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Drop-tower Experiment Involving Dynamic Axial Loading of Human Cadaver Spines

Authors: Tyler A. Kress, David J. Porta, P. David Halstead, et al.
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ABSTRACT

A drop-tower experiment involving dynamic axial loading of human cadaver spines was performed to provide information to support the hypothesis that the common mechanisms behind vertebral column failure under axial loading is the inertial effects of the torso mass. Six specimens, each consisting of a portion of the basilar skull, the entire spine, the pelvis, and the proximal third of the thighs, were raised to varying heights and allowed to drop freely and impinge upon an aluminum impact plate that actuated a force transducer. The injury results were documented through pre- and post-test x-rays and dissection. All injuries occurred in the mid-thoracic region and the conclusion is that the major mechanisms causing injury is the inertial effects of upper body mass.

INTRODUCTION

It is well understood and documented that axial loading of the spine through contact with the head results in fractures to the cervical region. Diving injuries and spear-tackling football injuries are often fractured cervical vertebrae. On the other hand, resultant injuries can be quite different if the axial load is transmitted through the pelvic region (via contact with the ischial tuberosities). If an individual is loaded in this fashion (e.g. bottoming out while seated in a vehicle or falling from a height and landing rear first), failure of the vertebral column at the region near the bottom of the rib connections (i.e. thoracic-12 vertebrae) is expected. These failure patterns are clearly related to the inertial

effects of the torso mass. A drop-tower experiment involving dynamic axial loading of human cadaver spines was performed to provide auxiliary information to support the hypothesis that the common mechanisms behind vertebral column failure under axial loading is the inertial effects of the torso mass.

METHODOLOGY

To test the hypothesis of this experiment, six specific anatomical specimens were dissected from embalmed cadavers and used in a drop-tower apparatus. Each specimen consisted of a portion of basilar skull, the entire spine, the pelvis, and the proximal third of the thighs. Four of the six specimens had an accelerometer-instrumented, 5.5 kilogram, magnesium dummy head attached. The head was attached with large hose clamps to the sectioned basilar skull and contained a uniaxial accelerometer at the center of gravity.

The experimental apparatus consisted of a 3-meter drop-tower/guide rail with the upright specimen attached at its basilar skull end. The specimens were raised to varying heights and allowed to drop freely upon an aluminum impact plate that actuated a force transducer.

The experimental matrix is shown in Table 1 on the following page.

TABLE 1. Experimental Matrix

Specimen #	Drop Height (cm)	Calculated Impact Velocity (m/s) (mph in parenthesis)	Dummy Head
1	130	1.6 (3.6)	Yes
2	130	1.6 (3.6)	Yes
3	225	2.1 (4.7)	Yes
4	315	2.5 (5.6)	Yes
5	295	2.4 (5.4)	No
6	265	2.3 (5.1)	No

RESULTS

Pre- and post-test x-rays were taken of all specimens. Each specimen was also dissected in order to fully characterize the injury results as summarized in Table 2.

TABLE 2. Primary Injury Results

Specimen #	Fractured Vertebral Bodies	Involved Disks
1	T4,T5	T3/T4, T4/T5
2	T8,T9	T7/T8, T8/T9, T9/T10, T10/T11, T11/T12
3	T6	T6/T7
4	T4, T5	T4/T5, T5/T6
5	None	None
6	None	None

DISCUSSION

As the drop height and final impact velocity were increased, the measured forces increased and the resultant injuries were more severe. The major observation was that all of the injuries occurred in the mid-thoracic region. The vertebral column injuries usually involved two adjacent vertebrae and included impacted vertebral body fractures, disk ruptures and tears, and tears/lacerations in longitudinal ligaments. It is important to note that the specimens with minimal upper mass (no head) had no detectable injury. The conclusion is that the major mechanisms causing injury is the inertial effects of the upper mass.

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