Influence of Posture Adjustment Methods for Human Body Models on Injury Prediction

Tatsunori Ando, Yuichi Kitagawa and Andre Eggers

I. INTRODUCTION

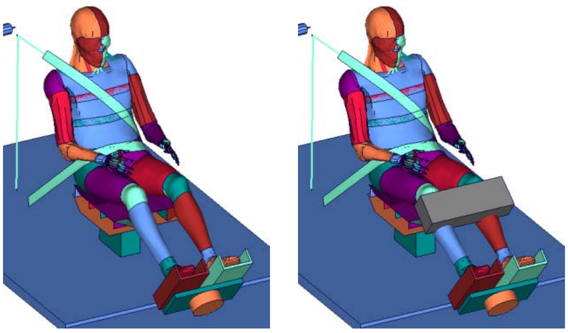
Human body models (HBMs) are meanwhile widely used to simulate occupant injuries in vehicle collisions. In most occupant models, the initial geometry assumes the standard driving posture. Users need to change the geometry to investigate various postures. The occupant posture is usually specified by body landmarks such as H-point, head, hands, feet and the body parts angles of the head, torso and extremities. Several methods are proposed to adjust the posture of HBMs, and the order of adjustment is arbitrary. It is possible that the resulting geometries of internal parts such as the vertebrae vary between methods even if the landmark points and body parts angles are identical. The study objective is to investigate the influence of posture adjustment methods for HBMs on occupant injury prediction in vehicle collision simulations. The study focuses on rib fracture risk which is a common research interest in occupant protection.

II. METHODS

A generic buck model, developed in a previous project [1], was used to imitate a vehicle cabin. THUMS-TUC V201801_Beta [2] was used to represent the occupant. First, the occupant model was positioned at the target H-point. Then the posture was adjusted so that the torso angle became the target value. Two methods were examined in this study. Method 1 was to rotate the entire model around the H-point to reach the target torso angle then to adjust the rest of the body. Method 2 was to move T1, knee and ankle at the same time translationally in simulation to reach the target torso angle, femur angle and tibia angle with the H-point fixed. The spine geometry changed in the latter case. A crash pulse was applied to the entire model to simulate a frontal collision at 35 kph. Simulations were conducted without and with a knee bolster as used in [3]. Table I shows the simulation matrix. Fig. 1 shows the buck models with and without knee bolster. A rib strain-based probabilistic risk prediction method [4], was used to predict NFR3+ rib fracture risk.

TABLE I
SIMULATION MATRIX

Case#	Adjustment method	Knee bolster	Belt type	Load Limiter
1	Method 1	No	Three-point seat belt	Medium
2	Method 2			
3	Method 1	Yes		
4	Method 2			



Without knee bolster With knee bolster

Fig. 1. Sled test configuration

III. INITIAL FINDINGS

Table II shows the description of angular measurements of body part angles. Fig. 2 shows the definition of body part angles. Table II compares the angles after positioning between two methods. Note that the pelvis angle in Method 1 was larger than that in Method 2, while the thoracic spine angle was smaller in Method 1. Fig. 3 compares the rib fracture risks among the cases. The risk in Case 1 and 2 were 54 % and 37 %, respectively. Fig. 4 plots the lap belt force and the pelvis forward displacement. The maximum pelvis forward displacement in

T. Ando (e-mail: tatsunori_ando@mail.toyota.co.jp; tel: +81-565-94-2298) is Engineer in Advanced Vehicle Engineering Development Div. and Y. Kitagawa, PhD, is Chief Professional Engineer, both at Toyota, Japan. A. Eggers, PhD, is Researcher at the Federal Highway Research Institute (BASt), Germany.

Case 1 and 2 were 147 mm and 137 mm, respectively. In Cases 3 and 4, with knee bolster, the rib fracture risks were relatively low. The maximum pelvis forward displacements were also smaller than those without knee bolster.

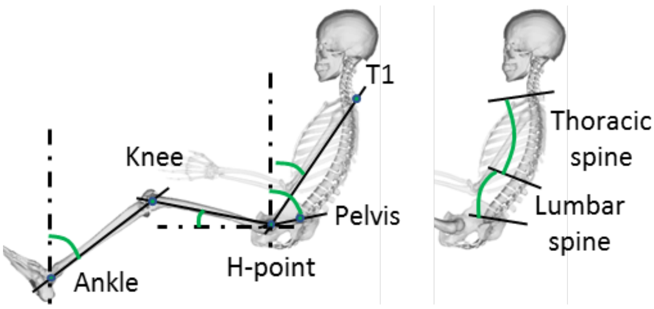


Fig. 2. Definition of body part angles

TABLE II
BODY PART ANGLES AFTER POSITIONING

Angle	Method 1 [deg]	Method 2 [deg]
Torso	34	34
Pelvis	78	72
Femur	11	11
Tibia	54	54
Thoracic Spine	47	54
Lumbar Spine	46	45

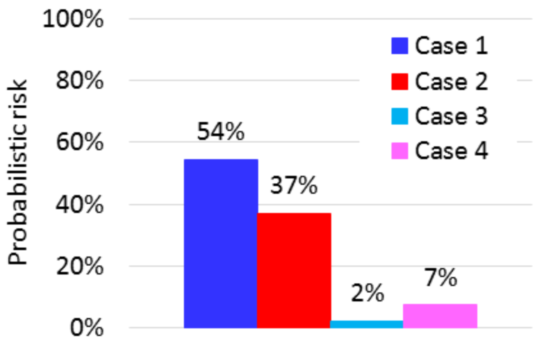


Fig. 3. Probabilistic risk of rib fracture (NFR3+)

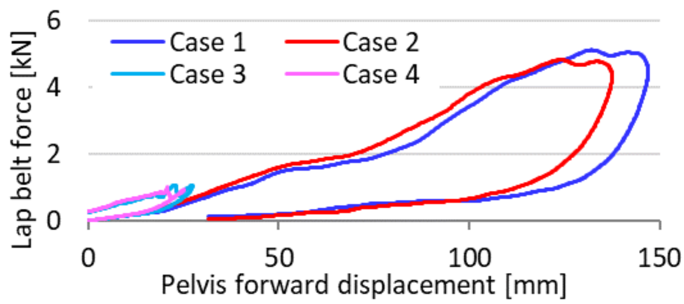


Fig. 4. Comparison of pelvis engagement

IV. DISCUSSION

It was considered that the large pelvis angle after positioning in Case 1 allowed large pelvis forward displacement during the collision compared to that in Case 2. In Method 1, the pelvis angle was simply raised when rotating the torso. While in Method 2, the increase of pelvis angle was relatively small because it was indirectly raised through the spine when T1 was moved. That resulted in the difference of 6 degrees in pelvis angle as shown in Table II. The more the pelvis angle grew, the less the pelvis was engaged with the lap belt. The large pelvis displacement in Case 1, as shown in Fig. 4, actually indicates the less engagement. The less pelvis engagement required compensation by the restraint of the upper body. That generated chest deflection and resulted in high rib fracture risk. This is the mechanism considered based on the results without knee bolster (Cases 1 and 2). The difference was not notable in the cases with knee bolster (Cases 3 and 4). The pelvis forward displacement was mostly stopped by knee bolster. The difference in the pelvis angle after positioning did not influence the pelvis engagement much. As a result, there was not significant difference in rib fracture risk between the two adjustment methods. The study results suggest two points. First, the posture adjustment needs to be conducted targeting both torso angle and pelvis angle. Secondly, the influence of the pelvis angle after positioning cannot be negligible when the pelvis engagement with the lap belt is dominant such as the frontal collision case without knee bolster. It is recommended to specify multiple internal target references along the spine in order to assure comparable injury prediction results using HBMs.

V. REFERENCES

[1] Eggers, A., Ott, J., et al. , ESV, 2017
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[4] Forman, J., et al., AAAM, 2012