

Child Occupant Protection in Buses and Coaches: A Parametric Study of Restraint Systems in Frontal Crashes

M. Valdano; S. Roka; O. Martínez; F.J. López Valdés

Abstract-

Objective:The newly approved UN Regulation No. 170 addresses the proper protection of children in buses and coaches. This study aims to evaluate the head kinematics and spinal loads of 3-and 6-year-old child human body models with and without a child restraint system (CRS) in bus seats under frontal crash scenarios for buses and coaches, in light of the new UN regulation. **Methods:** A parametric computational study was conducted using the PIPER Human Body Model (HBM) to represent both a 3-year-old and a 6-year-old child. The HBM was seated in a bus seat, with and without a booster seat, and exposed to a frontal collision scenario. 14 conditions were simulated: 2 child sizes, x 2 belt systems (2-point and 3-point) x 3 CRS conditions (none, booster seat without harness, booster with ISOFIX), + unrestrained with each child size (n=2). A delta-v of 30 km/h was applied in accordance with UNECE R80 and R170. Head kinematics and spinal loads were assessed. **Results:**The 2-point seatbelt configurations for 3-year-old and 6-year-old child models resulted in head excursions exceeding 550 mm, even with a booster seat, potentially leading to head contact with the forward seat. In contrast, 3-point seatbelts (with and without a booster seat) reduced these excursions to 205-321 mm for 3-year-olds and 229-316 mm for 6-yearolds compared with the 2-point configuration. The most effective configuration was the 3-point seatbelt paired with a booster seat, which further reduced head excursion by 77-109 mm compared to non-booster seat setups. The integration of ISOFIX anchorages showed only marginal improvement (about 10mm) in head excursion reduction compared to non-ISOFIX installations. **Conclusions:**This research highlights that 2-point seatbelts in buses and coaches may be insufficient to provide adequate restraint for child occupants, leading to excessive head excursion in frontal crashes. Conversely, 3-point seatbelts combined with booster seat effectively managed occupant kinematics, preventing contact with the interior environment. Although ISOFIX offered some benefits, the most significant factor in reducing injury risk is the transition from 2-point to 3-point seatbelts. Further studies focusing on younger children and other child restraint systems may be needed to fully evaluate their safety.

Index Terms- UN R170, Children, buses, coaches, PIPER HBM, CRS

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