Biomechanical Tolerance and Injury Pattern of Whole Lumbar Spines Subjected to High Vertical Acceleration Loading

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Introduction

Multiple studies reported fractures of the lumbar spine in military environments, falls from height, and motor vehicle accidents. However, major shortcomings of these studies were the use of short-segment models and employment of testing systems that fail to replicate the real-life inertial-based loading scenario. Short segment models lack the ability to demonstrate differing injury patterns and locations. This shortcoming is important to address, as study by others have shown nearly 60% of lumbar fractures affecting the multiple lower lumbar spines. This study quantifies lumbar spine injury tolerance using whole lumbar column specimens and a custom-built drop tower that replicates the loading scenario experienced by civilians and military personnel in falls from height and motor vehicle events.

Methods

24 intact human lumbar spines (T12-L5, age: 44 ± 13 years) subjected to dynamic axial loading using a custom-built drop tower (Figure 1), undergoing a total of 62 sub-failure and failure producing tests. Peak acceleration and axial force were quantified. Biomechanical metrics were assessed using survival analysis to identify significant independent predictors of injury.

Results

A total of 29 fractures were identified with mean fracture force of 5182 ± 1086N. Both axial force and peak acceleration were lower for L1 level only injury as compared to any other level of injury (L1-L5, Figure 2). Using AO classification, type A fractures occurred more often at the cranial spinal levels mostly at L1 or L2. Type B fractures were more evenly distributed across the lumbar spine. Peak acceleration was 27% greater in specimens that sustained fractures in type B (Figure 3). Peak force and peak acceleration were significant predictors of injury ($p<0.0001$). Survival analysis demonstrated ninety five percent probability of injury was associated with 7,257 N and 21.9 G's (Figure 4 -5, Table 1 &2).

Conclusions

This study quantified axial tolerance of intact lumbar spine using a custom built drop tower, and demonstrated that both axial force and peak acceleration are significant predictors of lumbar spine injury. Unstable injuries occurred at higher axial force and peak acceleration as compared to stable fractures.

Learning Objectives

The learning objective of this study is the understanding of biomechanical tolerance, fracture pattern, and stability of lumbar spine injuries when subjected to dynamic axial loading.

References

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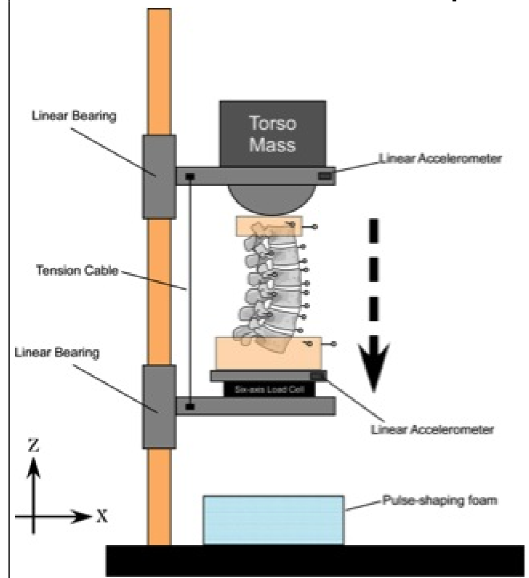
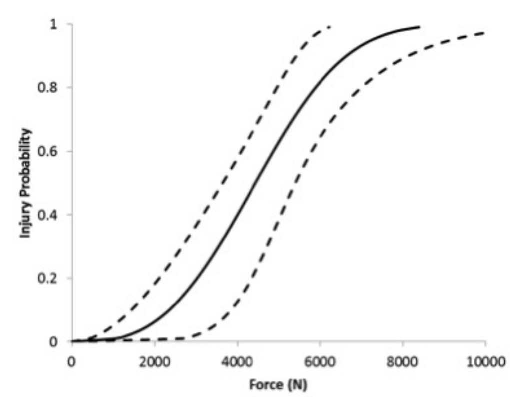
Vertical Accelerator Test Setup



Injury Probability Curve



The plot shows the mean curve and 95% confidence intervals