Failed Rib Regions in a Computational Human Model vs. Observed PMHS Fractures: A Comparative Study

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Road traffic injuries are a large and growing share of the global health burden. The thorax is the second most commonly-injured body region in such incidents. ATDs are used in regulatory and consumer tests to determine injury risk based on correlative predictions of thoracic injury, however determining localized injury (e.g. rib fracture) is beyond their current capability. Local rib strains can be measured on PMHS, but overhead requirements and specimen variability vis-à-vis biomechanically relevant measures like age, corpulence, and bone mineral density complicates their use. Computational human body models provide another potential avenue for study. While such models have been used in the study of kinematic and kinetic response, further comparison of model outcome to experimentally-observed injury are needed to develop robust localized injury criteria. The objective of this study is to compare failed regions (FRs) in the rib from a computational human body model using two different methods vs. PMHS rib fractures observed in published hub and sled tests.

The Global Human Body Models Consortium (GHBMC) 50th percentile male occupant model (M50-O, v4.3) was used in all simulations. Fourteen simulations were conducted with rib FRs either predicted probabilistically (PFR) or deterministically (DFR). The impacts were as follows: a 6.7 m/s chest hub, a 12.0 m/s lateral plate, a 6.7 m/s shoulder hub, a 6.7 m/s thoracoabdominal hub, a 6.0 m/s abdominal bar, a 10 m/s lateral pelvis, and a 6.7 m/s Heidelberg-type lateral sled. Prediction of DFRs was achieved through a recently published scheme that analyzes eliminated elements, based on effective plastic strain exceeding 0.018 in 4 contiguous elements (Guleyupoglu et al. 2017, Li et al, 2010). Prediction of PFRs used an analysis of maximum principle strains in the ribs (Forman et al, 2012) and a default age of 35 years.

In the pelvic block impact there was 1 DFR and 2 PFRs compared with an average of 1.5 fractures found by Bouquet et al, 1998. The lateral plate impact had higher predictions with 43 DFRs and 28 PFRs whereas the average fracture count in the study by Kemper et al, 2008 was 22.5. The chest hub impact conducted by Kroell et al (1971, 1974) found 9.4 ± 7.2 fractures and in our simulations, 5 DFRs and 11 PFRs were predicted. Finally, in the lateral sled case, 21 PFRs and 26 DFR’s were predicted compared to an average of 14 in the PMHS tests. The average age of all PMHS was 64.8 years old.

The criteria for FRs should to be further tuned to match experimental values. When fracture counts are high in the experiments, the DFRs and PFRs surprisingly both exceed the reported value, despite the lack of eliminated elements in the PFR scheme. However, in cases where fractures were low, better agreement was found between experimental, DFR and PFR 2 predictions. Future work will focus on the effect of cortical thickness, and age as a predictor; either making material adjustments as function of age in the DFR scheme or explicitly accounting for it in the PFR scheme.