The effect of neck-strength and pre-release activation state on head angular displacement during a body-first fall

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Introduction

- Head impacts are a major contributor to concussion and traumatic brain injury (TBI) across sport, recreation, transportation and fall-related injuries[1,4]
- Many investigations have looked at direct impacts; mechanisms of real-world injury involve a body-first loading paradigm[2]
  - Body-first; where the torso impacts and object or surface before the head modifying the resultant head kinematics.
- Despite the prevalence, body first impacts in sport and fall-related injuries, limited ground-truth data exist in describing the dynamic response of the head during these events
  - Measure neck strength have been correlated with concussion injury reporting in sport.[1]
  - A keen interest in understanding how the body employ the neck muscles in the management of the head during an impact.[3]

Methods

- 42 (20M/22F) participants' neck strength was assessed and completed the fall protocol.
- Participants were outfitted with surface EMG on the neck muscles, opto-electric motion capture
- Held themselves up with a rope and completed a series of falls onto their back and side, at different activation conditions (Relaxed, 20% MVC and 60% MVC). Biofeedback was provided to the participant for achieving pre-release activation state
- To measure loading rate, they landed on force plates in the impact configuration space.

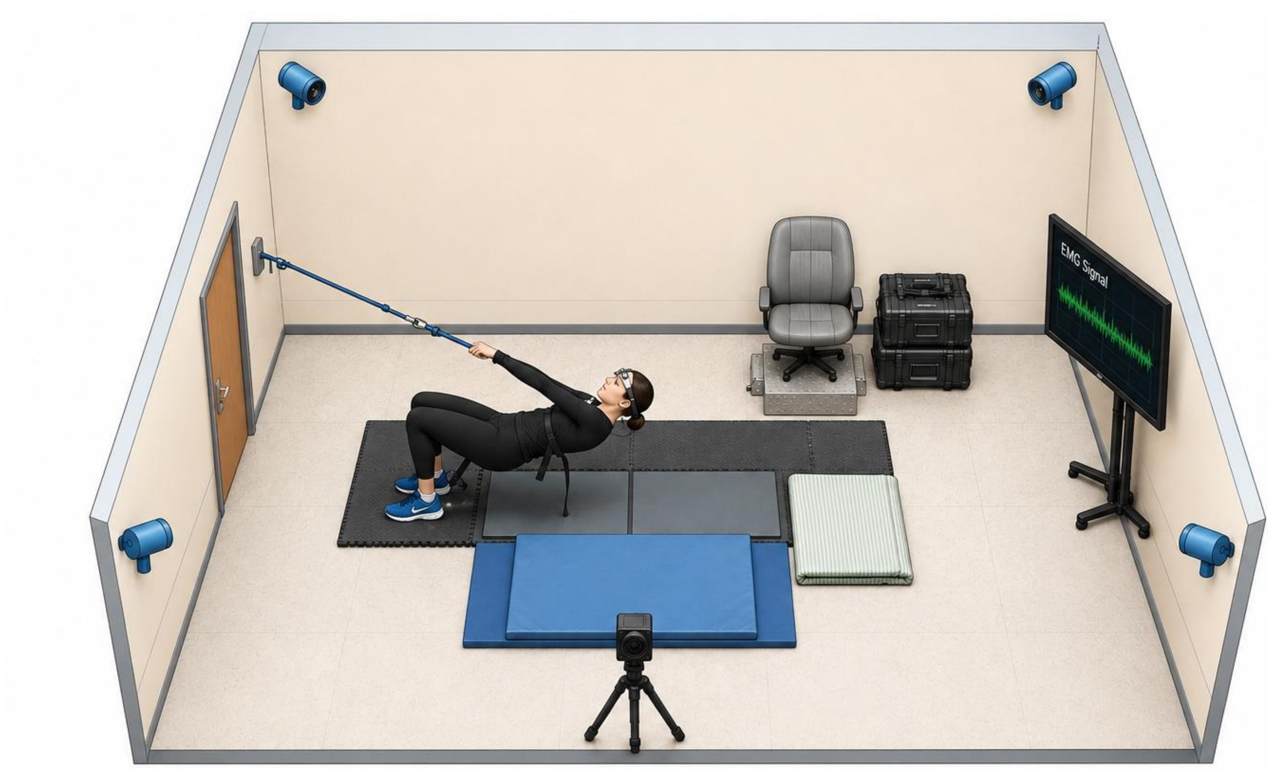

Figure 1: The collection space displacing the 3D marker capture cameras (blue) the biofeedback, the positioning of the participant over the force plates as well as the placement of the highspeed camera (black) (generated, 2026)

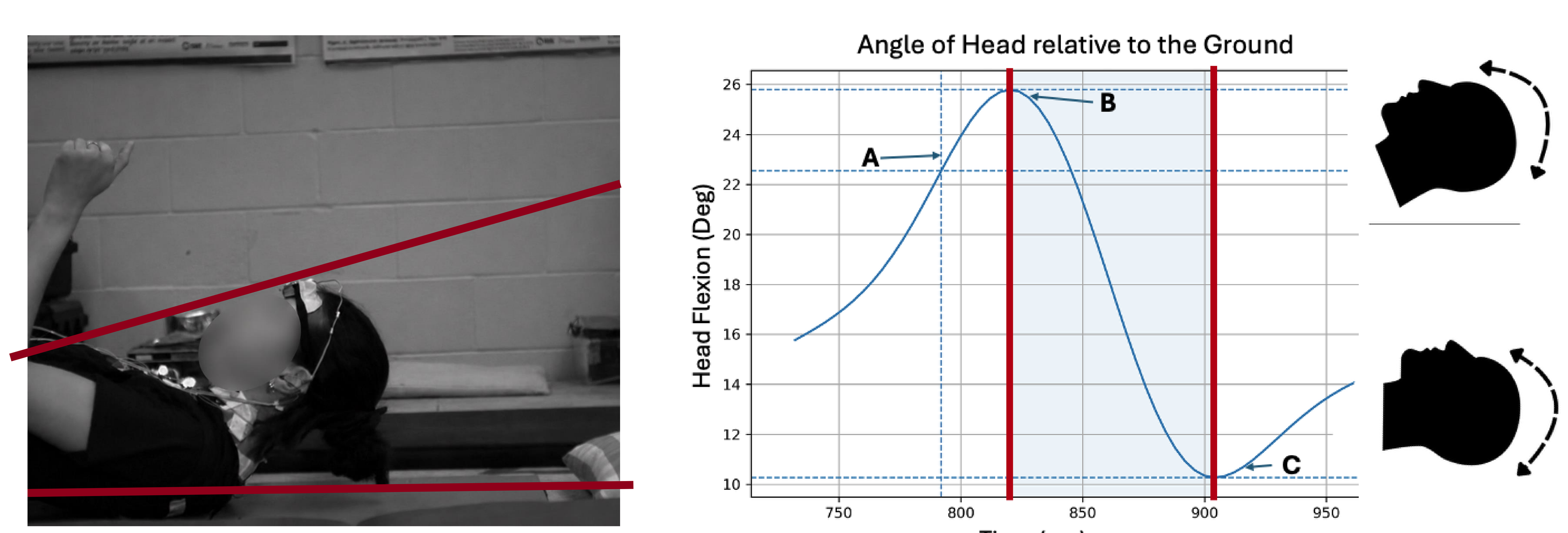

Figure 2: High-speed view to verify the fall mechanics as well as the head-to-ground angle calculation, A is the position of the head at impact, B is the peak angular position of the head and C is the stopping position after this body-first loaded motion. B-to-C is the angular displacement (the 3D motion capture was used for the Euler angle calculation not the high-speed video).

Research Questions

1. **Does neck strength affect the angular displacement of the head during a simulated impact?**
2. **Does pre-release activation state affect angular displacement of the head during a simulated impact?**

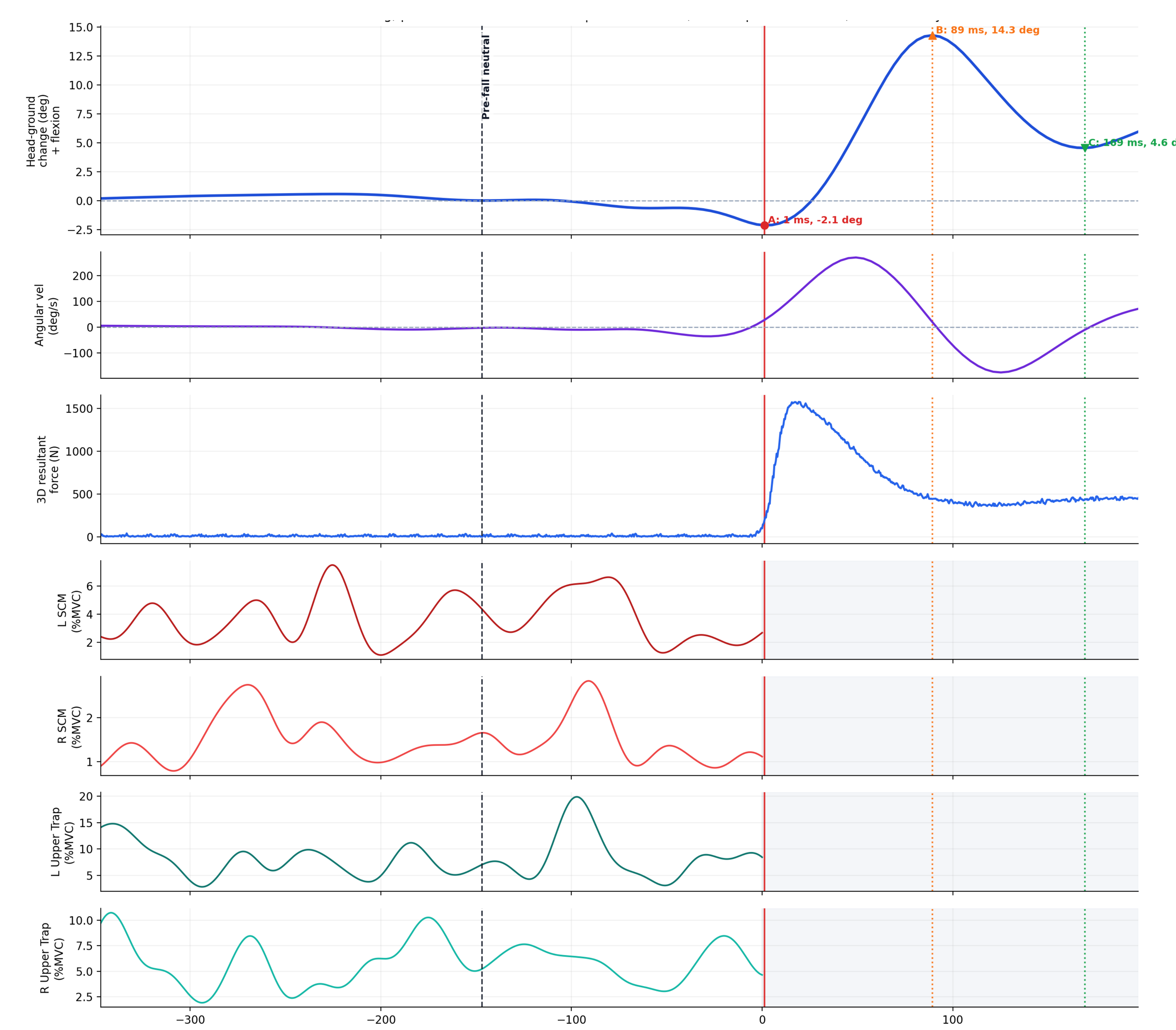

Figure 3: Alignment data sources for the analysis pathway from start of trial to impact, Head-to-ground angle, angular velocity of the head, the vertical force, and muscle activation up to impact.

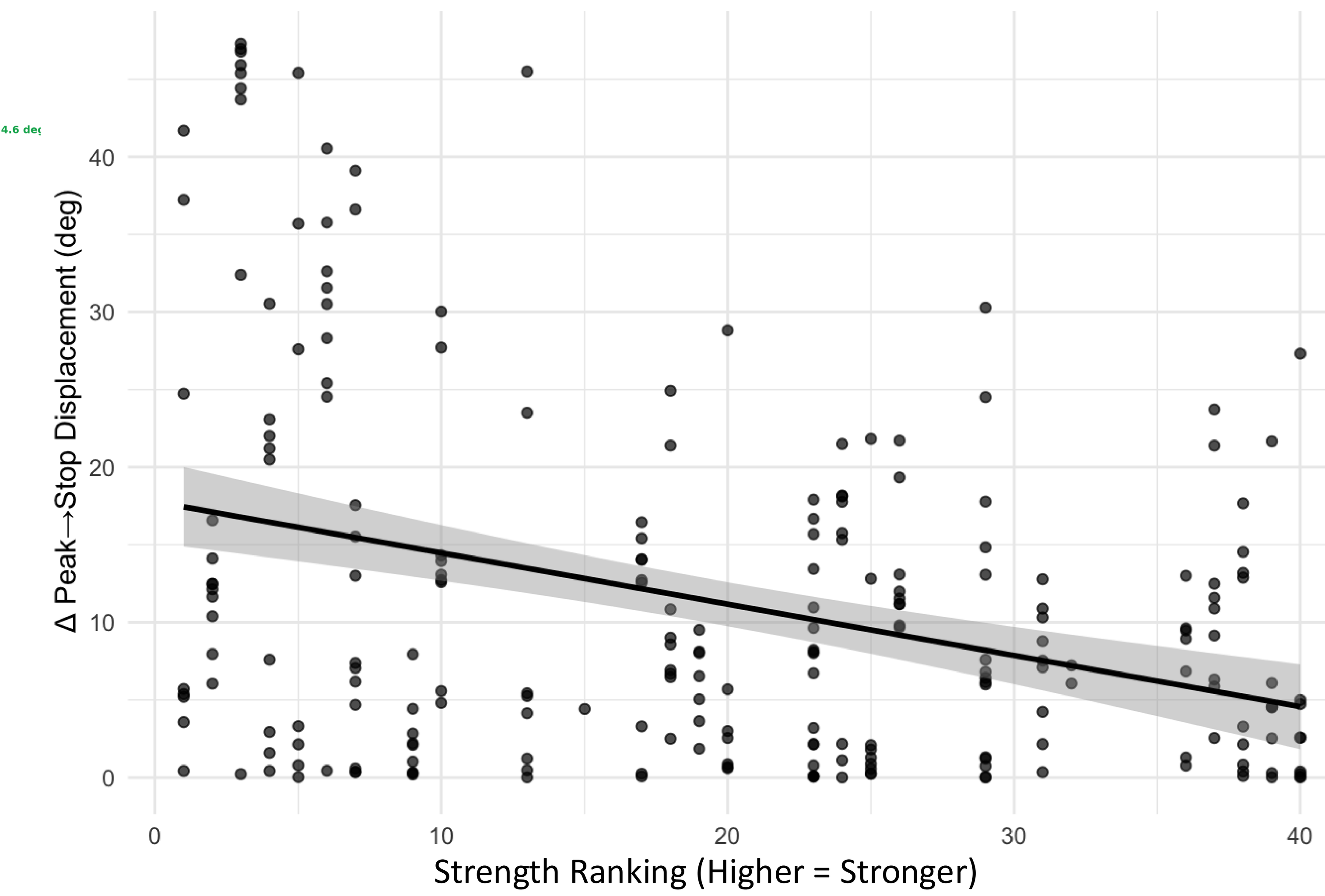

Figure 4: There was no significant main effect of pre-release activation level (F(2, 52) = 0.015, p = 0.985, p < .001), indicating that pre-release activation state did not influence angular displacement of the head following body impact. There was a weak but significant relationship ($r(233) = -0.35$, $p < .001$) showing that participants with higher measured MVC demonstrate less angular displacement of the head following an impact.

Significance

- Controlling neck muscle activation state at release did **not** produce significant differences in head angular kinematics.
- Future analysis should **examine other fall directions**, this dataset only analyzed the **backwards portion of the dataset**.
- Time-series EMG analysis may provide more insight into the **control mechanisms** used during body-first impacts.
- Participants with greater **neck flexor MVC strength** may reduce head motion by Increasing neck muscle activity at impact, increasing the effective mass/stiffness of the head-neck system, and decreasing head angular displacement.
- This work guides ongoing reconstruction studies looking at the body protecting the head during complex kinematic impacts.

References:

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