Federation Equestre Internationale
FEI
Safety Committee Helmet Presentation

Barry Miller, PhD
Virginia Tech Helmet Lab

bmiller21@vt.edu

VIRGINIA TECH™

Virginia Tech Helmet Lab

Stefan Duma, Steven Rowson,
Mark Begonia, Barry Miller,
Bethany Rowson, Megan Bland,
Eamon Campolettano,
Emily Kieffer, Tessa Reiber

Brett Griesemer, Mike Goforth,
Taylor Langon

Gunnar Brolinson, Mark Rogers

Stephen LaConte
Allison McKinnon

VIRGINIA TECH

VCOM
Edward Via College of Osteopathic Medicine
VIRGINIA CAMPUS

Sports Medicine

VTC | Fralin Biomedical Research Institute

bmiller21@vt.edu

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Virginia Tech Helmet Lab

- National Institutes of Health, National Institute of Neurological Disorders and Stroke (R01NS094410) Biomechanical Basis of Pediatric mTBI Due to Sports Related Concussion
- NCAA – DOD Grand Alliance, Advanced Research Core (ARC) and Clinical Study Core (CSC) – CARE Consortium
- The Lewis Family Foundation
- Insurance Institute for Highway Safety (IIHS)

Edward Via College of Osteopathic Medicine

INSTITUTE FOR CRITICAL TECHNOLOGY AND APPLIED SCIENCE
VIRGINIA TECH

- *No financial interest in any helmet, sensor, or company*

The Problem

Helmets are certified to “standards” on a pass/fail basis. (only use linear acceleration values)

Consumers are left without information on how well a given helmet surpassed the baseline “certification or standard” test.

Current Standard for Equestrian Helmets in the United States

American Society for Testing Materials (ASTM) – F1163-15 (300g). (1998, 2004).

- Other Standards
  - European Equestrian Riding Helmet Standard: EN1384
  - British Standard: PAS015: (1998, 2011)
  - New Australian standard **ARB HS 2012** *provided they are SAI Global marked*
  - *VGI Interim European Standard 01:040:2014-12*
  - AS/NZS 3838 – Australia and New Zealand (1998, 2003, 2006)
  - Snell E2001 (300g) - (2001)
  - Proposed Standard EN13097-11 from the European Committee for Standardization (CEN)

The Solution

Create a sport specific rating system to supplement the certification/standard based on real-world injury scenarios and concussion risk for that sport!

Virginia Tech Helmet Lab

- Founded in 2007 by Drs. Stefan Duma, Steve Rowson
- Instrumented football helmets
- First ever STAR (Summation of Tests for Analysis of Risk) Rating for football helmets 2011
- Currently Rate Helmets for:

Football	**Youth Football**	**Flag Football**
Soccer	**Cycling**	**Ice Hockey**

In development: ***Baseball, Softball, Snow Sports, Water Sports, Lacrosse, *Equestrian***

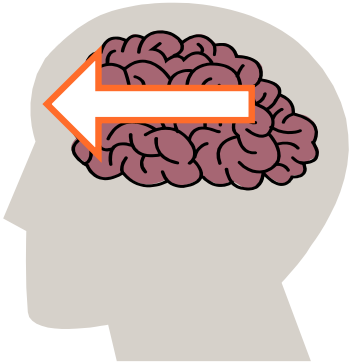
Experimental Concussion Research

Cadaver Data	Animal Data	NFL Data	Volunteer Data
1954 Ford funds WSU 1960 Gurdjian, Lissner origin of WSTC 1966 Gadd: GSI or SI (General Motors) 1971 Versace: HIC (Ford) 1997 Mertz: scaling 2007 Hardy: brain strain and pressure As linear acceleration increases, risk of injury increases.	Over 200 Primate tests performed in six sets from 1966 – 1983 1966 Ommaya, Hirsch first primate tests *More recent analysis*: 1985 Ommaya:4500r/s2 concussion 1992 Margulies,Thibault DAI at 16,000 r/s2 1998 Arbogast, and Margulies: properties 2003 Gennarelli: concussion values 2009 Davidsson: DAI	Mid-90s to present: extensive research utilizing dummy reconstructions and other evaluations 2003: Pellman, Viano HIII reconstructions 2003: King, analysis of tests with model	2003 – Present, instrumented high school and college football players
As linear and rotational acceleration increase, brain pressure and motion increase	As linear and rotational accelerations increase, brain injury in primates increases	Linear and rotational accelerations are significantly correlated to concussion risk	Linear and rotational accelerations are significantly correlated to concussion risk

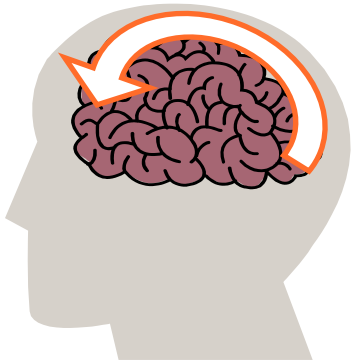
Acceleration-Based Brain Injury

Acceleration is a metric used to characterize concussion risk

- Skull acceleration is indicative of the inertial response of the brain to impact loading
- Skull acceleration does not cause injury, but the pressure and strain response within the brain tissue does
- Linear and rotational head kinematics both contribute to injury risk



Transient intracranial pressure gradients



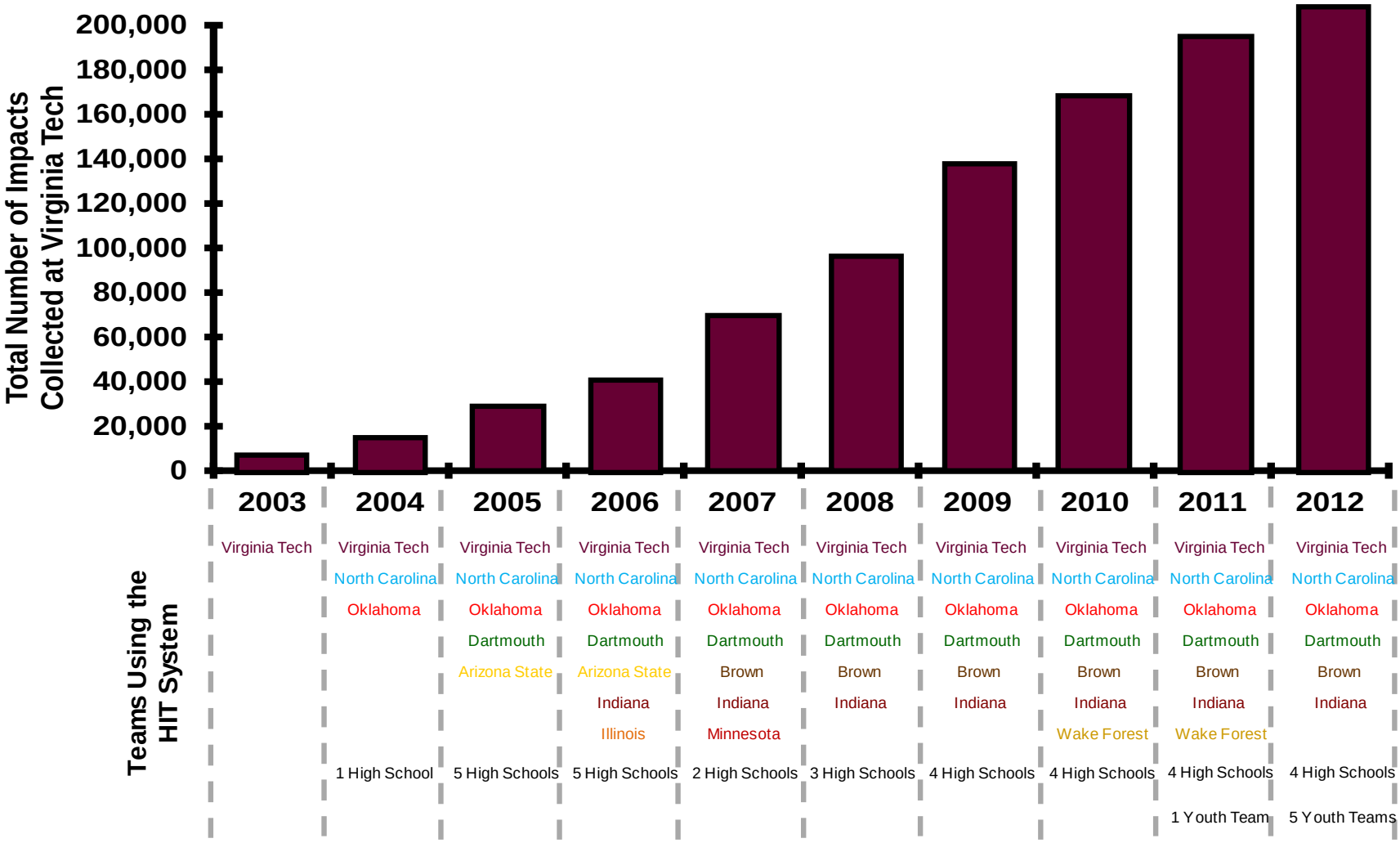
Relative brain motion and strain

Measuring Head Accelerations in Humans

Helmet-mounted accelerometer arrays, clinical test battery

Cumulative HITS Data Collection

2,000,000+ impacts recorded at all institutions



bmiller21@vt.edu

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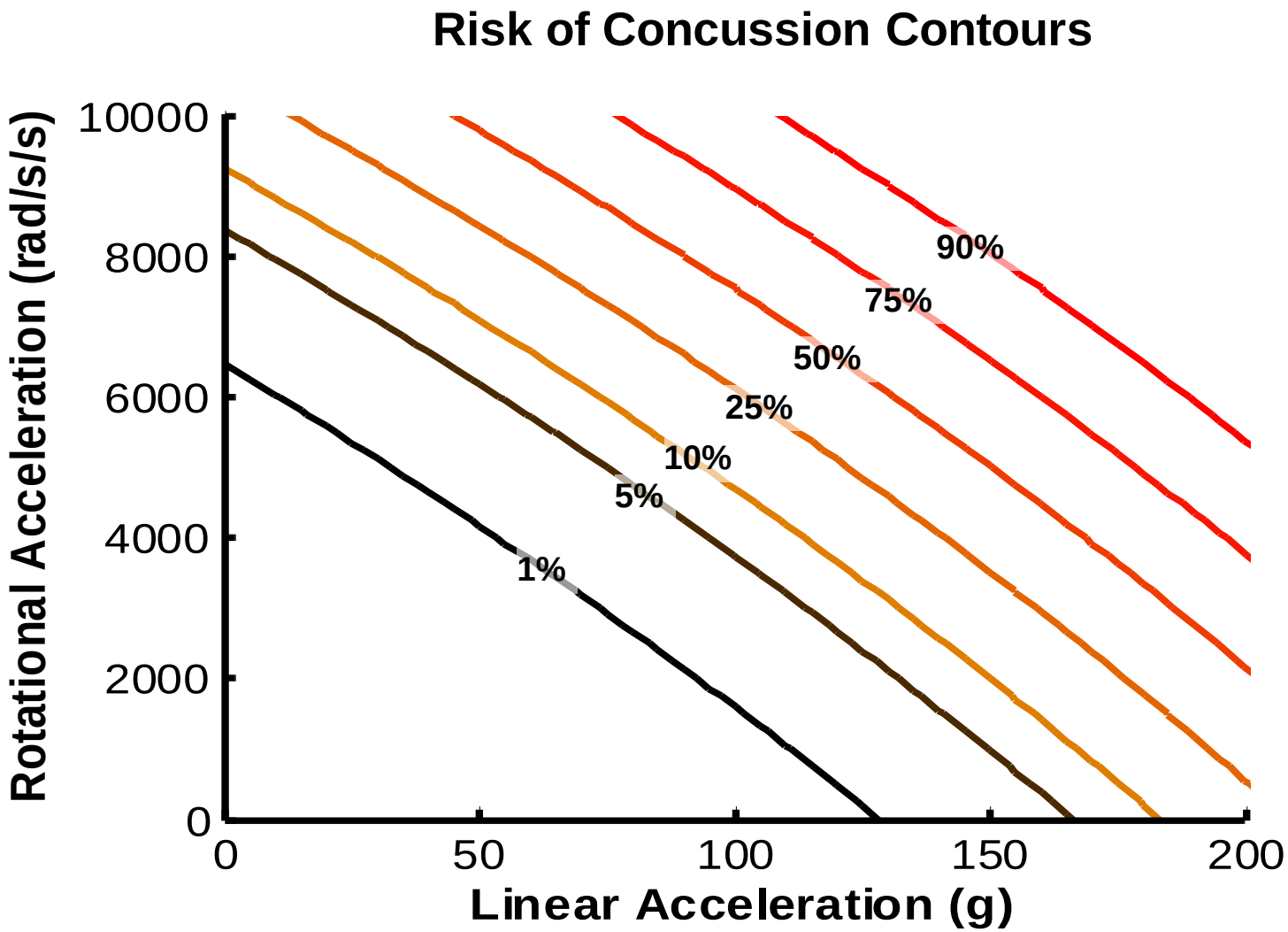
Combined Linear and Rotational Risk



Virginia Tech Helmet Ratings Program

Two primary objectives

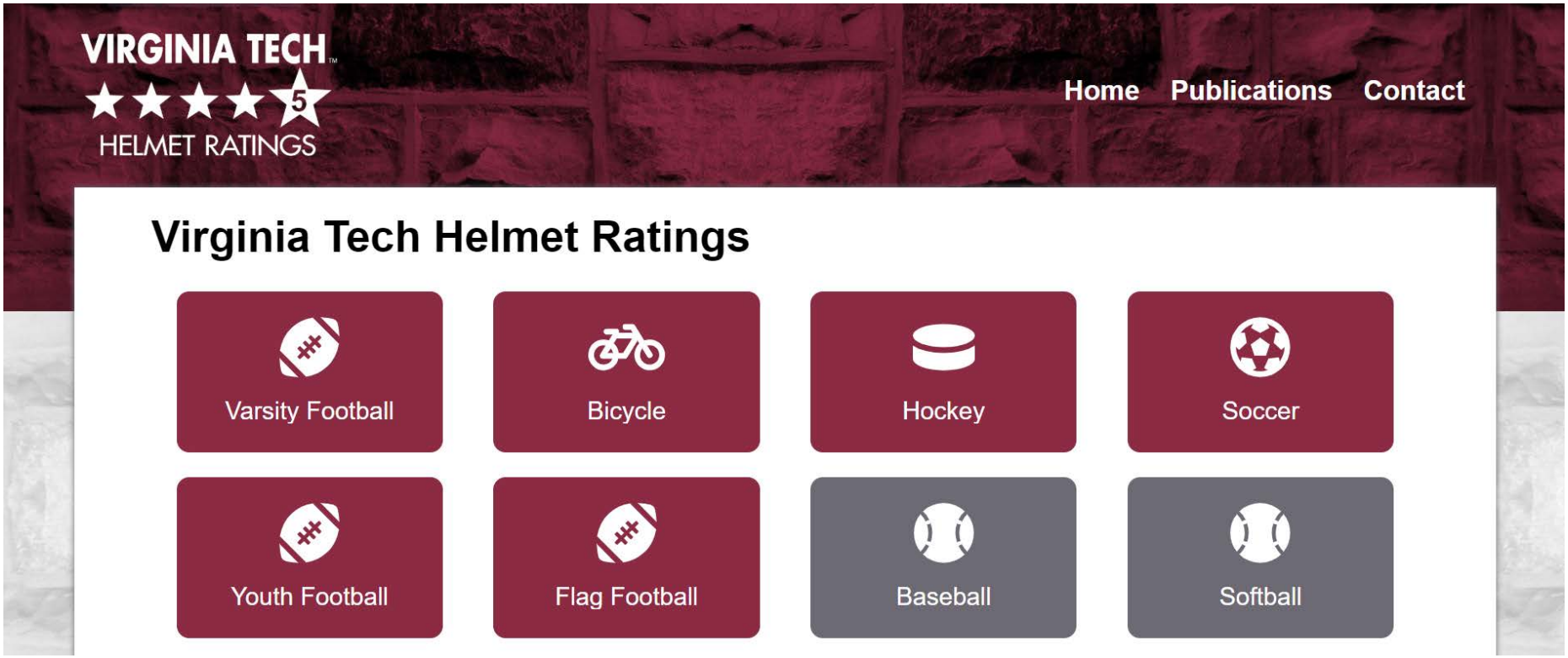
1. Inform consumers of relative differences between helmets in the context of lowering concussion risk
2. Provide manufacturers with a design tool to optimize helmet design to best reduce concussion risk






bmiller21@vt.edu

Virginia Tech Helmet Ratings



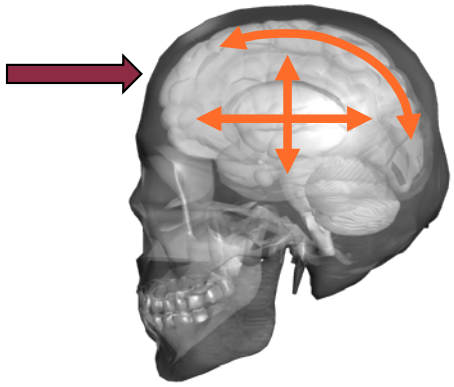
General STAR Evaluation Approach

Two fundamental concepts

1. Tests are weighted based on how often they occur
2. Helmets that lower head accelerations reduce risk

Underlying features

- Consideration of linear and rotational head acceleration
  - Exposure data
  - Risk analysis
  - Laboratory measurement



STAR Formulation

STAR stands for **S**ummation of **T**ests for the **A**nalysis of **R**isk

$$STAR = \sum_{L=1}^{4} \sum_{V=1}^{3} E(L,V) \cdot R(A,\alpha)$$

- Exposure as a function of impact Location and Velocity
- Risk of concussion as a function of linear (*A*) and rotational (α) headform acceleration

Fundamental form is the same
Incidence = Exposure x Risk

Equestrian Sports

There are over 30 million "rides" per year in USA
- 50,000 emergency room visits (1 emergency room visit per 600 rides); most are head injuries

Varieties of equestrian sporting
- Eventing, Jumping, Equitations, Hunting, Dressage, Polo, Flat-Racing, Steeplechase, etc.

Horses weigh an average of 1500 lbs and travel up to 40 mph
- Rider's head positioned 9 ft off the ground
- Horse unpredictability

Carrillo EH, Varnagy D, Bragg SM, Levy J, Riordan K (2007). "Traumatic injuries associated with horseback riding". *Scand J Surg*. **96** (1): 79-82.

Havlik, H. S. (2010). Equestrian Sport-Related Injuries: A Review of Current Literature. *9*, 299-302. doi: 10.1249/JSR.0b013e3181f32056

Equestrian Injuries Continued

- Low incidence, high severity

- 1 in 5 equestrians will suffer a serious injury during their lifetime

- Incidence
  - Equestrian: 0.49/1000 hours
  - Polo: 7.8/1000 hours
  - Soccer: 17-29/1000 hours
  - Rugby: 53/1000 hours

- Novice riders are 3 to 8x greater risk

More Statistics

- National Trauma Databank (2003-2012) 4788 adult-sports related TBI (representing 18,310 incidents nationally)
- Equestrian sports: greatest contributor of sports related TBI, 45.2%
    - 2nd leading cause of TBI was falls/hits from contact sports, 20.2% (soccer & football)
- Current helmet use in all equestrian sports is less than 25%
- Authors noted a 50% risk reduction in TBI with use of currently available equestrian helmets

Demographics of Sport-Related TBI by Age and Sports Mechanism of Injury

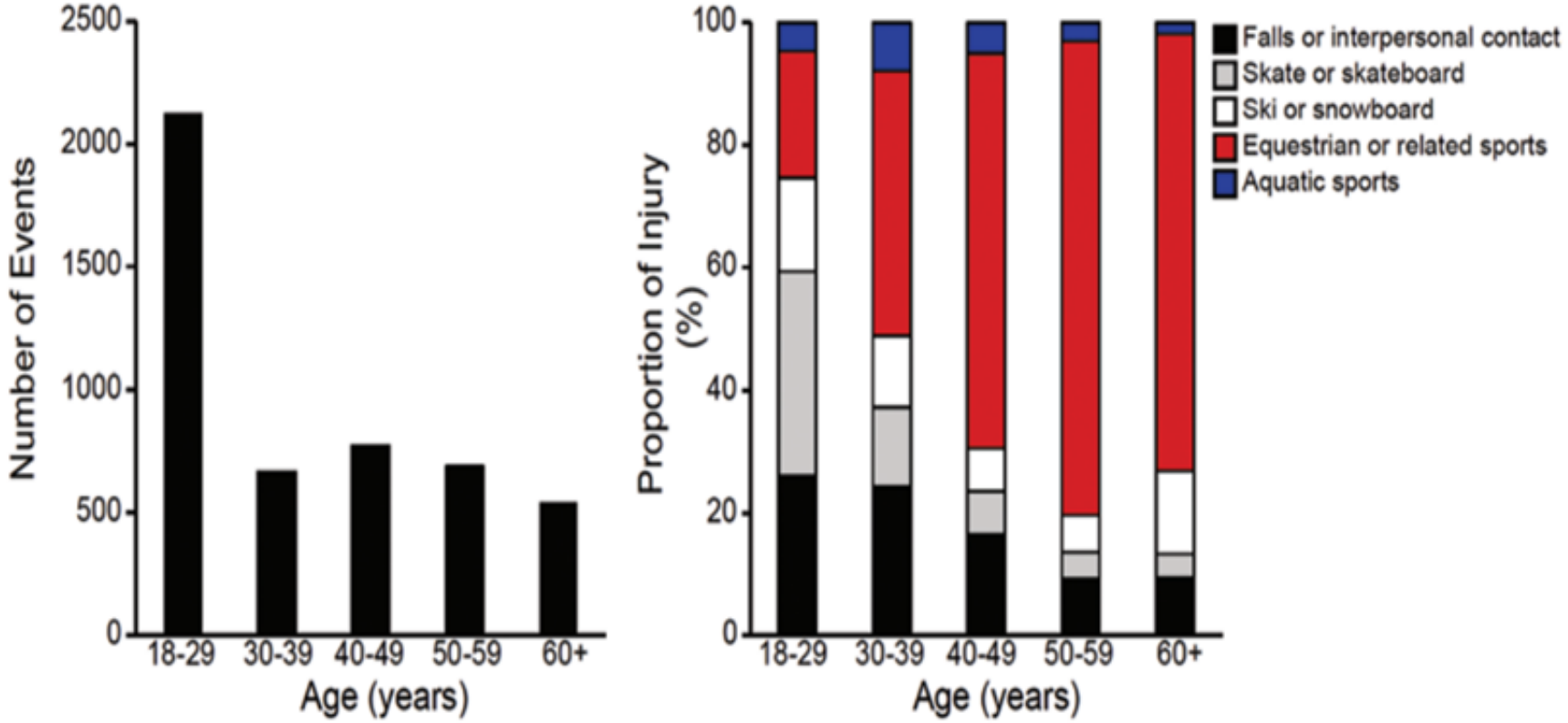


FIG. 2. Demographics of sports-related TBI by age and sports mechanism of injury. **Left:** Graph depicting the number of sports-related TBI events in each adult age group. **Right:** Graph depicting the proportions of sports-related TBI attributed to FIC, roller skating/skateboarding, skiing/snowboarding, equestrian and related sports, and aquatic sports in the 5 age groups.

Current Equestrian Testing

Equestrian Helmets Tested to Date:
- Ovation (Deluxe, Jump Air)
- Troxel (Spirit, Sport)
- Charles Owens (JR8)
- One K (Defender)
- UoF
- Kask
- **Football Helmets** as controls and comparisons:
  - Riddell Speed, SG DBS.001, Schutt F7

- **Tested 5 locations** (2 low energy, 3 high energy)
  - Low = L Front boss, R Side
  - High = R Front Boss, L Side, Back

- **Used 2 Energy Levels** - 6.7 m/s, 4.7 m/s (90 and 65 degrees on pendulum)

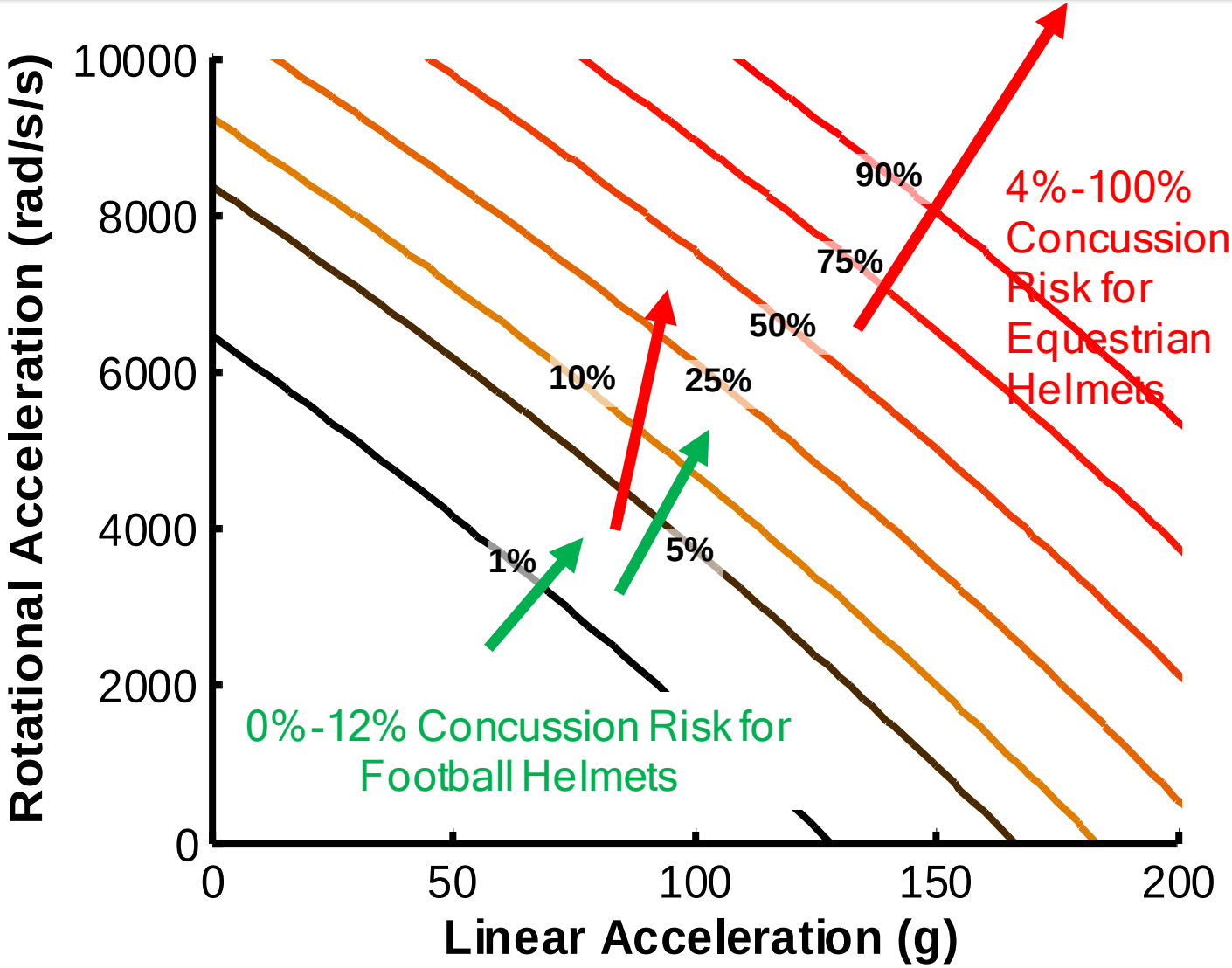
***Special thanks to GPA, Troxel, English Riding Supply for providing testing helmets!!**

Equestrian Helmet Testing

Development Test Findings

Helmets	Low Energy – R Side	Low Energy - L Front Boss	High Energy – L Side	High Energy – R Front Boss	High Energy - Back
Equestrian – Avg. Peak Linear (g)	***98.7***	***81.5***	***157.2***	***134.6***	***171.3***
Football – Avg. Peak Linear (g)	58.6	55.9	94.6	90.2	79.1
Equestrian – Avg. Peak Rotational (Rad/S^2)	***7,317***	***4,120***	***10,936***	***6,326***	***6,577***
Football – Avg. Peak Rotational (Rad/S^2)	3,903	3,943	5,979	5,466	5,039

Equestrian vs Football Helmets



Equestrian STAR Rating Proposal

3 Major Components

1) Background, research, and field work

2) Laboratory system development

3) Data analysis, evaluation, and STAR Ratings

Task 1 - Background, Research, Field Work

The proposed research will study head impact and concussion risk in an equestrian environment. We will work with the United States Hunter Jumper Association (USHJA) and other organizations associated with them or the United States Equestrian Federation (USEF).

To quantify boundary conditions we will collect field video data on a variety of equestrian events with significant attention to jumping where many injuries occur (Figures 1 and 2). Head cannons will be utilized on-site to shoot headforms into the ground to determine boundary conditions of impacted surfaces. The surfaces (grass, dirt, sand, synthetic compositions) of the head impacts will also be studied in the field using shore hardness drop tests, durometer hardness tests, and other applicable techniques. Collectively, this field and background work will inform testing parameters in the laboratory setting.

Figure 1. Competition Photo USHJA

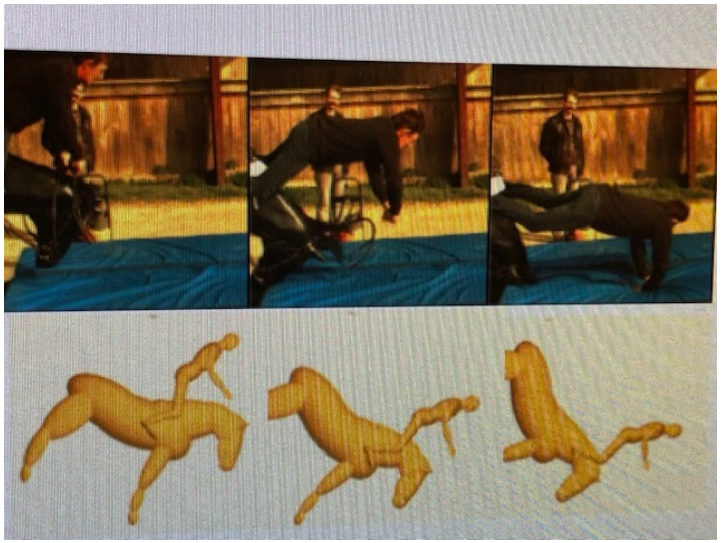


Figure 2. Sample of Rider Fall Illustration (Bourdet, Willinger 2015)

Task 2 – Laboratory System Development

- From the data collected in Task 1, head impacts will be reconstructed in the laboratory to simulate real-world injury scenarios

- The head impact locations and kinematics (linear and rotational accelerations) will be simulated by building testing rigs specific to equestrian conditions based on data collected in Task 1

- The lab will use test dummy head forms equipped with sensors to collect kinematic data

- Figure 3 is a photo of a pendulum impactor with a NOCSAE headform equipped with sensors and a football helmet

- Figure 4 is a close up photo depicting the various locations used for football helmet testing (4 locations under 3 energy levels)

Figure 3: Pendulum Impactor

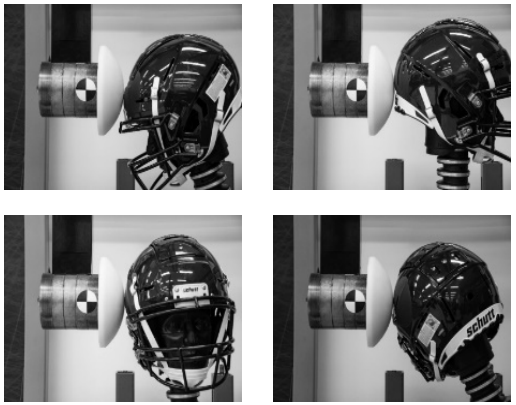


Figure 4: Pendulum Impactor Sample

Task 3 - Data Analysis, Evaluation, STAR Rating:

- From the analyzed data collected in Tasks 1 and 2, we will develop a STAR (Summation of Tests for Analysis of Risk) rating system for equestrian helmets

- The rating will consist of a standardized test protocol (various locations, impactor types, and energy levels specific to equestrian sports) that can be used to evaluate real-world helmet performance

- A robust sampling of consumer available equestrian helmets will be acquired, tested, and rated for consumer use

- The Equestrian Helmet STAR rating webpage will be established and updated on a rolling basis as new helmets are tested and rated

Deliverables and Outcomes

- This project will set the framework to better understand concussive biomechanics in the equestrian industry and better inform helmet manufacturers for improvement with environment-specific design.

- From our experience with other sports, the release of VT Equestrian Helmet Ratings will drive manufacturers to compete and improve helmet performance.

Virginia Tech Equestrian Helmet Ratings:

Add Equestrian Helmets to list of covered sports to better inform the industry

Publication Plans:

2 journal publications (video analysis to Journal of Sports Engineering, head impact biomechanics to Clinical Journal of Sports Medicine)

Presentations:

Biomedical Engineering Conferences, USHJA, USEF

bmiller21@vt.edu

Questions?