Influence of Fall Simulation Paradigm, Sex, and Trochanteric Soft Tissue Thickness on Femoral Neck Stresses and Fracture Risk during Lateral Falls

Steven P. Pretty, Iris C. Levine, Andrew C. Laing
Department of Kinesiology, University of Waterloo, Waterloo, ON

Introduction:

The mechanical nature of factors influencing hip fracture rates are not fully understood. Fracture risk during a fall can be modulated through impact dynamics and/or underlying femur morphology; however, risk assessment efforts have focused on the latter. An approach sensitive to both skin-surface impact dynamics as well as underlying femur morphology could provide additional insight into the mechanical nature of clinical risk factors. The purpose of this study was to evaluate the influence of fall simulation paradigm (FSP), sex, and trochanteric soft tissue thickness (TSTT) on femoral neck stresses and fracture risk. Insights gained through coupling of experimental data and tissue-level models could inform the development of protective devices and increase the accuracy of clinical screening tools.

Methods:

Transverse plane TSTT ultrasound images from 33 healthy, young adult participants (17 female) were stratified into low-, mid-, and high-TSTT groups based on values observed in an older adult population [1]. Participants completed a series of FSP (Figure 1) ranging from highly controlled vertical drops (pelvis release) to kneeling and squat releases, which more closely resemble falls observed in long term care settings [1]. In each FSP, participants impacted their left hip on a RSscan pressure plate and an in-series force platform. Kinematics of the impacting thigh were collected using an Optotrak Certus system. At the instant of peak force, the net impact vector orientation and anatomical point of application, and local force magnitude over the greater trochanter (circular r=5 cm) were extracted.

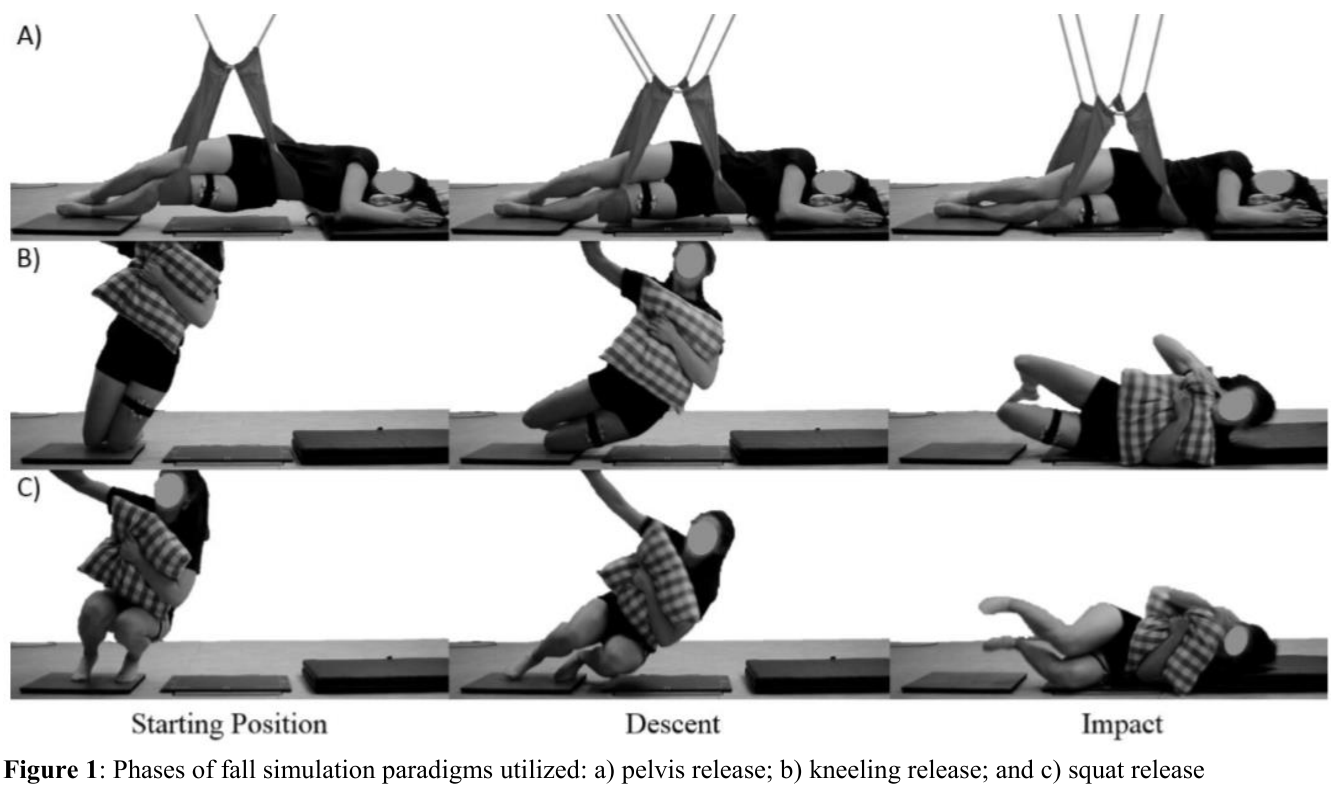

Figure 1: Phases of fall simulation paradigms utilized: a) pelvis release; b) kneeling release; and c) squat release

Participants subsequently underwent left (impacting) hip dual-energy X-ray absorptiometry imaging. Participant-specific beam models were generated through extraction of femur morphology [2] and application of experimental loading conditions. Femoral neck stresses at the superior-lateral (SL) and inferior-medial (IM) cortices, as well as a cross-sectional fracture risk index (FRI) were calculated for each experimental fall simulation.

Results & Discussion:

Pelvis release, which had lower resultant impact force, elicited lower femoral stresses and FRI (Figure 2) than FSP incorporating lateral motion (all $p<0.01$). Kneeling release loading was directed more perpendicularly to the femoral shaft and elicited greater SL compressive stresses, and lower IM tensile stresses, than squat release (all $p<0.05$); however, FRI did not differ between kneeling and squat release ($p=0.960$).

Despite greater and more localized impact force in males (both $p<0.01$) than females, no differences in stresses or FRI (Figure 2) were observed ($p>0.484$). Secondary analysis revealed males had greater resistance to stress generation and yield stress than females (all $p<0.05$).

Greater force magnitudes were observed for higher-TSTT participants; however, these loads were applied peripherally from the greater trochanter (both $p<0.01$). Although no differences in force applied directly over the proximal femur were observed ($p=0.578$), low-TSTT participants had greater stresses and FRI (Figure 2) than high-TSTT due to differences in femur morphology (all $p<0.05$).

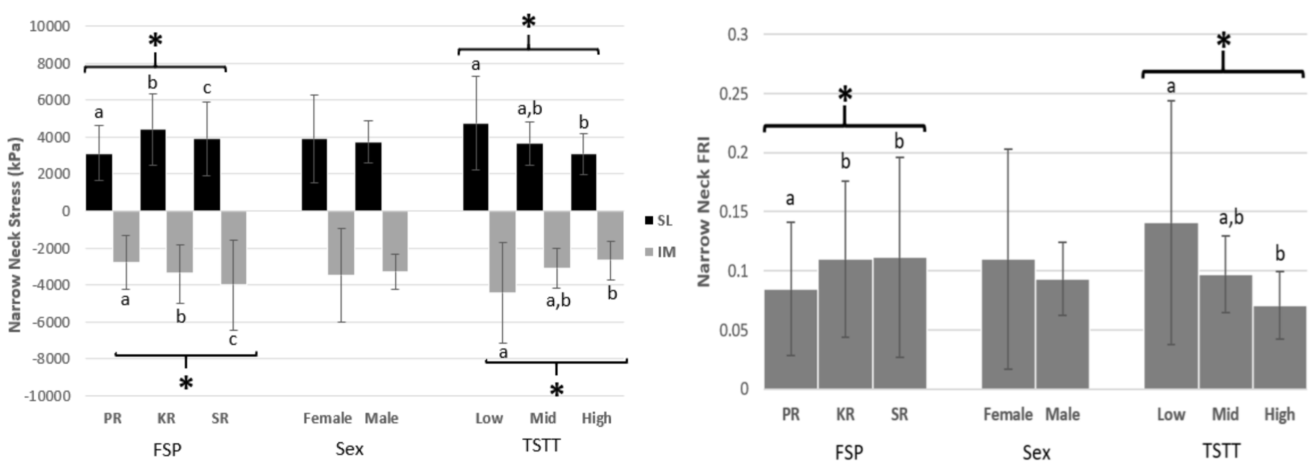

Figure 2: **(Left)** Stresses (+ compression) at the superior-lateral (SL) and inferior-medial (IM) cortices and (**Right)** narrow neck fracture risk index across FSP, sex, and TSTT (*significant main effect; letters refer to significant pairwise differences at $\alpha = 0.05$)

Conclusion:

We found that FSP, sex and TSTT had independent effects on metrics of impact severity and femur strength. Towards mirroring contributing factors, hip fracture risk analyses should consider both impact dynamics and underlying femur morphology.

References:

[1] Levine IC. (2017). *PhD Dissertation, UWSpace.*

[2] Mourtada FA et al. (1996). *J Orthop Res;* **14**: 483-9