Variation in pedestrian injury response concerning pre-impact avoidance maneuvers

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Introduction:

Previous studies on pedestrian injury biomechanics with finite element human body models (FE-HBMs) have primarily focused on a limited range of standard postures, such as standing or typical gaits. However, real-world field data suggest that pedestrians often attempt to avoid the imminent crash through various active maneuvers. The large variations in pre-collision postures can significantly impact the injury responses predicted by HBMs. Therefore, it is essential to quantitatively assess the difference through a systematic sensitivity study.

Objective:

This study aims to quantitatively evaluate the differences in whole-body injury responses between HBMs in standard and collision-avoiding poses under a 40 km/h lateral impact. The analysis focuses on the similarities and differences in six representative injury metrics between the standard and collision-avoiding pedestrian groups. The findings are expected to offer constructive insights into real-world injuries and inform the development of future testing protocols.

Methodology:

An immersed virtual-reality (VR) test platform was built to collect volunteers' active maneuvers when exposed to oncoming vehicle crashes. A total of 34 experiments involving 19 volunteers were conducted. Three major avoidance modes were found – forward avoidance, oblique stepping, and backward avoidance. The avoidance group included 15 posture-specific models (5 poses per mode), generated by a fast and biofidelic repositioning toolbox based on THUMS AM50 V4.1 pedestrian model. The standard group consisted of 7 models: a standing baseline and six gait stances representing 10%, 25%, 40%, 60%, 75%, and 90% of the gait cycle. A validated sedan model ran into each pedestrian model at 40 km/h laterally under conditions derived from the VR experiments. Six injury metrics were recorded, including head (Head Injury Criterion [HIC] and Cumulative Strain Damage Measure [CSDM], thoracic (AIS 3+ injury risk), and knee ligament forces (Medial Collateral Ligament [MCL], Posterior Cruciate Ligament [PCL], and Anterior Cruciate Ligament [ACL]). The mean ± standard deviation was used to report specific injury response ranges for both groups. The relative size of injury ranges was calculated as the ratio of the avoidance group's range to the standard group's range, while the degree of overlap was assessed by the ratio of the overlapping region to the standard range.

Preliminary Results and Current Conclusions:

Metrics with over 90% overlap include CSDM (100%), PCL force (100%), HIC (93%), and thoracic injury risk (92%). The relative range sizes are: CSDM = 1.49, PCL = 2.80, HIC = 3.74, and thoracic injury risk = 1.09. For these metrics, the standard posture group's injury response range is almost entirely encompassed within that of the avoidance group. Notably, the standard posture group shows inadequate capability to predict the ranges of head injury metrics and PCL force. In contrast, the overlaps for MCL

and ACL forces are limited at 21% and 14%, respectively, with relative range sizes of 0.62 and 1.01. Additionally, the mean MCL and PCL forces in the standard group (MCL = 2.0 kN, PCL = 1.4 kN) are higher than those in the avoidance group (MCL = 1.2 kN, PCL = 0.9 kN). This suggests that THUMS in standard postures may overestimate certain ligament forces in real-world accidents.

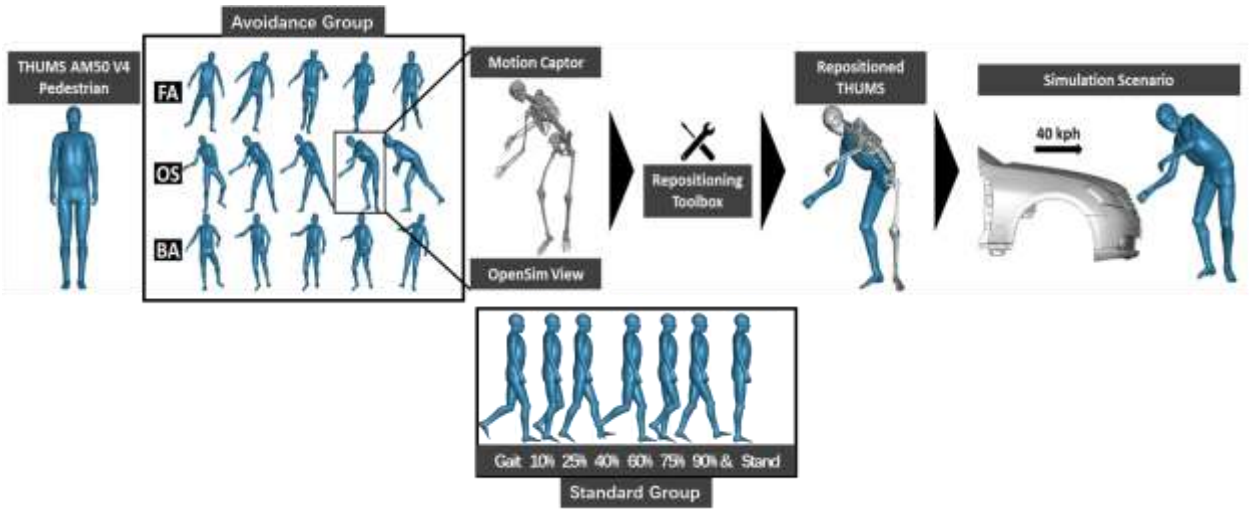

Figure 1. The overall dataflow of the current study. The baseline THUMS model is repositioned to 15 avoidance postures and 7 standard postures, respectively, and subsequent car-to-pedestrian impacts are simulated thereafter.