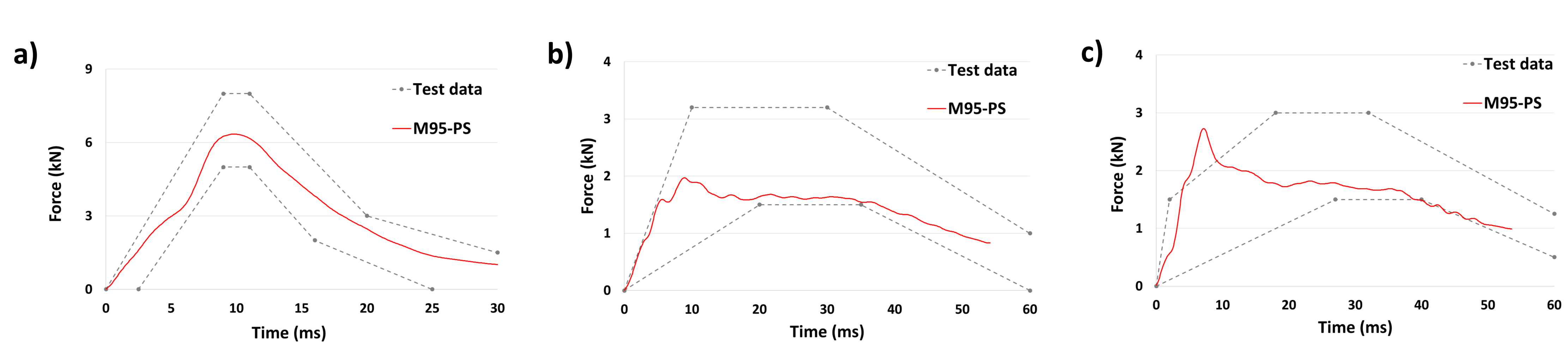

Figure 4. The time history of the upper body impact force at low velocity: FE model vs. PMHS test a) Pelvis at 5.2 m/s, b) Thorax at 4.4 m/s, c) Abdomen at 4.8 m/s

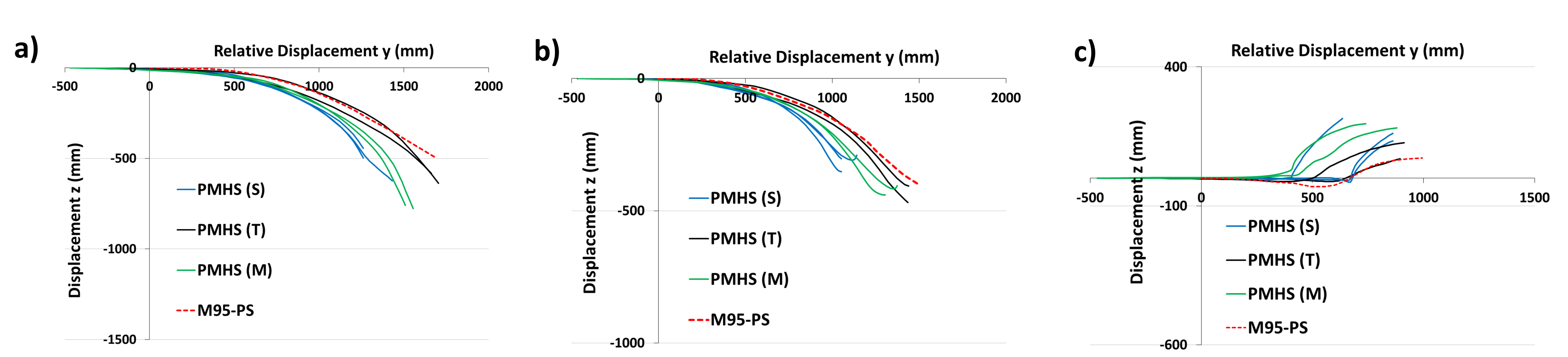

Figure 5. The M95-PS model kinematics-marker trajectories relative to the vehicle: FE model vs. PMHS test a) Head CG, b) T1, c) Sacrum, S: shorter, T: taller, M: mid-sized specimens

Discussion

- This is the first human FE model that is based on geometric data acquired from a subject with anthropometric characteristics close to those of a 95th percentile male.
- Higher stiffness than the curves corresponding to the PMHS test data scaled to 50th percentile male anthropometry can be observed in the M95-PS model response possibly due to its higher stature (Fig. 3) .
- The impact force gradients were close to the upper corridor of the PMHS test data due to the higher mass of M95-PS than that of PMHS specimens at the beginning, then a large decrease of impact force was observed possibly due to its simplified abdominal cavity (Fig. 4).
- The kinematic trajectories of head's center of gravity (CG), first thoracic vertebra (T1), and sacrum relative to the vehicle obtained from the CPC simulation were close to the trajectories recorded on tall PMHS specimens test data (Fig. 5).
- Overall, the model showed good results and promising capability to predict the injury risk of pedestrian during lateral vehicle impact.
- To better understand the overall contributions of pedestrian anthropometry and lower limb material/failure properties, a sensitivity study is needed in the future.

Acknowledgement

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Reference

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