WRIST KINETICS DURING IMPACT ARE AFFECTED BY HAND SYMMETRY

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INTRODUCTION: Falls onto the outstretched hands are the most frequent cause of upper extremity injury, and it has been estimated that older adults experience wrist fractures at a rate of 8 to 10 per 1000 person-years [1]. Previous work has quantified impact forces during symmetrical simulated falls [2,3], and several groups have shown that cadaver wrists fracture when loaded with 1.5 to 3.6 kN [4]. There is evidence that many falls result in temporally and spatially asymmetrical hand impacts [5], however no experimental studies have examined the sensitivity to wrist kinematic and kinetic measures to asymmetry.

The present study was undertaken to quantify wrist kinetics during asymmetrical impacts, and specifically to address three questions. How is spatial asymmetry at impact related to temporal asymmetry? Do asymmetrical impacts result in larger resultant forces than symmetrical impacts? How is loading direction affected by asymmetry?

METHODS: Nine adults participated in this institutionally reviewed and approved experimental protocol. Each subject performed 15 forward falls from a kneeling position onto two force plates. Five asymmetrical combinations of four targets, A_1 through A_5, were selected (Figure 1), based on hand dominance. Each subject performed three consecutive trials at each combination. Force plate data were captured at 2400 Hz. Motion data were captured at 240 Hz (Motion Analysis, Santa Rosa CA).

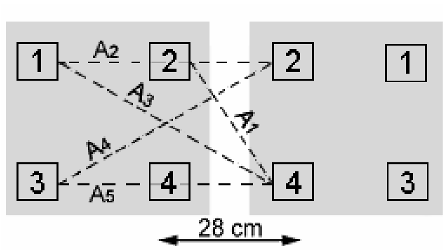

Figure 1 Force plates showing the locations of the four targets. Combinations A_1 through A_5 for a right-handed individual are shown with dotted lines.

The instant of force-plate contact was determined as the time at which each plate measured ≥ 5% body weight (BW). The instant of peak force was measured when the maximum resultant force was reached on each plate. Temporal offset (dtime) between hand-hits was determined for each subject (dtime>0, dominant hand hit first). Force direction for each arm was determined relative to the axis of the forearm (from wrist center to elbow center, Figure 2) and expressed in directional cosines.

RESULTS AND DISCUSSION: Spatial asymmetry caused a temporal offset abs(dtime) between hand-hits of 33±25 ms. On average, 25±9 ms elapsed between the instant of contact and the instant of peak force. In contrast, symmetrical falling data collected with the same set of targets resulted in significantly smaller temporal offsets of 12±11 ms [5].

Asymmetry did not influence peak resultant force magnitude (symmetrical: 92 ± 38 %BW, asymmetrical 94 ± 30 %BW).

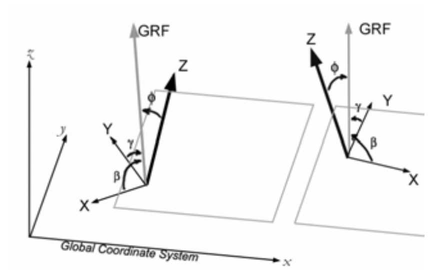

Figure 2 Arm-specific coordinate systems with direction cosines. The z-axis of each system is aligned with the axis of the forearm at the instant of peak force. The axes are mirror-images of each other such that a positive x-value indicates laterally directed force, relative to the forearm (i.e. the left hand coordinate system has left-handed axes). Direction cosine angles are defined such that β is the angle from the x-axis, γ is the angle from the y-axis, and φ is the angle from the z-axis. A force is directed along the axis of the forearm when β=90, γ=90, and ϕ=0. Note that in all cases $\cos^2\beta+\cos^2\gamma+\cos^2\phi = 1$.

However, at the same target location (1 through 4), asymmetry significantly influenced force direction. In targets 1, 2, and 4, asymmetry caused the resultant force to be more axially directed. The 95% C.I. for peak force direction across all asymmetrical positions ranged from 100% axially loaded to β=82.5°, γ=70.4°, ϕ=29.5° (87% axially loaded).

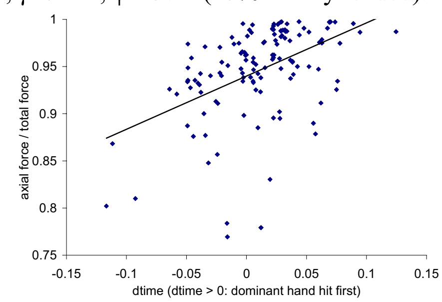

Figure 3 Dominant hand axial force versus temporal offset.

Larger temporal offsets were associated with axially directed resultant ground reaction forces in the first hand to hit (i.e. dominant axial/total force ~ dtime, r = 0.454 $p<0.001$, non-dominant axial/total force ~ dtime, r = -0.335 $p<0.001$, Figure 3). When the ground is contacted asymmetrically, the first hand may be used to reduce the downward and forward velocity of the body, while the second hand may play a more important role in preventing body rotation and in reducing shear.

Although asymmetry doesn't appear to affect peak force magnitude, it does cause more axially directed forces. This appears to be modulated by the magnitude of temporal offset. The extent to which fracture mechanics of the radius are affected by loading direction is still unknown. Furthermore, spatial asymmetry has been shown to cause temporal asymmetry, even for this self-initiated falling task.

REFERENCES: [1]Vogt et al. J Am Geriatr Soc 2002;**50**(1), [2]DeGoede et al. J Biomech 2002;**35**(6), [3]Kim and Ashton-Miller Clin Biomech 2003;**18**(4), [4]Augat et al. J Orthop Res 1998;**16**(5), [5]Troy and Grabiner, ASB Proceedings 2004

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