Applicability of CPR-based thoracic stiffness and damping properties to the motor vehicle crash environment

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Abstract

A biofidelic ATD is essential for developing crash safety systems for occupants. The ubiquitous Kroell blunt hub impacts to the thoraces of PMHS have formed the biofidelity requirements for the adult-sized ATD thorax. Recently collected thoracic force-deflection data from cardio-pulmonary resuscitation patients offer a large dataset of biomechanical data across a broad age range. However, the applicability of this CPR data to inform ATD biofidelity requirements is unknown. Thus, the objective of this study was to evaluate the performance of CPR-derived thoracic stiffness and damping properties in a mathematical model of blunt thoracic impact validated to the Kroell experimental data.

A previously validated (Neathery 1971) spring-mass-damper (SMD) model of the adult chest during thoracic impact was recreated in MatLab. The model was modified (SMD-CPR), with mass and flesh stiffness from SMD, and thorax stiffness and damping from CPR. Comparison of the two models revealed that the damping constant from CPR was too low to produce a model that could be validated to the Kroell experiments. Thus, we created a third model (SMD-CPR-K), by changing the damping of SMD-CPR model back to the value from SMD model. During blunt hub impact simulations, the SMD-CPR-K model yielded a 41.9% to 47.0% increase in chest deflection from the SMD model, over impact velocities of 4.9 to 7.1 m/s.

The SMD-CPR-K model was then parameterized to quantify the mass, stiffness and damping effects on the force-deflection response. Increases to sternum mass or flesh stiffness led to increased force only in the first 20 mm of deflection. Increased thorax stiffness led to increased maximum thorax deflection only. Finally, increased thorax damping led to increased force in the first 20 mm of deflection and decreased maximum deflection.

These results indicate that stiffness but not damping characteristics from CPR are compatible with the impact environment.

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