

# Quantifying Kinematic and Vibrational Responses in Hockey-Style Catcher's Mask

Richard A. Gillespie, Eric J. Shunk, Mark Begonia,  
Nicole E.-P. Stark, Steve Rowson  
Correspondence: richardag313@vt.edu

## Background

- Tipped foul balls are the most common cause of concussion in baseball
- The average concussion accelerations in baseball are lower than those in other sports
  - Baseball: 30 g and 3100 rad/s<sup>2</sup>
  - Football: 100 g and 5500 rad/s<sup>2</sup>
- Short impact durations (<5 ms) lead to wider frequency excitation
- High-frequency (HF) content (300-3000 Hz) could cause resonance in the skull, allowing efficient transfer of energy to the brain
- **The Floating Mask Design (FMD) was created to limit vibration through:**
  - Elongating impact durations by increasing stroke
  - Mask decoupling
  - Vibration damping from VN740 padding



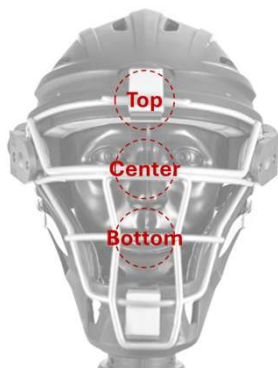
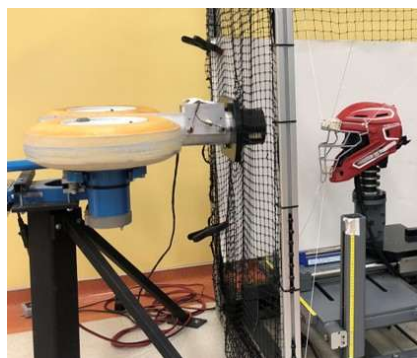
Unaltered Helmet

FMD Prototyped Helmet

This study's **objective** was to evaluate the **kinematic** and **vibrational content** of catchers' masks when impacted by baseball, and to **design the FMD prototype to reduce high-frequency content**

## Methods

- Regulation High School baseballs launched from a custom pitching machine through a laser speed gate
  - Kinematics evaluation:
    - Peak linear acceleration (PLA)
    - Peak rotational acceleration (PRA)
  - Vibration measured:
    - Cranium Resonance Index (CRI)
      - $t_1$ : Beginning of impact duration
      - $t_2$ : End of impact duration
      - $a_{bp}$ : HF linear acceleration
- $$CRI = \sqrt{\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \|a_{bp}\|^2 dt}$$
- 2 impact speeds, 3 impact locations, 2 helmet configurations, 4 impact conditions, 3 repetitions



## Findings

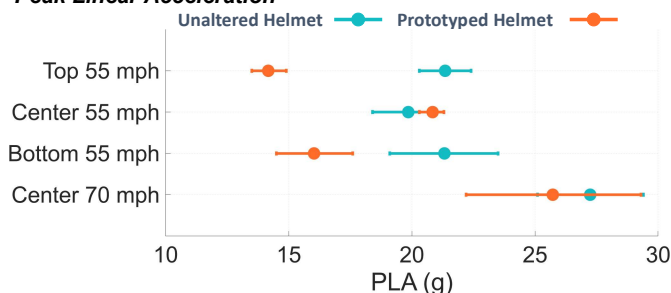
- Kinematic and vibrational changes with the FMD prototype:

	Top 55 mph	Center 55 mph	Bottom 55 mph	Center 70 mph
PLA (%)	-33.6	5.0	-24.8	-5.6
PRA (%)	-42.0	-32.3	-43.9	-23.1
CRI (%)	-52.3	-54.9	-56.4	-41.0

*Percent decreases in PLA, PRA, and CRI with the use of the prototype*

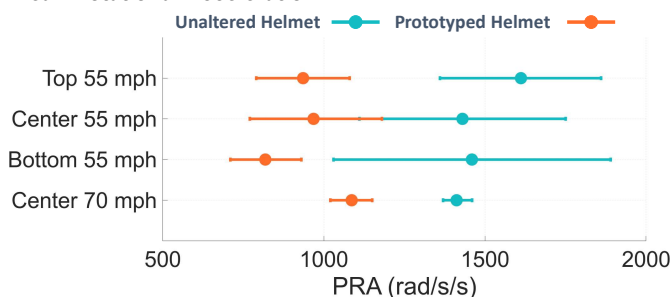
- Discrepancies at the center location may be due to increased effective stiffness when simultaneously impacting the paddings, both increasing PLA while decreasing high-frequency vibration

### Peak Linear Acceleration



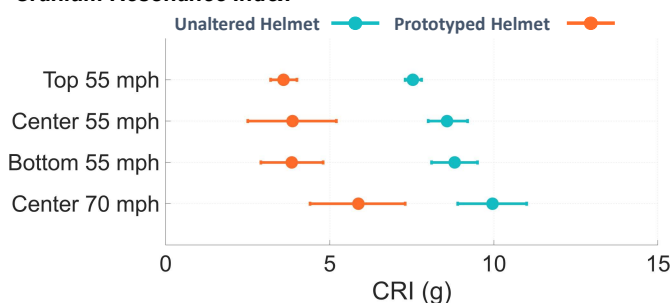
*Changes in PLA between the unaltered and prototyped helmets for each impact condition*

### Peak Rotational Acceleration



*Changes in PRA between the unaltered and prototyped helmets for each impact condition*

### Cranium Resonance Index



*Changes in CRI between the unaltered and prototyped helmets for each impact condition*

## Takeaway Message

- Kinematic concussion risk for catchers is already <1%, yet concussions are still sustained
- Oscillatory acceleration from the unaltered helmet became triangular with the FMD prototype, showing impact duration elongation and high-frequency content reduction
- Further learning about the mechanism of injury and innovation of mask design for catchers should be done
- **Significance:** Headform vibration can be mitigated in higher frequencies through design alteration