Comparison of Head Impact Biomechanics Across Multiple Sports

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

(1) Mechanical Engineering, University of British Columbia, Vancouver, British Columbia, Canada

(2) School of Biomedical Engineering, University of British Columbia, Vancouver, British Columbia, Canada

(3) Faculty of Medicine, University of British Columbia, Vancouver, British Columbia, Canada

Athletes face numerous head impacts during sport, leading to potential neurological consequences [1]. Instrumented mouthguards (iMG) enable real-world sport head impact data collection, offering insights into brain injury risk and sport-specific mechanisms [2]. Most existing iMG studies focus on investigating a single sport, lacking quantitative analysis of impact biomechanics across sports. Uniquely, we have gathered head impact data across multiple sports using similar sensors and methodologies that enable comparison of impact biomechanics between ice hockey, American football, soccer, and rugby. Our analysis aims to (i) determine biomechanical differences between sports by comparing peak kinematics and impulse duration, and (ii) characterize and compare head impact directionality across sports.

The database included iMG data from university-level men's American football (MF), men's ice hockey (MH), women's rugby (WR), and women's soccer (WS). MH and WR wore Prevent Biometrics iMG's [3], WS wore Wake Forest Center for Injury Biomechanics mouthpieces [4], and MF used Stanford University iMG's [5]. All iMG head impact data were uniformly processed to compute peak linear acceleration (PLA), peak angular velocity (PAV), and peak angular acceleration (PAA) in all planes of motion. Impulse duration was calculated by determining the width of impulse at half the maximum values of linear and angular accelerations. Dominant planes of head rotation were characterized by determining if PAA in any anatomical plane (coronal - x, sagittal - y, transverse - z) exceeded 90% of the resultant PAA.

Comparing sports, we observed MF to have the highest median peak linear acceleration (24.6g), peak angular velocity (11.7 rad/s), and angular acceleration (1996 rad/s^2). Pairwise comparisons for resultant PLA, PAV, and PAA showed statistically significant differences between sports, except for resultant PAA between WR and WS (Figure 1). Unhelmeted sports (WR and WS) had slightly higher median impulse durations (11 ms) than helmeted sports (MH and MF, 10 ms), however, pairwise comparisons revealed no significant differences (Figure 2). WS involved more impacts with dominant sagittal plane rotation (50%), MH showed more transverse plane dominance (31%), MF showed more coronal plane dominance (33.4%), while WR involved multi-directional head rotations with no particular directional dominance (Figure 3).

In summary, our study is among the first to compare head impact biomechanics across multiple sports using real-world head impact data. We observed differences in impact magnitude and direction between-sports with injury risk implications and unexpected impulse duration findings that call for further investigation of helmet effects on impact biomechanics. In future work, we aim to expand our dataset to better match sports for further understanding of the influence of sex, equipment, and playstyle on head impact biomechanics.

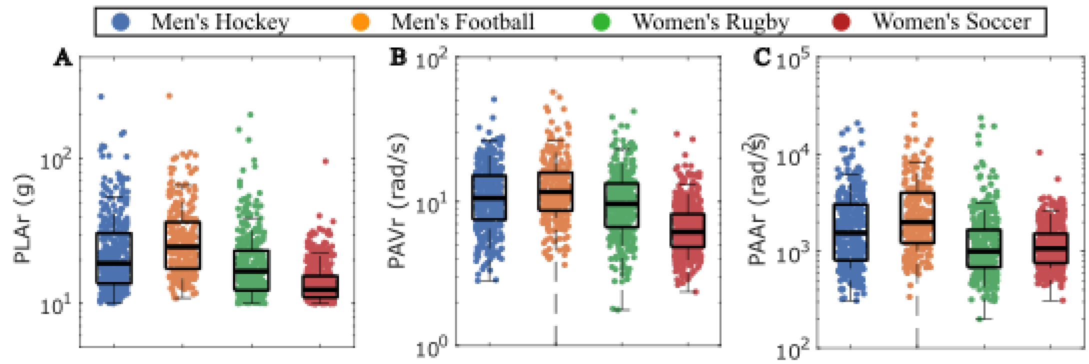

Figure 1: Resultant PLA (A), PAV (B), and PAA (C) for all head impacts across sports.

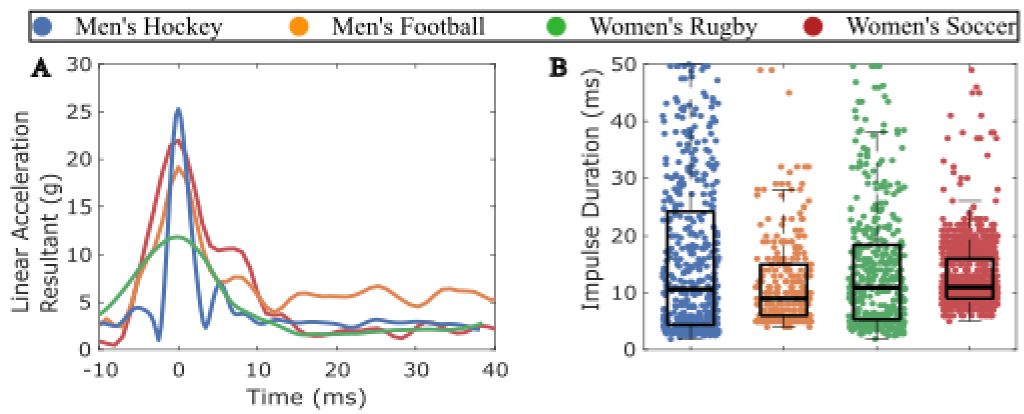

Figure 2: Resultant Linear Accelerations for example impacts showing impulse duration differences (A). Impulse duration comparison across sports (B).

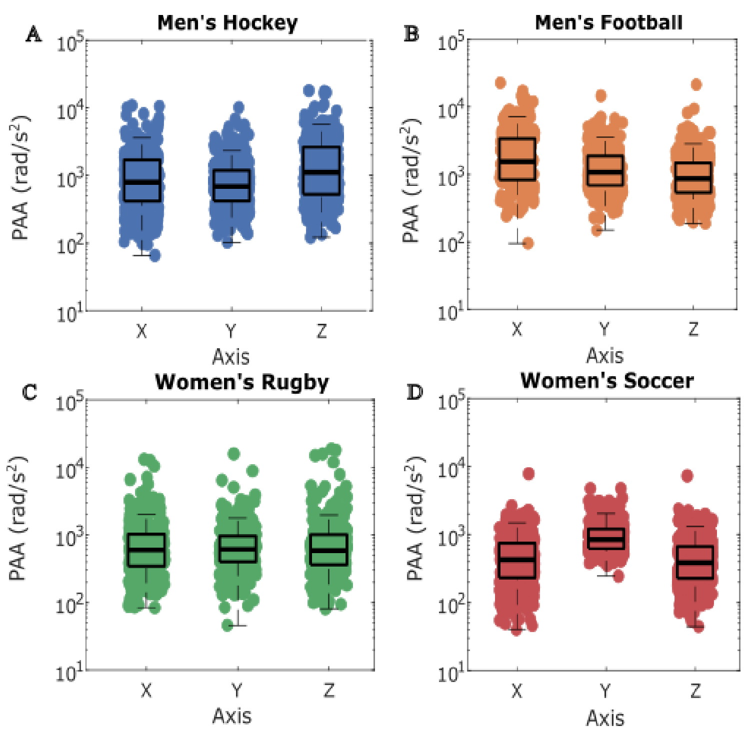

Figure 3: Per axis comparison of PAA for all head impacts.

References

[1] Bailes, J et al., J Neurosurgery, 119:1235-1245, 2013.
[2] Kuo, C et al., Annals of Biomedical Eng, 50: 1372-1388, 2022.
[3] Bartsch, A et al., Annu Int Conf IEEE, 2068-2072, 2019.
[4] Rich, A et al., Annals of Biomedical Eng, 47:2109-2121, 2019.
[5] Wu, L et al., IEEE Transactions on BME, 61: 2659-2688, 2014.