INTRODUCTION

Hip fracture is a debilitating and often deadly injury that affects a large portion of the Canadian population. While much research has gone into understanding femoral fracture mechanics, the high-rate behaviour is not well defined.

Force traces from isolated pelvis impact tests [1] have a bimodal behaviour with each local maximum having nearly the same magnitude, but the first having a lower duration. We believe that the initial force peak in this data was caused by the inertia of the femoral head and lateral pelvis, which are almost rigidly connected to the femoral neck. To date, test apparatuses used to model falls to the side have not reproduced the inertia of these structures but instead have focused on modelling the inertia of the body delivered through the pelvis. The rate of loading will affect the strain rate in the femoral neck; since bone properties are influence by strain rate, we believe that this initial, high-rate pulse could be critical to modelling and understanding the behaviour of the proximal femur in a sideways fall. To this end, we sought to include models of the tissues and structures surrounding the femur in a drop tower simulation of a sideways fall, replicating their inertial effects and elastic properties.

METHODS

A single surrogate femur model (large, 3rd generation, left femur, Sawbones, Vashon, WA) was positioned in the Orthopaedic and Injury Biomechanics Group drop tower in the literature standard fall orientation [2]. Nineteen millimetres of closed cell foam representing the trochanteric soft tissue, and a spring with a stiffness of 50 kN/m, representing the pelvis, were placed in a stationary location between the drop tower gantry and the surrogate femur [3]. Two masses totalling 2 kg were suspended from the gantry. These masses represented the effective mass of the femoral head and lateral pelvis and would bypass the pelvic spring, applying a shock load to the specimen buffered only by the trochanteric soft tissue. The gantry was loaded to a total mass of 32 kg, representing the body mass in a sideways fall [4], and was raised to a height of 62 cm for a target impact speed of 3.5 m/s [4]. Loads were applied on the greater trochanter.

High-speed video was collected at 11,000 frames per second from two views, one showing the anterior side of the femoral neck and the other showing the entire setup. The greater trochanter platten was fitted with a 6-axis load cell, and the femoral head platten was fitted with a single-axis load cell. Load cell data were collected at 88 kHz, synchronized to the video and filtered using a 4th order, low pass Butterworth filter with a 3 dB cutoff at 500 Hz (MatLab v.R2011b, The Mathworks, Natick, MA).

RESULTS

![Compressive Load](image)

Figure 1: The compressive load recorded under the femoral head. The 2.9 kN local maximum at 17 ms was created by the unsprung mass, while the 3.8 kN global maximum at 47 ms was created by the body mass.

The compressive forces recorded under the femoral head are shown in Figure 1. The force trace shows the bimodal behaviour, with two force peaks, one at 17 ms with a magnitude of 2903 N and a second at 47 ms with a magnitude of 3761 N. The first peak is created by the 2 kg masses that bypass the pelvis spring, and the second was created by the body weight being transferred through the pelvis spring.

DISCUSSION

We created an isolated femur impact model that includes not only the body mass transmitted through the pelvis, but also the shock loading of the femoral head and lateral pelvis. This shock load creates loading rates that are higher than those created by the body load only.

Tests by other researchers simulating the same event do not show this bimodal shape [5]; however, the shape is seen to some degree in both isolated pelvis tests and human pelvic release experiments [3].

Simulation of this event could help understand the protective role of soft tissue in sideways fall – as it is the only energy absorbing structure involved in reducing the force pulse delivered by inertia of the lateral bony masses – as well as understand the high strain rate fracture dynamics that occur in falls to the side.

REFERENCES