Eng, vol.7, no.2, pp.61-1-61-18, February, 2026.

Effect of Varying Child Restraint System Seatback Angle on Spinal Loading of 1.5 YO and 3 YO PIPER Human Body Models in Frontal Impacts

S. Tushak; M. Valdano; J. Kerrigan; F.J. López Valdés

Abstract-

This computational study examined how variations in the seatback angle of two generic child restraint systems (CRSs) affect spinal loading in young occupants (1.5 YO and 3 YO) during frontal impacts, performed according to the specifications included in UNECE R129. CRS seatback angle dictates torso recline, which in turn influences head, chest, and spine kinematics and loading. While manufacturers typically recommend 30–45° for rear-facing CRSs and an upright position for forward-facing CRSs, little is known about the biomechanical implications of deviating from these guidelines. Using PIPER human body models representing a 1.5-year-old in a rear-facing CRS and a 3-year-old in a forward-facing CRS, simulations were performed under UN-R129 frontal impact conditions. The seatbacks were rotated 5° and 10° more upright or reclined relative to the nominal angle, with occupants restrained by a five-point harness and CRSs secured with ISOFIX, top tether, or three-point belt. The results showed that reclined configurations generally increased the predictions of spinal loading (forces and/or moments) given by the PIPER model, while nominal or more upright angles reduced loads, particularly in the lumbar spine of the 3-year-old model. Overall, the study highlights how computational tools can guide CRS design improvements to optimize spinal protection and enhance child safety beyond current regulatory requirements.

Index Terms- child occupant; forward-facing; rear-facing; seatback angle; cervical spine; lumbar spine; PIPER

Citation:
Tushak, S.; Valdano, M.; Kerrigan, J.; López-Valdés, F.J. "Effect of Varying Child Restraint System Seatback Angle on Spinal Loading of 1.5 YO and 3 YO PIPER

Human Body Models in Frontal Impacts", Eng, vol.7, no.2, pp.61-1-61-18, February, 2026.