Peak pressure and contact profile: links with individual characteristics and falling configuration

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It has been theorized that the soft tissues overlying the hip modify risk of hip fracture by increasing contact area between the pelvis and floor, and decreasing pressure at the hip [1, 2]. This general theory supports the design of compliant hip protectors [3] and safety floors [4]. However, better understanding of the three-dimensional nature of load distribution may improve prediction of hip fracture risk, protective equipment design, and identification of "high-risk" falling configurations. Further, while estimation of the forces applied to, and distributed between body segments during a fall can be achieved through multibody modeling, Hertzian and volumetric contact models assume circular contact profiles.

No published literature has linked falling configuration or soft tissue thickness (STT) with peak pressure or contact profile**. Therefore, the objective of this study** was to quantify differences in a) peak pressure, and b) contact profile, between sexes, falling simulation method, and STT group during simulated falls.

Forty-four young, healthy participants (23 female) consented to undergo an eighteen-trial fall simulation protocol (FSP). STT was assessed (via ultrasound) in a side-lying position, similar to that expected during the impact phase of the fall simulations. The protocol comprised six blocks, each block consisting of one pelvis release, squat release and kneeling release, in randomized order (Fig.1).

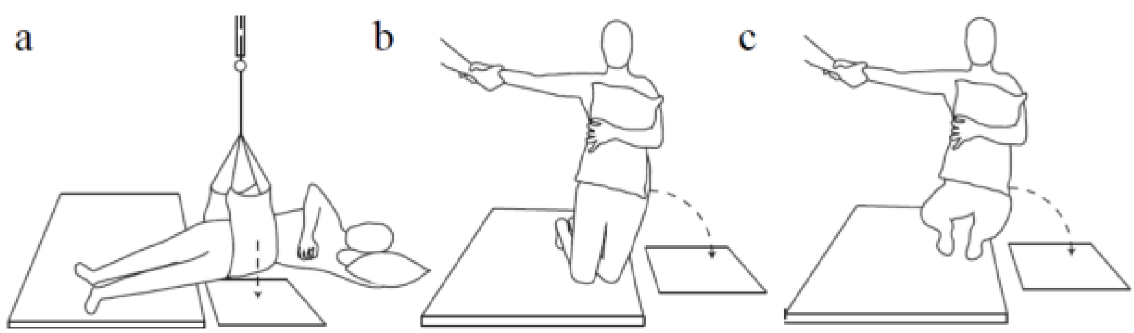

Fig. 1: Initial position and motion path of the pelvis release (a), kneeling release (b), and squat release (c). A controlled, vertical motion path is produced during pelvis release, while kneeling release has equal vertical and lateral motion, and squat release has more lateral than vertical motion.

Time-varying pelvis-floor contact pressure, and pelvis and hip kinematics were collected for each trial. Peak pressure and contact area and ellipse descriptors (eccentricity, radial Fourier harmonics, Fig.2) were quantified at time of peak pressure.

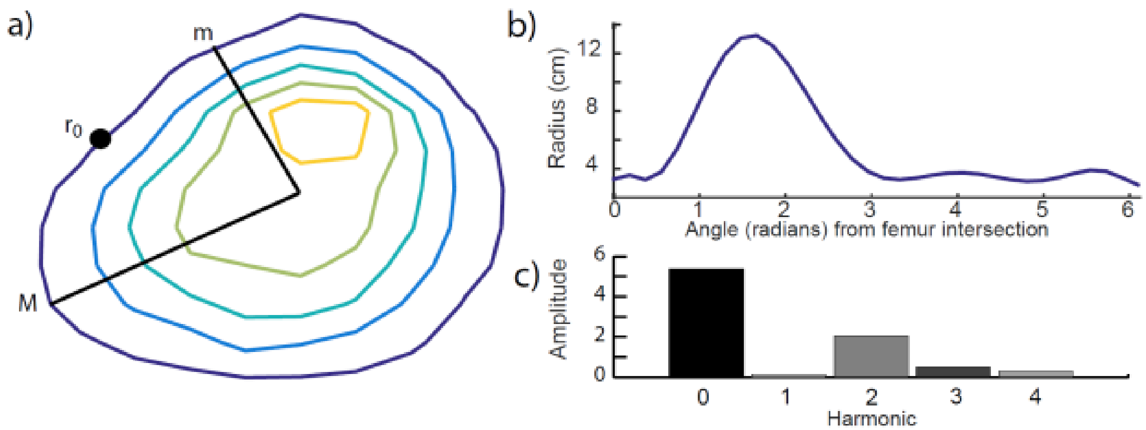

Fig. 2: Analysis of the floor-pelvis contact profile. The perimeter of the contact area (indigo line, a) is used to develop a waveform (b). Beginning at the femur intersection point (r_0), radii are determined, including major axis (M) and minor axis (m). Eccentricity is calculated as M/m. Fourier analysis of the waveform (c), with the harmonic number indicating the lobe number, and the amplitude indicating the dimensionality of the lobe of that harmonic.

Peak pressure was greatest during squat release ($F=21.3$, $p<0.001$), but not different between sexes or STT. Contact area and amplitude of harmonic 0 (mean radius) were lower for males ($F=16.3$, $p<0.001$; $F=4.1$, $p=0.042$) and low-STT fallers ($F=40.9$, $p<0.001$; $F=9.1$, $p<0.001$), but not different between FSP. Eccentricity and magnitude of harmonic 1 (roundness) were greatest for pelvis release and lowest for squat release ($F=13.9$, $p<0.001$; $F=4.4$, $p=0.012$); however, harmonic 1 results did not differ between FSP when normalized to harmonic 0.

Females and high-STT fallers benefit from greater soft tissue distribution of loading, consistent with current hypotheses. This supports use of interventions that mimic increased soft tissue, such as compliant floors or hip protectors. Greater peak pressure during squat release, despite no change in contact area, may be related to hip flexion and floor-pelvis alignment, reducing STT redistribution of pressure during the protocol. Falls with impact configurations similar to the squat release, therefore, may result in greater loading at the hip. Eccentricity was greatest for pelvis release, reflecting simultaneous pelvis and thigh contact, and potential for load distribution distal to the hip. However, eccentricity and Fourier harmonic analysis provided conflicting results regarding contact profile; further work will be required to determine the implications of the contact profile on model roundness assumptions.

References

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