The University of British Columbia

On-field instrumented mouthguard coupling

David Luke[1,2], Rebecca Kenny[3], Daniel Bondi[2], Adam Clansey[1], Lyndia Wu[1,2]

[1]Mechanical Engineering, University of British Columbia, Canada; [2]Biomedical Engineering, University of British Columbia, Canada; [3]Pediatrics, University of British Columbia, Canada

Introduction

On-field instrumented mouthguard coupling and its effect on data quality have yet to be investigated.

- Instrumented mouthguard (iMG) sensors can measure sports head acceleration events (HAEs) in brain injury research [1].
- Proper iMG coupling is crucial for accurate head kinematics measurements [2], though this has not been investigated on-field.
- This study aims to assess on-field iMG coupling using infrared proximity sensing and investigate its effects on kinematics.

Methods

We used proximity sensors in instrumented mouthguards to characterize coupling during head acceleration events and investigate potential kinematics effects from poor coupling.

- 42 university-level women's rugby (n=21) and men's ice hockey athletes wore Prevent Biometrics [3] iMGs during 6–7 month periods (**Fig. 1A**).
- On-field proximity sensor data classified video-verified HAEs into four main iMG coupling categories (**Fig. 1B**), which were compared for potential kinematics signal differences.

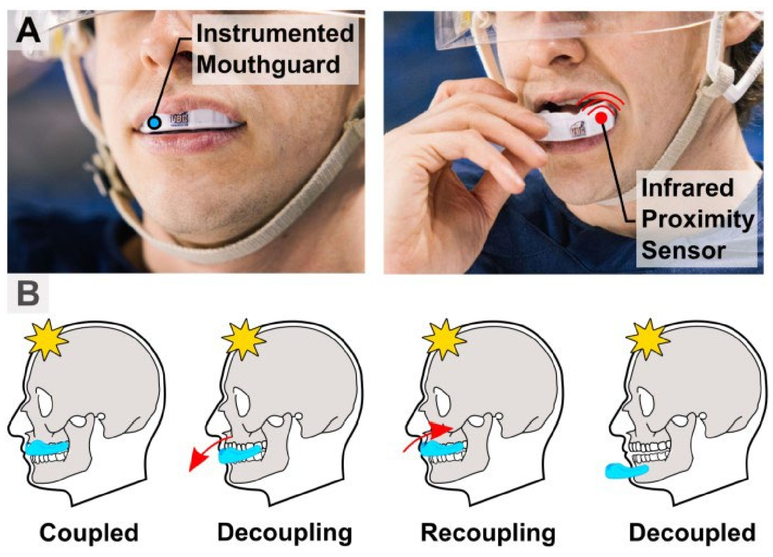

Fig. 1: Proximity sensors measure iMG coupling (A). Coupling during HAEs can be described using proximity values (B).

Coupling Characterization

- The proximity sensor takes readings surrounding each acceleration event (AE).
- Clustering of field proximity data can determine on-teeth coupling thresholds.
- Using the on-teeth thresholds, the most immediate pre- and post-AE proximity samples can characterize coupling throughout the HAE (**Fig. 2**).

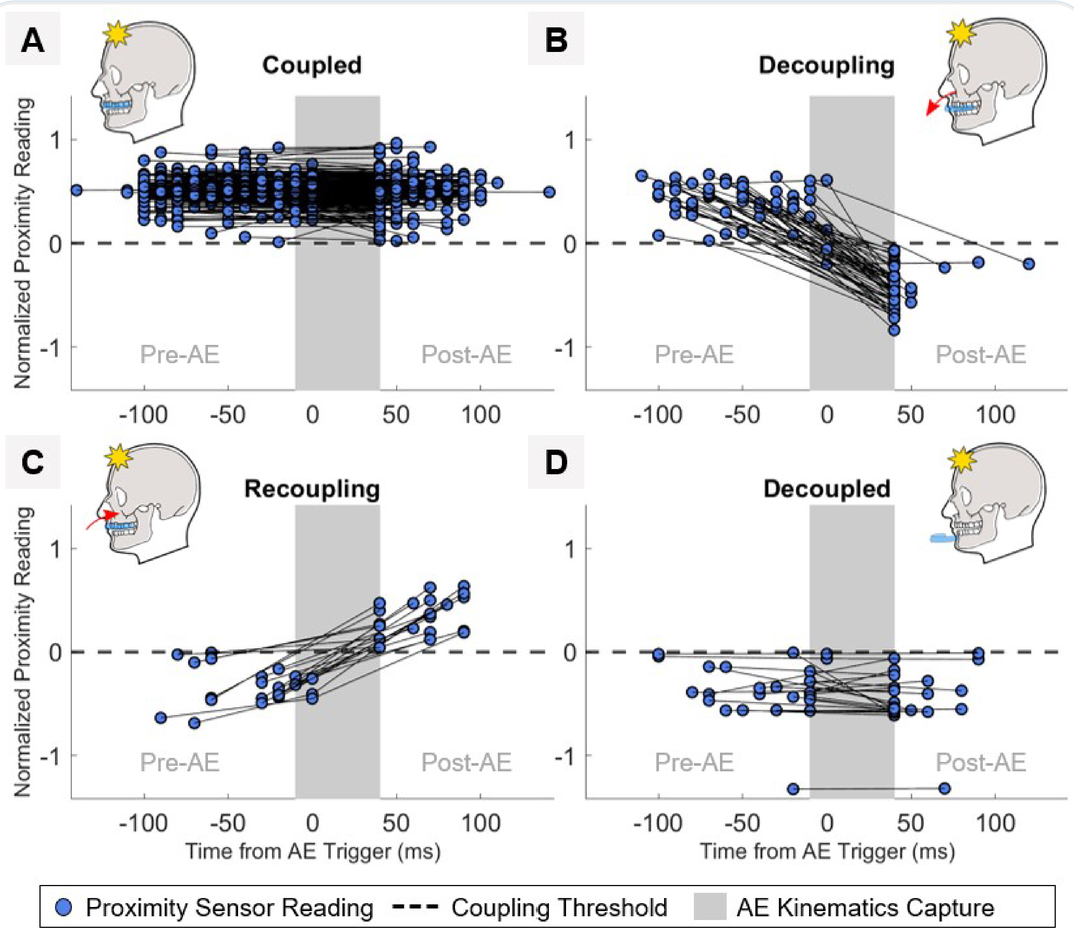

Fig. 2: Proximity sensor readings for video-verified HAEs. Four coupling categories: coupled (A), recoupling (B), decoupling (C), and decoupled (D).

Results

Poorly coupled HAEs demonstrated potential angular acceleration and high-frequency noise.

- Poorly-coupled HAEs have higher peak angular accelerations ($p<0.001$) vs. coupled HAEs (**Fig. 4**).
- Poorly coupled HAEs have higher high-frequency linear and angular acceleration ($p<0.01$) power vs. coupled HAEs (**Fig. 5**).
- Even video-verified AEs included poorly-coupled HAEs.
- iMG coupling patterns varied between the men's hockey and women's rugby teams.

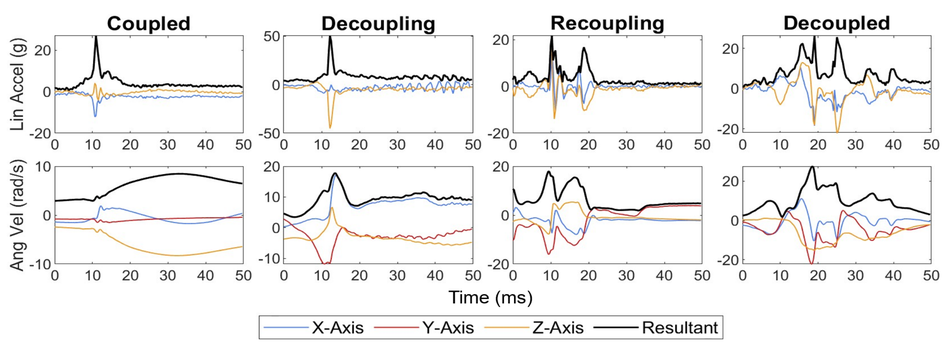

Fig. 3: Example kinematics from verified HAEs in each coupling category.

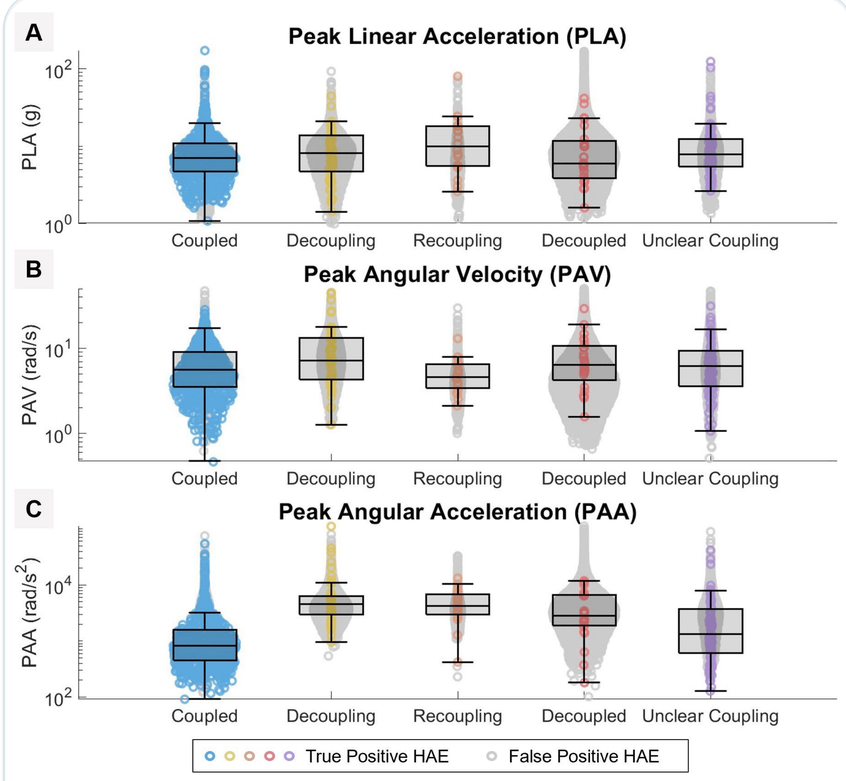

Fig. 4: Peak kinematics for video-verified HAEs by coupling category. Peak linear acceleration (A), peak angular velocity (B), and peak angular acceleration (C).

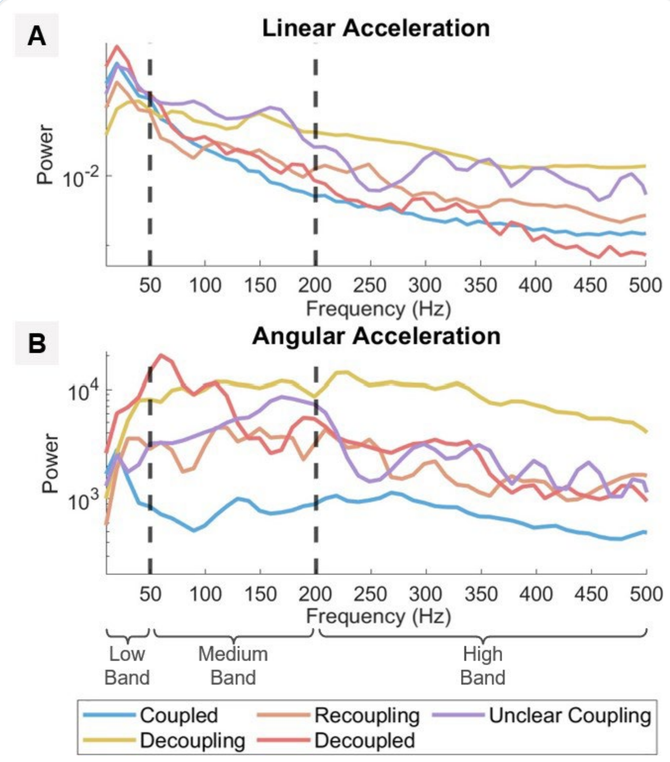

Fig. 5: Power spectral density of linear (A) and angular (B) acceleration by coupling category. Low (0–50 Hz), medium (50–100 Hz) and high (>200 Hz) frequency bands were compared across categories.

Discussion & Conclusion

We developed a method to characterize on-field instrumented mouthguard coupling using proximity sensor data and used it to uncover potential high-frequency kinematics noise in poorly coupled head acceleration event recordings.

- We found HAEs to exhibit the ideal coupled state (coupled) as well as poorly coupled states (decoupled, decoupling, recoupling) that may imply relative movement of the iMG with the teeth during the HAE.
- Utilizing this data screening process in conjunction with video review may mitigate a key source of sensor noise and enhance the overall quality of on-field sports HAE datasets.

References

[1] Wu, Ann Biomed Eng, 44:1234-1245, 2016.
[2] Wu, IEEE Trans Biomed, 61:2659-2668, 2014.
[3] Bartsch, Conf Proc IEEE Eng Med Biol Soc, 2019.

Acknowledgements

The study is supported by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and UBC's School of Biomedical Engineering.