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The effects of pad geometry and material properties on the biomechanical effectiveness of 26 commercially available hip protectors

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ABSTRACT

Wearable hip protectors (padded garments) represent a promising strategy to decrease impact force and hip fracture risk during falls, and a wide range of products are currently marketed. However, little is known about how design features of hip protectors influence biomechanical effectiveness. We used a mechanical test system (simulating sideways falls) to measure the attenuation in femoral neck force provided by 26 commercially available hip protectors at three impact velocities (2, 3, and 4 m/s). We also used a materials testing machine to characterize the force–deflection properties of each device. Regression analyses were performed to determine which geometric (e.g., height, width, thickness, volume) and force–deflection properties were associated with force attenuation. At an impact velocity of 3 m/s, the force attenuation provided by the various hip protectors ranged between 2.5% and 40%. Hip protectors with lower stiffness (measured at 500 N) provided greater force attenuation at all velocities. Protectors that absorbed more energy demonstrated greater force attenuation at the higher impact velocities (3 and 4 m/s conditions), while protectors that did not directly contact (but instead bridged) the skin overlying the greater trochanter attenuated more force at velocities of 2 and 3 m/s. At these lower velocities, the force attenuation provided by protectors that contacted the skin overlying the greater trochanter increased with increasing pad width, thickness, and energy dissipation. By providing a comparison of the protective value of a large range of existing hip protectors, these results can help to guide consumers and researchers in selecting hip protectors, and in interpreting the results of previous clinical trials. Furthermore, by determining geometric and material parameters that influence biomechanical performance, our results should assist manufacturers in designing devices that offer improved performance and clinical effectiveness.

1. Introduction

Hip fractures (i.e., fractures of the proximal femur) are a major public health problem for older adults. The lifetime risk for hip fracture in the USA is 17% for Caucasian women and 6% for Caucasian men (Cummings and Melton, 2002). While bone density is a major determinant of fracture risk, the majority of hip fractures occur in persons who do not suffer from osteoporosis (Dargent-Molina et al., 1996; Taylor et al., 2004). Instead, fall mechanics and the resulting loads applied to the proximal femur during impact are the factors most closely associated with the risk of suffering a hip fracture (Cummings and Nevitt, 1994). Sideways falls increase hip fracture risk by 5-fold when compared to forwards or backwards falls (Hayes et al., 1993); the risk increases by 32-fold when direct impact to the greater trochanter occurs (Nevitt and Cummings, 1993). Accordingly, protective devices that reduce the force applied to the proximal femur during fall-related impacts have the potential to reduce hip fracture risk.

Wearable hip protectors (padded garments) are a promising strategy for decreasing hip fracture risk by reducing the loads applied to the proximal femur during fall-related impacts. Until recently there were no established guidelines for assessing the biomechanical and clinical effectiveness of these devices (Cameron et al., 2010; Robinovitch et al., 2009). Consequently, there are currently more than two dozen commercially marketed

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