Initial Observations of Human Surrogate Response in Forward-facing Reclined Seats

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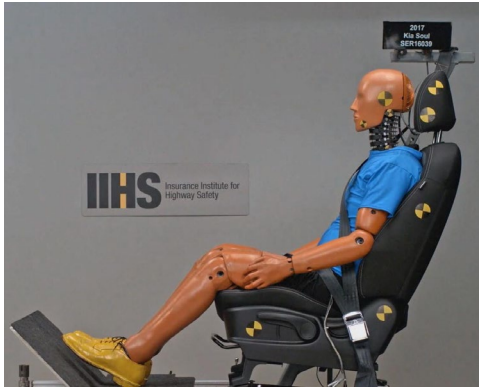
Project Background



Standard automotive posture

Kinematics
Submarining risk
Injury risk
Biomechanical response

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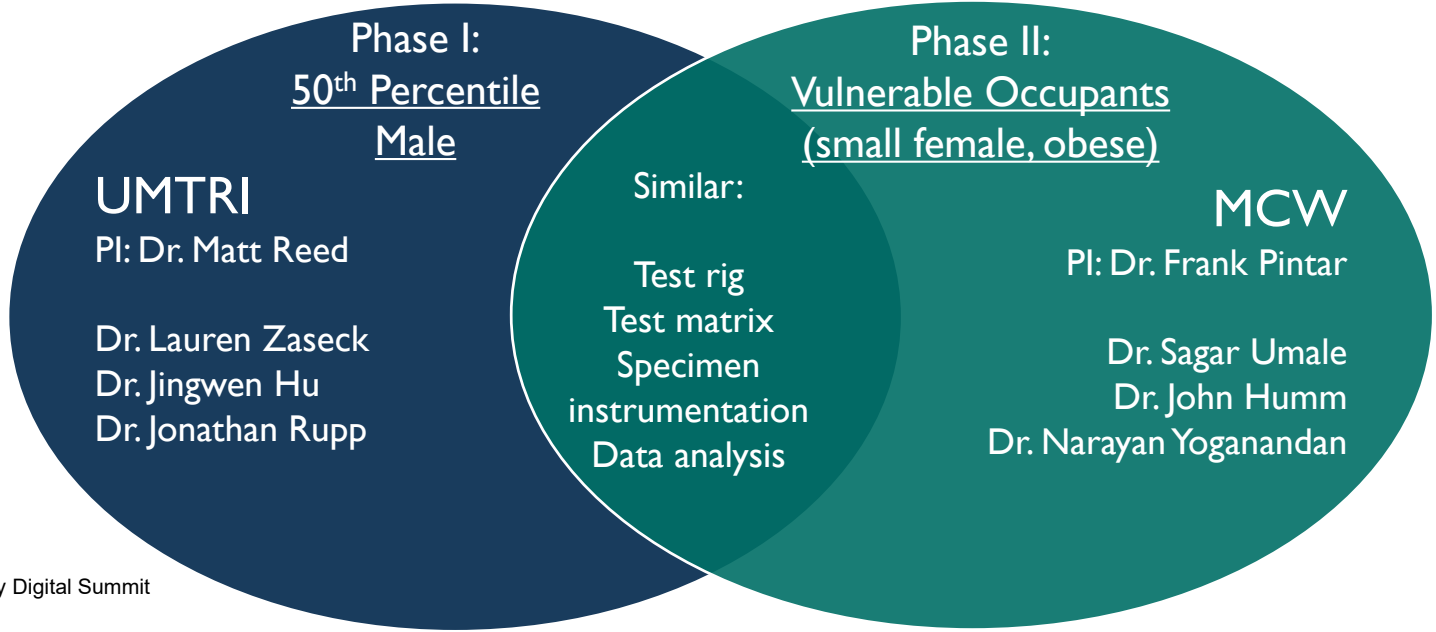
Volvo concept autonomous vehicle design with reclined posture

- 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

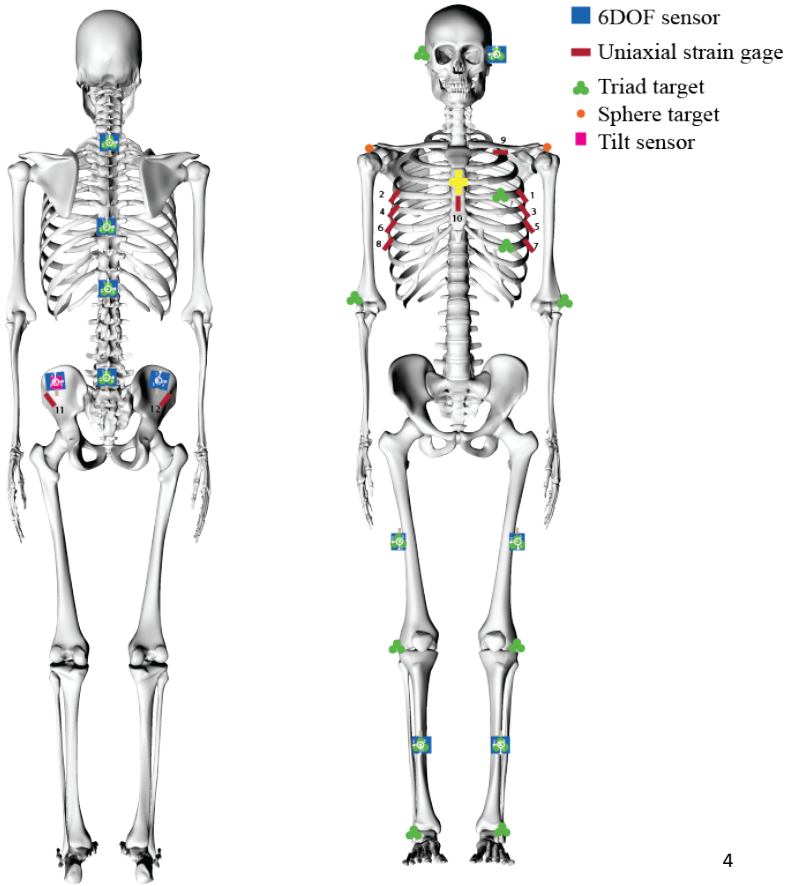
Project Organization and Participants

- NHTSA-funded frontal impact tests on PMHS with a focus on highly reclined occupants
- Primary outcome: cohesive dataset that can be used for future validation of ATDs and human body models



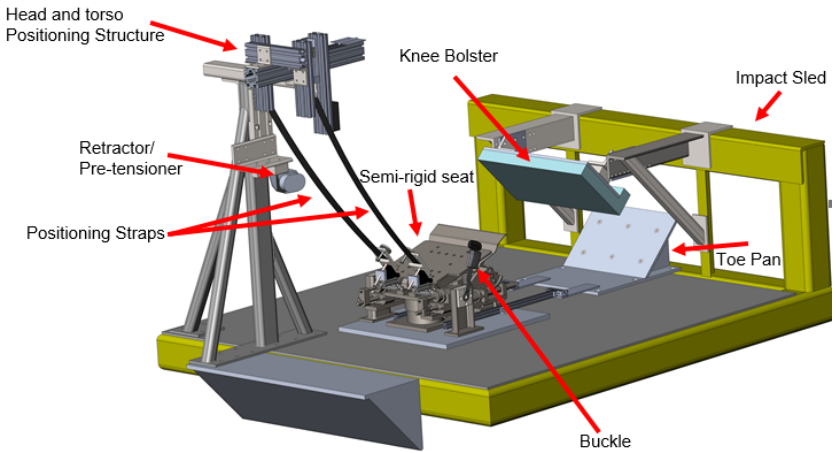
Subject Instrumentation

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

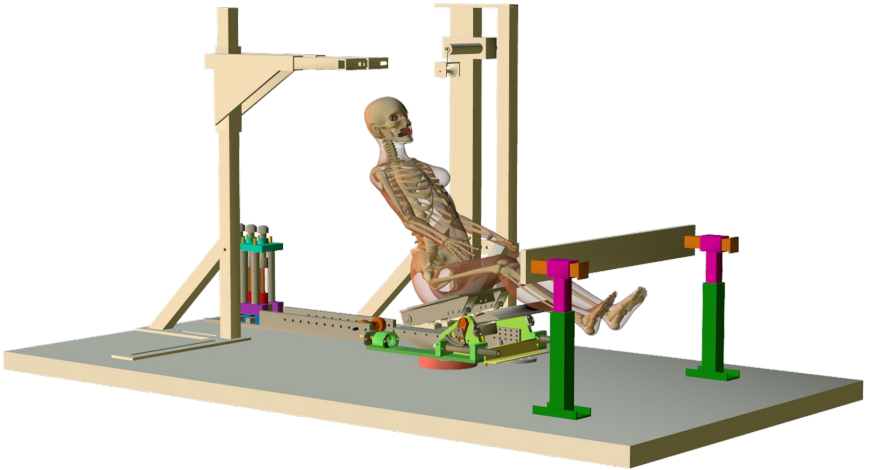


Test Rigs

UMTRI

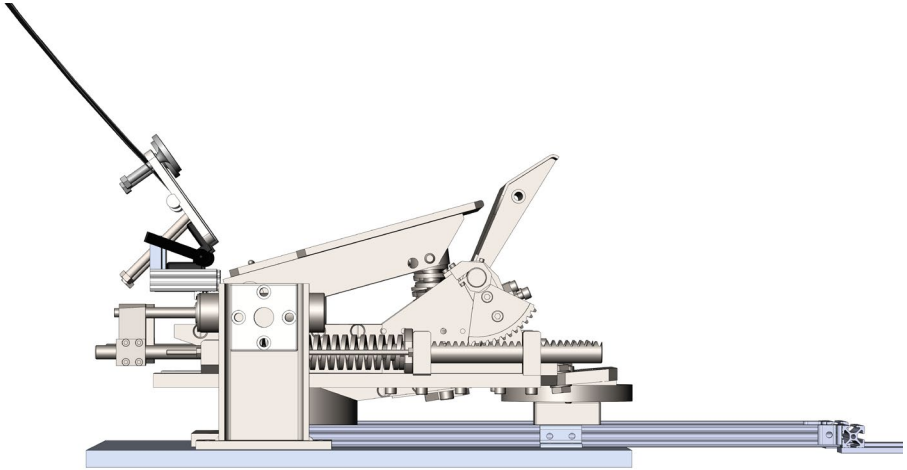


MCW



- 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

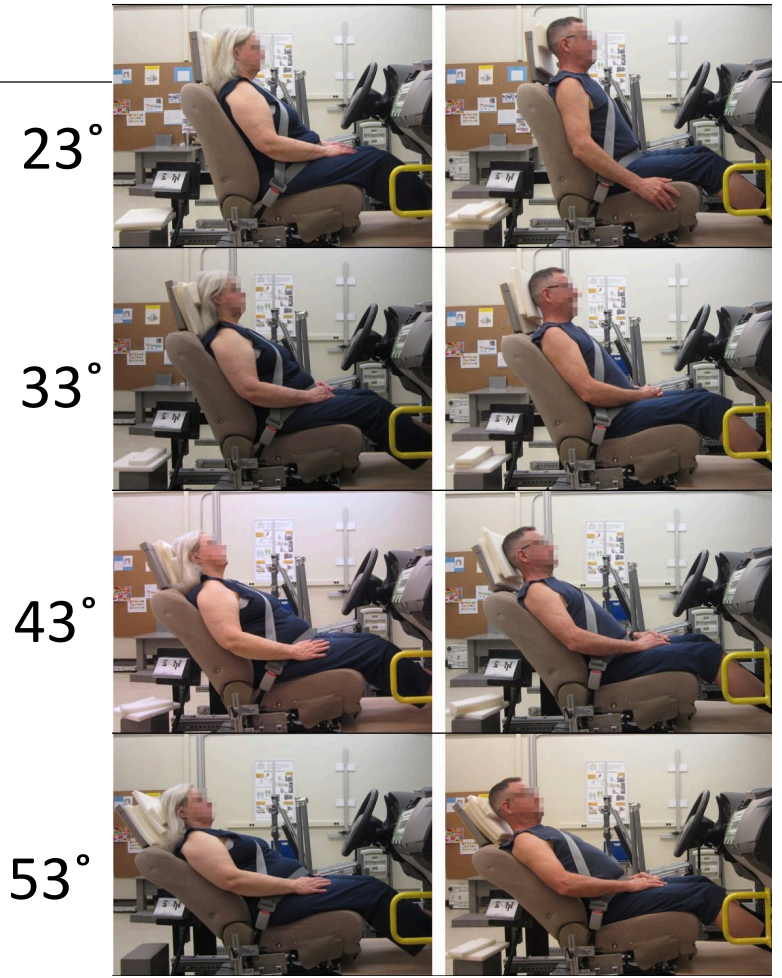
Test Matrix

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

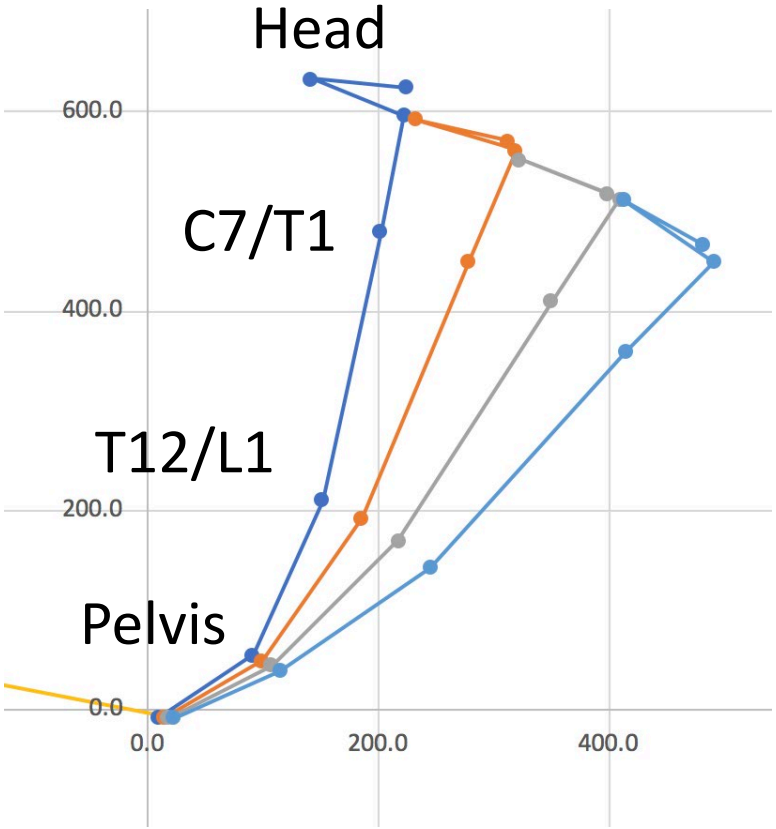
Subject Positioning

- 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

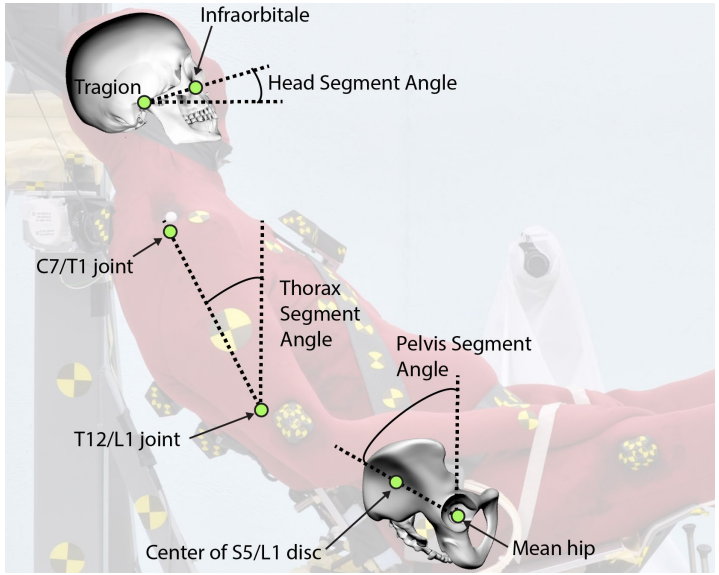


Subject Positioning

- 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



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

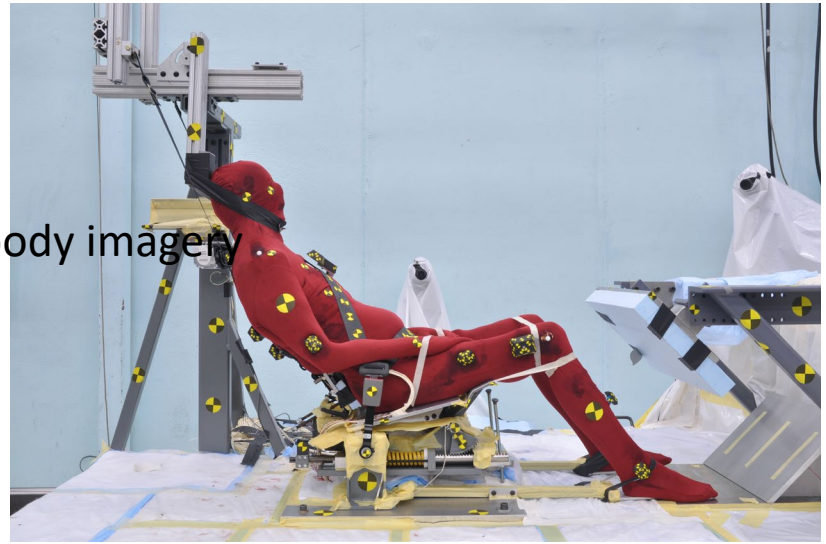
50th Percentile Male, Initial Observations

- Two tests conducted at UMTRI to date

AV2003 - 32 kph, 25° recline

Warning: graphic body imagery

AV2002 - 32 kph, 45° recline



50th Percentile Male, Initial Observations

- Two tests conducted at UMTRI to date

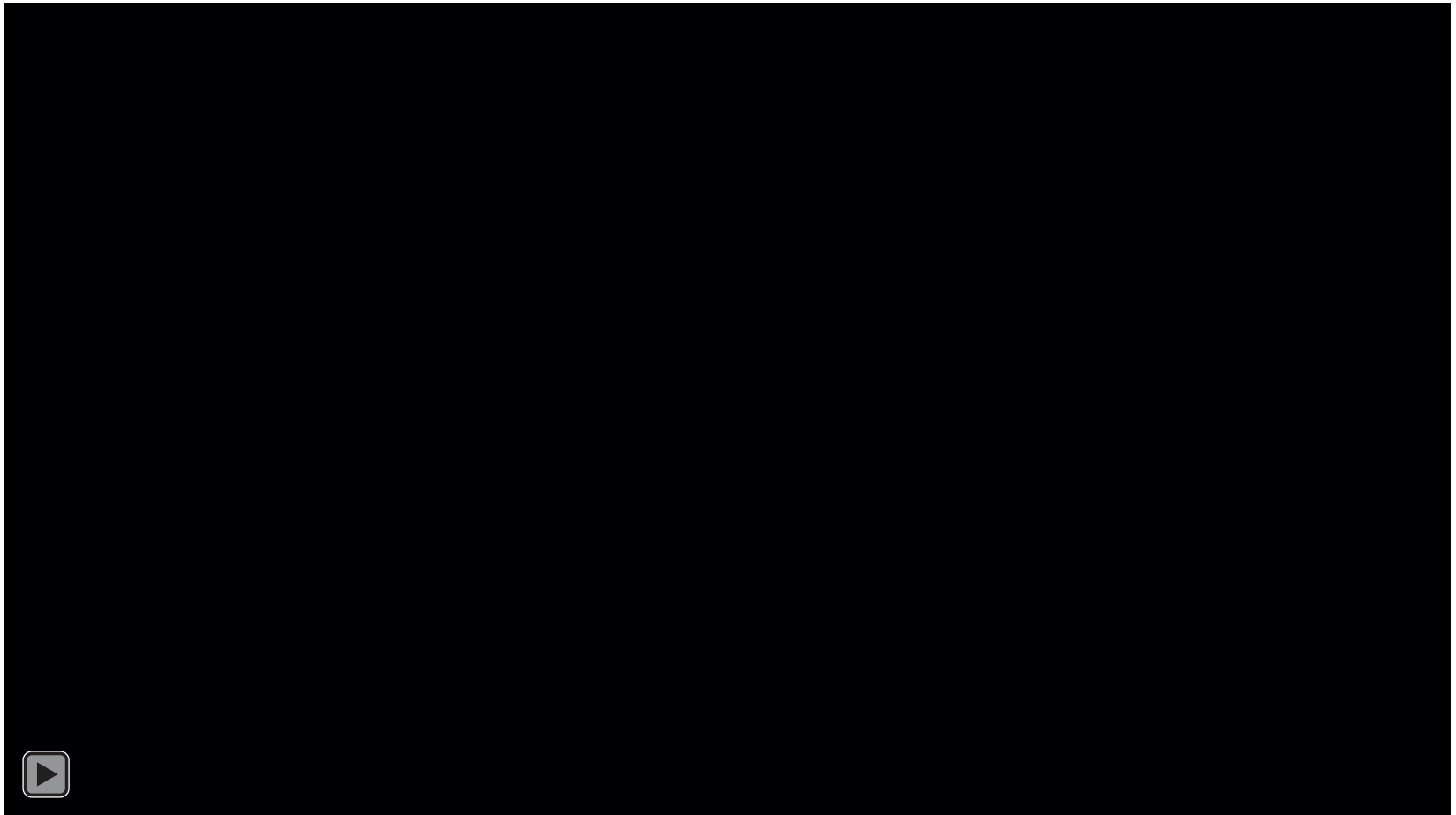
AV2003 - 32 kph, 25° recline

Test Reference ID	AV2003
Sex	Male
Age	72
Stature (cm)	174.2
Mass (kg)	64.4
BMI (kg/m2)	21.2
Cause of Death	COPD, Anemia
Skeletal anomalies:	C6/C7 spinal fusion, right forearm to hand missing postmortem

AV2002 - 32 kph, 45° recline

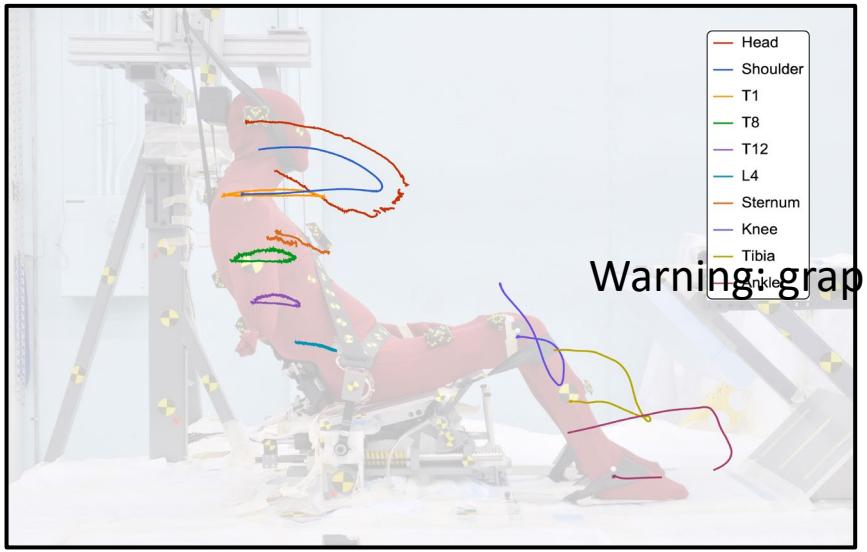
Test Reference ID	AV2002
Sex	Male
Age	91
Stature (cm)	174.9
Mass (kg)	76.1
BMI (kg/m2)	24.9
Cause of Death	End stage heart failure, GI bleed, renal failure
Skeletal anomalies:	Ribcage asymmetry (left side inferiorly shifted). Preexisting anterior cartilage fracture on left rib 6.

50th Percentile Male, Initial Observations: Videos

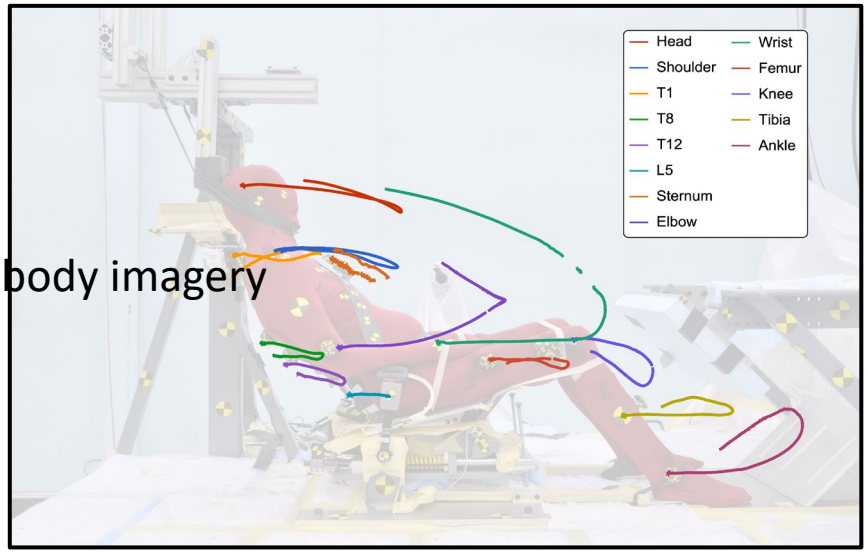


50th Percentile Male, Initial Observations: Kinematics

25° recline



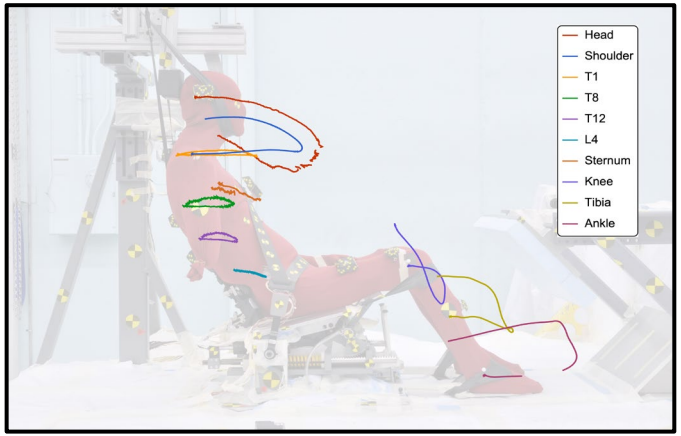
45° recline



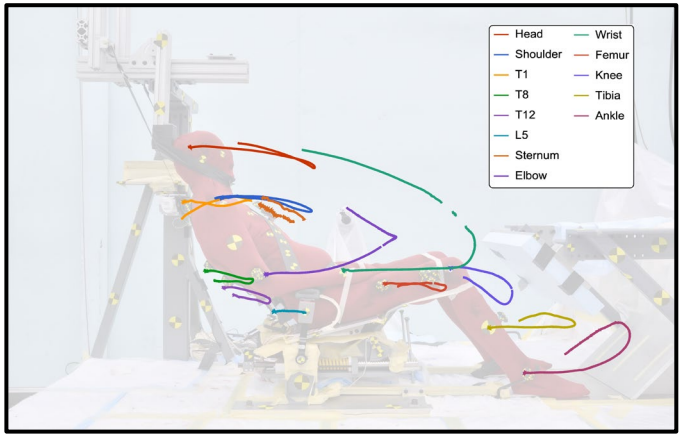
Warning: graphic body imagery

50th Percentile Male, Initial Observations: Kinematics

25° recline



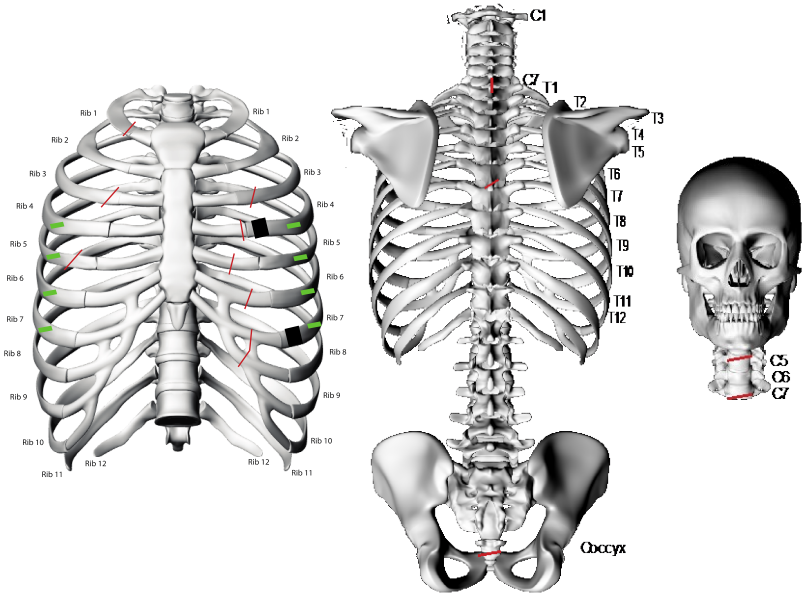
45° recline



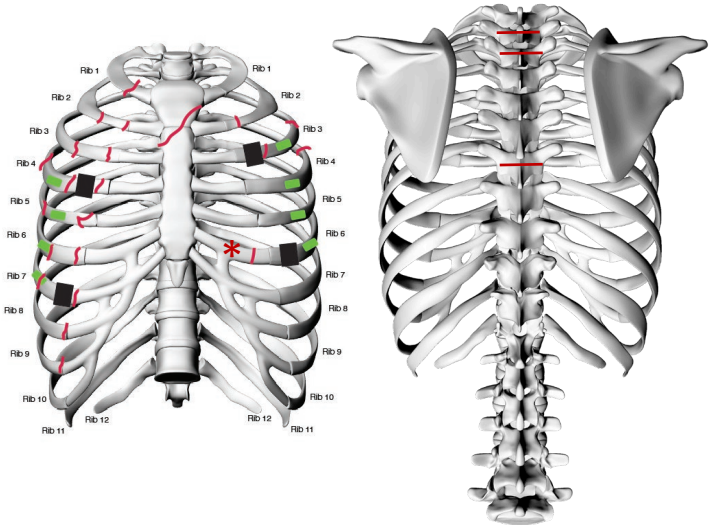
Max Translation (mm)	X	Z	X	Z
Head CG	369.7	**232.5**	**397.5**	125.3
Sternum	120.3	52.4	**154.1**	**90.0**
T1	**231.4**	5.7	211.5	**53.5**
T8	148.5	3.7	**169.0**	**47.8**
T12	110.1	8.8	**159.9**	**56.3**
L4	91.0	20.0	**127.8**	**20.7**
Right Hip Joint	100.1	**8.4**	**190.4**	1.1
Right Mid Femur	103.4	53.0	**202.3**	**141.3**
Right Mid Tibia	183.4	**48.8**	**286.5**	0.6

50th Percentile Male, Initial Observations: Injuries

25° recline



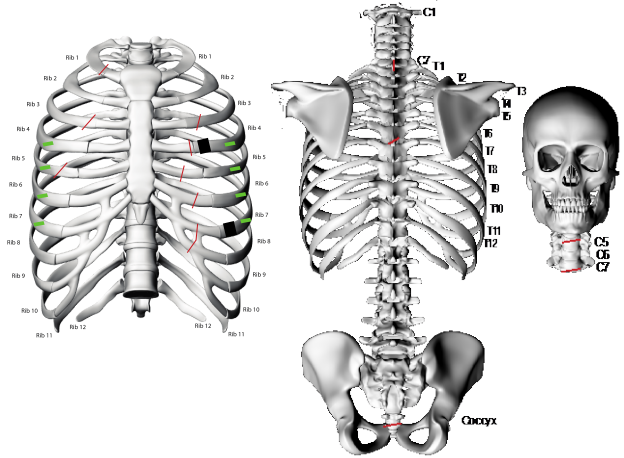
45° recline



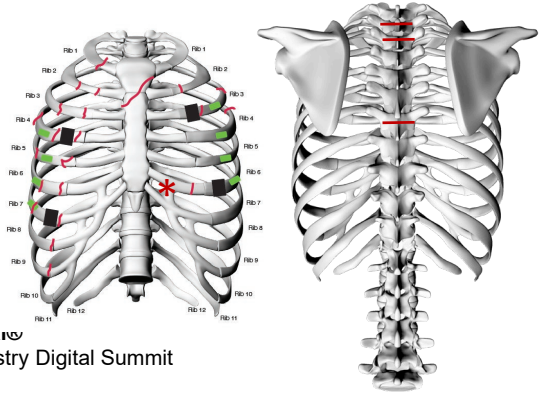
*Preexisting fx

50th Percentile Male, Initial Observations: Injuries

25° recline



45° recline

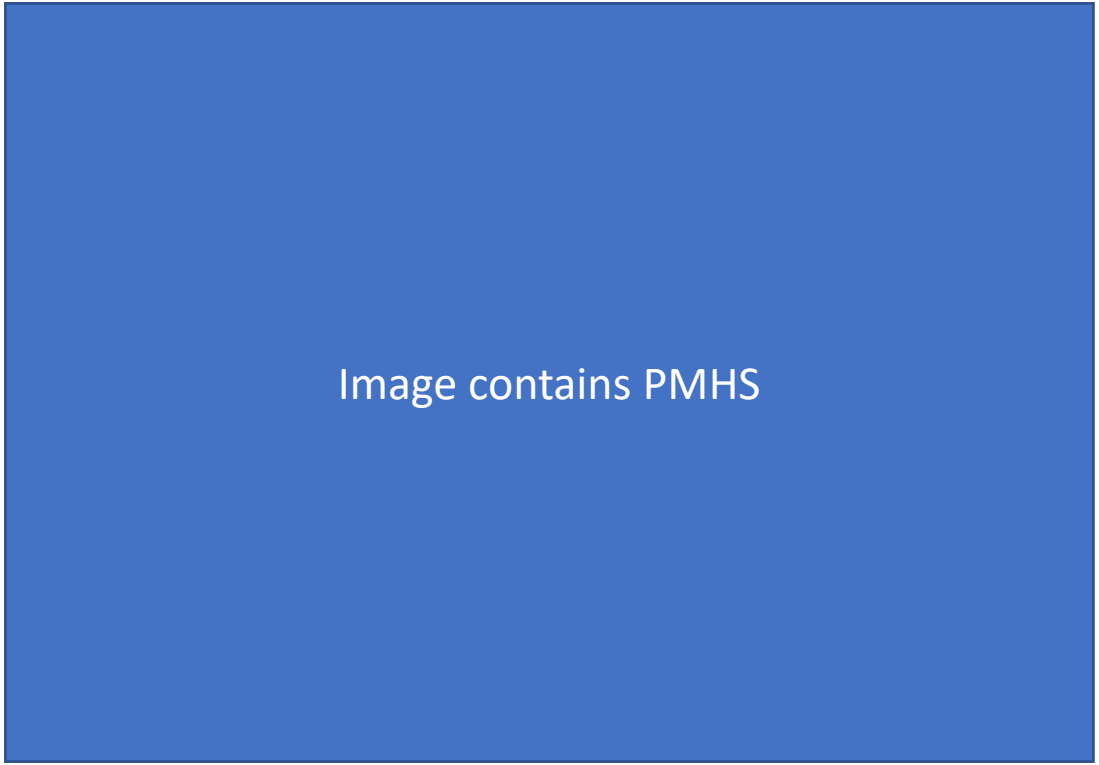


	32 kph	
	25° recline	45° recline
Sternum		2
Left Ribs	3	3
Right Ribs	3	4
C5	2	
C6		
C7	3	
T1		
T2		2
T3		2
T4		
T5		
T6	1	
T7		2
T8		
T9		
T10		
T11		
T12		
L1		
L2		
L3		
L4		
L5		
Sacrum/Coccyx	2	
Pelvic Ring		
Other		
Max AIS	3	4

MCW Test Protocol

- Same seat/buck as UMTRI
- Same seating procedure
- Population: Small female and obese occupants
- 2 Tests/PMHS
  - 15 km/h → No pretensioner
  - 32 km/h → Pretension and load limiter

Obese Occupant, Initial Observations: Posture

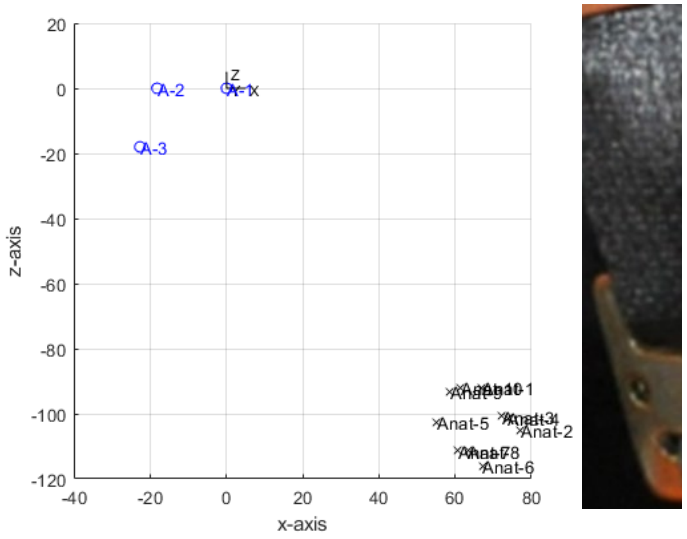


Test ID	ObO#1
Sex	Female
Age (years)	59
Stature (m)	1.626
Mass (kg)	105
BMI (kg/m^2)	39.7
Occupant Category	Obese

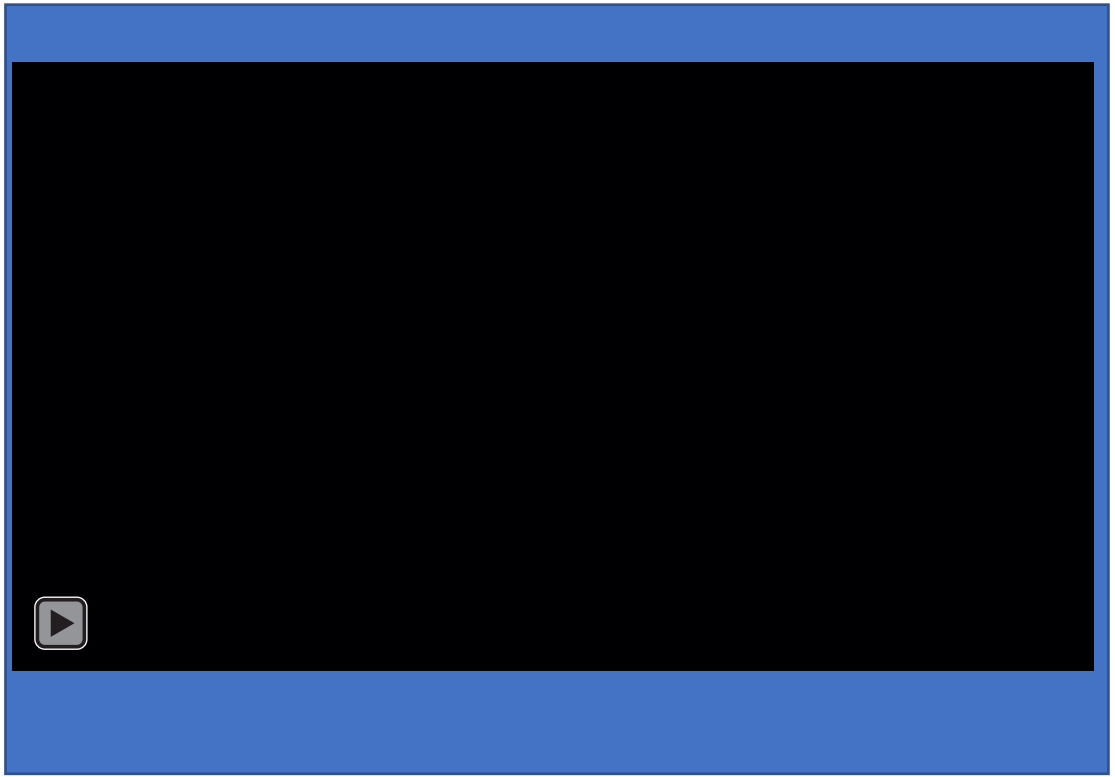
Parameter	Target
Seat Back Angle (deg)	45
Head Angle (deg)	32.4 ± 5
Thorax Angle (deg)	23.5 ± 5
Pelvis Angle (deg)	45.3 ± 5
Knee Spacing (mm)	348 ± 20

Obese Occupant, Initial Observations: Posture

	15 kph	32 kph
Head Angle (deg)	31.6	29.5
Thorax Angle (deg)	25.6	22.4
Pelvis Angle (deg)	42.6	47.8
Knee Spacing (mm)	350	350



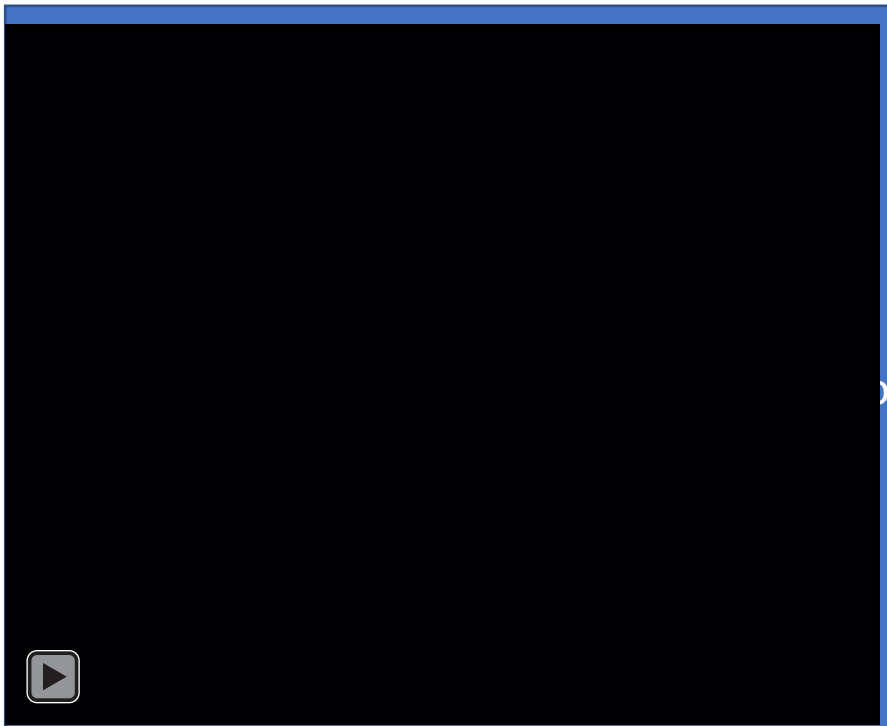
Obese Occupant, Initial Observations: Posture



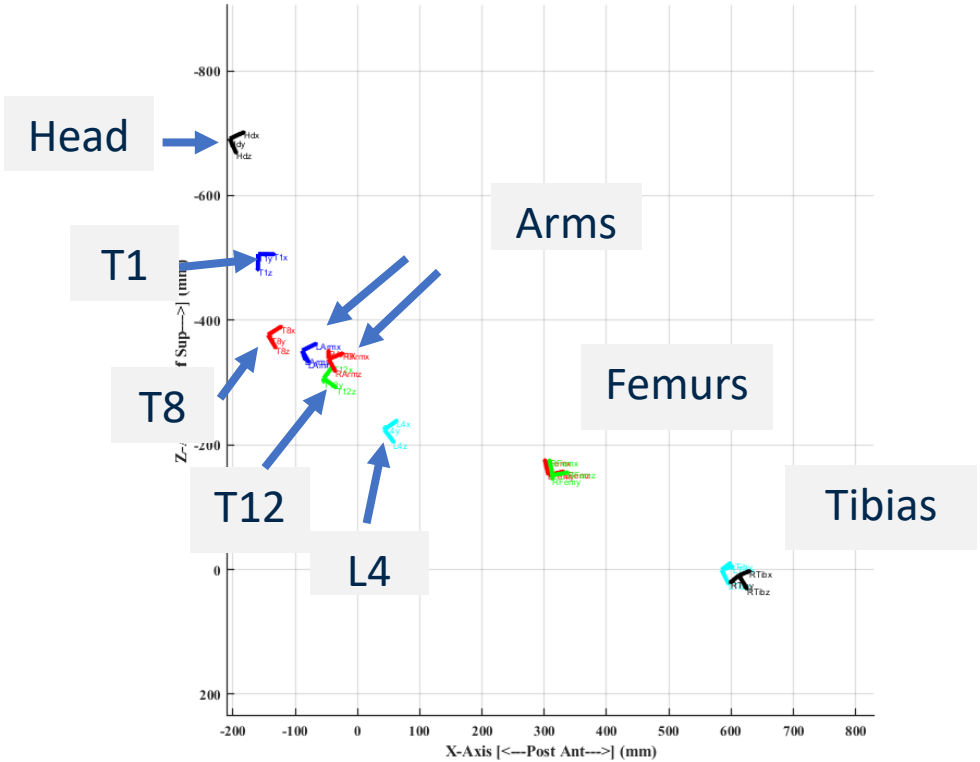
Obese Occupant, Initial Observations: Kinematics

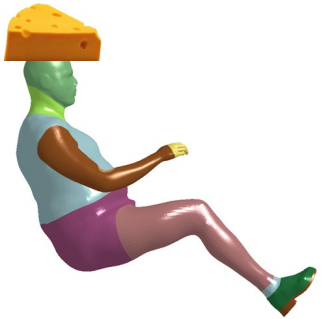
15 kph

32 kph



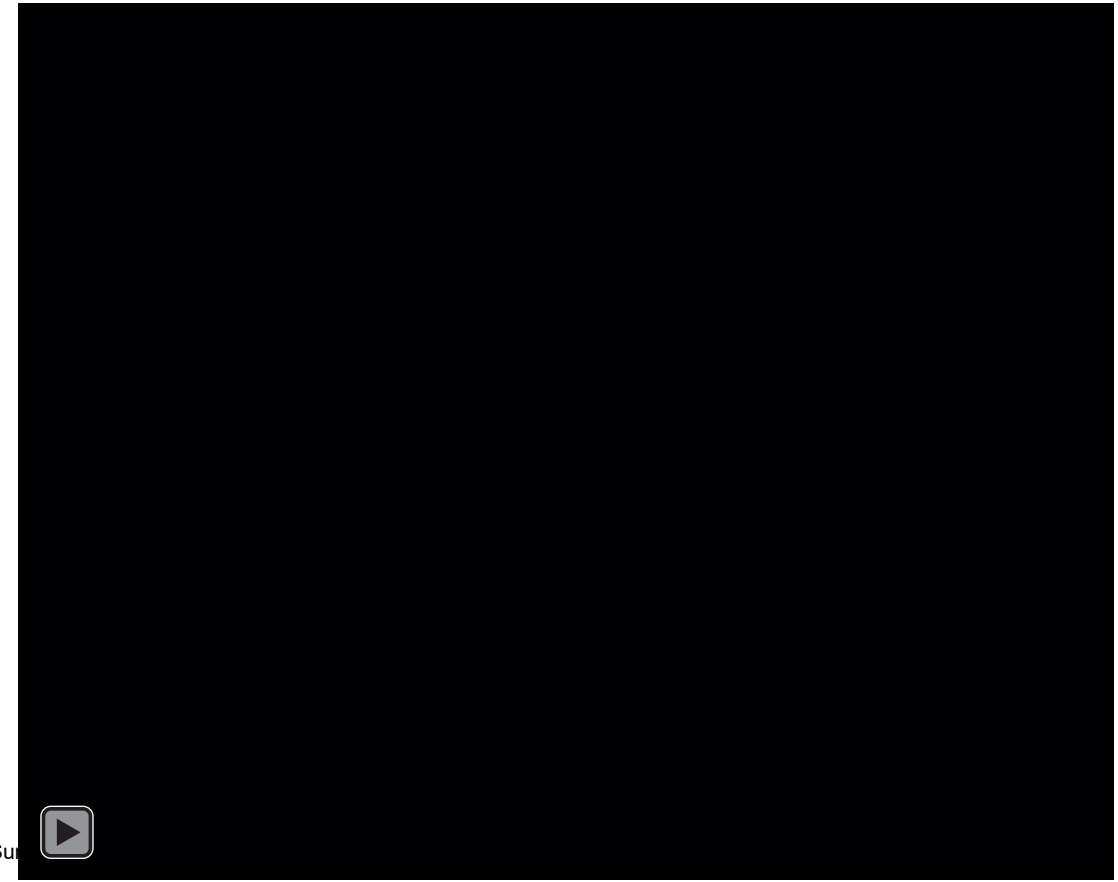
Obese Occupant, Initial Observations: Kinematics

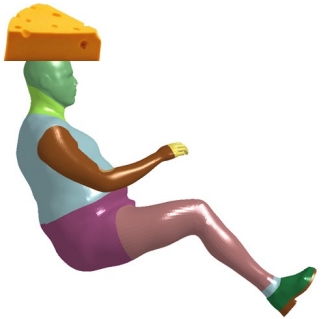




15 kph

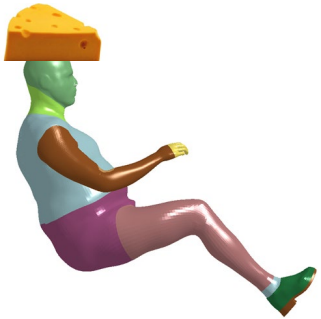
Obese Occupant, Initial Observations: Kinematics





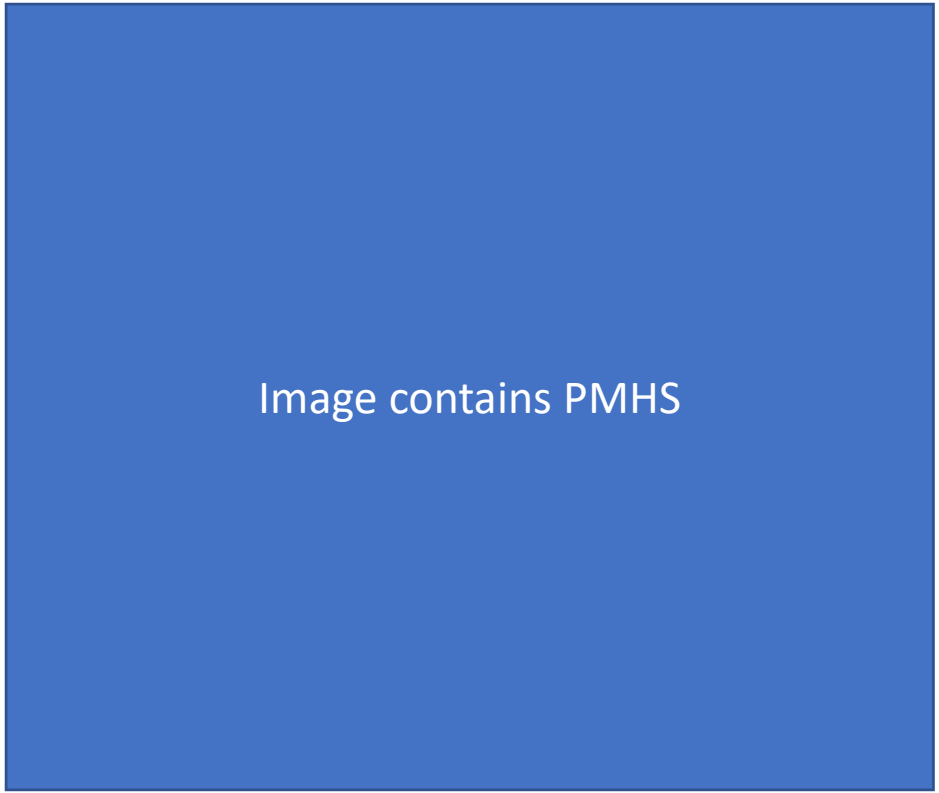
15 kph

Obese Occupant, Initial Observations: Kinematics



32 kph

Small Female Occupant, Initial Observations: Posture



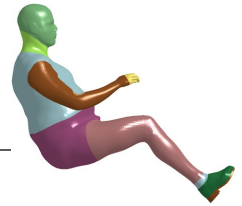
Test ID	SFO#1
Sex	Female
Age (years)	64
Stature (m)	1.53
Mass (kg)	59.1
BMI (kg/m^2)	25.2
Occupant Category	Small Female

Parameter	Target	Target
Seat Back Angle (deg)		45
Head Angle (deg)	24.0 ± 5	32.4 ± 5
Thorax Angle (deg)	33.2 ± 5	23.5 ± 5
Pelvis Angle (deg)	65.1 ± 5	45.3 ± 5
Knee Spacing (mm)	228 ± 20	348 ± 20

Small Female Occupant, Initial Observations: Kinematics

32 kph

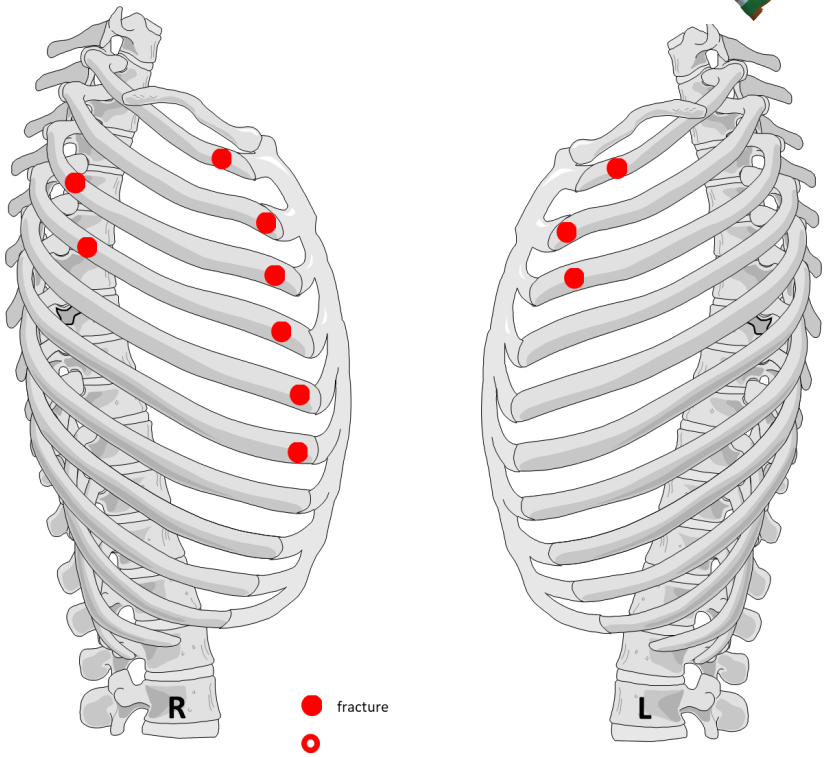
Obese Occupant, Initial Observations: Injuries



ObO #01	AIS
Musculoskeletal Injuries	
Rib Fx's • L Ribs 1-3 • R Ribs 1-6	450203.3

Rib #	Total # Fx	Fx #	Aspect	V (cm) Down	S (cm) Over	
1L	1	1	ant	0	5.0	BC
2L	1	1	ant	4.0	4.5	BC
3L	1	1	ant	7.5	4.5	BC

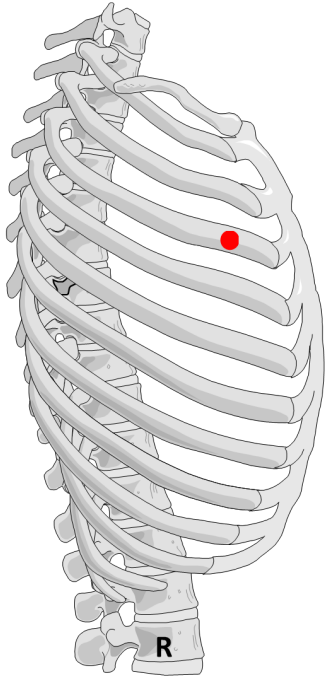
Rib #	Total # Fx	Fx #	Aspect	V (cm) Down	S (cm) Over	
1R	1	1	ant	0	5.0	BC
2R	1	1	ant	4.0	4.5	BC
3R	2	1	ant	7.5	7.5	BC
		2	postero-lat	0.7	16.8	BC
4R	2	1	ant	10.0	8.0	BC
		2	postero-lat	3.5	18.1	BC
5R	1	1	ant	14.5	9.0	BC
6R	1	1	ant	17.3	10.2	BC

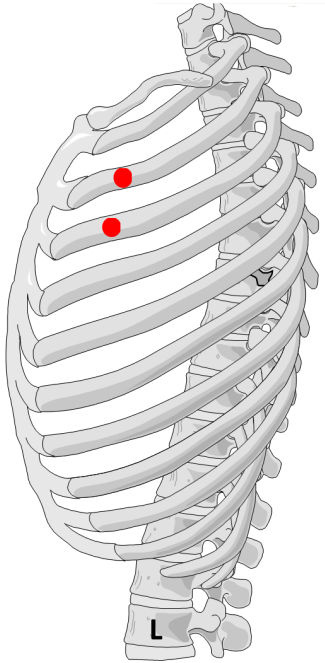


No evidence of abdominal injuries

Small Female Occupant, Initial Observations: Injuries

SFO #01	AIS
Musculoskeletal Injuries	
Rib Fx's • L Rib(s): 2,3 • R Rib(s): 3	450203.3
Sternum: Body Fx (non-displaced) immediate to sternal angle	450804.2





No evidence of abdominal injuries

Summary

- Results from 2 PMHS
- MCW: 4 PMHS 45 deg recline angle – 32 km/h
  - 2 Obese
  - 2 Small Female
- Posture based on seated study of volunteers
- Kinematics of head, spine, and extremities
- Conduct 20 PMHS in the next 12 months
- Include higher speed tests 56 km/h
- Compare results UMTRI and MCW

Thank You

- Sponsor – National Highway Traffic Safety Administration, Contract No. DTNH2215D00017

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- UMTRI
  - Dr. Matt Reed, Dr. Jonathan Rupp, Dr. Jingwen Hu
  - Carl Miller, Ann Bonifas, Nichole Orton, Miranda StAmour, Kyle Boyle, Brian Eby, Jen Bishop
- MCW
  - Dr. Frank Pintar, Dr. Narayan Yoganandan

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