EFFECT OF MUSCLE CONTRACTION ON IMPACT VELOCITIES OF THE HEAD DURING BACKWARD FALLS IN YOUNG ADULTS

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INTRODUCTION

Falls are a direct cause of head injuries in older adults, and 60% of traumatic brain injuries are due to a fall, accounting for 32% of hospital admission and 50% of death from falls [1,2]. Most head impacts in older adults in long term care occur from backward falls [3], and a recent kinematic analysis of video-captured real-life falls in older adults suggested that contracting the core and neck muscles during decent and impact may help to prevent, or lessen the severity of head impact during backward falls [4]. In this study, we have conducted falling experiments with young adults to determine how muscle contraction during a fall influences the impact velocity of the head during backward falls.

METHODS

Healthy young adults (n=8) aged between 19 and 35 participated in falling experiments. Participants were taught and trained to mimic older adults backward falls on the buttock, back and head, captured by surveillance cameras installed in long-term care facilities [5] (Figure 1). The experiment was approved by the IRB of Chapman University, and all participants provided written informed consent.

For all falls, participants were instructed, “fall naturally while imagining you are falling on a hard surface”, and were not allowed to use their arms to arrest fall. Participants were also instructed to fall in three different ways: a. “fall backward and prevent your head from impacting the ground”, b. “fall backward and allow your head to impact the ground, but with minimal impact severity”, and c. “fall backward and allow your head to impact the ground, while inhibiting your efforts to reduce head impact severity”. All participants wore wrist guards and helmets, and fell onto a padded mattress. Reflective markers were placed on bony landmarks of the body to monitor participants’ fall kinematics through 10 Raptor motion analysis cameras (Motion Analysis Corp, Santa Rosa, CA) at a sampling rate of 250 Hz. Muscle activation of the core and neck muscle was monitored through electromyography (EMG) electrodes placed bilaterally on the skin over the rectus abdominis and sternocleidomastoid muscles, at a sampling rate of 2,000 Hz (Noraxon EMG DTS system, Scottsdale, AZ).

Outcome variables included the vertical and horizontal velocities of the head at impact, and the integrated EMG (IEMG; a measure of the intensity of muscle activity) over the time period a. between fall initiation and head impact for falls resulted in head impact, or b. between fall initiation and a moment when the head marker was at its lowest point in z axis for falls involved no head impact. The time of fall initiation was defined as 10 frames (40 ms) after the instant when the greater trochanter started to move downward. The time of head impact was defined as the moment that the head marker

Figure 1. Self-initiated backward fall on a 12” thick gymnastics mat. Participants mimicked older adults’ backward falls and head impacts, based on video-captured backward falls in long term care.
passed a threshold height 240 mm above the mat surface [6]. EMG data were full-wave rectified and low-pass filtered with a cut-off frequency of 20 Hz (4th order Butterworth algorithm). IEMG data from right and left sides were averaged for each muscle.

ANOVA was used to test whether our outcome variables associated landing type during backward falls (3 levels). We also conducted a regression analysis to test whether impact velocity associated muscle activity. All analyses were conducted with SPSS using a significance level of alpha = 0.05.

\[ y = -0.08x + 2.9 \]

**Figure 2.** Association between vertical head impact velocity and neck muscle activity during backward falls.

**RESULTS AND DISCUSSION**

The experimental instruction associated with neck muscle activity (p=0.009), but not with core muscle activity (p=0.14). On average, neck muscle IEMG was 197% greater in falls where participants attempted to avoid head impact when compared to falls where they allowed head impact, while inhibiting efforts to reduce impact severity (13.4 versus 4.5 mV*S) (Table 1). The falling instruction also associated with vertical head impact velocity (p<0.0005) and horizontal impact velocity (p<0.0005). Overall, vertical head impact velocity was 82% greater in falls where participants inhibited efforts to reduce impact severity versus impacted softly (3.24 versus 1.78 m/s).

Furthermore, our regression analysis indicated that vertical head impact velocity associated neck muscle activity (p=0.01, R^2=0.28) (Figure 2). Our average value of vertical head impact velocity in falls where participants inhibited protective responses (3.24 m/s) is similar to the mean value (2.91 m/s) we recently observed from analysis of real-life falls in older adults captured on video in long term care [4].

Our results provide novel measures of head impact velocities during backward falls in humans, to inform the design and testing of protective gear (helmets, crash mats). Our results also indicate the essential role, in reducing the frequency and severity of head impacts in backward falls, of neck and core muscle activation during the descent and impact phases of falling. Further research is required to understand age-related changes and the role of neck and core strengthening exercises to prevent fall-related head injuries in older adults.

**REFERENCES**

3. Schonnop R et al., *CMAJ* 185, 803-10, 2013

**Table 1: Average values of outcome variables (with SD shown in parentheses).**

<table>
<thead>
<tr>
<th>Backward fall</th>
<th>No head impact</th>
<th>Minimize impact severity</th>
<th>Inhibit protective responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sternocleidomastoid_IEMG (mV*S)</td>
<td>13.4 (6.2)</td>
<td>10.1 (5.3)</td>
<td>4.5 (2.4)</td>
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<tr>
<td>Rectus Abdominis_IEMG (mV*S)</td>
<td>12.8 (7.3)</td>
<td>10.4 (4.0)</td>
<td>7.1 (3.8)</td>
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<tr>
<td>Vertical head impact velocity (m/s)</td>
<td>...</td>
<td>1.78 (0.6)</td>
<td>3.24 (0.4)</td>
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<tr>
<td>Horizontal head impact velocity (m/s)</td>
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<td>1.50 (0.5)</td>
<td>2.73 (0.5)</td>
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</tbody>
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