SAE INTERNATIONAL

GOVERNMENT INDUSTRY MEETING
April 3-5, 2019 | Washington, DC

Restraint Optimization for Obese Occupants

Hamed Joodaki[1], Vivek Maripudi[2]

[1]University of Virginia Center for Applied Biomechanics

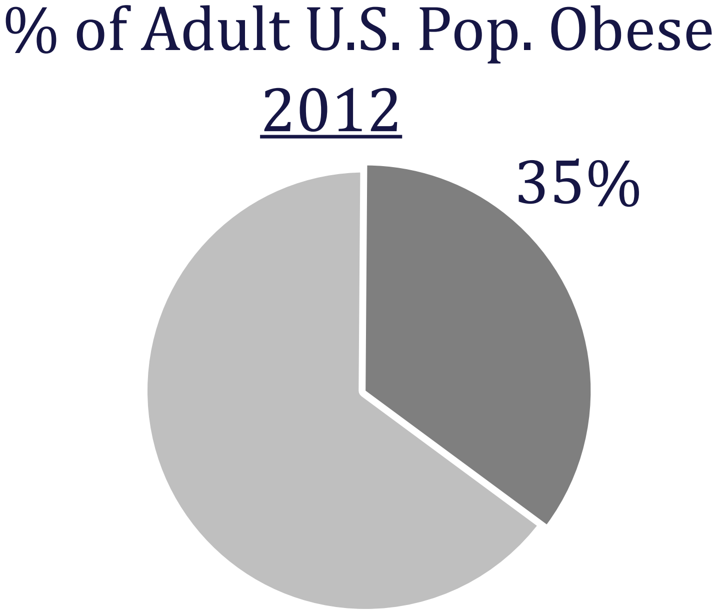
[2]Joyson Safety Systems

*This meeting is co-located with

THE WASHINGTON AUTO SHOW
The Public Policy Show

Motivation

VIANO 2008, JEHLE 2012, MOCK 2002, ZHU 2006, RUPP ET AL. 2013



2011-2012: 78.6 million U.S. adults obese (Ogden et al. 2014)

Rear-seat frontal impact sled tests

BMI 35

Experimental test video
Obese subject

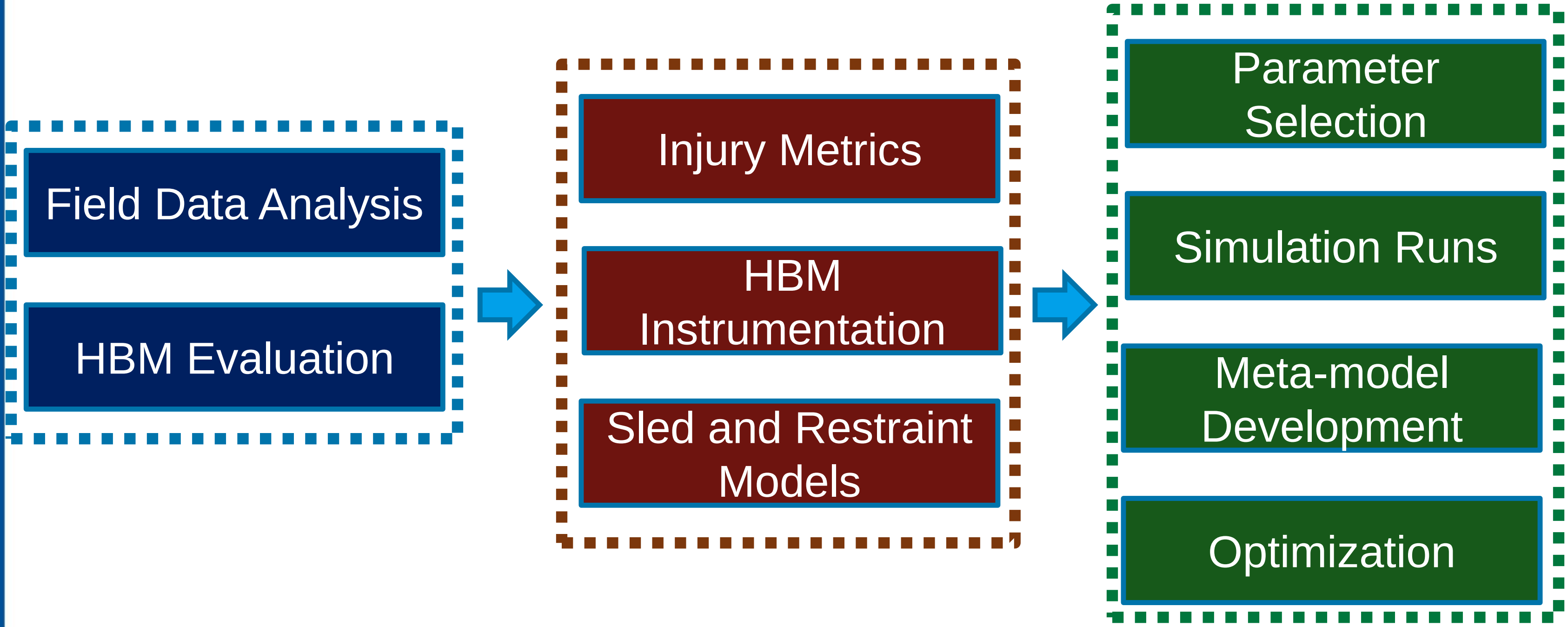
BMI 22

Experimental test video
Non-obese subject

Objective

Restraint system optimization for obese occupants

Overview


Field Data Analysis
HBM Evaluation
Injury Metrics
HBM Instrumentation
Sled and Restraint Models
Parameter Selection
Simulation Runs
Meta-model Development
Optimization

FURTHER UNDERSTANDING THE ISSUE

FIELD DATA ANALYSIS

Restrained occupants in frontal crashes

Data

- **NASS-CDS**
- **Frontal crashes (PDOF -30º to 30º)**
- **Belted occupants only**
- **Air bag deployed**

Restrained occupants in frontal crashes

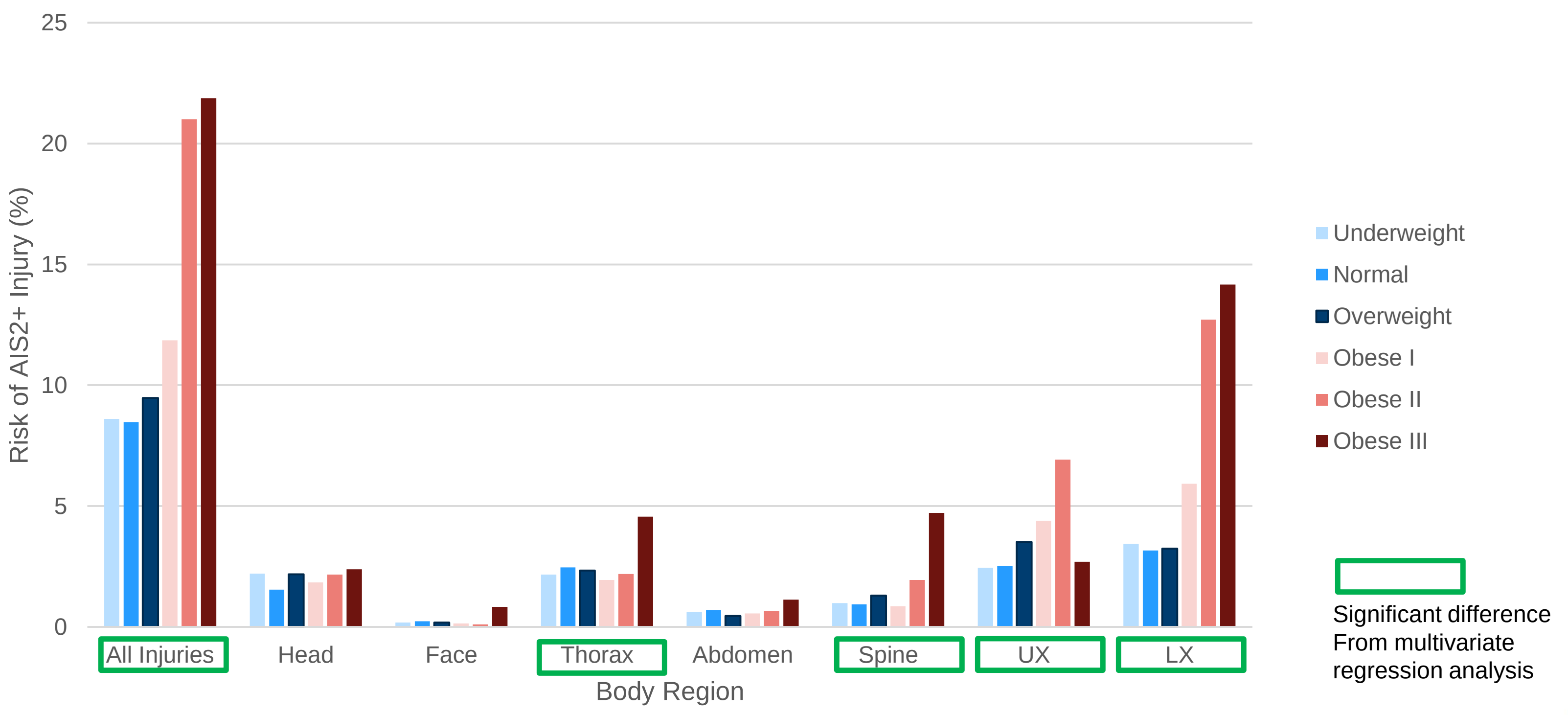
Data

- NASS-CDS
- Frontal crashes (PDOF -30º to 30º)
- Belted occupants only
- Air bag deployed

Objectives

- **BMI vs Risk of AIS2+ injury to different body regions**
- **Most common injuries of obese vs non-obese**
- **Injury mechanism speculation**

BMI vs Risk of Injury to Different Body Regions



Most common injuries of obese

Rank	risk for obese > risk for non-obese
1st frequent	Talus fracture
2nd	Tibia NFS; medial malleolus; open/ displaced/ comminuted
3rd	Metatarsal or tarsal fracture
4th	Carpus or Metacarpus fracture
5th	Patella fracture
6th	Radius Fracture NFS with or without styloid process including Colles
7th	Knee NFS sprain
8th	Fibula fracture; any type but NFS as to site; head, neck, shaft
9th	Rib Cage NFS; 2-3 multiple rib fractures; any location or multiple fractures of single rib; with stable chest or NFS (OIS Grade I, II, III)
10th frequent	Rib Cage NFS; multiple rib fractures NFS; >3 ribs on one side and no more than 3 ribs on other side, stable chest or NFS

Injury mechanism speculation

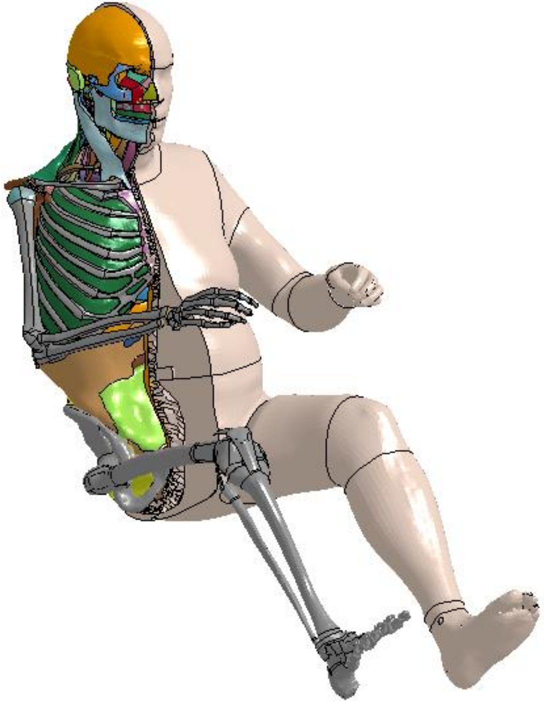
- Large forward motion
  - Higher risk of LX and UX injury
  - Foot/ankle/tibia injuries
- Limited by knee bolsters
  - knee injuries commonly observed
  - no difference in abdominal injuries

MORPHED GHBMC

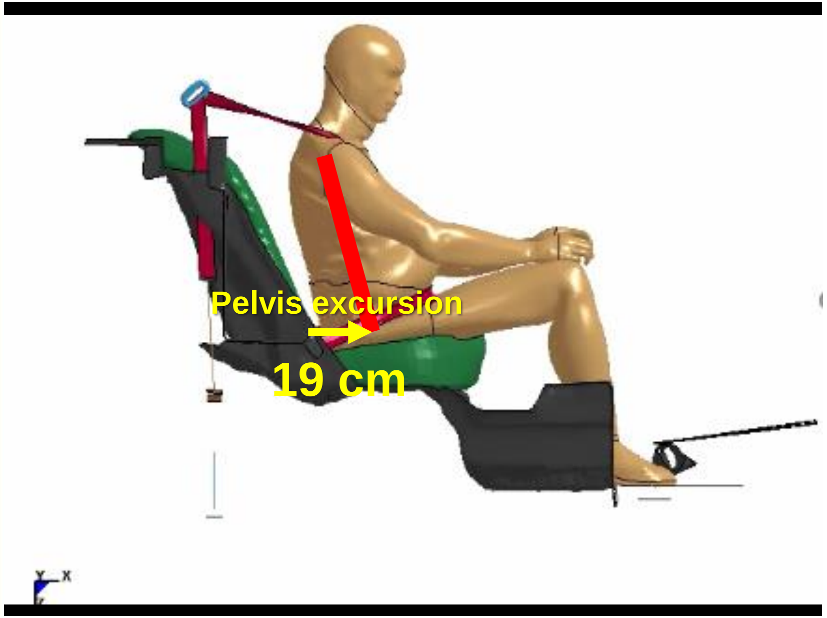
OBESE HBM EVALUATION

Obese HBM

- Baseline GHBMC morphed
  - External body contour
  - Rib cage and lower extremity skeletons geometry
- 3 BMIs, 2 heights, 2 ages



29 km/h Tests



Experimental test video

48 km/h Tests

Experimental test video

Reasons contributing to decreased protection of obese

1- Big body mass → higher belt force required

2- Thick adipose tissue → delayed engagement of lap-belt with pelvis

→ Mimicked by HBM

3- Submarining → penetration into abdomen

↓

HBM unable to submarine due to large shear stiffness of flesh

Conclusion

- HBM and PMHS behaviors comparable in test with no submarining
- Pelvis motion restrained for driver
- → HBM useful

RESTRAINT MODELS

SIMULATION SET-UP

Restraint models

Sled

Seat belt

- Standard and inflatable
- Buckle and anchor pre-tensioner

Adaptive vent driver air bag

Knee air bag

- Low-mount
- Mid-mount

Under-the-seat air bag

Curtain air bag

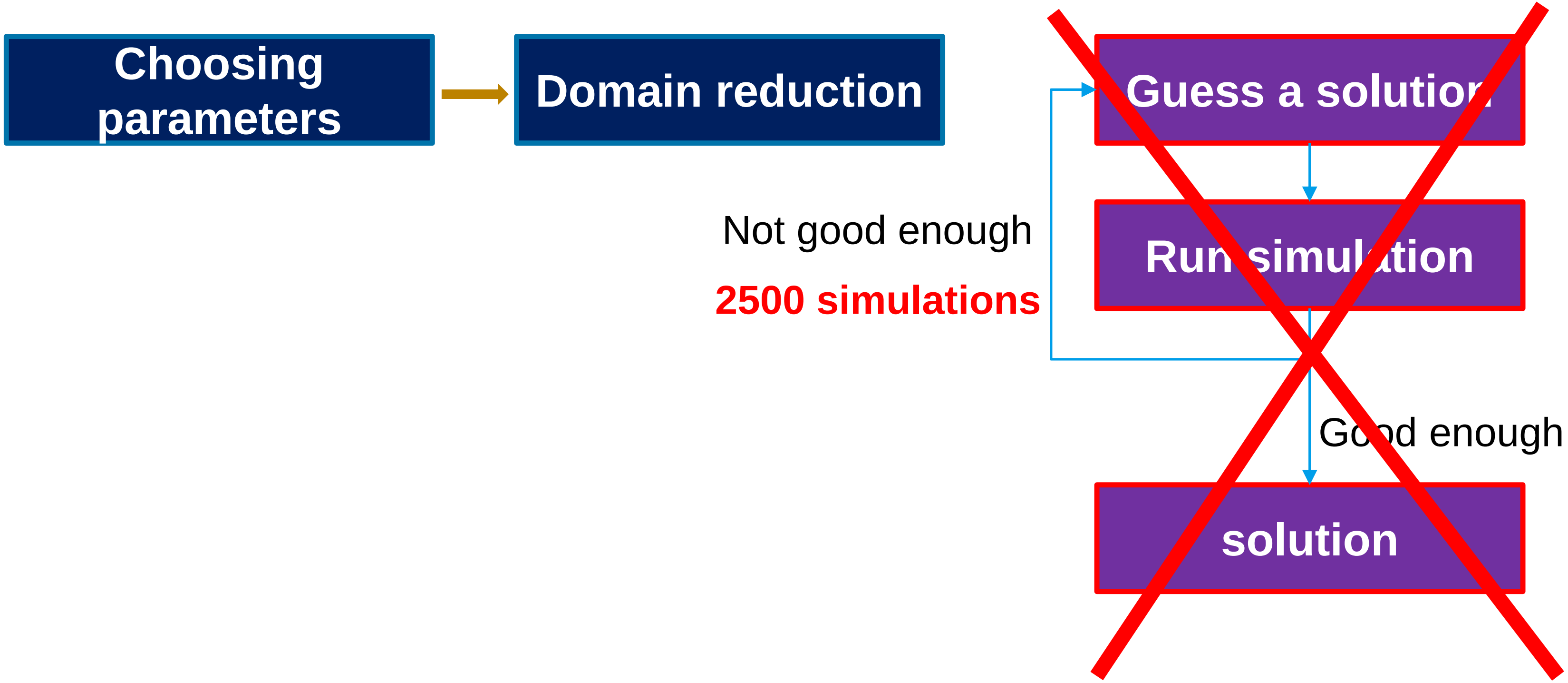
OPTIMIZATION

Optimization method

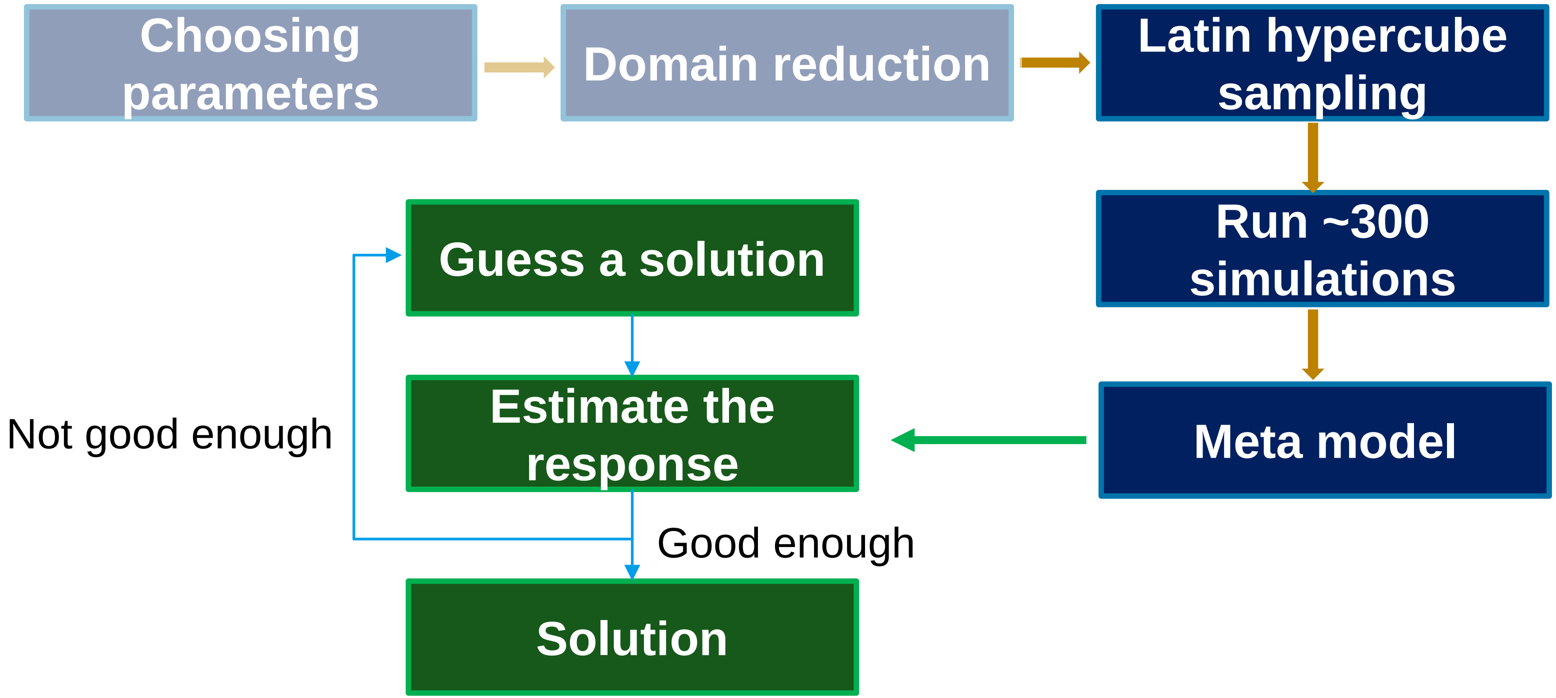
Choosing parameters

- Seat belt
    - Buckle vs anchor pre-tensioner
    - Load limiter and pre-tensioner levels
    - Air-belt vs no air-belt
    - Air-belt pressure
- Pressure of different air bags
- Force level of collapsible steering column

Optimization method



Optimization method



Objective Function

Functional Capacity Index ← Risk of Injury to different body regions ← at

SAE INTERNATIONAL

GOVERNMENT INDUSTRY MEETING
April 3-5, 2019 | Washington, DC

Restraint Optimization for Obese Occupants

Hamed Joodaki[1], Vivek Maripudi[2]

[1]University of Virginia Center for Applied Biomechanics

[2]Joyson Safety Systems

*This meeting is co-located with

THE WASHINGTON AUTO SHOW
The Public Policy Show