Neck posture and muscle activation: a human volunteer study comparing the effect of upright and inverted postures

Newell, R.[1,2*], Siegmund, G.P.[3,5], Blouin, J.S.[3,4], Street, J.[2,5], Cripton, P.A.[1,2]

[1]Orthopaedic & Injury Biomechanics Group, Departments of Mechanical Engineering and Orthopaedics (Division of Orthopaedic Engineering Research), University of British Columbia; [2]International Collaboration on Repair Discoveries (ICORD), University of British Columbia; [3]School of Human Kinetics and [4]Brain Research Center, University of British Columbia; [5]MEA Forensic Engineers & Scientists, Richmond; [5]Combined Neurosurgical and Orthopedic Spine Program, University of British Columbia

ORTHOPAEDIC & INJURY BIOMECHANICS GROUP

Introduction

Rollover accidents are highly dynamic and complex events in which occupants frequently contact the interior of the vehicle. Injuries to the head, spine and spinal cord, due to head-first impact, are common in occupants involved in rollover accidents. Cadaveric drop tests at the University of British Columbia have shown that the type of injury sustained in a head-first impact depends on compressive neck muscle forces and the alignment of the cervical vertebrae. However, there is little understanding of how the neck posture changes when someone is upside down or how muscle control can alter this posture.

Research Aim

The aim of this study is to quantify which neck muscles are active and what the spinal posture is in an upside-down configuration.

Methods

• Subjects (n=3) were placed in an upright and inverted configuration using a custom built chair apparatus (Figure 1).
• For both conditions, neck muscle activity was recorded using electromyography (EMG) and vertebral alignment was measured using fluoroscopy.

Figure 1: Photos of a subject in the inverting device.

Methods – Electromyography (EMG)

• Indwelling wire electrodes (Figure 2) were used to measure neuromuscular response of 7 cervical muscles (Figure 3) and surface EMG was used to measure Sternohyoid activity.

Figure 2: Indwelling electrodes

Figure 3: Cross-sectional view of the cervical muscles [1]

Sternocleidomastoid (SCM)	Levator scapulae (LS)
Trapezius (Trap)	Splenius (SPL)
Semispinalis capitis (SsCap)	Semispinalis cervicis (SsCerv)
Multifidus (MultC4)	Sternohyoid

Methods - Fluoroscopy

• A fluoroscopic c-arm was used to capture dynamic x-rays of the cervical spine (Figure 4)
• Cervical Curvature Index (C.C.I.) was used to quantify the changes in neck posture [2]

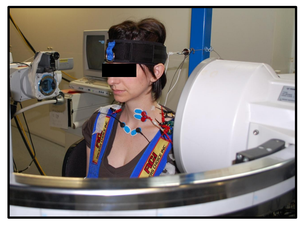
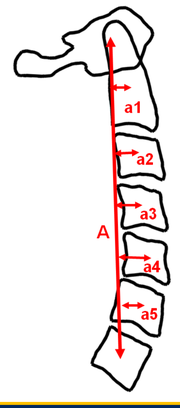


Figure 4: Subject with c-arm



$$\text{C.C.I.} = \frac{100 \times (a1 + a2 + a3 + a4 + a5)}{A}$$

Results

• Neck muscle activity increased in the inverted position; for the SCM and SPL it was >10 times higher (Figure 5).
• Compared to the upright configuration, the C.C.I. increased slightly when the subjects were inverted and looking forward, and doubled when they relaxed (Figure 6).

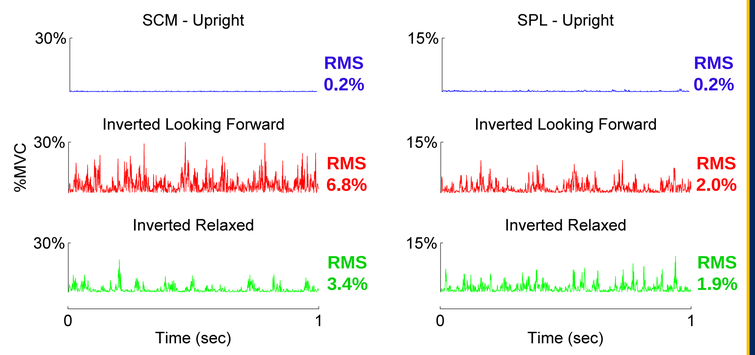


Figure 5: Representative plots of SCM (left) and Sternohyoid (right) EMG activity normalized to percent maximal voluntary isometric contraction (MVC) for relaxed upright (blue), inverted and looking forward (red) and relaxed (green) conditions.

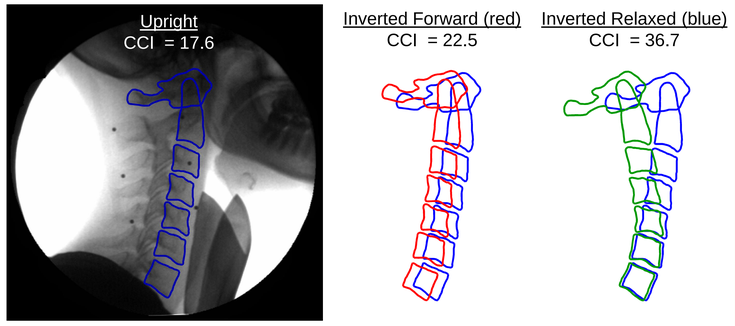


Figure 6: The vertebral body outlines from the lateral x-ray images and Cervical Curvature Index (C.C.I.) of one subject for three conditions: relaxed upright posture (blue), inverted looking forward (red) and inverted relaxed (green).

Expected Contributions

This study provides a unique *in vivo* data set of vertebral and muscular response to inverted configurations, which can be used to develop, improve and validate head-first injury models. Ultimately, application of this data has the potential to advance injury prevention strategies through vehicle design and improved sporting equipment.

*Contact: newellr@interchange.ubc.ca

References: *[1] Siegmund et al, 2007, J Biomech Eng, 129(1), pp.66-77*
[2] K. Takeshita*, et al.*, 2001, *J Orthop Sci,* 6, pp. 223-226