Biomechanical Analysis of Equipment Modifications to Reduce Concussion Risk due to Projectile Impacts in Women's Lacrosse

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VIRGINIA TECH

Background

- Participation in women's lacrosse has grown **97%** in college and **131%** in high school.
- **1/5 to 1/3** of all in-game injuries are concussions.
- **22–32%** of concussions are caused by ball-to-head impacts.
- **Headgear is NOT mandated in women's lacrosse**, though research suggests headgear can reduce concussion incidence.
- **ASTM F3137** specifies requirements for optional soft-shell headgear but is limited in evaluation capabilities.
- For short impulse impacts, not only is **rigid-body motion (RBM)** of interest, but also the **vibrational** response of the head, which can excite resonant frequencies of the skull.

This study aimed to quantify **risk-reduction interventions** in women's lacrosse by evaluating changes in **biomechanical responses.**

Headgear Models

Cascade LX

Cascade LXP

Lacrosse Balls

Rubber
Traditional

Polyurethane
Greaseless

Lightweight
20% reduced mass

Methods

- A pitching machine launched lacrosse balls at an instrumented, medium NOCSAE headform with a Hybrid III neck mounted to a linear slide table.
- **3 ball types**
- **3 headgear conditions**
- **4 impact locations**
- **2 impact speeds**
  - 15 m/s and 30 m/s
- **3 trials** per condition combination

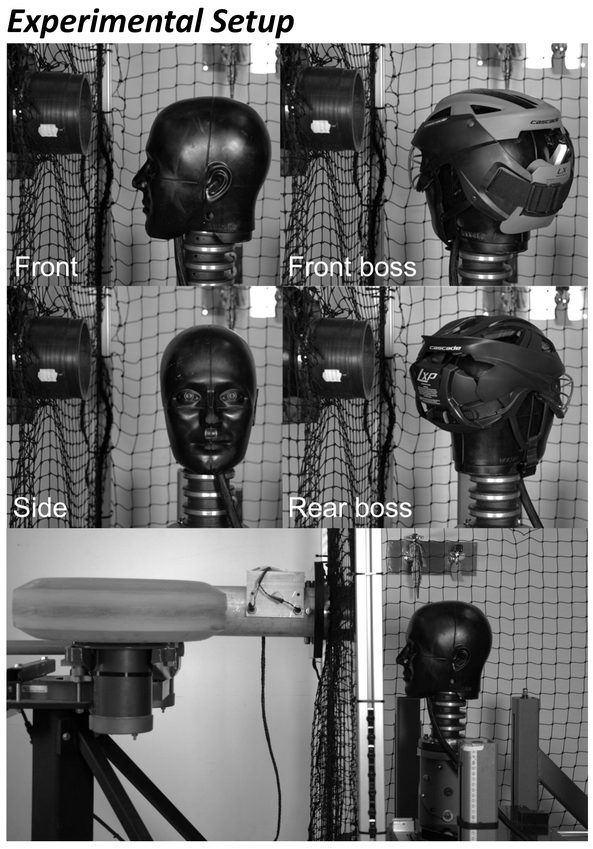
Data Filtering

- **RBM:** 300 Hz cutoff, low-pass filter
  - Response variables: Peak linear acceleration (PLA) and peak rotational acceleration (PRA)
- **Vibrations:** 300–3000 Hz cutoff, band-pass filter
  - Response variable: Cranium Resonance Index (CRI)

$$CRI = \sqrt{\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} \|a_{vib}(t)\|^2 dt}$$

t_1 = beginning of impact duration
t_2 = end of impact duration
a_{vib} = Band-pass filtered vibrational data

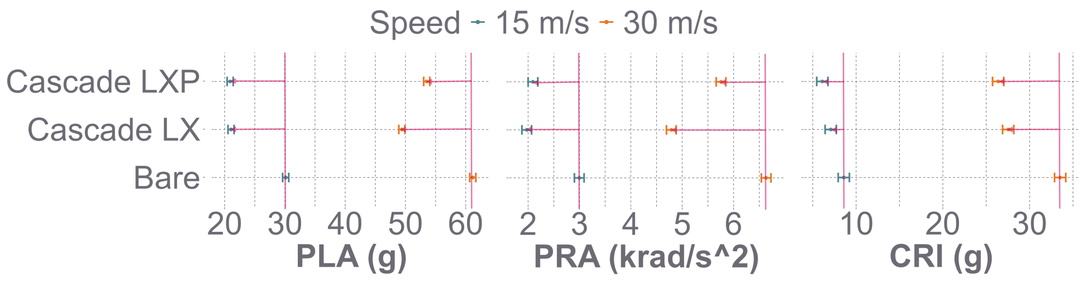
Experimental Setup



Impact locations (top). The pitching machine (bottom left) and headform set-up (bottom right) used for projectile impact testing.

Findings

Headgear Intervention



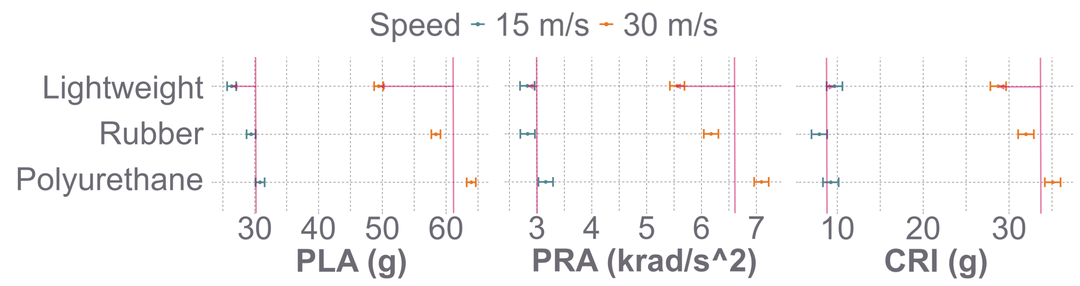
PLA reduction with headgear:
30.4% for 15 m/s
15.9% for 30 m/s

PRA reduction with headgear:
32.1% for 15 m/s
20.5% for 30 m/s

CRI reduction with headgear:
23.2% for 15 m/s
19.6% for 30 m/s

- Headgear better attenuated **RBM and vibrations at low speed.**
- Cascade LX reported greater reductions in RBM than Cascade LXP.
- Cascade LXP reported greater reductions in CRI than Cascade LX.

Ball Type Intervention



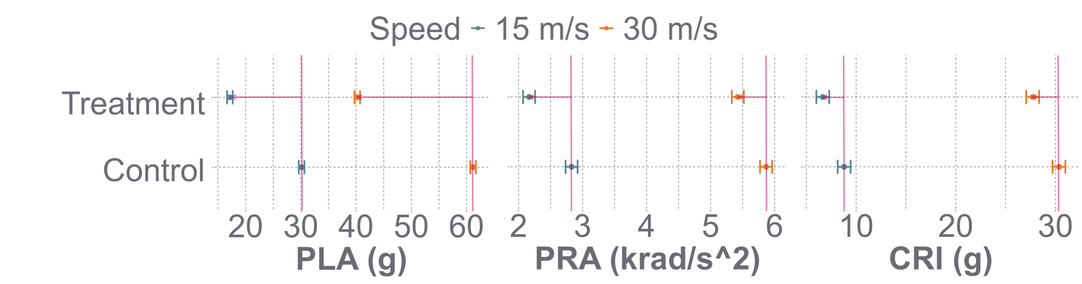
PLA reduction with lightweight ball:
12.5% for 15 m/s
19.2% for 30 m/s

PRA reduction with lightweight ball:
5.7% for 15 m/s
16.2% for 30 m/s

CRI reduction with lightweight ball:
-12.9% for 15 m/s
14.3% for 30 m/s

- Ball type percent reductions **are lower than headgear reductions.**
- Lightweight ball better attenuated **RBM and vibrations at high speed.**
- Rubber ball outperformed polyurethane for both RBM and CRI.

Combined Treatment Intervention



PLA reduction with total treatment:
43.1% for 15 m/s
34.3% for 30 m/s

PRA reduction with total treatment:
47.9% for 15 m/s
37.5% for 30 m/s

CRI reduction with total treatment:
29.6% for 15 m/s
34.3% for 30 m/s

- Combined treatment reported the **greatest overall reductions** between any individual intervention.
- Combined treatment better attenuated **RBM at low speed** and **vibrations at high speed.**

Takeaway Message

- Though both headgear and lightweight ball-type interventions were individually effective at reducing concussion risk in women's lacrosse, the **combination of the two treatments** against tests with standard balls on a bare headform **resulted in the largest overall reductions of RBM and vibrations**.
- **Significance:** There exists a high potential to decrease unnecessarily large concussion rates in women's lacrosse through the implementation and modification of equipment.