Status of NHTSA’s Crash Test Dummy Research

Kevin Moorhouse, Ph.D.

August 14, 2019
2019 N.A. Crash Meeting
Detroit, MI
• Transportation Research Center Inc.
  – Research Scientists & Engineers
  – Engineering Technicians
  – Machine Tool Operator
  – Secretaries & Receptionists
  – Potentially other expertise as needed

• Ohio State University
  – Professors (Engineering, Anatomy)
  – Research Scientists & Engineers
  – Students (Graduate and Undergraduate)
  – Post-Mortem Human Subjects → Biomechanics Research
Vehicle Safety Research Overview

Cem Hatipoglu, Ph.D.
Associate Administrator
For Vehicle Safety Research
NSR-010

Tim Johnson
Vehicle Research and Test Center
NSR-100

Vacant
Office of Vehicle Crashworthiness Research
NSR-200

Vacant
Office of Vehicle Crash Avoidance & Electronic Controls Research
NSR-300

Kevin Moorhouse, Ph.D.
Applied Biomechanics
NSR-110

Matt Craig, Ph.D.
Human Injury Research
NSR-220

Vacant
Human Factors / Engineering Integration
NSR-310

Frank Barickman
Applied Crash Avoidance
NSR-120

Stephen Summers
Structures & Restraints Research
NSR-210

Rob Heilman
Intelligent Technologies Research
NRS-320

Donald T. Willke
Applied Crashworthiness and Defects Analysis
NSR-130

Bob Kreeb
Electronic Systems Safety Research
NSR-330
NHTSA Biomechanics Research Overview

• Human Injury Research Division
  – Division Chief: Matt Craig, Ph.D.
  – NHTSA Headquarters, Washington DC
  – Ellen Lee, Dan Parent, Rodney Rudd, Erik Takhounts
  – Biomechanics ID/IQ - various universities / test labs

• Applied Biomechanics Division
  – Division Chief: Kevin Moorhouse, Ph.D.
  – NHTSA’s Vehicle Research & Test Center, East Liberty OH
  – Will Millis, Dan Rhule, Heather Rhule, Jason Stammen
  – Sole source contracts: TRC, OSU
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• THOR 50\textsuperscript{th} Male
• WorldSID 50\textsuperscript{th} Male
• THOR 5\textsuperscript{th} Female
• WorldSID 5\textsuperscript{th} Female
• BioRID II
• LODC
• Pedestrian Protection
• Biomechanics Research & ATD Applicability
• Location for NHTSA Research Reports:
  – National Transportation Library
    • rosap.ntl.bts.gov

  – NHTSA Vehicle Safety Research Website:
    • https://www.nhtsa.gov/vehicle-safety-research
**Complete:**

- Finalize and publish seating procedure
- Conduct full dummy evaluation (Biofidelity, R&R, Durability)
- Finalize Qualification Manual, PADI, drawing package
- Develop Injury Risk Curves
- Evaluate in-dummy data acquisition system option

**Ongoing/Upcoming Work:**

- Evaluate/consider ABISUP abdomen
- Evaluate alternative thorax deflection measurement devices
- Investigate alternative face inserts
Published:
- Biofidelity Evaluation (Parent et al, Stapp 2017)
- Seating Procedure [DOT HS 812 746]
  - https://rosap.ntl.bts.gov/view/dot/40786

Completed/Approved - in NTL queue:
- Qualification Manual
- Drawing Package
- PADI
- Durability

Draft reports:
- Repeatability & Reproducibility (R&R)
- Rationale and Methodology (R&M) for Qualification Tests
- Injury Risk Curves
Complete:

- Finalize and publish seating procedure
- RibEye evaluation
- Neck torsion qualification procedure and response corridors
- Modifications to improve usability and durability
  - Shoulder pad support
  - Split thorax pad
  - Sleeveless suit
- Conduct full dummy evaluation (R&R, Durability)
- Develop Injury Risk Curves

Ongoing Work:

- Conduct lab-to-lab qualification R&R tests and update report/corridors
- Develop qualification procedure and response corridors for an Individual arm test
- Develop generic DAS specifications ("grey space")
WorldSID 50th Percentile Male – Report Status

Published:
• Seating Procedure [DOT HS 812 729]
  • https://rosap.ntl.bts.gov/view/dot/41900

Completed/Approved - in NTL queue:
• Determination of Optimal RibEye LED Locations

Draft reports:
• RibEye Implementation/Evaluation
• Qualification manual
• Repeatability & Reproducibility (R&R)
• PADI
• Drawing Package
• Durability
• Injury risk curves
Complete:
• Inspection and acceptance of three dummies
• Biofidelity evaluation

Ongoing:
• Conduct R&R evaluation
• Evaluate/finalize qualification procedures
• Develop seating procedure
• Develop injury risk curves
• Evaluate enhancements/improvements
  – Improved face insert, pelvis flesh, etc.

Upcoming:
• Durability evaluation
• Evaluate in crash/sled tests
Published:
- Biofidelity Evaluation
  - Wang et al, IRCOBI 2018

Draft reports:
- Detailed biofidelity report
- Drawing Package

Upcoming:
- Qualification manual
- Repeatability & Reproducibility (R&R)
- PADI
- Durability
- Seating Procedure
- Injury risk curves
Ongoing Work:
- Conduct biofidelity evaluation
  - Develop new response targets
  - Refine BioRank system
  - Compare WorldSID 5th to SID-IIs
- Develop seating procedure

Upcoming:
- Evaluate RibEye in Dummy
  - Updated with smaller controller
- Modifications to improve usability and durability (from WorldSID-50M)
- Conduct R&R and Durability evaluations
- Develop injury risk curves
- Evaluate in crash/sled tests
Draft reports:
• Biomechanical Response Target Development
• Biofidelity Evaluation

Upcoming:
• RibEye Implementation/Evaluation
• Qualification manual
• Repeatability & Reproducibility (R&R)
• PADI
• Drawing package
• Durability
• Seating Procedure
• Injury risk curves
BioRID II – Research Status

Complete:
- Develop PMHS flexion-based whiplash injury criteria

Ongoing Work:
- Develop extension-based whiplash injury criteria
  - Paired PMHS and BioRID sled tests
  - Modified head restraint to induce extension
- Procure/install Qualification mini-sled

Upcoming:
- Evaluate qualification procedures/corridors
- Conduct full dummy evaluation (R&R, Durability)
- Work to improve BioRID neck flexion response
- Additional biofidelity evaluation?
- Finalize injury risk curves (extension or extension/flexion)
- Seating procedure
- Evaluate in sled tests
BioRID II – Report Status

Published:
- Biofidelity Evaluation (Moorhouse et al, Stapp 2012)
- Various other Stapp/IRCOBI/ESV/TIP publications

Upcoming:
- Repeatability & Reproducibility (R&R)
- Seating Procedure
- Qualification manual
- Durability
- PADI
- Drawing package
- Additional biofidelity evaluation?
- Injury risk curves
LODC – Research Status

Completed:
- CChIPS Round Robin (external evaluation)
- Initial full dummy evaluation (biofidelity, R&R, durability)
- Evaluation in sled tests

Ongoing Work:
- Evaluate laser-based chest deflection system
- Develop seating procedure
- Finalize drawing package & PADI
- Conduct final full dummy evaluation
- Assess shoulder & thorax response relative to ongoing biomechanics studies at OSU
- Develop pediatric-specific injury risk curves
  - Head, Neck, Thorax, Abdomen
- Develop LODC FE model
Published:
- Biofidelity Evaluation (Stammen et al, Stapp 2016)
- LODCrev4/5 evaluation [DOT HS 812 755]
  - [https://rosap.ntl.bts.gov/view/dot/41843](https://rosap.ntl.bts.gov/view/dot/41843)

Draft reports:
- Drawing Package
- PADI
- Qualification Procedures

Upcoming:
- Final dummy evaluation report
- Chest deflection measurement comparison
- Seating Procedure
- Injury risk curves
Pedestrian Protection – Research Status

Complete:
- Full evaluation of headforms and legforms
- Evaluation of test procedures / vehicle fleet assessments
- Real-world injury data studies

Ongoing Work:
- Evaluate and compare aPLI and Flex-PLI w/ UBM
- Investigate whether head/leg countermeasures are also beneficial to the thorax

Upcoming:
- Examine how CA/CW pedestrian countermeasures can be evaluated sequentially
Pedestrian Protection – Report Status

Published:
• Test Tool Evaluations
  – Headforms
  – FlexPLI
  – Upper Legform [DOT HS 812 659]
    • [https://rosap.ntl.bts.gov/view/dot/41916](https://rosap.ntl.bts.gov/view/dot/41916)
• U.S. Vehicle Fleet Assessment [DOT HS 812 723]
• Relative Frequency of Injuries Associated with Risk Measured in Pedestrian Tests [DOT HS 812 658]

Completed/Approved - in NTL queue:
• Test Tool Specifications (drawings, PADI, qualification)
• Analysis of Pedestrian Injuries by Vehicle Model Year
• Evaluation of Active Hood System Performance
• Vehicle Bumper Performance in Part 581 vs. Pedestrian Leg Protection

Draft reports:
• Pedestrian Knee Ligament Injury Patterns
• Pedestrian Injury Risk Functions
Biomechanics Research & ATD Applicability

Population-Specific Thorax → All ATDs
ADS Biomechanics → all ATDs
Pediatric Shoulder → LODC
Biomechanics Research & ATD Applicability

Relative motion of dura, arachnoid, and cortical surface

Head-rotation fixture

Subdural Hematoma $\rightarrow$ THOR 50th/5th

Elderly Side Impact $\rightarrow$ WorldSID 50th/5th

Rear Impact Injury Criteria $\rightarrow$ BioRID

Pressure Abdomen $\rightarrow$ THOR/LODC

Figure 2: Pose-test positioning of DASH on the test sled device (A) Linear potentiometer on man; (B) Force transducer on sled; (C) Seatbelt load cells; (D) Load cells attached to thoracic and lumbar back plates; and (E) String potentiometer attached to sled.