



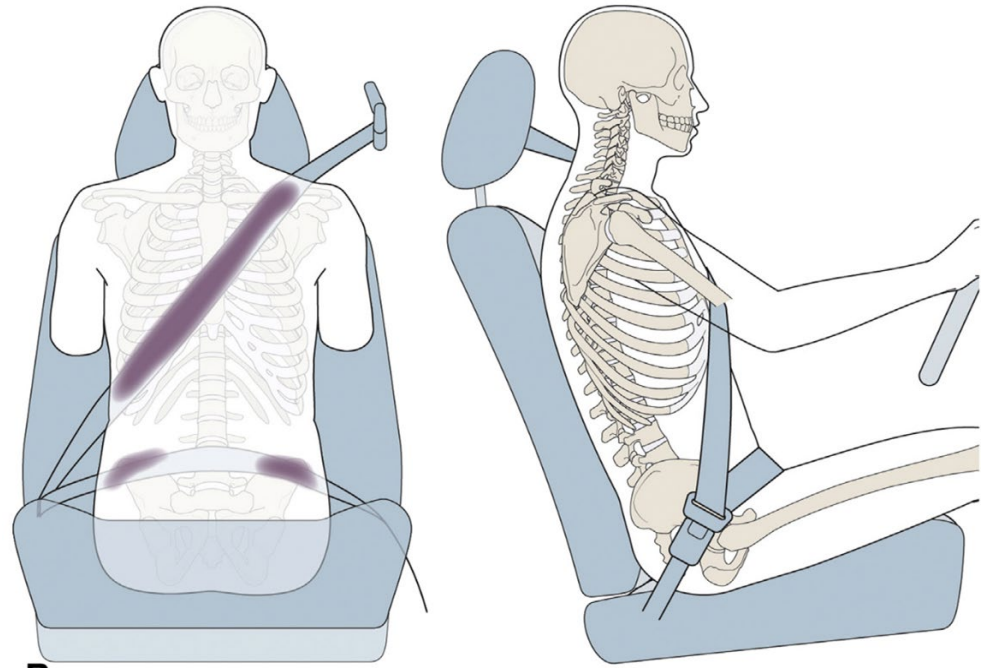
# THE EFFECTS OF SEX, BODY SHAPE, POSTURE, AND BELT TENSION ON BELT FIT RELATIVE TO THE SKELETON

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# Motivation

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Seat belts are designed to engage with the skeleton; however, poor belt fit can result in submarining behavior and injuries to the lower extremity and abdomen.

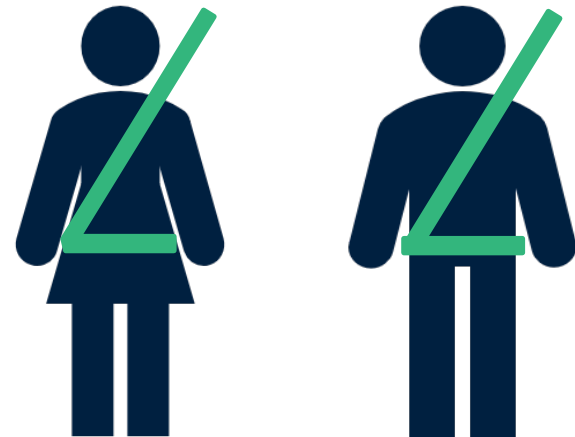


# Motivation

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In matched severity automotive collisions, the odds of a belt-restrained female driver sustaining serious injuries is **47%** higher than that of a belt-restrained male.

- Anatomical Differences?
- Submarining?
  - Seatbelt tensioning



# Motivation

Interested in the effects of posture:

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## Phase 1

- 10 participants
- Methodology development
- Looking at sex, age, BMI and seatback recline

Methodology to measure seat belt fit in relation to skeletal geometry using an upright open MRI (2022)

- In Traffic Injury Prevention

Variability in body shape, superficial soft tissue geometry, and seatbelt fit relative to the pelvis in automotive postures – volunteer data collection with Open MRI (2023)

- in JBME

## Phase 2

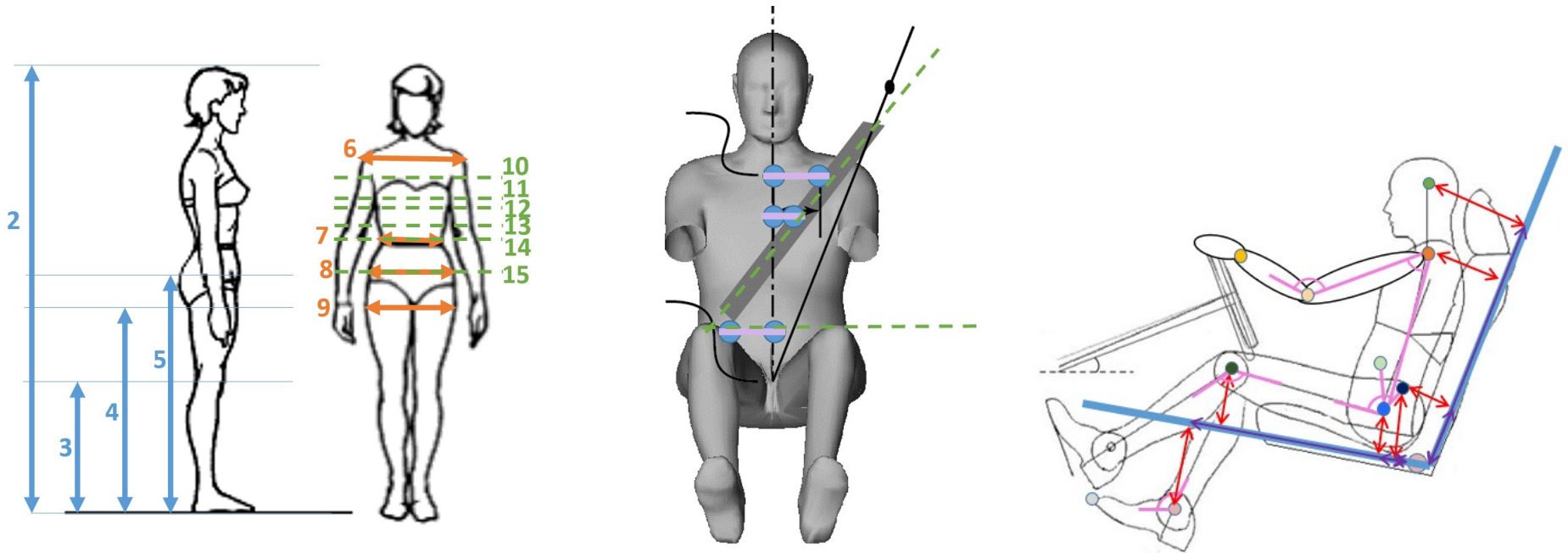
- 6 participants
- Improved Seat belt visualization
- Modified the belt and added increased seat belt tension
- Reduced number of in-car measurements
- increased # of scans, modified imaging sequences
- Looking at sex, age, BMI, seatback recline and seatbelt tension

# Our participants

	Subject ID	Sex	Age	Height (cm)	Weight (kg)	BMI	Preferred position Back Angle (°)
Phase 1 (Previous Project)	3	M	25	182	101	30.6	20
	7	F	27	165	64.1	23.5	20
	4	M	31	186	96.7	28.0	20
	8	F	34	171	63.0	21.5	20
	5	F	24	163	74.1	27.9	10
	9	F	41	179	67	20.9	16
	6	M	30	174	69.8	23.1	20
	12	F	56	158	57.5	23.0	10
	14	M	52	155	57.5	23.9	10
	15	M	56	188	94.5	26.7	20
Current project	1b	F	56	162	64.6	24.6	20
	2b	F	26	170	68	23.6	20
	3b	M	55	183.4	86.8	24.5	20
	4b	F	49	165	68	25	20
	5b	M	40	178.5	100	31.4	30
	6b	F	42	167	61.5	22.1	20

# Methodology: Anthropometric and In-car Measurements

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# Methodology: The seat



## MRI Considerations:

- Non-ferromagnetic
- Recreated the seat geometry using parts from the same seat used for in car measurements and custom-made parts.
- The seat back was constructed to be as thin as possible to minimize the distance between the MRI coil and the subject.



# Methodology: The seat

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- The seat base height was minimized to accommodate tall subjects within the scannable volume.
- The front of the seat base was angled 12 degrees up from the horizontal.
- An adjustable seat back angle, head restraint height, seat belt anchor location, and vertical and horizontal position of seat back.

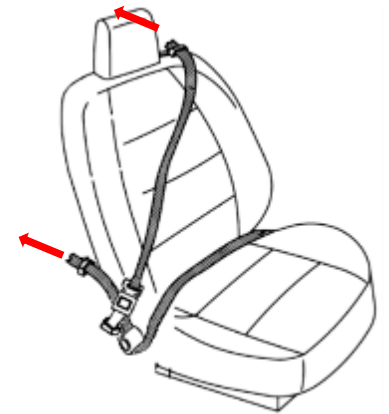
# Methodology: The Tension!

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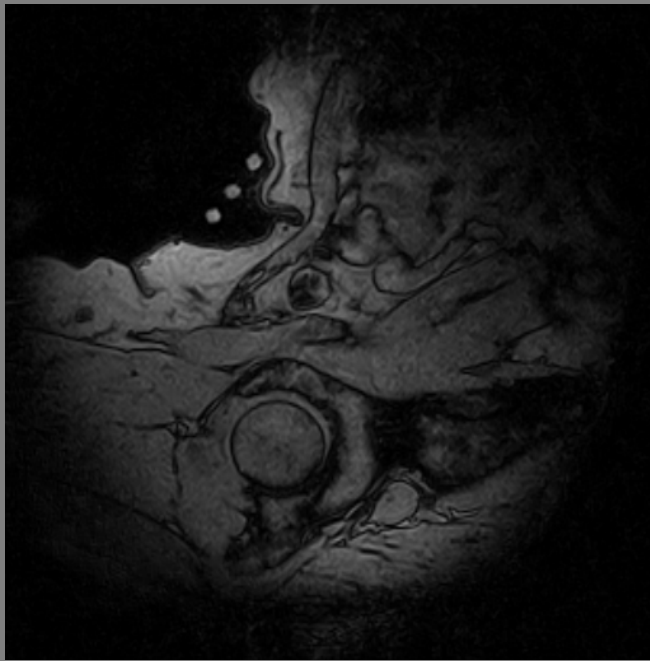
2 sets of pilot scans

- Tensioning levels
- Tension method: weight and pulley system
- Seatbelt visibility



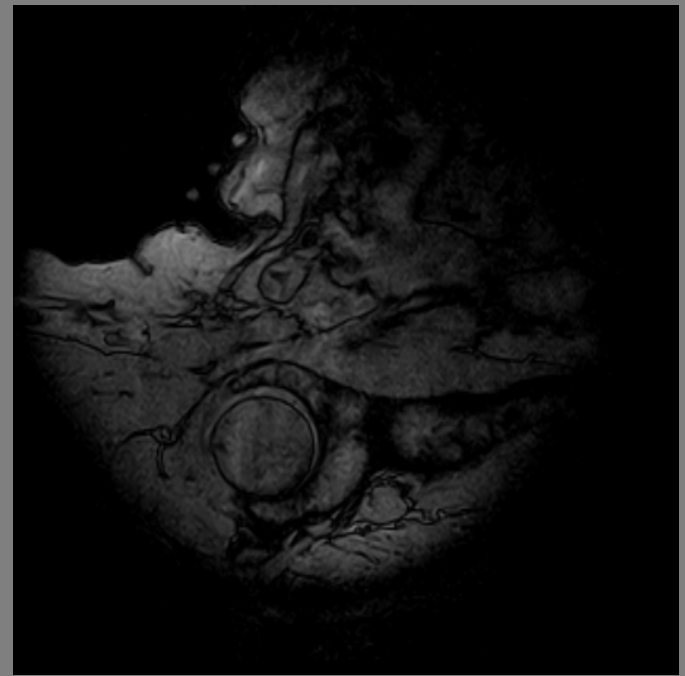
# Pilot Scans: Male volunteer, Sagittal pelvic scans

TENSIONED (258 N)



Anterior  $\longleftrightarrow$  Posterior

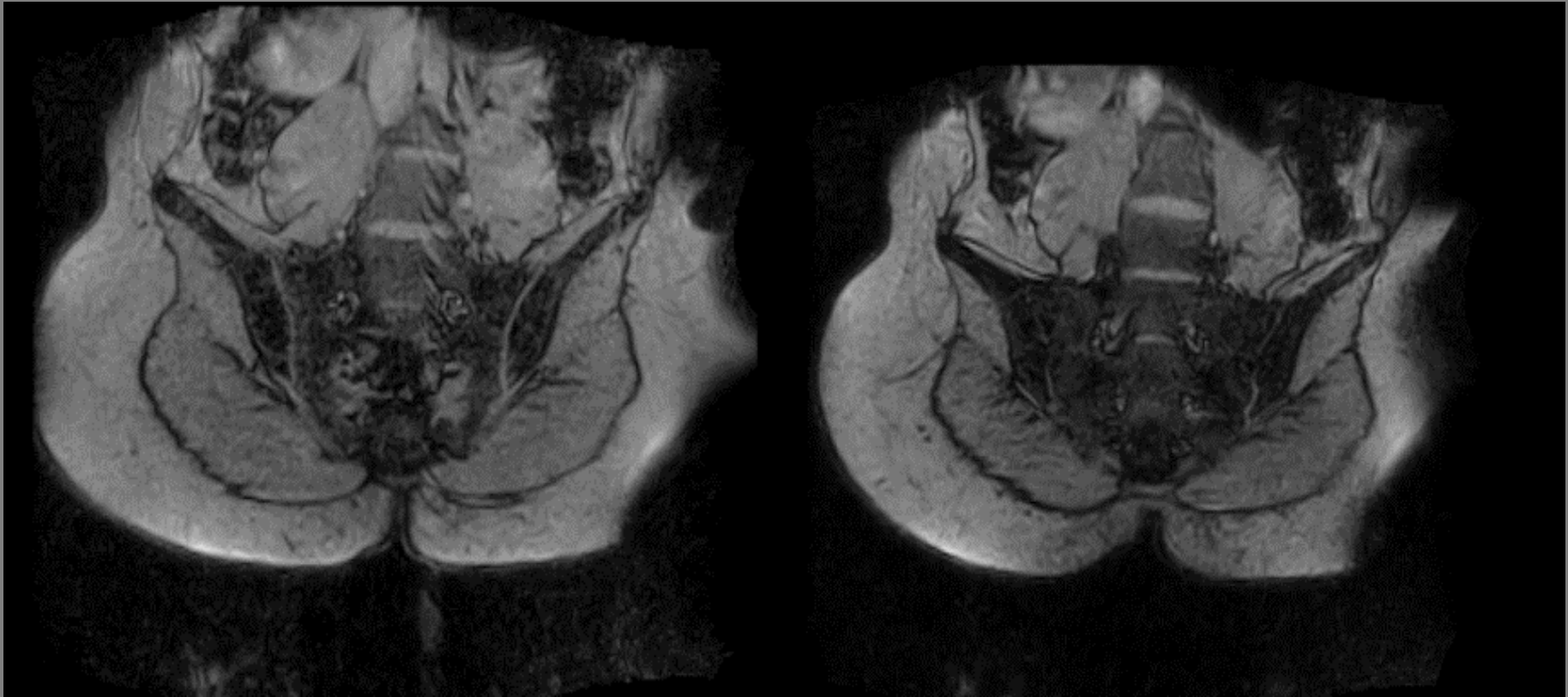
UN-TENSIONED (3.65N)



Anterior  $\longleftrightarrow$  Posterior

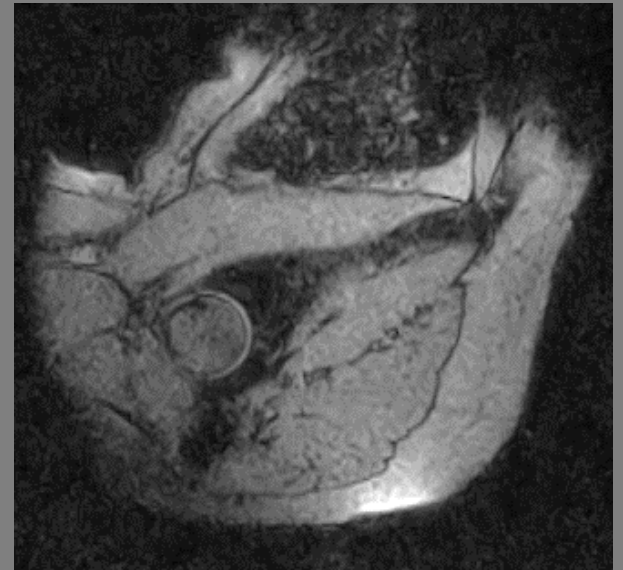
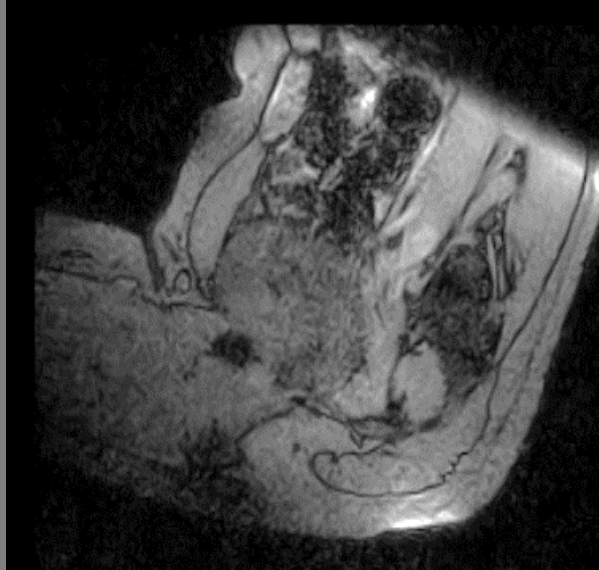
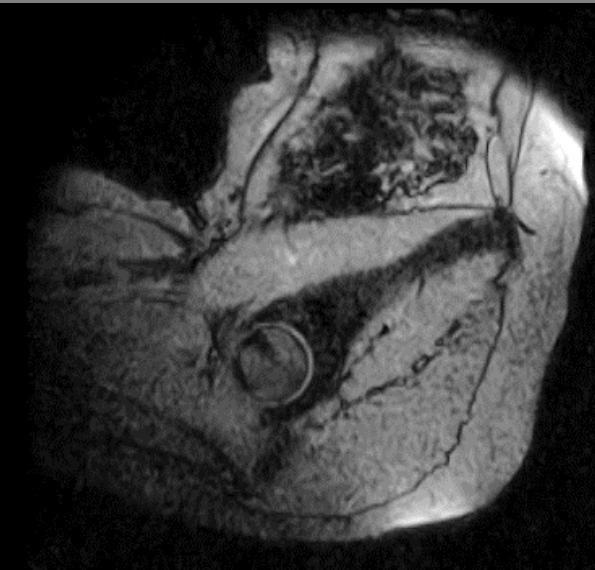
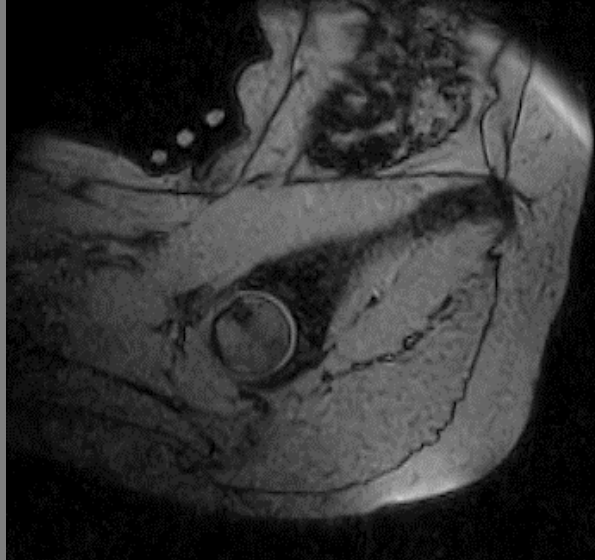
- Seatbelts sitting more posterior/deep
- Seatbelts sitting lower
- Differences in adipose tissue positioning

## Pilot Scans #2: Female Volunteer 25 years old, Normal BMI



Un-tensioned belt the left (3.65N), tensioned belt on the right (258 N)

Pilot Scans #2: Female Volunteer 25 years old, Normal BMI



Top: Tensioned Belt (258 N)

Bottom: Un-tensioned Belt (3.65 N)

# MRI Belt Markers

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Previously Vitamin E tablets were used as markers on the seat belts

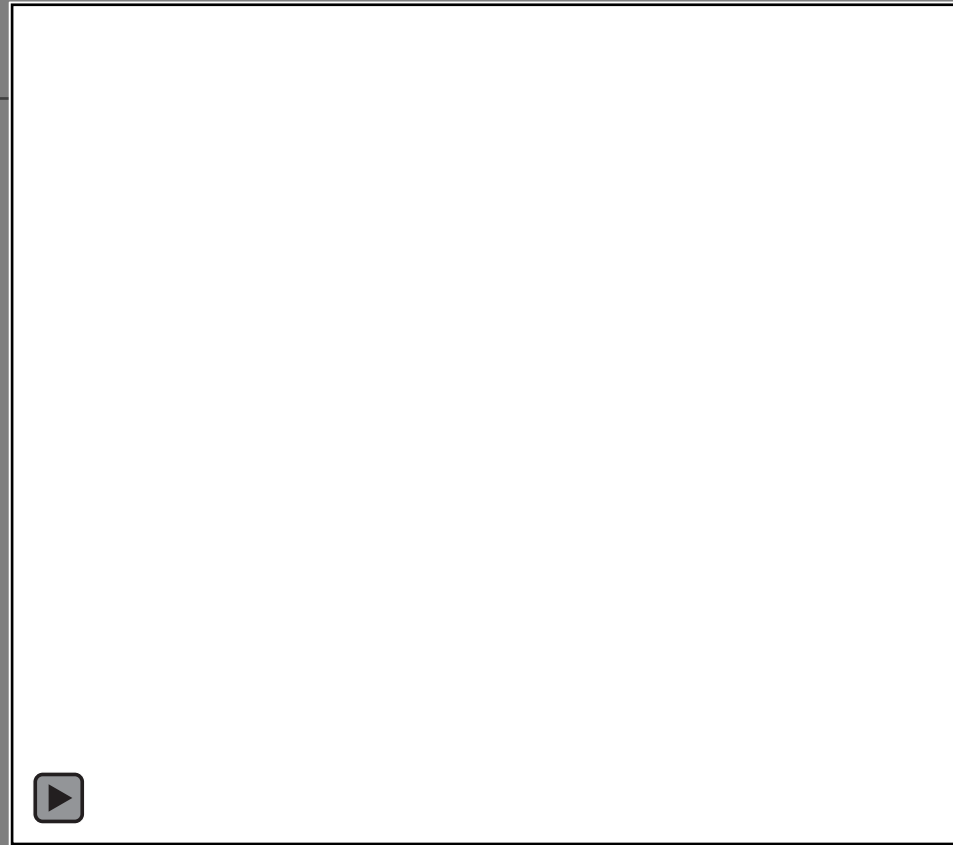
Modified design includes four tubes filled with Cod liver oil

This allowed:

- Better visualization of the belt
- The belts is visualized in every scan



Female Volunteer, Normal BMI, Pelvis scans  
Un-tensioned belt(left) tensioned belt(right)





# Participant Recruitment

		Age					
		19-32		33-46		47-60	
		M	F	M	F	M	F
BMI	18.5-24.9	X	<del>XX</del>		<del>XXX</del>	<del>XX</del>	<del>XX</del>
	>=25	<del>XX</del>	X	<del>X</del>		X	<del>X</del>

- Phase 1
- Phase 2

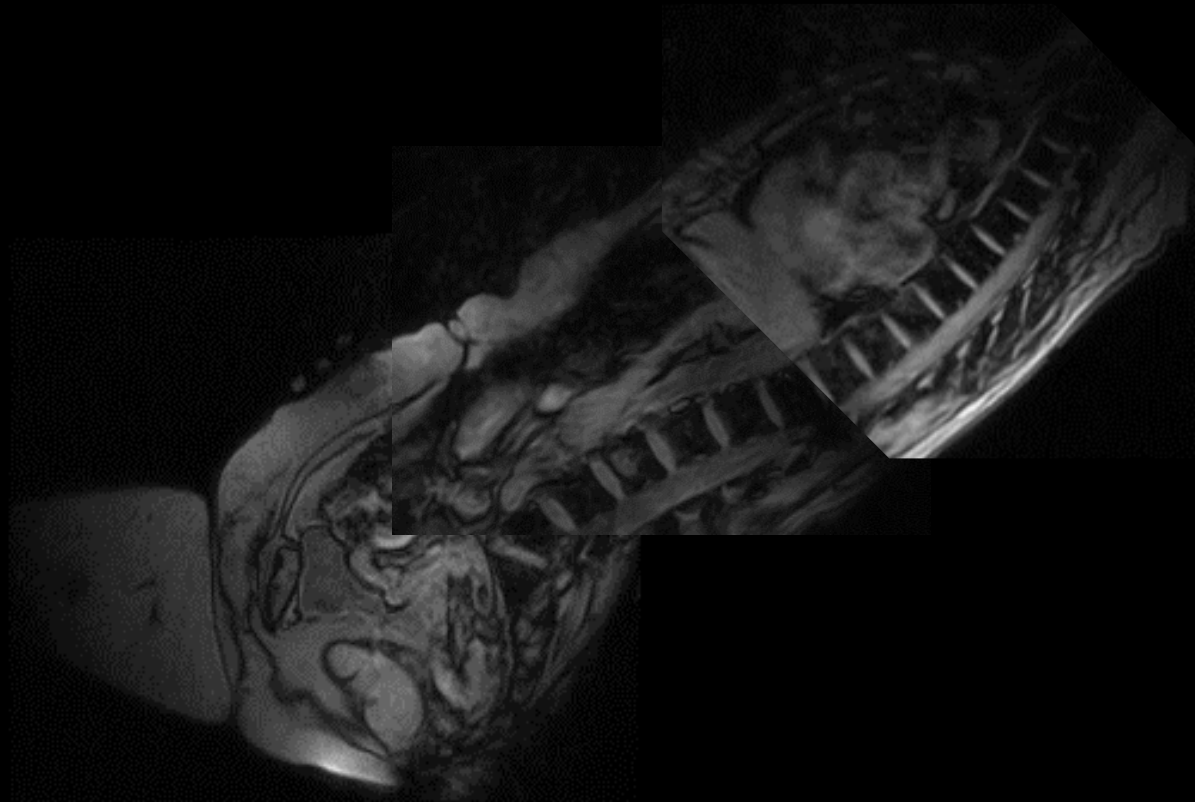


# Registered Scans – Male Preferred



3b

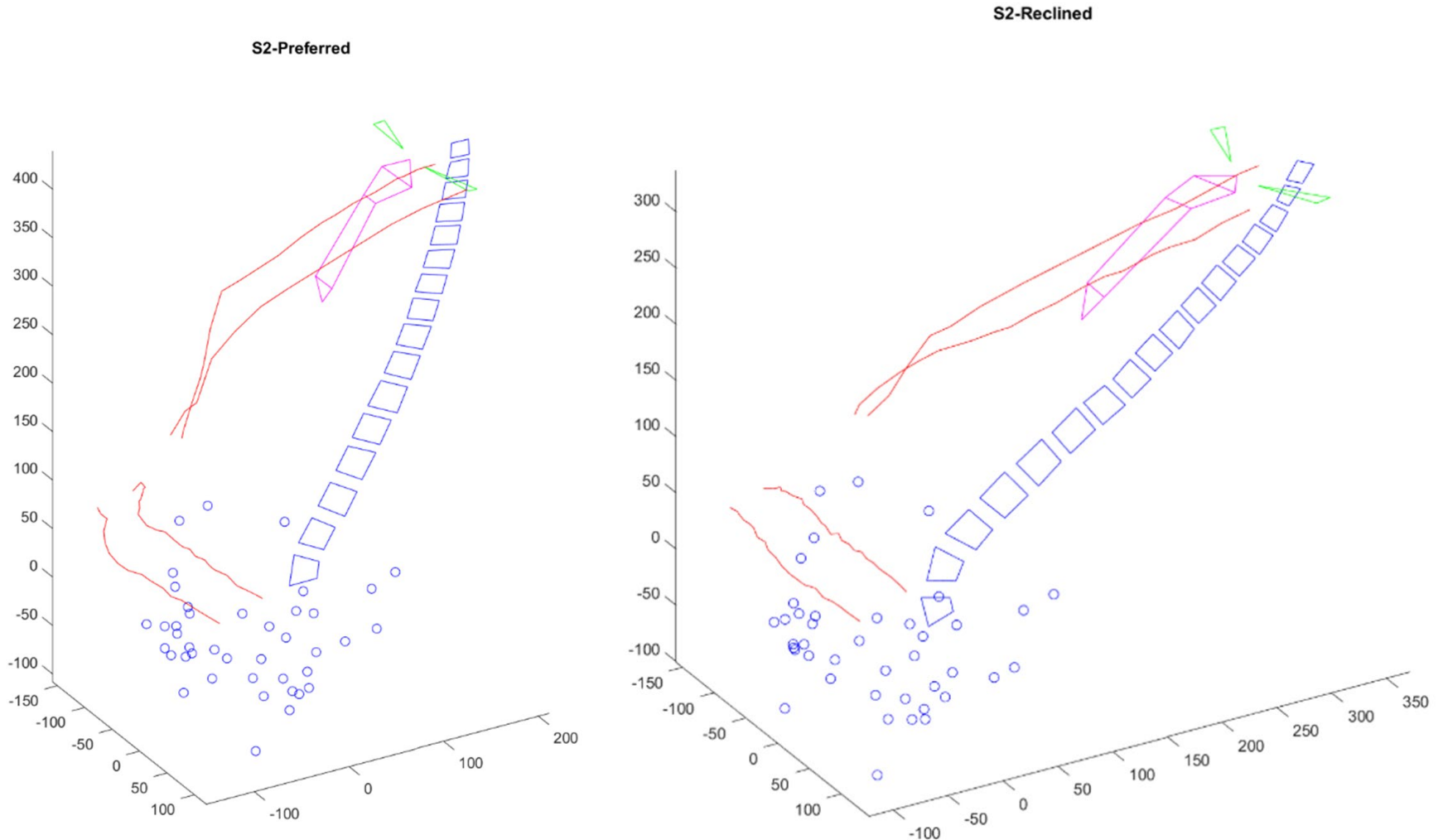
# Registered Scans – Female Reclined



B: 5: reclined untrens pelvis A SAG

1b

# Relative position of skeletal anatomy relative to the seat belt



## RESULTS AND DISCUSSION

- Sex-based Differences were observed in the local geometry of the soft tissue, particularly around the lower abdomen and pelvis near the lap belt interface
  - *In males abdominal adipose tissue tended to overhang the pelvis*
- Quantitative measures of the changes in pelvis angle and lap-belt-to-pelvis distance between the various volunteer postures (upright vs. reclined and belt-to-ASIS distances due to belt tension) were captured.
  - *On average the pelvis rotated 40% of the seatback angle change with recline without tension*
  - *On average the pelvis rotated 52% of the seatback angle change with recline with tension*
  - *On average the belt to ASIS distance decreased with belt tension for both preferred (~14 mm female and ~4 mm male) and reclined (~5 mm female and 9 mm male) seat positions.*
- The effect of tension level on adipose tissue and pelvic rotation

THANK YOU!

