INITIAL OBSERVATIONS OF HUMAN SURROGATE RESPONSE IN FORWARD-FACING RECLINED SEATS

Lauren Wood Zaseck, PhD

University of Michigan Transportation Institute

John Humm, PhD

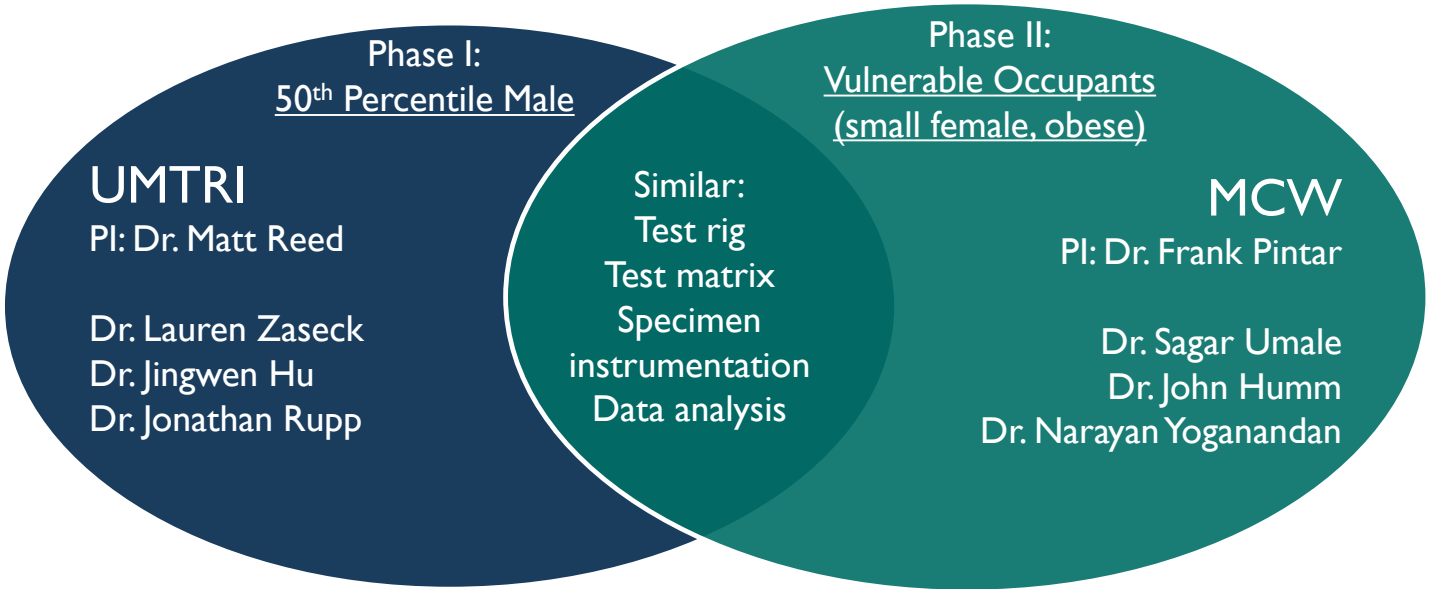
Medical College of Wisconsin

UMTRI

DISCLAIMER: The opinions, findings, and conclusions expressed in this presentation are those of the authors and not necessarily those of the Department of Transportation or the National Highway Traffic Safety Administration. The United States Government assumes no liability for its contents or use thereof. If trade or manufacturers' names are mentioned, it is only because they are considered essential to the object of the publication and should not be construed as an endorsement. The United States Government does not endorse products or manufacturers.

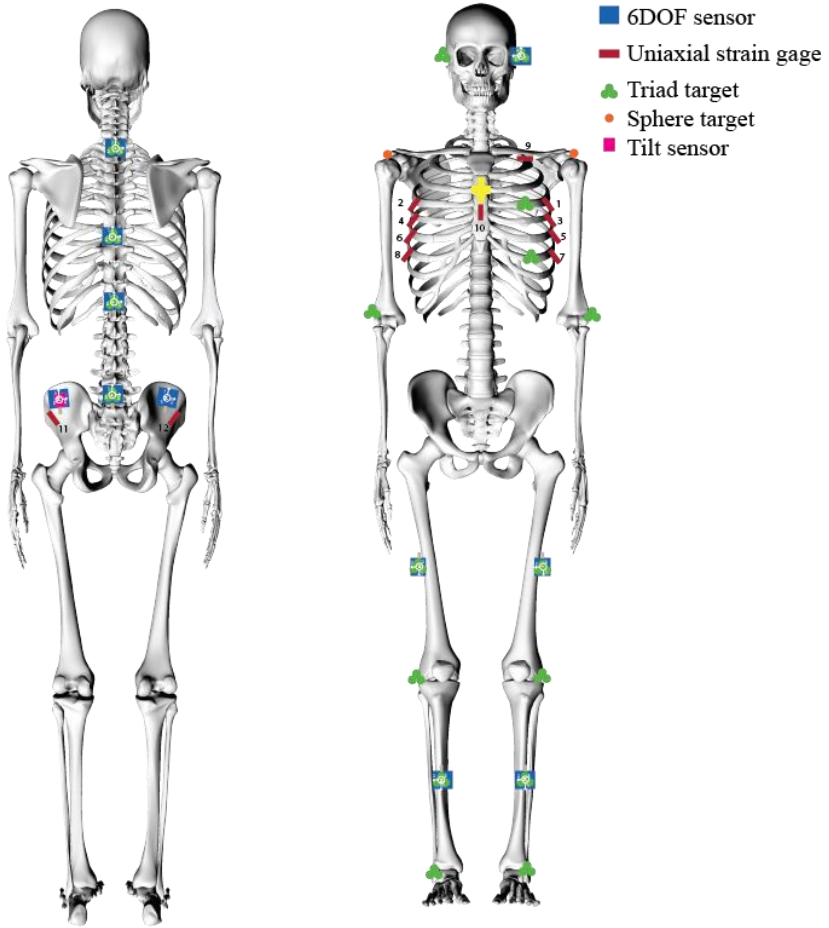
PROJECT ORGANIZATION AND PARTICIPANTS

- NHTSA-funded frontal impact tests on PMHS with a focus on highly reclined occupants
  - Current safety standards are based on occupants seated in standard posture (~24° recline)
  - Improvements to seats and restraint systems may be needed to ensure good protection for people in alternative postures
- Primary outcome: cohesive dataset that can be used for future validation of ATDs and human body models



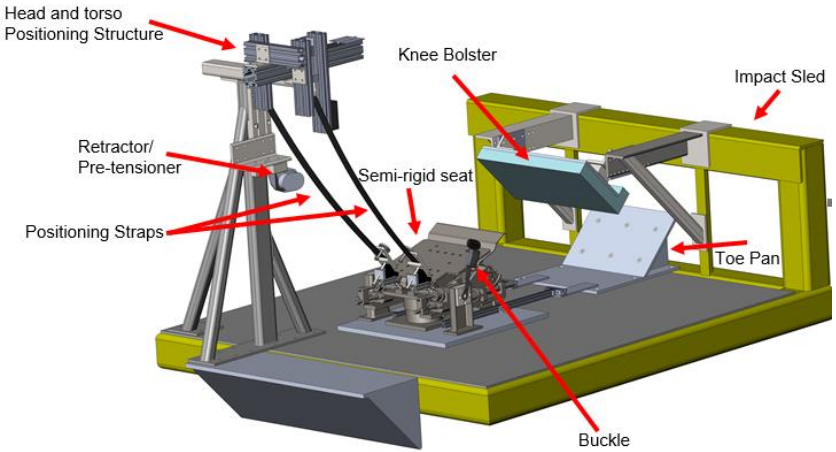
SUBJECT INSTRUMENTATION

- Whole body kinematics
- Spine, head, pelvis, lower extremity accelerations and angular rotations
- Chest deflection
- Subject surface scans

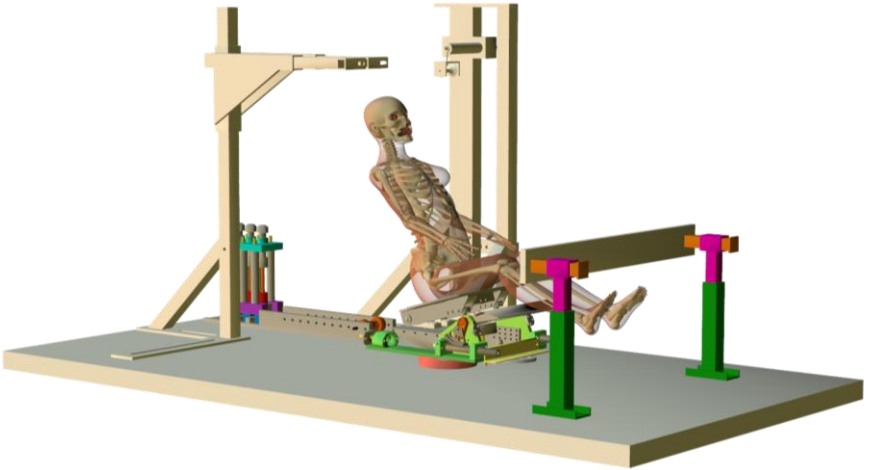


TEST RIGS

UMTRI

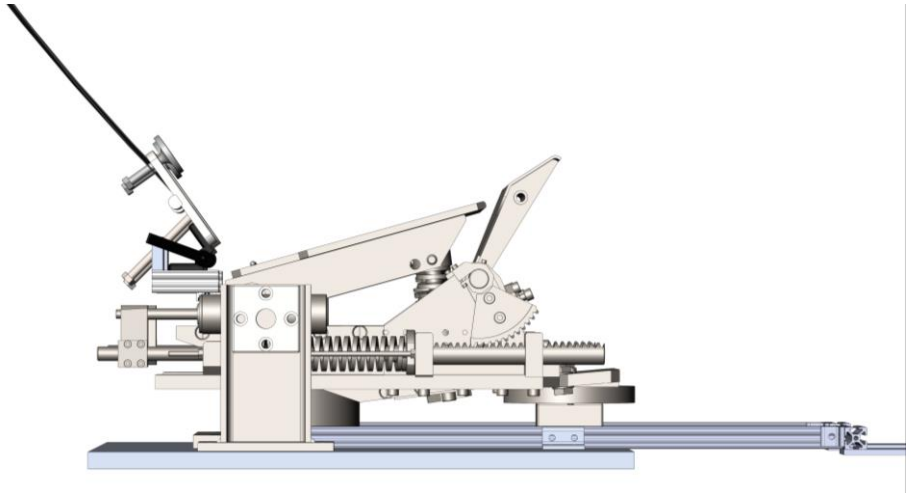


MCW



- Open seat back allowing for recline up to 90 degrees
- Simulated integrated restraints

SEATING ENVIRONMENT



- Controlled-response seat with seat pan and anti-submarining ramp (from Uriot et al., 2015)
- Mimics response of production seats but is well characterized, and easily reproduced and modeled

TEST MATRIX

Number of Tests	Delta V (kph)	Seat Back Angle (deg)	Restraint Configuration	Knee Bolster
3	32	25	Baseline	Out of contact
3	56	25	Baseline	Out of contact
3	32	45	Baseline	Out of contact
3	56	45	Baseline	Out of contact
3	TBD	TBD	TBD	TBD
3	TBD	TBD	TBD	TBD
3	TBD	TBD	TBD	TBD
3	TBD	TBD	TBD	TBD

- MCW also conducting low speed (15 kph) tests on each PMHS prior to 32/56 kph tests
- Remainder of test matrix determined after completion of first 12 tests

SUBJECT INCLUSION CRITERIA

Sex	**Male**
Age (years)	≥18
Stature (cm)	170 – 181
Mass (kg)	–
BMI (kg/m^2)	18.5 – 30
Bone mineral density (mg/cc)*	≥ 80
HIV, HepC, COVID-19 negative	
No hip replacements, spinal fusions, artificial discs, or pre-existing fractures to spine, pelvis, or femur	

*from CT, average from 3 lumbar spine sections

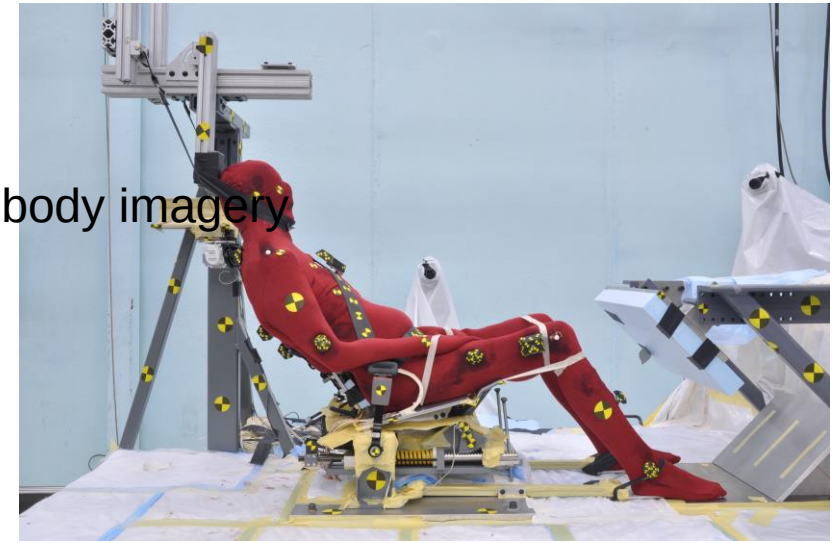
50TH PERCENTILE MALE, INITIAL OBSERVATIONS

32 kph, 25° recline (n=3)

NHTSA Biomechanics database test #s:
12796 (reference no:AV2003)
13109 (reference no:AV2104)
13119 (reference no:AV2106)

32 kph, 45° recline (n=2)

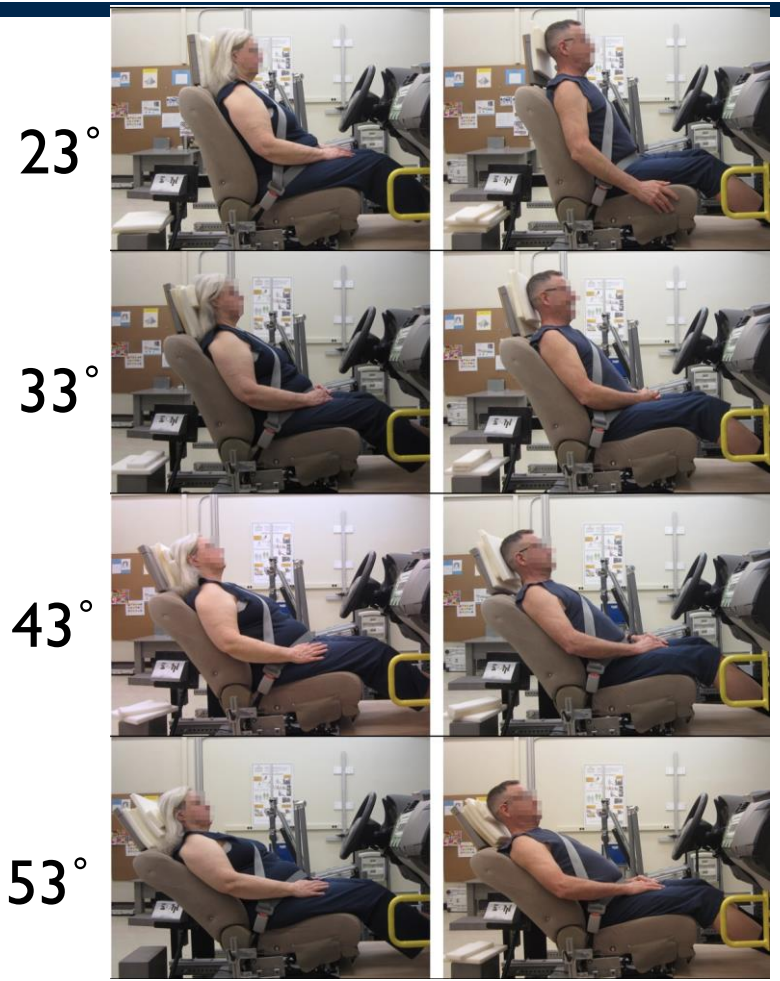
Warning: graphic body imagery



NHTSA Biomechanics database test #s:
12795 (reference no:AV2002)
13110 (reference no:AV2105)

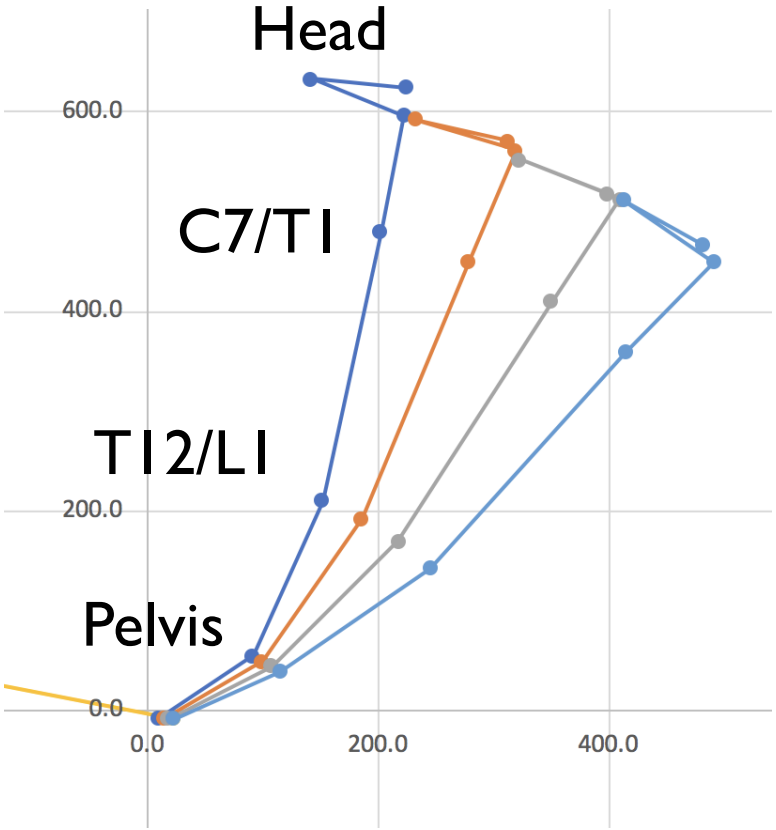
SUBJECT POSITIONING

- Based on UMTRI volunteer study (Reed et al., 2019)
  - 24 men and women
  - laboratory mockup
  - 4 seat back angles (23, 33, 43, 53 deg)
  - sitter-selected head support
  - posture measurement using FARO Arm



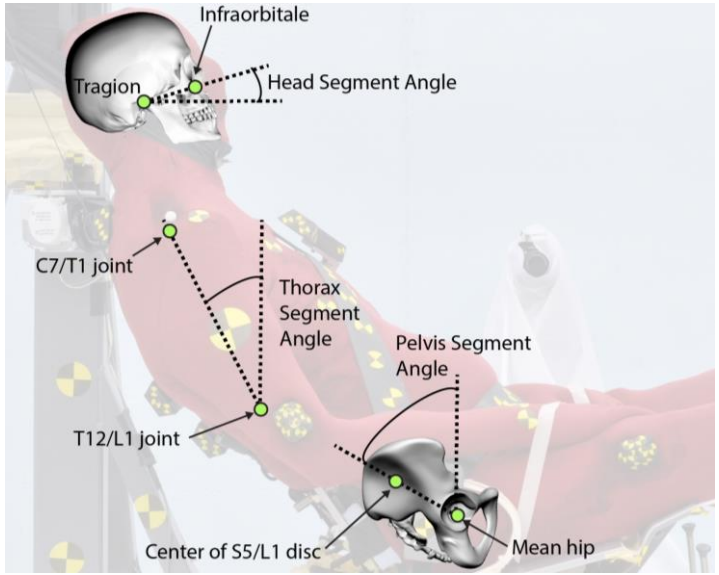
SUBJECT POSITIONING

- Posture Prediction:
  - Statistical modeling of torso posture
- Inputs:
  - Stature
  - Erect Sitting Height
  - Body Weight
  - Seat Back Angle
- Outputs:
  - Head and torso landmarks
  - Torso joint center locations
  - Pelvis angle



Warning: graphic body imagery

SUBJECT POSITIONING



Variable	Definition	Calculation
Pelvis Segment Angle (deg)	Sideview angle of vector from hip joint to L5/S1 joint wrt vertical	84.8 - 1.37 BMI + 0.331 BA
Thorax Segment Angle (deg)	Sideview angle of vector from T12/L1 joint to C7/T1 joint wrt vertical	8.8 - 0.670 BMI + 0.919 BA
Head Segment Angle (deg)	Sideview angle of vector from tragion to infraorbitale wrt horizontal	-31.6 + 0.584 BMI + 0.907 BA
Knee Spacing (mm)	Lateral distance between suprapatellar landmarks	-459 + 0.35 Stature + 6.0 BMI

BA = back angle

Warning: graphic body imagery

50TH PERCENTILE MALE, INITIAL OBSERVATIONS: POSTURE

25° recline

	Target	Achieved
Pelvis angle (°)	54.6 ± 5	56.4
Thorax angle (°)	13.3 ± 5	11.3
Head angle (°)	7.5 ± 5	9.5

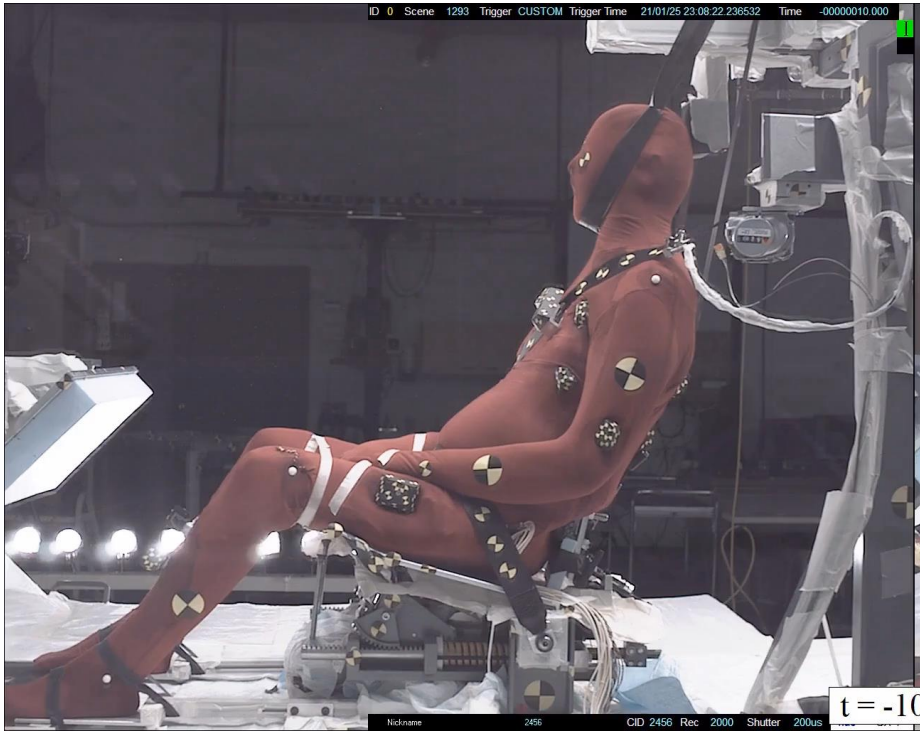
45° recline

Target	Achieved
65.6 ± 5	66.0
33.5 ± 5	33.7
23.8 ± 5	23.3

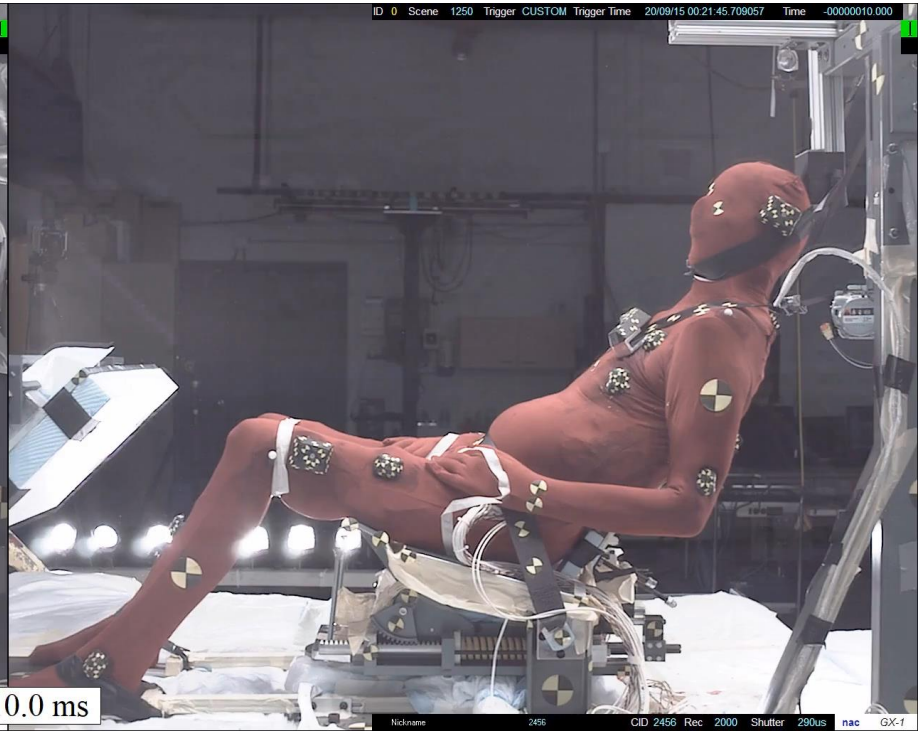
Warning: graphic body imagery

50TH PERCENTILE MALE, INITIAL OBSERVATIONS: VIDEO

25° recline (AV2104)



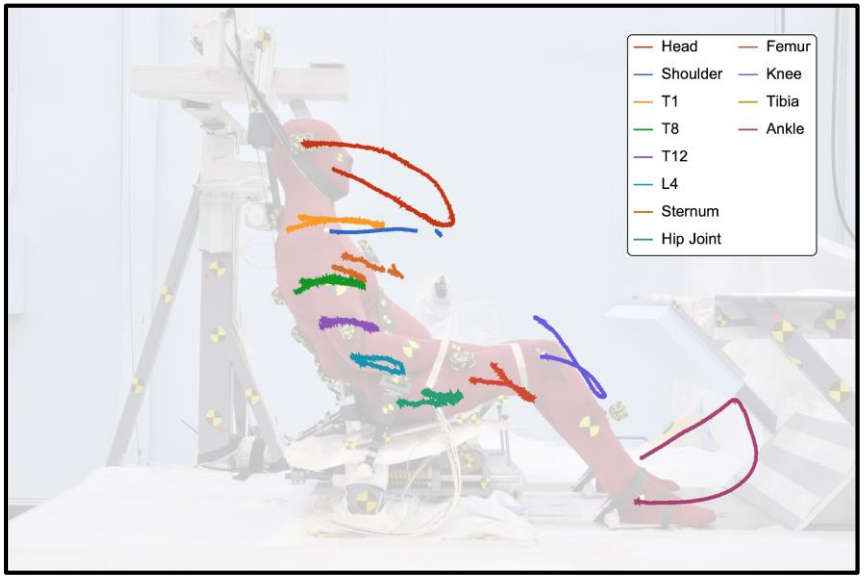
45° recline (AV2002)



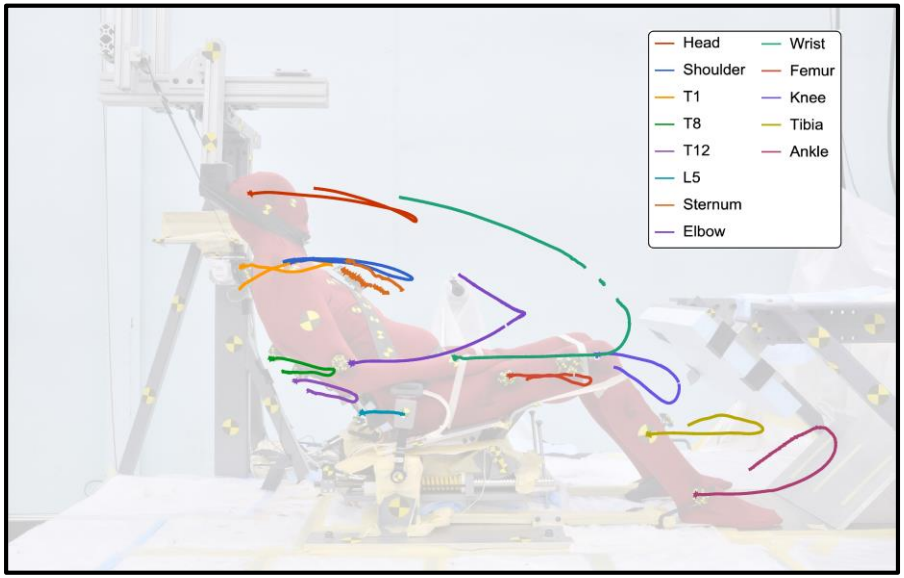
Warning: graphic body imagery

50TH PERCENTILE MALE, INITIAL OBSERVATIONS: KINEMATICS

25° recline (AV2104)

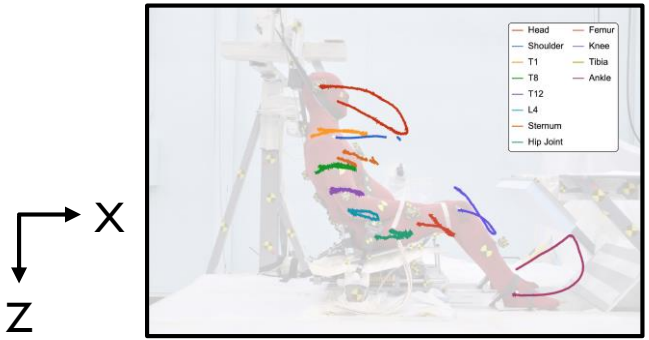


45° recline (AV2002)

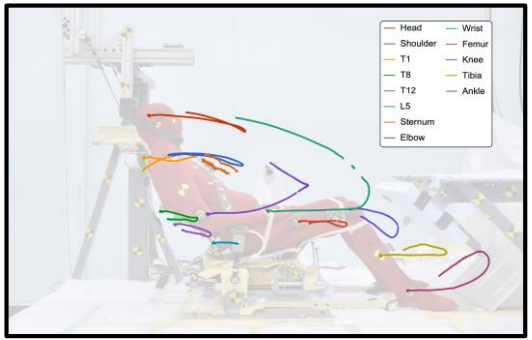


50TH PERCENTILE MALE, INITIAL OBSERVATIONS: KINEMATICS

25° recline



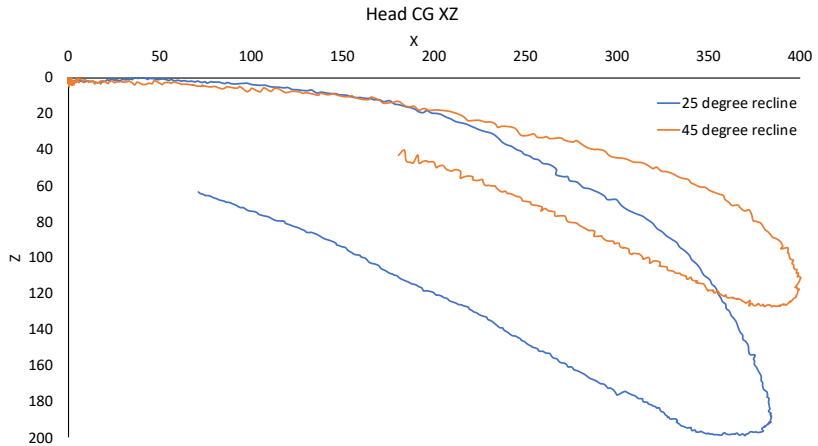
45° recline

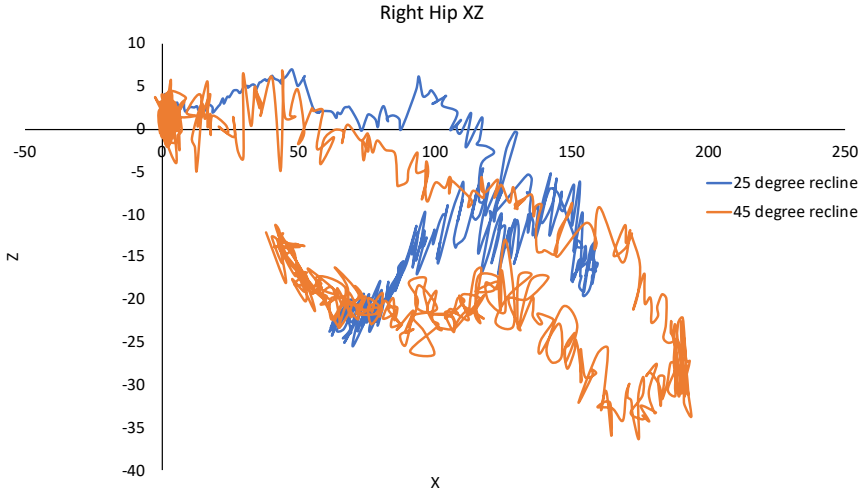


Max translation, AV2104 and AV2002 (mm)	X	Z	X	Z
Head CG	385	**196**	397	125
Sternum	146	59	**154**	**90**
T1	212	22	211	**53**
T8	161	12	169	**48**
T12	142	23	159	**56**
L4	130	37	127	**21**
Right Hip Joint	158	23	**190**	**42**
Right Mid Femur	158	49	**195**	45
Right Mid Tibia	231	34	**286**	**1**

Bolded, red values are ≥20% different between conditions

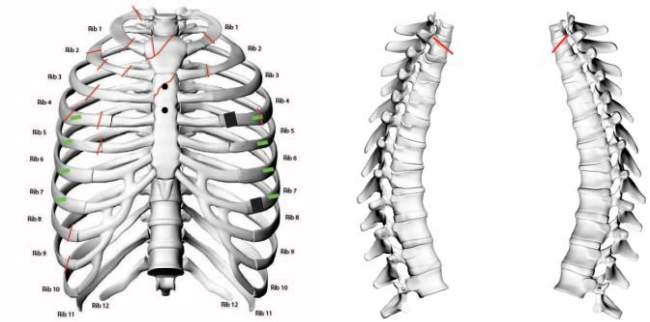
50TH PERCENTILE MALE, INITIAL OBSERVATIONS: KINEMATICS



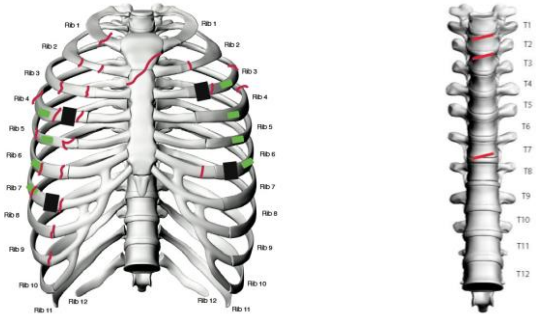


50TH PERCENTILE MALE, INITIAL OBSERVATIONS: INJURIES

Example injuries: 25° recline (AV2104)



Example injuries: 45° recline (AV2002)



	25° recline			45° recline	
	AV2003	AV2004	AV2106	AV2002	AV2015
Sternum		2	2	2	2
Left Ribs	3	3	3	3	5
Right Ribs	3	3		4	5
C5	2				
C6					
C7	3				
T1					2
T2		2		2	
T3				2	
T4					2
T5					
T6	1				
T7				2	
T8					
T9					
T10					1
T11					1
T12					2
L1					
L2					
L3					
L4					
L5					
Sacrum/Coccyx	2				1
Pelvic Ring					
Other					
Max AIS	3	3	3	4	5