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Biofidelity Implications for Developing Design Concept of Female Physical Test Device based on Human Body Simulations

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Abstract

Introduction

Studies have shown that most of the whiplash injuries are caused by the rear crashes [1,2], and therefore, there is a need for evaluate restraint systems in this specific type of crash. Currently, BioRID is the most biofidelic Anthropometric Test Device (ATD) for rear impacts and it represents an average male anthropometry [3]. However, epidemiological data has shown that females have a higher risk for whiplash injury compared to males [4]. Presently, there is only a prototype female ATD developed for evaluating whiplash injuries with respect to rear impacts [5]. This study was conducted to evaluate biofidelity of design changes in a Finite Element (FE) human body model of an average sized female with objective to provide a design concept of a physical test device. The results of this study could provide guidance for development of the future ATDs.

Methods

The open source ViVA 50th percentile female model [4] was adopted as a baseline model for this study. The FE simulations were conducted with the solver LS-DYNA (LSTC, Livermore, CA). Simplifications were made to the spinal column. Design-1 had a rigid thoracolumbar spine (T1-L5), and Design-2 had a rigid thoracic spine (T1-T12). Output were parameters such as cervical spine curvatures and kinematics. A rear impact was simulated with the models positioned on a simplified rigid seat [4].

Results

Design-1 and 2 both had almost similar head kinematics. The cervical kinematics changed when the inferior spinal portions were made rigid. After positioning the models with gravity, the initial cervical curvatures were different with more pronounced lordosis and superior location of T1 in the Design-1 and Design-2.

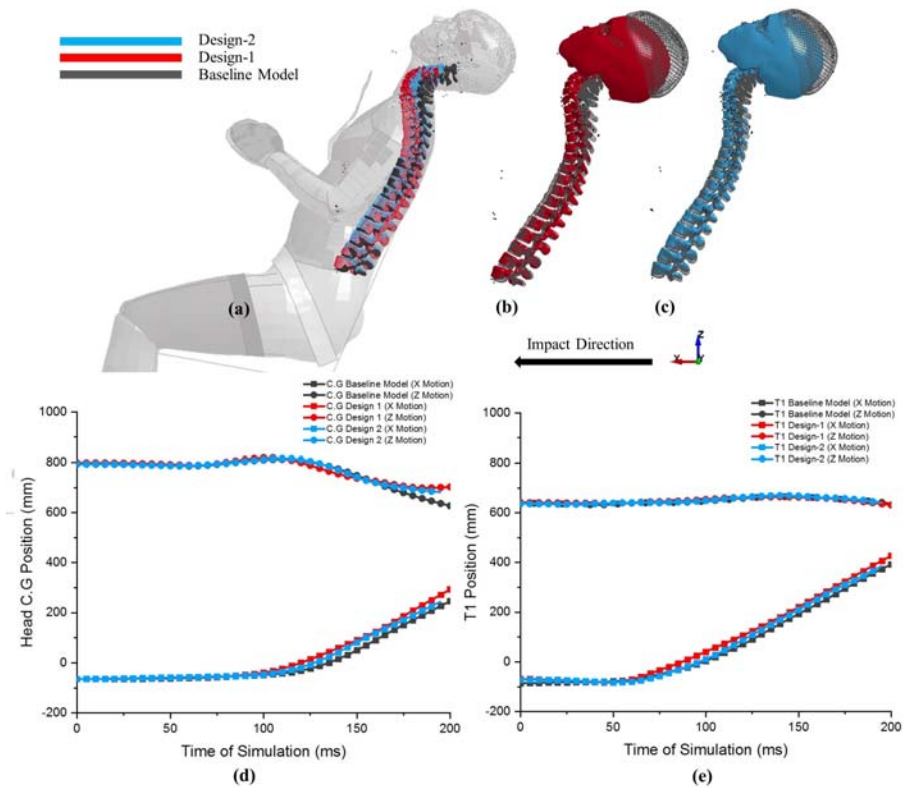


Figure 1. (a) Spinal curvatures comparison between all designs at 150 ms, (b) Spinal curvatures comparison between Baseline model and Design-1, (c) Spinal curvatures comparison between Baseline model and Design-2, (d) Head Centre of Gravity (C.G) motions in X and Z directions, (e) T1 motions in X and Z directions.

Discussion

This study indicates the importance of thoraco-lumbar spinal curvature and stiffness on the cervical kinematics in rear impacts. In the design with rigid thoraco-lumbar spine, the cervical joints will be subjected to larger flexion-extension motions with slightly difference in head kinematics. This study is a first attempt to identify simplifications of the spine for implementation in a physical model with maintained main characteristics that allow the model to identify injury protective performances of the seat. Simulations with different seat models will be needed to ensure that the simplifications do not affect the ability of the model to distinguish between such characteristics of a seat.

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