Structural Properties of Ribs in Dynamic Frontal Loading as a Function of Age

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Abstract

Few studies have looked at the structural properties of human bones across the entire age spectrum tested using the same repeatable method. The goal of this study is to define linear stiffness and other structural properties of human ribs across a wide range of ages. Ribs are of particular interest because they are often fractured during motor vehicle crashes and can lead to further injuries to internal organs such as the heart and lungs. Multiple rib fractures can also be linked to a high risk of mortality, particularly in elderly individuals and children.

A total of 141 ribs from individuals with ages ranging from 6 to 99 years (mean = 56 years) were tested in a custom fixture simulating a dynamic frontal impact. Rib ends were potted and fixed in rotating cups for testing. Each rib had two strain gages applied on the pleural and cutaneous surfaces to determine time of fracture. A pendulum impacted the sternal end of each rib at 1 or 2 m/s. A 6-axis load cell measured forces and moments on the vertebral end and a linear string potentiometer measured displacement.

The displacement at the time of fracture as a percentage of total span length of the rib was calculated and compared across ages. Percent displacement showed a distinctive negative trend with increasing age. Force in the primary loading direction (x) at fracture was highest in the young adult range, which corresponds to the timing of achieved peak bone mass. Effective stiffness (K) was calculated from the linear portion of the force-displacement curve. K-values indicate increased variation for younger subjects than older subjects, but a significant ($p<0.05$) relationship with age.

Investigating the differences in the structural properties of ribs can contribute to the development of better physical and virtual models of the human thorax, which could ultimately lead to improved safety standards. Additionally, information from this study can provide insight into how bone structural properties are affected by the aging process and enhance approaches to clinically-based injury prevention and identification of fracture risk.