

PERFORMANCE OF A HIP PROTECTOR DEPENDS ON ITS POSITION DURING A FALL

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INTRODUCTION

Hip protectors are designed to attenuate and redistribute the force applied to the hip region during a fall, and thereby reduce risk for hip fracture [1]. However, little information exists on the effectiveness of hip protectors in achieving these goals, and how this is altered by displacement of the hip protector relative to the greater trochanter (GT). In the current study, we tested these issues.

METHODS

Biomechanical impact tests were conducted with a hip impact simulator. The surrogate hip was dropped onto a dual arrangement of an 2D pressure distribution plate (RSscan International) and a force plate from fall heights of 5 cm, 10 cm and 20 cm. Trials were acquired without a hip protector, and with three different soft shell hip protectors: 14 mm and 16 mm thick horseshoe-shaped pads (SafeHip, Tytext A/S), and a 16 mm thick continuous pad (Hipsaver). For each drop height, each protector was tested in nine positions: located centrally in its intended location over the GT, and displaced by either 2.5 cm or 5 cm in the superior, posterior, inferior, and anterior directions (Figure 1b). Three trials were acquired for each condition.

During each trial, we collected total hip impact force, pressure distribution and trochanteric force. All measures were acquired with a 500 Hz sampling rate. The RSscan plate had 4096 pressure sensors (64 by 64 array), a resolution of 0.01 kPa, range of 3 to 1270 kPa and accuracy (maximum error between the actual applied pressure and the value measured by RSscan plate) of 0.37 kPa, based on in-house calibration.

Our main outcome variables were the magnitude and location of peak pressure, trochanteric force and

forces applied to four defined hip regions. We defined four C-shaped regions over the hip centered about the GT, and named the central area (area A) the ‘danger zone’ since it represented direct impact on the GT and femoral diaphysis (Figure 1a). We calculated the integrated force applied to each region by summing the product of sensor area multiplied by pressure measured by each sensor within the area of interest.

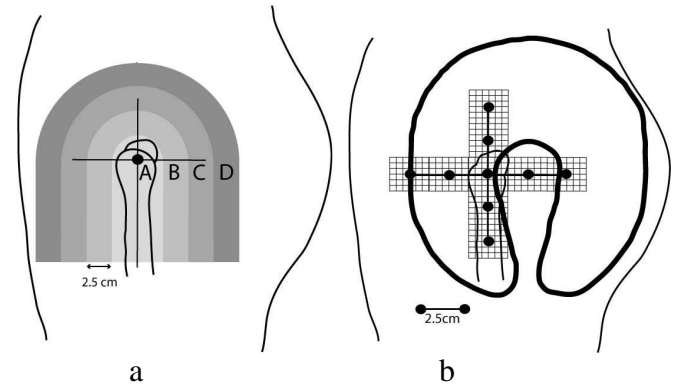


Figure 1 **a**: definition of four different areas over the hip region: area A, danger zone (light gray) consisted of a C-shaped region of width 5 cm (sum of a half-circle of radius 2.5cm centered at GT and a 16 cm long rectangle extending distally from the GT); areas B, C, and D (progressively darker gray) consisted of C-shaped hollow regions of width 10 cm, 15 cm, and 20 cm each **b**: pad displaced 2.5 cm in the posterior direction

Randomized group ANOVA was used to test whether each of our outcome variables was associated with drop height (3 levels), hip protector type (4 levels), and pad displacement (9 levels). The significance level in all tests was set to $\alpha = 0.05$, and all analyses were conducted in SPSS 16.0.

RESULTS AND DISCUSSION

The integrated force that impacted on the danger zone (area A) was associated with drop height ($p < 0.0005$), hip protector type ($p < 0.0005$) as well as

hip protector displacement condition ($p < 0.0005$). For 20 cm drops, 83 % of the total force was applied to the danger zone in the unpadded condition, but the percent force was reduced to 34 % and 19 % with 14 mm and 16 mm horseshoe protectors, and to 40 % with the 16 mm continuous protector (Figure 2). The force distribution to areas B, C and D was also associated with fall height ($p < 0.0005$), hip protector type ($p < 0.0005$) and hip protector displacement condition ($p < 0.0005$). For 20 cm drops, hip protectors redistributed the forces applied on the hip region by lowering and deflecting much of the force away from the danger zone and onto adjacent soft tissue areas B, C and D. This protective effect was reduced when the hip pads were displaced away from their optimal location.

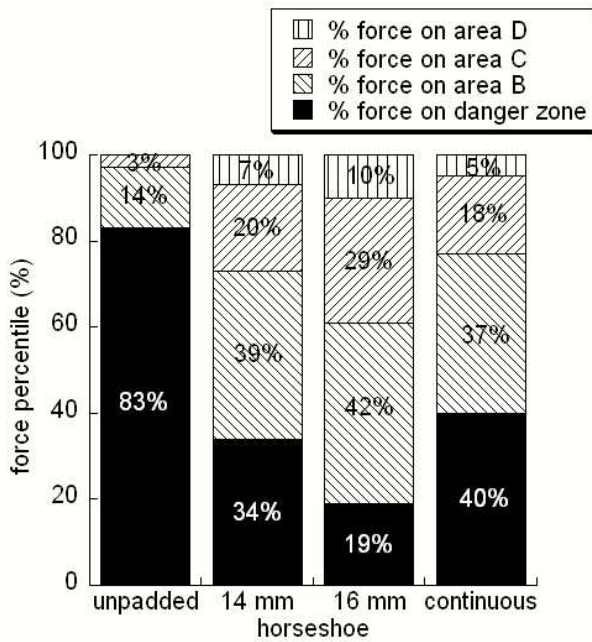


Figure 2 Force distribution to four different areas over the hip.

The trochanteric impact force was also associated with fall height ($p < 0.0005$), hip protector type ($p < 0.0005$) and hip protector displacement condition ($p < 0.0005$). For 20 cm falls with hip protectors centrally placed, trochanteric force averaged 45 % lower with the 16 mm horseshoe protector, 38 % lower with the 14 mm horseshoe, and 30 % lower with the 16 mm continuous protector, compared to the unpadded condition (Figure 3). The trochanteric force was 29 % higher for 5 cm pad displacement in the anterior direction, compared to centrally placed pads. There was a significant interaction between hip protector and displacement condition, indicating that both the 14 mm and 16 mm thick horseshoe pad

protectors outperformed the 16 mm continuous protector in all but 3 displacements conditions.

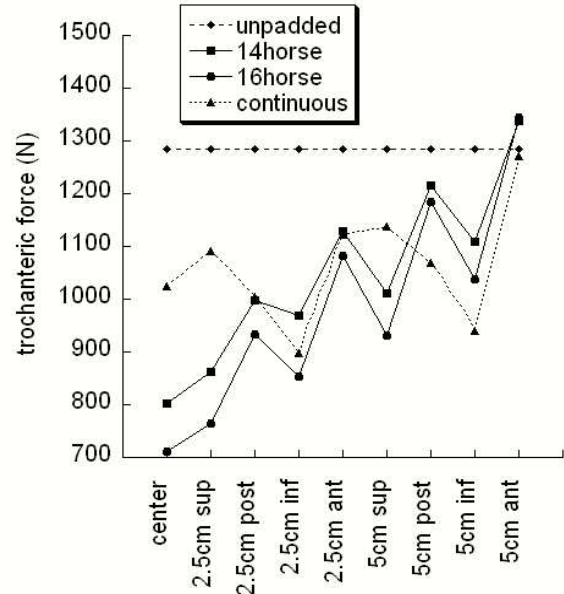


Figure 3 Effect of protector placement on the trochanteric force.

The peak pressure was reduced and shunted outside the danger zone by the optimally placed hip protectors, but the effectiveness declined when the protectors were displaced.

CONCLUSIONS

All three soft shell hip protectors we tested showed protective effects against external impact when optimally positioned in their intended location over the proximal femur. However, the horseshoe shaped protectors we tested provided superior protective benefit when compared to the continuous protector, and the 16 mm thick horseshoe protector performed better than the 14 mm horseshoe protectors. Furthermore, the protective effect was strongly dependent on correct placement of the protector with respect to the GT. Our findings are informative for developing more efficacious hip protectors and garments.

REFERENCE

1. Robinovitch SN, et al. *J Biomech Eng.* Nov;117(4):409-13, 1995

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