The Effect of Pre-Impact Bracing on the Peak Neck Muscle Activation and Onset Time in Headfirst Freefalls.

Loay Al-Salehi, Peter A. Cripton, Gunter P. Siegmund

I. INTRODUCTION

Headfirst impacts, often seen in diving, downhill mountain biking and motor vehicle rollovers, are dangerous events that can lead to catastrophic cervical spine injuries [1]. Pre-impact neck muscle activation can affect pre-impact head postures and injury severity in axial impacts [2-3]. Although the time from headfirst impact to cervical spine injury (2-19 ms [4]) is shorter than the reflex onset time of most cervical spine muscles (>50 ms [5]), some injurious events like motor vehicle rollovers develop over longer periods (>1 s [6]) and allow for both reflexive muscle activation and voluntary neck muscle bracing before impact. Our goals here were to compare muscle activation amplitudes and onset times in eight neck muscles between unbraced and braced conditions in headfirst drops and to compare the amplitude of the activation before and during the headfirst drop. These data will be useful for understanding the role of neck muscles in the genesis of neck injuries and to ultimately develop interventions to prevent catastrophic cervical spine injuries.

II. METHODS

Four healthy human subjects (3F, 1M) were secured by a 5-point harness (RCI Racers Choice Inc., Tyler, TX, USA) in an automotive racing seat (Kirkey Racing Fabrication INC., St. Andrew's West, ON, USA) fastened to a custom-built carriage that was inverted, elevated and dropped (Fig. 1A). The subjects' feet were secured to the carriage with snowboard bindings and the subjects' arms were secured to their thighs. The carriage was attached to a linear motor that was programmed to slowly raise the inverted carriage ~1 m above its resting position, allow it to freefall for 312.5 ms, and then to decelerate it at ~2 g to rest. Subjects experienced four drops: the first two were unbraced and last two were braced. Unbraced subjects were told to relax as much as possible while holding their head horizontal, whereas braced subjects were told to voluntarily brace for an impending headfirst impact.

Unilateral neck muscle electromyography (EMG) was recorded with indwelling electrodes (0.05mm Stablohm 800A, California Fine Wire Company, Grover Beach, CA, USA) inserted under ultrasound guidance into seven superficial and deep muscles: levator scapulae (LS), multifidus (MULT), semispinalis capitis (SSCAP) and cervicis (SSCERV), splenius capitis (SPL), sternocleidomastoid (SCM), and trapezius (TRAP) at the C4/C5 level. Surface electrodes (Ambu A/S, Ballerup, Denmark) were used for the sternohyoid muscle (STH). Raw EMG signals were amplified (x200), bandpass filtered (both indwelling and surface 50-2000 Hz, 60 Hz notch) and sampled at 4 kHz. The root mean square (RMS, 20 ms window) of all EMG signals were normalised by the maximum value of similarly processed EMG data acquired during maximum voluntary isometric contractions (MVICs) in flexion, extension, left/right axial rotations, left/right lateral bending, and four combinations of flexion/extension and lateral bending. All EMG data are thus expressed as %MVIC.

Some muscles were tonically active before the drop onset in both the braced and unbraced conditions. To account for this phenomenon, muscle onset was defined as the time, after drop onset, where the RMS EMG exceeded 20% of the peak RMS EMG for the specific muscle. We first compared differences in muscle onset times between the unbraced and braced conditions using a two-tailed paired t-test. We then compared peak EMG amplitude between the pre-drop and drop phases of motion using a one-tailed paired t-test (pre-drop<drop; braced and unbraced tested separately), after which we compared the EMG amplitude between the unbraced and braced conditions using a one-tailed paired t-test (unbraced<braced; pre-drop and drop phases tested separately). Results are given as the mean and standard deviation of the difference (Δ). To minimise the effect of habituation, we only analysed the first unbraced and braced trials.

L. Al-Salehi is a PhD student in Mechanical Engineering and P.A. Cripton is a Professor in Biomedical Engineering and Mechanical Engineering at the University of British Columbia in Vancouver, British Columbia, Canada. G.P. Siegmund is the Director of Research at MEA Forensic Engineers & Scientists in Laguna Hills, CA, USA (gunter.siegmund@meaforensic.com, +1 949 855 4632).

III. INITIAL FINDINGS

All subjects activated their neck muscles in response to the freefall drop (Fig. 1B). We found large variances between subjects in muscle onset times (Fig. 1C) and peak amplitudes (Fig. 1D). Mean muscle onset times ranged from 38.6 ms in STH to 141.3 ms in SPL. Muscle onset times were only shorter in LS (Δ=-30.3±25.1ms, p=0.047) in the braced condition (Fig. 1C). Compared to the pre-drop phase, peak EMG amplitude in the drop phase increased in MULT (Δ=111±72%MVIC, p=0.026), SSCAP (Δ=112±41%MVIC, p=0.006) and SCM (Δ=106±32%MVIC, p=0.004) for the unbraced condition (STH, SPL and SSCERV all had p-values of 0.06). Peak EMG amplitude in the drop phase also increased in MULT (81±52%MVIC, p=0.026) and SSCAP (61±51%MVIC, p=0.049) for the braced condition. Compared to the unbraced condition, peak EMG amplitude in the braced condition increased in MULT (50±43%MVIC, p=0.043), SSCERV (19±16%MVIC, p=0.030) and TRAP (40±69 %MVIC, p=0.028) before the drop. No significant differences in peak EMG amplitude between the two conditions occurred during the drop (p>0.10).

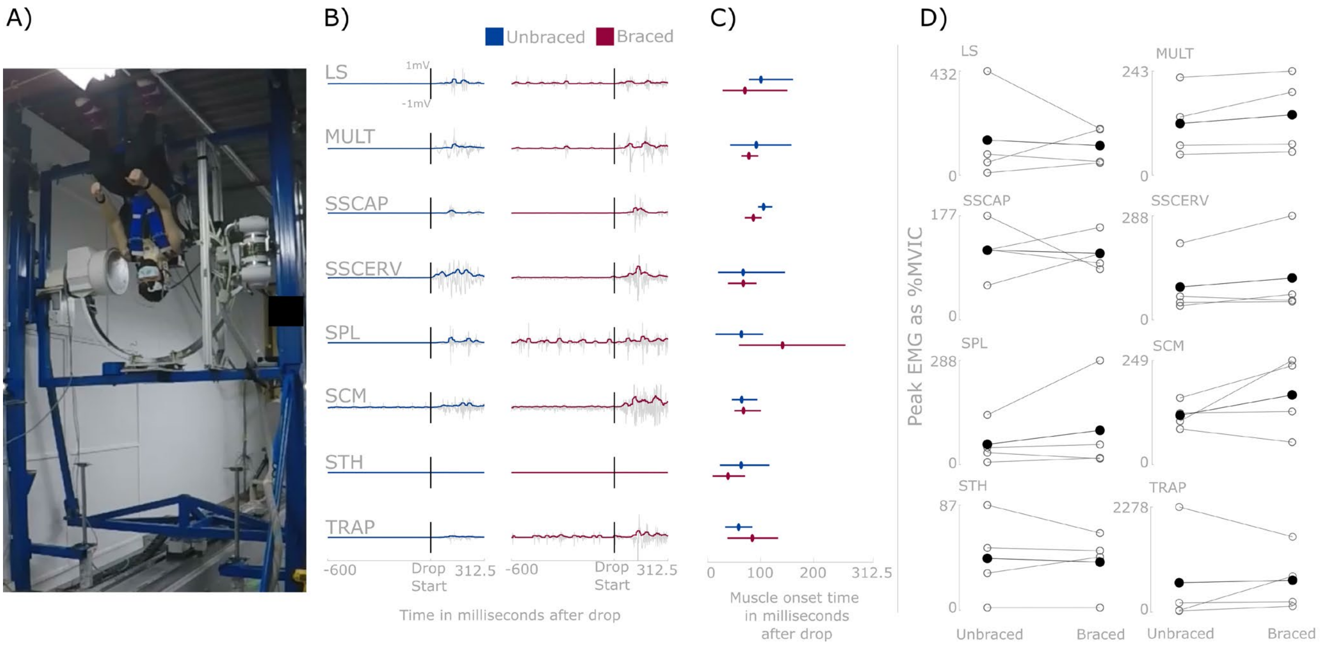

Fig. 1. (A) Experimental setup and beginning of the freefall drop of a typical experiment. (B) Exemplar EMG data from one subject for all muscles in an unbraced drop (blue) and braced drop (red). Red and blue traces show the RMS values; grey traces show the raw EMG. (C) Mean and range of muscle onset times. (D) Paired comparisons of peak EMG amplitude between the unbraced and braced conditions expressed as %MVIC on a linear scale for each volunteer (hollow circles) and the mean for four subjects (black circles) during the drop phase.

IV. DISCUSSION

In our initial four-subject cohort, we saw larger levels of muscle activation during the drop than during the pre-drop phase in both unbraced and braced subjects. During the drop phase, pre-impact bracing had little or no effect on the onset times or peak muscle activation levels in the neck muscles we measured. Given the large variances we observed in this and prior studies [7], more subjects are needed to support these initial findings. Muscle onset times seen in this study are typical [8] for the flexors and extensors in the neck. Based on some of the activation levels we observed, e.g., TRAP, 2278%MVIC, some subjects did not maximally activate some of their muscles during our MVIC tasks. This issue does not effect our results because of the paired nature of our analyses. Overall, our preliminary data and analysis indicate that pre-impact bracing may not affect the peak activation level of individual neck muscles during an inverted freefall; however, further work is needed to assess whether the net effect of small changes across all neck muscles affects the neck's posture or vertebral alignment.

V. REFERENCES

[1] NSCISC, 2021. [2] Stemper BD et al, Spine, 2011. [3] Fice JB et al, ABME, 2020. [4] Nightingale RW et al, JBiomech, 1996. [5] Siegmund GP et al, JPhysiol, 2001. [6] Young CR et al, SAE, 2020. [7] Newell RS et al, JBiomech, 2013. [8] Foust DR et al, SAE, 1973.