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Pressure Distribution Over the Palm During Falls on the Outstretched Hands

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Comments

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Pressure Distribution over the Palm During Falls on the Outstretched Hands

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INTRODUCTION:

Over 90% of wrist fractures are caused by falls on the outstretched hands (Palvanen et al., Osteoporos Int, 2000). Along with bone strength, fracture risk depends on the magnitude and distribution of force to soft and hard tissues during impact. In the current study, we examined how pressure distribution over the palm during a fall is affected by impact configuration, body mass index (BMI), palmer soft tissue thickness, and a 5 mm thick foam pad (simulating a protective glove).

METHODS:

Thirteen women with either high BMI (>25, n = 7) or low BMI (<18.5, n = 6) participated. We used ultrasound to measure participants' palmar soft tissue thickness over the scaphiod, hamate hook, and 2nd and 5th metacarpal heads. In the experimental trials, we simulated falls on the outstretched hand by suddenly releasing the participant from a suspended position, with the palms 5 cm above the ground. Trials were conducted with the arm inclined 20° or 40° from the vertical, and with and without a 5 mm thick foam pad secured to the palm. The experimental protocol was approved by the ethics committee at Simon Fraser University, and all participants provided written consent.

During each trial, we collected hand impact force from a force plate (Bertec, Columbus, OH) and pressure distribution from a pressure measurement plate (RSscan, Olen, Belguim). We also used a motion capture system (M.A.C., Santa Rosa, CA) to record the positions of reflective markers over the scaphoid, hamate, and metacarpal heads.

Outcome variables were the magnitude and location of peak pressure, total peak force and integrated force applied to three defined palm regions. The location of peak pressure with respect to the scaphoid was expressed by the angle (ϴ) from the scaphoid-hamate axis, and the distance (d) from the scaphoid (Figure 1). We calculated the force applied to three regions over the palm: (1) area A – a circle of 2.5 cm radius, centered at the scaphoid, (2) area B – an adjacent donut shape of 2 cm width and (3) area C – the remainder rest of the palm region. We refer to area A as the 'danger zone' because it includes the scaphoid and lunate, which articulate with and transmit force to the distal radius. Thus, force to the danger zone affects risk for fracture of the distal radius, scaphoid and lunate.

Repeated measures ANOVA was used to test whether the outcome variables were associated with pad condition (2 levels), impact configuration (2 levels), and BMI (2 levels). The Pearson correlation test was used to test relationships between palmar soft tissue thickness and normalized values of outcome variables. All analyses were conducted with SPSS 16.0, using a significance level of $\alpha = 0.05$.

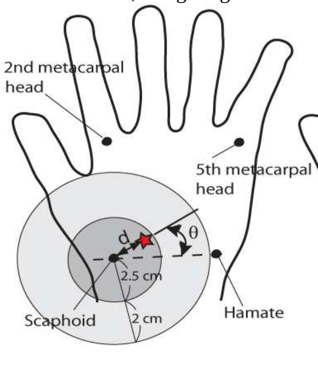

Figure 1

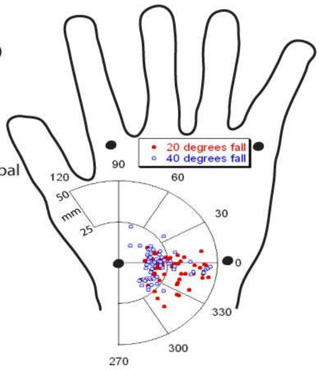

Figure 2

RESULTS:

The magnitude of peak pressure associated with pad condition (F = 22.2, p = 0.001) and BMI (F = 7.3, p = 0.02), but not with impact configuration (F = 2.6, p = 0.13), and there were no significant interactions. On average, peak pressure was reduced 83% by the pad (from 616 to 336 kPa), and was 77% higher in high BMI than low BMI individuals (608 versus 344 kPa; Figure 3).

Peak total force associated with impact configuration (F = 41.3, p = 0.0005) and with BMI (F = 29.4, p = 0.0005) but not with pad condition (F = 1.1, p = 0.29), and there were no interactions. Peak force averaged 12% greater in the 20° than 40° fall configuration (486 versus 431 N), and 47 % greater in high than low BMI individuals (547 versus 371 N).

The location of peak pressure associated with impact configuration (distance only; distance F = 5.9, p = 0.032, angle F = 3.2, p = 0.099), but not with pad condition (distance F = 1.0, p = 0.32, angle F = 2.7, p = 0.12) or BMI (distance F = 2.3, p = 0.15, angle F = 0.02, p = 0.88), and there were no interactions. Peak pressure occurred at 25 mm from the scaphoid and -9° from the scaphoid-hamate axis in the 20° fall configuration, and 21 mm from the scaphoid and -5° from the scaphoid-hamate axis in the 40° fall configuration (Figure 2).

Force on the danger zone associated with pad condition pad (F = 6.5, p = 0.027; decreasing 13% with the pad) and with BMI (F = 16.5, p = 0.002), but not with impact configuration (F = 4.4 p = 0.059), and there were no interactions (Figure 4).

Soft tissue thickness over the scaphoid correlated with distance (R = 0.79, p = 0.001), and normalized force applied to area C (R = 0.76, p = 0.002), but did not associate with peak pressure or peak total force.

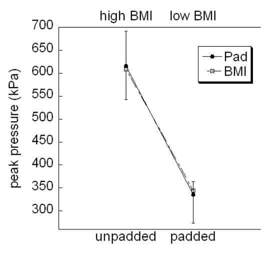

Figure 3

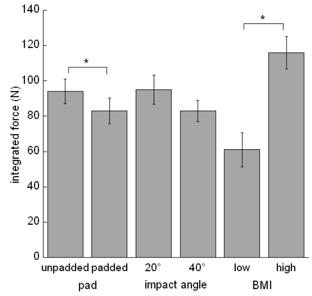

Figure 4

DISCUSSION:

Our results provide novel evidence of the distribution of force to the palm during a fall on the outstretched hand, and how this is affected by external padding, impact configuration, and BMI. The 5 mm thick pad we tested reduced peak pressure by 83%, and attenuated force to the danger zone by 13%. However, it had no effect on peak total force and the location of peak pressure. This suggests that the tested foam pad altered the local variation in stiffness over the palm (and thus pressure distribution) but had little influence on total stiffness (and peak force). These results provide a baseline for future studies on the optimal design of padded gloves to prevent wrist injuries in high-risk activities such as biking, motorcycle riding, and snowboarding, where rigid wrist guards provide an undesirable restriction on wrist mobility.

We were surprised to find that peak pressure averaged 77% higher in the high BMI than low BMI group, since we expected that individuals with high BMI would possess greater soft tissue padding, which would act as a natural shock absorber to reduce peak pressure, as observed for impact to the hip (Lauritzen et al., 1992; Robinovitch et al., 1995; Choi et al., in press). This discrepancy likely relates to the site-specific variation and association between soft tissue thickness and BMI. In our participants, soft tissue thickness over the greater trochanter averaged 23 mm thicker in the high BMI than low BMI group (46.8 versus 23.8 mm). However, tissue thickness over the scaphoid differed by less than 1 mm between the groups (7.7 versus 6.9 mm). Thus, individuals with high BMI benefit from the cushioning effect of thicker soft tissue over the hip (which offsets the effect of increased body mass), but not from greater soft tissue thickness at the palm.

Finally, our results suggest that the relationship between impact configuration and fracture risk is complex. Since bending stresses contribute to risk for Colles' fracture, one might surmise that our 20° fall configuration would create lower risk for fracture than the 40° fall configuration, due to the smaller moment arm. However, this may be offset by the 12% higher peak force observed in the 20° fall configuration. Future work should explore these trends in greater detail.

ACKNOWLEDGEMENTS:

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