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# Influence Of Pelvis Impact Angle During A Fall: On The Protective Benefit Of Hip Protectors

**Comments**
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**INFLUENCE OF PELVIS IMPACT ANGLE DURING A FALL ON THE PROTECTIVE BENEFIT OF HIP PROTECTORS**

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## INTRODUCTION

Over 90% of hip fractures are due to falls [1]. Laboratory measures have shown that wearable hip protectors reduce impact forces to the proximal femur during a simulated sideways fall on the hip [2, 3]. However, clinical evidence suggests that hip fractures still occur when hip protectors are worn [4]. Furthermore, while falls in real life result in a variety of impact configurations, biomechanical tests to date have focused only on lateral impact to the pelvis. In the current study, we examined how the force reduction provided by wearable hip protectors is affected by pelvis impact configuration during simulated sideways falls.

## METHODS

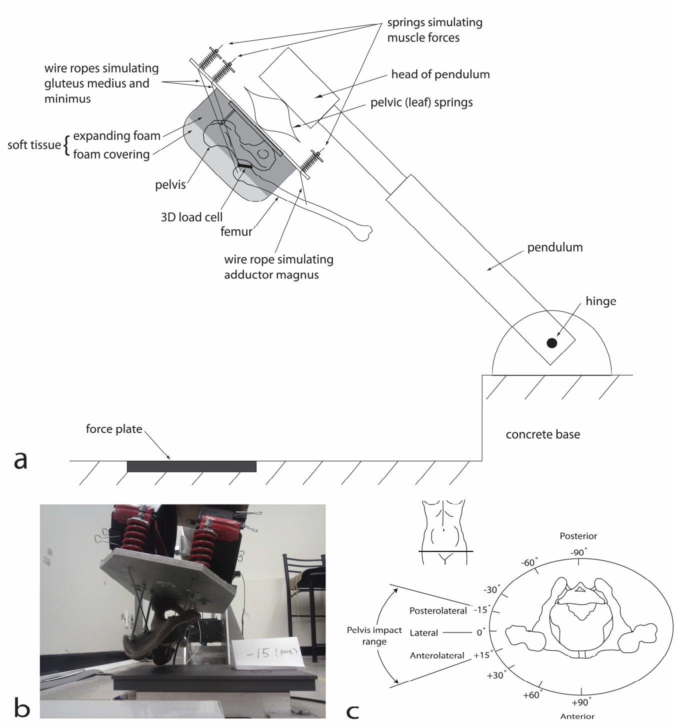


**Figure 1.** SFU Hip impact simulator, showing (a) schematic of the system, and (b) snapshot of surrogate pelvis (soft tissue covering removed) before impact with a pelvis rotation of 15° posterior along with (c) range of pelvis impact angle tested.

We conducted experiments with a second-generation "SFU hip impact simulator" consisting of a surrogate pelvis and pendulum [5]. The system (Figure 1a) allowed us to simulate falls involving different magnitudes of gluteus maximus and medius muscle forces, and pelvis impact angles, and systematically examine how these factors affect total force over the hip and 3D forces at the femoral neck (measured at 1000 Hz).

We used the system to simulate sideways falls involving an impact velocity of 2 m/s, and initial hip abductor muscle force of 700 N in each of the two abductor muscles. Trials were acquired for seven different impact configurations of the pelvis: (a) direct impact to the lateral aspect of the greater trochanter, and (b) impact to the pelvis when rotated (about the long axis of the pendulum) 5, 10 and 15° posterior or anterior to the frontal plane (Figure 1b and 1c). Trials were also acquired with no pad applied (unpadded) and with two commercially available hip protectors (HipSaver and SafeHip).

Our main outcome variable was the percent attenuation in peak compressive stress at the femoral neck provided by the padding devices, when compared to the unpadded condition:

$$\%attenuation = 100 \times \left(1 - \frac{\sigma_{padded}}{\sigma_{unpadded}}\right)$$

Secondary outcome variables (Figure 2) included the peak values at the femoral neck of: (a) axial force (Fz; aligned with the femoral neck axis), (b) shear force (vector sum of Fx and Fy), (c) bending moment, (d) shear stress, (e) compressive stress and (f) tensile stress (see inset to Figure 2a for equations used to calculate these parameters).

We used ANOVA to test whether the outcome variables associated with the padding devices (3 levels), and pelvis impact angle (7 levels). All analyses were conducted with SPSS using a significance level of alpha = 0.05.

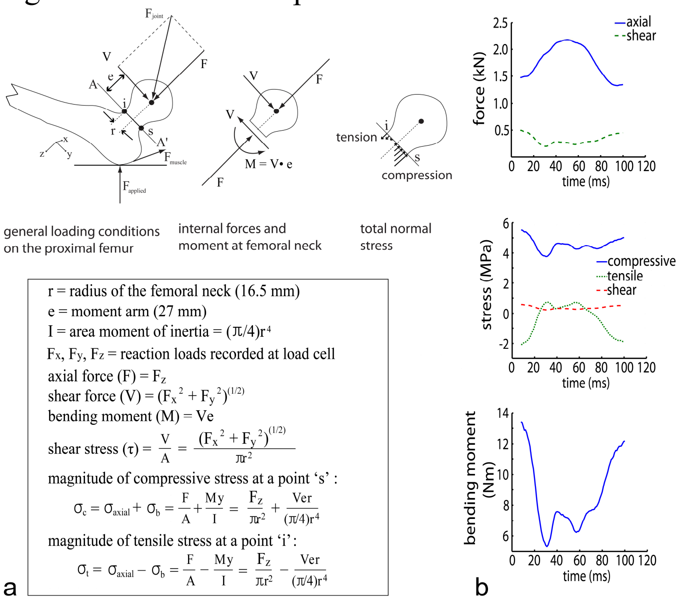


**Figure 2.** Experimental measures and calculated outcome variables. (a) Free body diagram and stress analysis at the proximal femur at impact from a fall. (b) Sample force and stress traces for SafeHip with +15° of pelvis rotation (anteriolateral impact).

## RESULTS AND DISCUSSION

Our main outcome variable (percent compressive stress attenuation at the femoral neck) associated with padding device ($p<0.0005$) and pelvis impact angle ($p<0.0005$). On average, the percent stress attenuation was greatest while falling with HipSaver (30.7%) than SafeHip (20.9%) (Figure 3). Furthermore, the percent attenuation was greatest while impacting slightly anteriorly (+5 or +10°; 35%) and least while impacting anteriolaterally or posteriolaterally (+15 or -15°; 17~18%) (Figure 3). There was a significant interaction between padding device and pelvis impact angle ($p<0.0005$).

All of other outcome variables associated with padding device ($p<0.0005$) and pelvis impact angle ($p<0.0005$). Furthermore, there were significant interactions between padding device and pelvis impact angle for all outcome variables ($p<0.0005$).

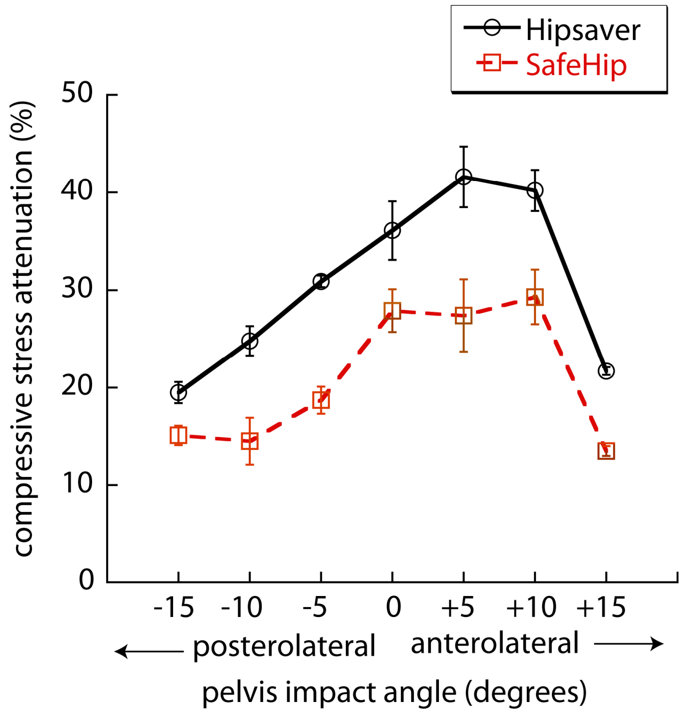


**Figure 3.** Effect of pelvis impact angle on percent compressive stress attenuation.

Our results confirm that padding devices help to reduce risk of fall-related hip fracture during a fall by attenuating peak compressive stress at the femoral neck up to 42%. However, our results also suggest that the protective effect may be compromised by pelvis impact configuration during fall impact, especially at the extremes of anteriorly and posteriorly directed impacts, where the point of contact was outside or at the edge of the padding device. These results agree with Choi et al (2010) who reported that performance of padding devices declines with poor positioning, for laterally-directed impacts [6]. These results should help to inform the design of improved padding devices that provide protection over a greater range of fall impact configurations [4].

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