Design of a Device and Procedure for Characterizing the Response of the Pediatric Thorax Utilizing Nonparametric System Identification Techniques

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Motor vehicle accidents are the leading cause of child thoracic trauma, representing nearly three-fourths of all blunt thoracic traumas [1]. Injuries to the thorax pose a greater risk of fatality than abdominal injuries and are second only to head injuries in children [1]. In addition, interactions of the thorax in frontal loading dictate the behavior of the spine, neck, and head. In an effort to protect child occupants, passenger restraint systems originally designed for adults have been adapted to protect children. The effectiveness of these passenger restraint systems is evaluated using anthropomorphic test devices (ATDs) representative of children's stature and mass. However, the design of the biofidelic response of the child ATDs is based largely on scaled adult post mortem human subject (PMHS) testing and testing with animal surrogates. The properties and geometry of skeletally mature adult bones and pediatric bones differ greatly; this is especially true of the thorax [2]. The purpose of this study is to determine the response of the pediatric thorax to compressive loading.

In order to improve the biofidelity of the pediatric thorax in ATDs used today, a technique to define the properties of the thorax is necessary. To accomplish this, a device was designed and built to load the thorax with small, non-injurious compression perturbations, while measuring the corresponding thoracic response forces. The device is capable of applying 10mm perturbations up to a nominal 2.5m/s. The system is comprised of a vector motor, parallel shaft gear reducer, high inertia flywheel, cam, and pushrod. To characterize the response of the pediatric thorax, input displacement perturbations are applied at varying rates and levels of initial thoracic compression, the corresponding thoracic response forces are measured, and the mechanical properties of the thorax (i.e., mass, damping, stiffness) are obtained utilizing nonparametric system identification techniques. Although the thorax is a nonlinear system, using sufficiently small displacement perturbations allows for the assumption that the thorax is operating within a linear zone or operating point. By obtaining the linear response of the thorax at many of these operating points, an overall nonlinear model of the pediatric thorax can be compiled. Many such thorax models can be constructed in diverse loading conditions which, in turn, can be used in the design of the biofidelic response of the next generation of child ATDs.

References

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