

# THORACIC STIFFNESS CHARACTERISTICS UNDER DYNAMIC COMPRESSIVE LOADING USING THE HUMAN FE MODEL

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## ABSTRACT

This computational study evaluated the response of human torsos to dynamic anterior loading by rigid rectangular impactors designed to approximate a shoulder belt loading. In order to verify the computational model, the simulation result was compared with the corresponding test data. The sensitivity study was performed with certain levels of thoracic material properties to investigate the characteristics of thoracic stiffness. While the stiffness of rib cage was found to be proportional with the values of elastic moduli, the elastic modulus of cortical bone was found to be the most influential factor.

## I. INTRODUCTION

Thoracic stiffness is generally accepted as the best parameter that correlates to rib and sternal injuries. Therefore, a biofidelic computational model under anterior loading can play an important role in the optimizing the occupant restraint systems. The objectives of this study are: (1) to evaluate the biofidelity of a thorax finite element (FE) model, and (2) to investigate the sensitivity of material parameters for the thoracic stiffness.

## II. METHOD

A thoracic FE model of a 50<sup>th</sup> percentile male (H-model) was used in PAM-CRASH to simulate the dynamic compressive tests (Shaw et al., 2007). In the experiments, the thorax, with soft tissues removed from anterior and lateral aspects, was fixed to the spine and pelvis sites, and then loaded dynamically with a rigid impactor (Figure 1). The impactor (52 X 102 mm), which approximates a section of shoulder belt, was moved in anterior-posterior direction at a loading rate (1 m/s) similar to that experienced during restraint belt loading in a frontal crash. The resultant force of impactor-thorax

interface was calculated from a FE simulation and compared with the force inertially compensated recorded in testing. The sensitivity study of the elastic moduli of cortical, trabecular, costal cartilage, and intercostal muscles was performed. The ranges of elastic moduli were defined by varying with  $\pm 20\%$  of their reference values.

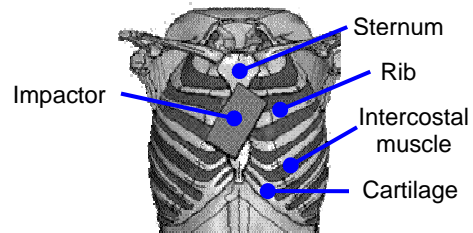


Figure 1. Test Set-up for Thoracic Impact Simulation

## III. RESULTS AND DISCUSSION

Since the force-deflection curve obtained from FE simulation showed a mostly linear variation after 5 mm deflection, the stiffness, calculated between 5 and 20 mm deflection, was relatively higher (27 N/mm) than the corresponding test data (16 - 24 N/mm). The cortical bone modulus was found to be the most influential factor, while the overall stiffness of rib cage showed to be proportional with the modulus values (Table1).

Table 1: The Elastic Moduli of Rib Cage and Main Effects (ME)

Factors	Cortical	Muscle	Trabecular	Cartilage
E (GPa)	14.7	0.01	0.75	0.02
ME (N/m)	5.13	1.03	0.87	0.77

## REFERENCE

1. G. Shaw, D. Lessley, J. Evans, J. Crandall, J. Shin, "Quasi-static and Dynamic Thoracic Loading Tests: Cadaveric Torsos," *IRCOBI Conference*, pp. 325-348, September 2007.