CAN PEAK IMPACT FORCES BE VOLITIONALLY REDUCED IN A FORWARD FALL ONTO THE HANDS ?

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INTRODUCTION

The use of the arms to protect oneself during a fall is a natural and often used arrest strategy among untrained individuals (O'Neill 1994; Hsiao 1998). However, this can lead to distal radius fracture (Loder 1988). In fact, the distal forearm is the most common fracture site in the body with 213 such fractures occurring annually per 100,000 individuals (Donaldson 1990). Since risk of distal radius fracture has been linked to the magnitude of the impact load applied to the hands (i.e. Myers 1993), a strategy to reduce that load should lower fracture risk.

We tested the hypothesis that in a forward fall, healthy young males could learn to reduce the peak impact force involved in arresting the fall within four trials.

PROCEDURES

We tested five healthy young male volunteers aged between 22 and 28 years. None of the subjects had any previous falls training. The institutional review board approved all test procedures, and all subjects read and signed a written statement of informed consent.

The subjects stood on a force platform and leaned forward against a supporting tether attached at the waist. The subjects then flexed at the waist to the point at which the center of their shoulder joint was 1 m above the ground. Upon release, they were instructed to arrest their forward fall with their arms. No practice trials were given. The hands contacted the ground during the arrest on two AMTI force-plates, covered with 2.4 cm thick compact rubber foam.

The subjects performed three additional arrests without further instruction. Next, we asked the subjects to arrest two falls while keeping their head as far off the ground as possible, essentially 'stiff-arming' the fall arrest. Finally, the subjects were instructed to try to minimize the peak force of impact on their hands as much as possible over four trials.

In all trials, we measured the kinematics of the fall arrest at 200 Hz with 11 infrared markers using the Optotrak motion analysis system. The force plates were sampled at 2,000 Hz.

The kinematic data were low-pass filtered with a fourth-order Butterworth filter (Matlab) with a cutoff frequency of 100 Hz. The force-plate data were similarly filtered with a cutoff frequency of 300 Hz.

A repeated measures ANOVA was performed to compare the impact forces associated with each subject's first natural, worst-case stiff-arm, and best minimum impact trials.

RESULTS AND DISCUSSION

The largest impact forces (1098±134 N) were found during the stiff-arm impact

(Figure 1). The peak force was significantly affected by the landing strategy employed by the subjects (ANOVA, $p<0.001$). In fact, the force was 15 % lower in the first natural fall than in the worst-case stiff-arm landing at 929±85 N, and 55 % lower when the subjects volitionally minimized the peak force (511±104 N). The secondary rise in the reaction force was also significantly affected by the landing strategy used, with the magnitude of this force being 27 % lower for the minimal-impact arrest than for the stiff-arm landing ($p<0.001$). There were no significant between-subject effects for either body weight or height.

The biomechanics of the arrest of a fall to the ground has received some attention recently (Sabick 1999; Chiu 1998; Robinovitch 1998). One of these studies investigated a martial arts break-fall technique for a lateral fall, and the other two explored stiff-arm arrests of 1 - 5 cm forward falls. However, data from a ballistic pendulum-arm impact experiment with a biomechanical analysis of a fall indicated that the peak force applied to the distal forearm in a fall arrest could potentially be reduced by as much as 50 % by making modest adjustments to the initial elbow angle and the impact velocity of the hands (DeGoede 1999). In the current investigation, we found that young healthy males were indeed able to reduce the peak ground reaction by 50 % in actual forward falls arrested with the arms.

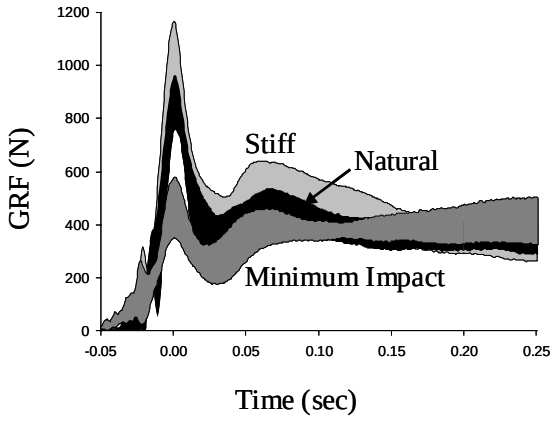

Figure 1: GRF at one hand during arrest of forward falls. Shaded regions indicate standard deviation envelopes for each of three different arrest strategies.

SUMMARY

This is the first demonstration that healthy young males can reduce the peak force applied to their hands by volitionally modifying their fall-arrest strategy. This may have implications for reducing the risk of wrist fracture in falls.

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