ARREST OF FORWARD FALLS ONTO OUTSTRETCHED HANDS IN HEALTHY YOUNG WOMEN

[1,2]Lisa Case, [1]Jia-Hsuan Lo, [1,2]James Ashton-Miller
[1]University of Michigan, Department of Mechanical Engineering
[2]University of Michigan, Department of Biomedical Engineering; email: lcase@umich.edu

INTRODUCTION

Fall-related injuries are projected to cost the United States $85 billion per annum by the year 2020 [1]. Some 60% of all falls in older adults are in the forward direction [2]. Past studies have examined the biomechanics of forward fall arrests from different heights, onto different surfaces, and using different strategies. These studies, however, involved men; none address how forward falls are arrested by women. This is surprising since elderly women have 1.2 to 2.2 higher rates of falls [3], and are 1.8 to 2.2 times more likely to sustain an injury in a fall [4], than men. We first quantified how a group of healthy young women use their upper extremities to arrest standardized forward falls from three different heights, one of which was similar to that used in a two-height test protocol developed for men [5]. We tested the null hypothesis in women that fall height would not affect the magnitude of the ground reaction force, pre- and post-impact arm kinematics, or arm muscle EMG patterns. Finally, by comparing these results with the published male data [5] obtained using similar methods, we tested the hypothesis that there is no effect of gender on these parameters.

METHODS

Ten healthy young women [mean (SD): age: 24.5 (2.1) yrs, body weight: 585 (61) N; height: 163.7 (4.3) cm] volunteered for this study. Kinematic markers were affixed to the subjects on both upper arms and forearms, left side of the head, neck and left thigh, as well as the left malleolus to collect kinematic data at 200 Hz with an Optotrak 3020 motion-tracking system. Three AMTI force plates were used to collect force and moment data at 2 kHz using the following protocol. RMS surface EMG was measured at 1 kHz in the left triceps, biceps, deltoid, pectoralis, neck extensor, and serratus anterior and a 50 ms window analyzed just prior to impact. Subjects were leaned 20° forward from vertical and held with a tether. The subject was then asked to bend at the waist with her arms out toward the force plates in front of her. The subject was then released, at the count of three, to arrest the fall, with each hand landing on a force plate. Two falls were performed from a neck marker height of 70 cm, followed by two falls from 80cm and three falls from 90 cm. Subjects were asked to fall naturally using only their arms. Because the fall heights were 75 and 100 cm in the male study and since the women's data appeared linear across fall heights, linearly-interpolated male values at 80 and 90 cm were used in the gender comparisons. Repeated measures analysis of variance (rm-ANOVA) were used to test the hypotheses (using $p<0.05$ for significance).

RESULTS AND DISCUSSION

In the women, the peak ground reaction force, F1, normalized by body weight, increased with fall height (Table 1, rm-ANOVA, $p<0.05$). Their elbow flexion angle at impact, Θ, did not vary significantly across the fall heights ($p>0.10$). The increase in elbow flexion from impact through the first 500 ms of the fall arrest, ΔΘ, however, did increase with fall height ($p=0.003$), leading us to reject the first hypothesis. Pre-impact triceps activation, EMG_{tri}, shown as a percentage of a maximum triceps contraction, did not vary with fall height ($p>0.05$). Comparing these parameters with published results for men [5], no gender difference was found in F1 after normalization by body weight ($p=0.376$). There was also no difference in the elbow flexion at impact ($p=0.177$) or in pre-impact triceps activation ($p>0.05$). The remarkable finding was the significant, almost 4-fold difference, in the post-impact increase in elbow angle ($p = 0.039$; Figure 1). Therefore, we rejected the null hypothesis of no gender differences in the forward fall arrest strategy under these test conditions. We speculate that these healthy young women may have limited post-impact elbow flexion to reduce the risks of elbow buckling and, thereby, head impact.

Table 1: *Mean (SD) initial elbow angle (**Θ**) at impact, post-impact increase in elbow angle (**ΔΘ**), maximum impact force (**F1**), and triceps EMG (**EMGtri,** % max) for the women. [Θ = 180° = full arm extension]*

Fall Ht.	Θ (°)	ΔΘ (°)	F1 (N)	EMG_{tri} (%)
70 cm	166 (6)	15 (7)	482 (75)	66 (30)
80 cm	169 (7)	22 (12)	584 (79)	67 (34)
90 cm	168 (7)	31 (12)	648 (90)	70 (31)

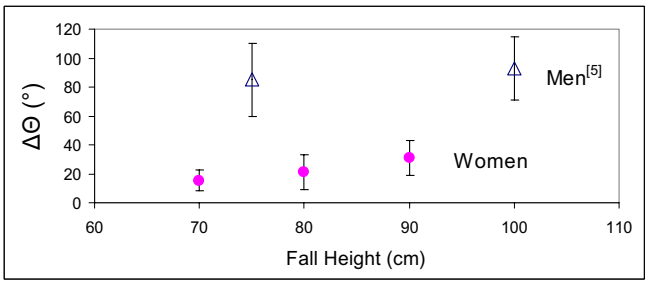

Figure 1: *A 4-fold gender difference in the mean post-impact change in elbow flexion (**ΔΘ**) was found. Bars denote SD.*

CONCLUSIONS

1) In healthy young women, increasing fall height:
   a. Did not affect elbow flexion angle at impact
   b. Did increase normalized impact forces
   c. Did increase post-impact elbow flexion.
2) Healthy young women permit significantly smaller increases in post-impact elbow flexion than men.

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