Predicting the Effects of Pedestrian Gait on Lower Limb Injuries

Guibing Li, Jikuang Yang, Ciaran Simms*

I. INTRODUCTION

Accident data indicate that 55% of pedestrians were walking when struck [1]. Research studies from Elliott et al. [2] and Peng et al. [3] have shown that pedestrian gait significantly influences pedestrian head impact conditions. However, the effect of pedestrian gait on lower limb kinematics and injuries has surprisingly not been analyzed. The purpose of this short communication is to investigate the effect of pedestrian gait on kinematics and on injuries to pedestrian lower limbs when struck by a sedan using finite element (FE) simulations.

II. METHODS

FE Human Body Model of Pedestrian (HBMP)

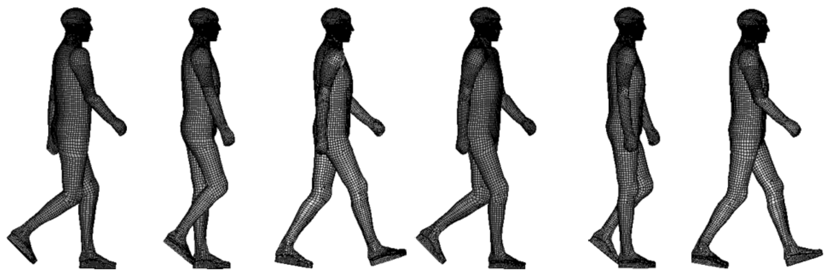
A HBMP was developed based on existing verified models of the human head, neck, lower limbs and thorax implemented in LS-DYNA, which have been individually validated and applied [4-7] by researchers at Hunan University. In this paper, these body components are assembled and validated for whole body motion for the first time by comparing the global pedestrian kinematics, trajectories of the head, T1, T8 and pelvis, and the head resultant velocity relative to the vehicle up to the instant of head contact on the vehicle for the HBM simulation, the scaled average PMHS, the PMHS corridors and the PMHS test C-3/220 from the study of Kerrigan et al [8].

FE Vehicle-front Model

An FE model of a sedan front was created for car-pedestrian collision simulations based on a full scale FE model of a sedan which was validated against frontal impact test results and used for impact simulations in a previous study [9].

Simulation Setup

The HBMP was configured in six gait cycle stances based on a previous study [10] and used to assess the influence of pedestrian gait on lower limb kinematics and injuries. The left leg was the struck leg for all simulations. As shown in Figure 1, in the 10%, 40%, 60% and 90% stances from [10], the legs do not overlap in the sagittal plane. However, for the 25% and 75% stances from [10], the lower legs are overlapped in the sagittal plane. For the 10% - 40% stances, the struck leg stands on the ground. For the 60% - 90% stances, the struck leg is in swing. Based on the above six pedestrian lower limb configurations and using the FE vehicle front model, vehicle-to-pedestrian simulations were developed. The vehicle impact speed was chosen as 40km/h. Only lateral impact was analyzed in the current study.



gait-10% gait-25% gait-40% gait-60% gait-75% gait-90%

Figure 1 Gait cycle stances for pedestrian gait study (the struck leg is the left leg)

III. INITIAL FINDINGS

The global pedestrian kinematics for the simulation and the cadaver test are compared in Figure 2. Overall, the finite element kinematics match those of cadaver C-3/220 [8] well in the phases of motion. The predicted tibia and knee ligament fractures in the struck leg are summarized in Table 1. The predicted knee shearing displacement and bending angle for different pedestrian gait stances are compared in Figure 3. The leg has a higher fracture frequency when the struck leg is in the stance position compared to when it is in the swing phase. The injury risk to a pedestrian's lower leg is lowest when the gait stance at impact is the struck leg lagging and in swing.

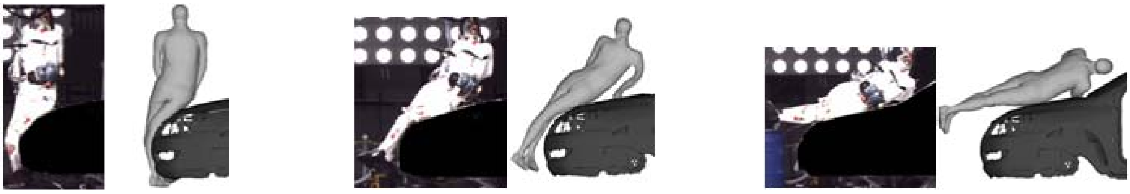


Figure 2 Comparison of pedestrian kinematics: HBM versus cadaver test C-3/220 [8]

Table 1 Tibia, fibula and knee injuries in struck leg

Gait cycle position (%)	10%	25%	40%	60%	75%	90%	× Tibia fracture
Sedan-to-pedestrian	×	×	○	□	□	□	○Knee ligament fracture □ No fracture

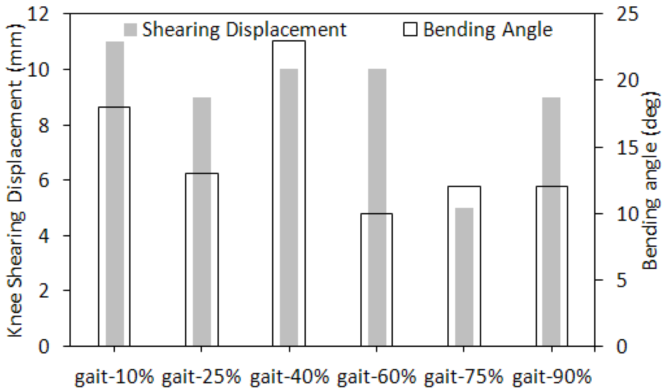


Figure 3 Comparison of maximum knee shearing displacement and bending angle in different gait stances

IV. DISCUSSION

The HBMP shows a good correlation with PMHS test kinematics and shows good agreements in lower limb injuries with real world accidents. It is thus suitable for the purpose of vehicle-to-pedestrian collision simulation to assess whole body kinematics and lower limb injuries.

Since the predicted leg injuries are highly dependent on the initial gait position, designing of safe car fronts for a single leg position may not result in significant improvements in accident cases where a broad range of initial gait positions can be expected.

V. REFERENCES

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Guibing Li is PhD student in Bioemechanics at Trinity College Dublin in Ireland. Jikuang Yang is Prof. of Biomechanics in the Department of Applied Mechanics at Chalmers University of Technology in Sweden (Tel: +46 31 7723656, fax: +46 31 7723690, email: jikuang.yang@chalmers.se). Ciaran Simms is Prof. of Biomechanics in the Department of Mechanical and Manufacturing Engineering at Trinity College Dublin in Ireland.