

Analysis of Rearward Pelvic Rotation in Human Body Model during Frontal Impact

Toshiharu Azuma¹⁾ Yuqing Zhao¹⁾ Koji Mizuno¹⁾ Kei Nagasaka²⁾ Takahiro Suzuki²⁾ Idemitsu Masuda²⁾

*1) Nagoya University, Graduate School of Engineering
Furo-cho, Chikusa-ku, Nagoya, 464-8603, Japan (E-mail: azuma.toshiharu.g9@s.mail.nagoya-u.ac.jp)*

*2) Suzuki Motor Corporation
300 Takatsuka-cho, Chuo-ku, Hamamatsu, Shizuoka, 432-8611, Japan*

KEY WORDS: Safety, Anthropomorphic dummy, Injury mechanism, Human body model, Submarining [C1]

In frontal impacts, the lap belt engages the anterior edge of the ilium to restrain the forward movement of the occupant. However, particularly in rear seats, submarining can occur where the belt slips off the Anterior Superior Iliac Spine (ASIS) and intrudes into the abdominal soft tissue. This is triggered by the combined effects of the forward displacement and the rearward rotation of the pelvis, when the relative angle between the pelvis and the lap belt exceeds a critical value.

In this study, we developed a dynamic analysis method for the pelvis using the finite element method and applied it to sled test simulations using a human body model (THUMS). By calculating all loads applied to the pelvis during a collision and quantifying the moments around its center of gravity, we analyzed the pelvic rotation mechanism from a mechanical perspective.

Assuming the pelvis as a rigid body, we described its rotational motion using Euler's equations of motion. We defined the velocity of the center of gravity, angular velocity, mass, and principal moments of inertia, and formulated the equations of motion from the forces applied at each point and the resulting moments around the center of gravity. By integrating this mathematical model with the THUMS analysis results, we quantitatively evaluated how external forces from the lap belt and seat contribute to the complex pelvic motion.

Results showed that lap belt tension compressed the anterior edge of the ilium, and because its line of action passes above the center of gravity, it induces rearward pelvic rotation. Conversely, when the lower abdominal soft tissue is sufficiently thick, it compresses the pubis, generating a strong forward rotational moment that suppresses the rearward rotation. Furthermore, the reaction force generated by the ischium and coccyx sinking into the seat cushion is crucial in preventing both the forward displacement and rearward rotation of the pelvis.

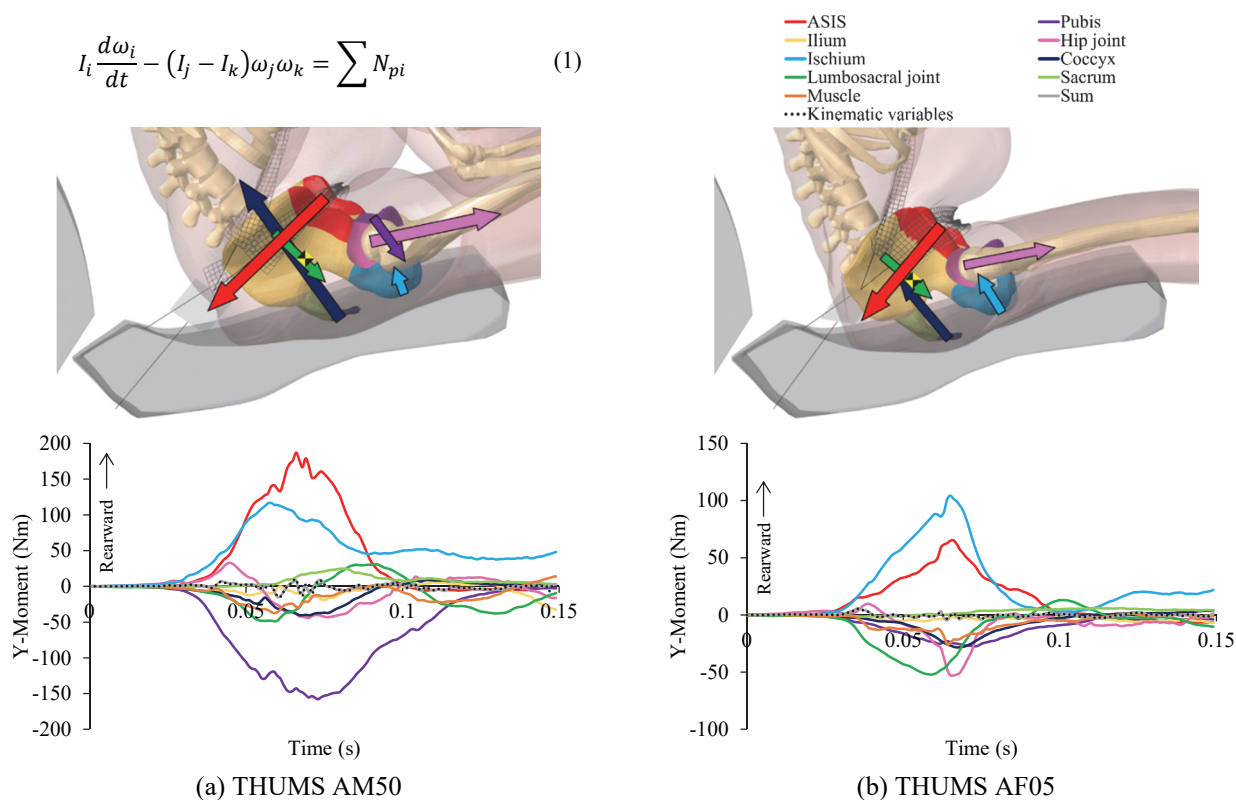


Fig. 1 Force vectors and moments acting on pelvis