

Improving Spine Biofidelity fo HYBRID-III 6-Year-Old ATD

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ABSTRACT

Because of the lack of pediatric biomechanical data, the Hybrid-III (HIII) child anthropomorphic test devices (ATDs) are essentially scaled from the mid-size male ATD based on geometric considerations. These ATDs inherit from the adult HIII ATDs rigid thoracic spine, which has been criticized as unrealistic. Therefore, the objective of this study is to explore possible design modifications for improving the spine biofidelity of the HIII 6-year-old ATD using computer modeling and optimization techniques. All available pediatric biomechanical data suitable for evaluating the spine design of the child ATD were used in this study. They included child volunteer spine range of motion data from UMTRI, child volunteer low-speed crash test data from CHOP, pediatric cadaver cervical spine tensile test data from Duke University, child cadaver crash test data from University of Heidelberg, and two real-world motor vehicle crashes from CIREN. A modified HIII 6YO MADYMO ATD model was used as the baseline model in this study. This model incorporated modified pelvis and abdomen designs for improving the model prediction of submarining, and was previously validated against child passenger sled tests with and without submarining. ATD design modifications included adding an additional joint to the thoracic spine region, modifying back geometry and changing the joint characteristics at the cervical and lumbar spine regions. The biomechanical data selected above were considered as the design targets for modified ATD model to match. The normalized errors between simulation results and each set of test results or accident injury outcomes were calculated and defined as the objective functions to be minimized by optimization techniques. The results showed that with an additional thoracic spine joint and optimized joint characteristics in the cervical, thoracic, and lumbar spine joints, the modified ATD model provided significantly better biofidelity than the original ATD in terms of the overall spine curvature, head excursion, and head injury criterion in frontal crashes. Even though the loading conditions are different in the biomechanical datasets selected in this study, the optimizations for different datasets provided fairly consistent recommendations for the ATD modification. In particular, the translational characteristics of the cervical and lumbar spine in the current child ATD need to be reduced to achieve realistic spine flexibility. The optimal ranges of spine joint parameters presented in this study provided references for future child ATD modifications. The child ATD model developed in this study can be used as an important tool to improve child ATD biofidelity and child restraint system design in MVCs.