# The Role Of Acceleration Pulses On Thoracolumbar Spinal Disc Forces From Vertical Impact To The Pelvis

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## I. INTRODUCTION

Injuries to the dorsal spine are reported to occur to restrained occupants in automotive environments and to military personnel in combat events [1-4]. Early recognition of these injuries in the former scenario was from frontal impacts in vehicles equipped with airbags. Studies conducted in Europe confirmed and reported the prevalence of such injuries from its databases [5]. Military literature identified the prevalence of thoracolumbar spine injuries to soldiers in combat situations [6]. The majority of injuries were compression-related trauma in the form of vertebral body fracture with or without the involvement of the ligament complex [2][6-7]. Burst fractures were also present [8]. Injury analysis in both scenarios attributed the spine trauma to an external vertical loading vector [4][8]. Laboratory studies have been conducted to replicate the field injuries by applying the impact load at the sacral end to the isolated post-mortem human subject (PMHS) spine specimens and the pelvis via the seat to the whole-body surrogates [9-10]. Preliminary injury risk curves are available from the former experimental model [11]. The role of the acceleration pulse on forces transmitted to the proximal end of the spinal column has not been delineated in these experimental studies. The aims of this study were, therefore, to understand the mechanism of load transfer and to determine the loads sustained by the thoracolumbar discs with different pulses, i.e. investigate the role of external acceleration pulse, using finite element (FE) modelling.

## II. METHODS

The global human body modelling consortium FE model, GHBMC, version 5, was used. Briefly, the thoracolumbar spine of this whole-body model consists of the vertebral bodies and their posterior elements, intervertebral discs, and ligaments. Each body consists of the cortical shell, cancellous bone, endplate, and the posterior bony structure complex is attached to the body. The anterior longitudinal ligament, posterior longitudinal ligament, supraspinous ligament, interspinous ligament, the flavum, capsular and intertransverse ligament, and the nucleus and annulus components were included in the definition of the intervertebral discs in the spinal column. Mid-size male and small-size female models were used. The acceleration rig consisted of a rigid seat and a footrest, both modelled with 2-D elements. The seat and footrest were constrained. The HBM was seated upright and faced forward, with the Frankfurt plane oriented parallel to the ground and gravity settled into the seat, before the application of the acceleration pulse. After settling the model on the seat, it was restrained with a five-point seatbelt with no payout [12]. The harness was modelled as a combination of 2-D and 1-D seat-belt elements. The fabric material was assigned to the 2-D seat-belt elements. Automatic surface-to-surface contact with a friction coefficient of 0.3 was used for the HBM-to-seatbelt interaction. The input seat acceleration pulse had a duration of 100 ms, with a peak of 23 g. This input was parameterised by varying the pulse duration and acceleration magnitude while maintaining the total energy. The thoracolumbar disc loads were obtained for pulses ranging from 50 ms to 200 ms in steps of 25 ms, and the peak accelerations were different to match with the iso-energy criterion. The peak forces were evaluated against the risk of injuries from PMHS experimental data for both models and all parametric cases.

## III. INITIAL FINDINGS

The time histories of the male and female spinal forces are shown for the baseline pulse, i.e. the 100 ms acceleration pulse (Fig. 1, left). Forces were lower in the female than the male spines for all cases. Figure 1 (right) shows the injury risks for the male spine for all cases. The dashed line in the figure shows the 95% confidence intervals corresponding to the force magnitudes for the male spine. In general, forces were approximately 35%

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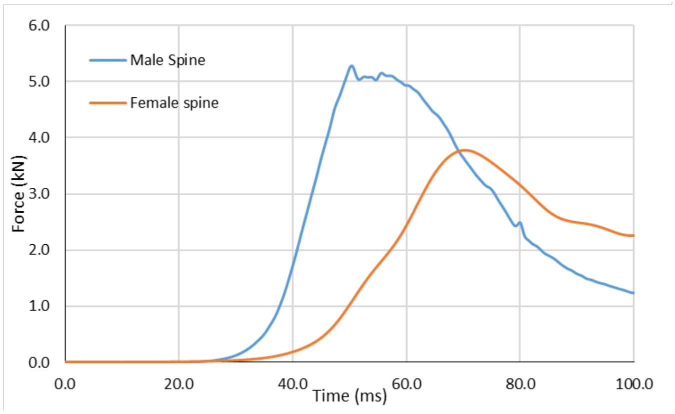
lower in the female spine than the male spine.



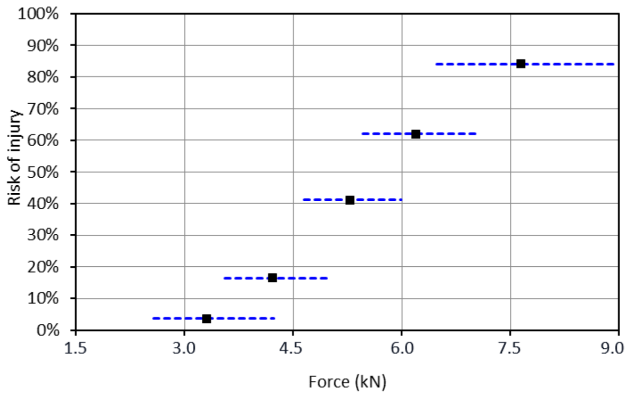




Fig. 1. Left: shows the time histories of force at the thoracolumbar discs for the male and female spines. Right: shows the injury risk levels corresponding to the peak forces (squares) and associated upper and lower confidence interval bounds (dotted lines) for each pulse (top to bottom: 50 ms, 75 ms, 100 ms, 150 ms and 200 ms).

## IV. DISCUSSION

As stated in the Introduction, the aims of the study were to determine the role of the acceleration pulse on the forces in the male and female spines from vertical impacts. Depending on the external and interior design of the vehicle, the same type of impact acceleration (iso-energy input) imparts differing pulses to the seated occupant; padding and seats are different in military vehicles. For example, at the same input acceleration to the vehicle, a padded seat tends to widen the pulse, whereas a rigid seat does the opposite. The delineation of the role of the pulse on occupant loading is best done using a computational model due to repeatability, hence it was chosen in the present study. Further, the models used in the study represent the mid-size male and small female, which are the two most commonly used surrogates for crashworthiness applications and human safety.

The present study quantified the expected greater forces and, therefore, higher risks with shorter pulse durations using a computational model. While forces were lower for female spines, specific injury risk values were not given in this study as injury risk curves for this population are not available. Although lower forces are expected for female spines, their risks may not parallel the male, as female spines and responses are not a scaled-down version of male spines. The postures are different between males and females, and this has been shown in a recent image-based study presented at this conference [13-14]. While the present modelling approach did not account for such variations, these results are a first step in understanding the role of the acceleration pulse on male and female spine responses and risk levels from vertical impact loading.

## V. ACKNOWLEDGMENTS

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