

Kinematic Comparison of Human and ATD Responses for Children in Low Speed Frontal Crash Conditions

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TK Holdings



Applications of Pediatric ATD

- Validated through component level tests for use in regulatory testing
- Increasingly used in diverse test conditions outside regulatory procedures
 - Falls (Deemer 2005)
 - Rear Impacts (Saczsalski 2003)
 - Wheelchair loading (Fuhrman 2009)
- Future restraint & vehicle design
- Biofidelity outside current regulatory tests conditions has not be well established



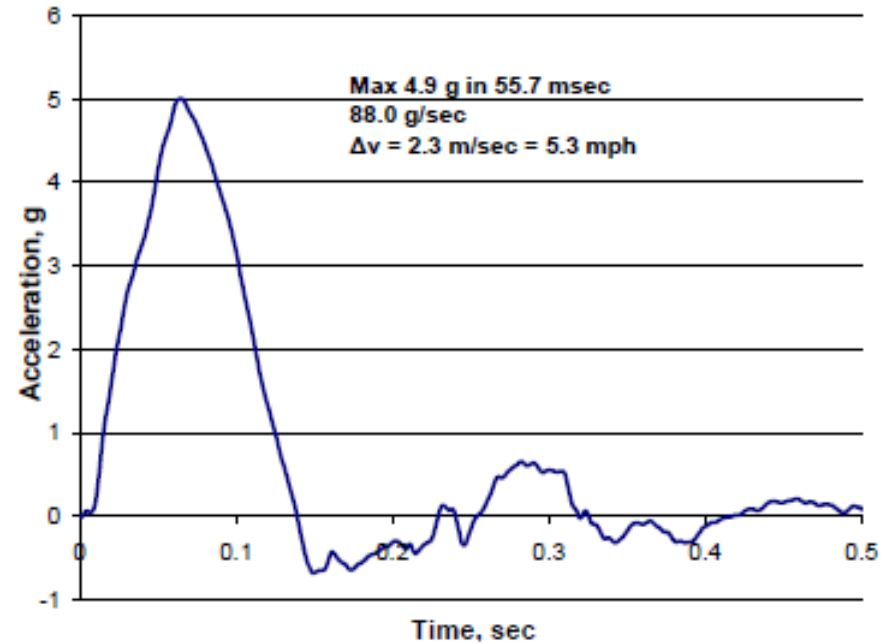
Traditional Methods of Evaluating ATD Biofidelity

- Post Mortem Human Subjects
 - Whole body pediatric PMHS rare
- Animal Studies
 - Useful for component testing, not necessarily whole body kinematics
 - Age equivalency limitations
- Human Volunteers
 - Safe, non-injurious levels

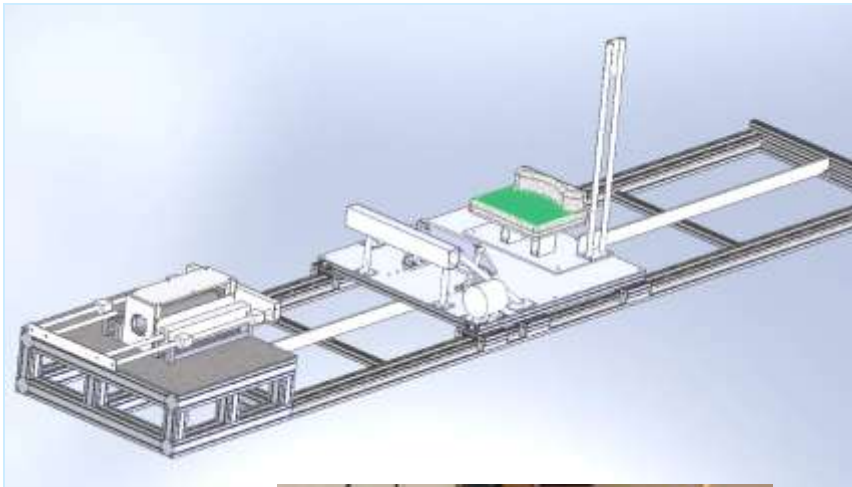
Objective

To compare head and neck kinematic responses of the Hybrid III 6 yr old to size-matched pediatric volunteers in low-speed frontal crash conditions.

Safe Crash Pulse: Bumper Car to Wall Chosen for Safety of Human Volunteers



Low Speed Volunteer Sled



Frame –

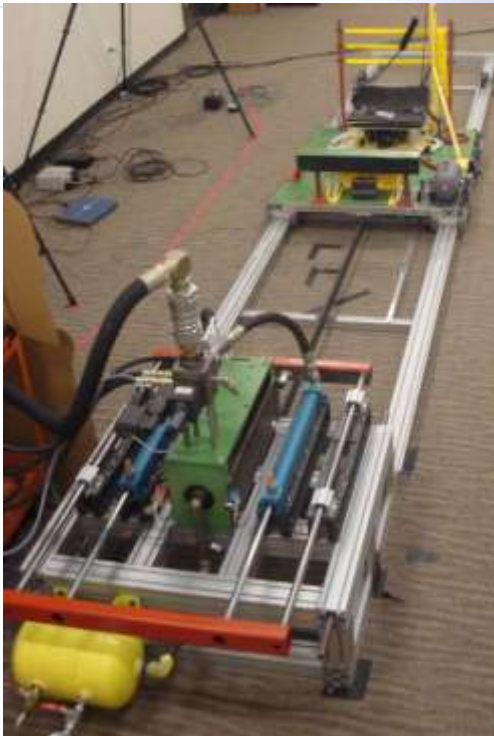
- Low friction 18' rail system with sliding cart

Actuator –

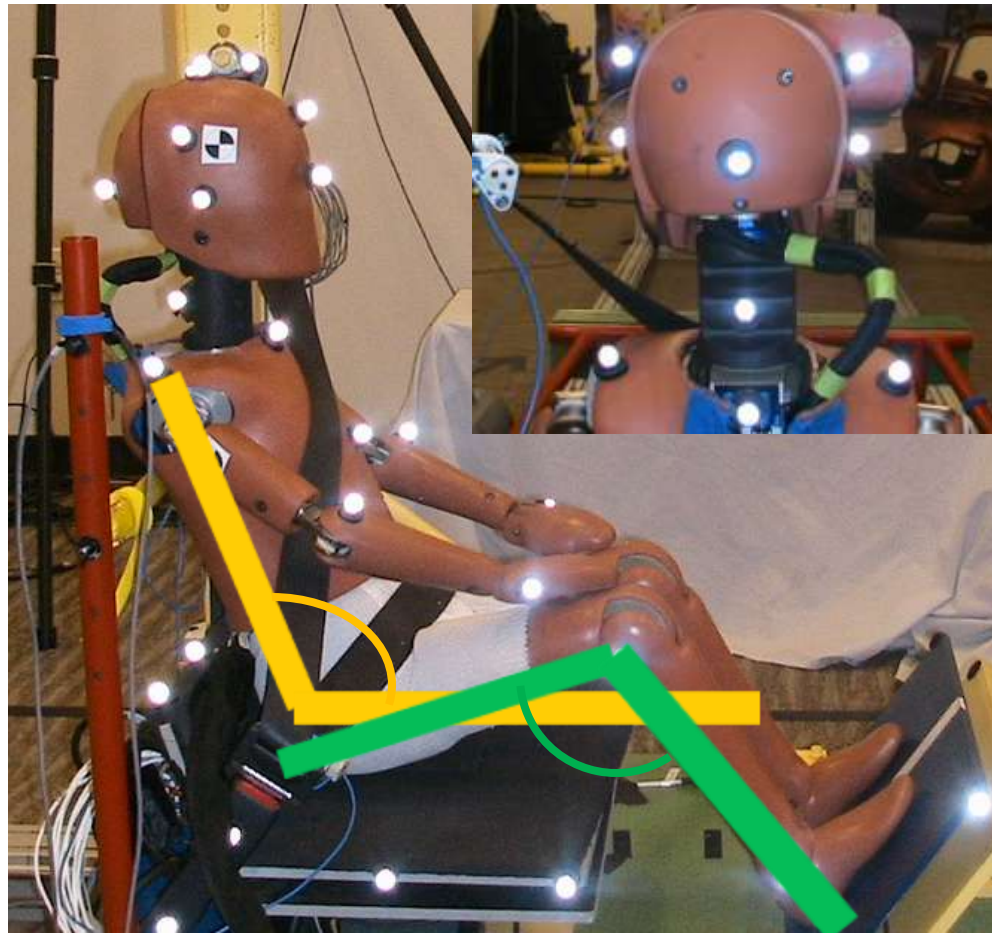
- Pneumatic powered – hydraulic controlled actuator ram

Seating buck –

- Pneumatic braking system
- Onboard 16 channel T-DAS acquisition system



ATD Instrumentation



Knee and Torso Angle @ 110°

For both ATD and humans



Motion Analysis:

- Head Top, Op, Nasion, EAM, C4, T1, Iliac Crest

ARS Sensor on head

Load Cells:

- Foot Rest
- Seat Pan
- Shoulder Belt
- Lap Belt

Three tests completed

Exemplar Hi-Speed Video



Size-Matched Pediatric Volunteers (PV)

Subject	Age (yrs)	Seated Height (cm)	Weight (kg)
Hybrid III	6	63.5	23.4
PV	6	69.0	24.1
PV	7	66.0	23.6
PV	9	65.5	25.2

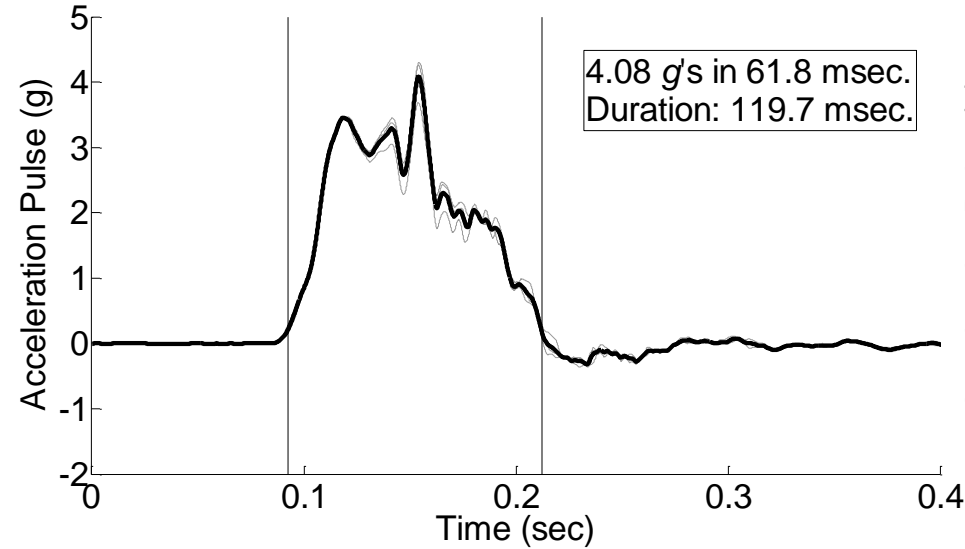
Inclusion Criteria:

- $\pm 10\%$ ATD Seated Height
- $\pm 10\%$ ATD Mass

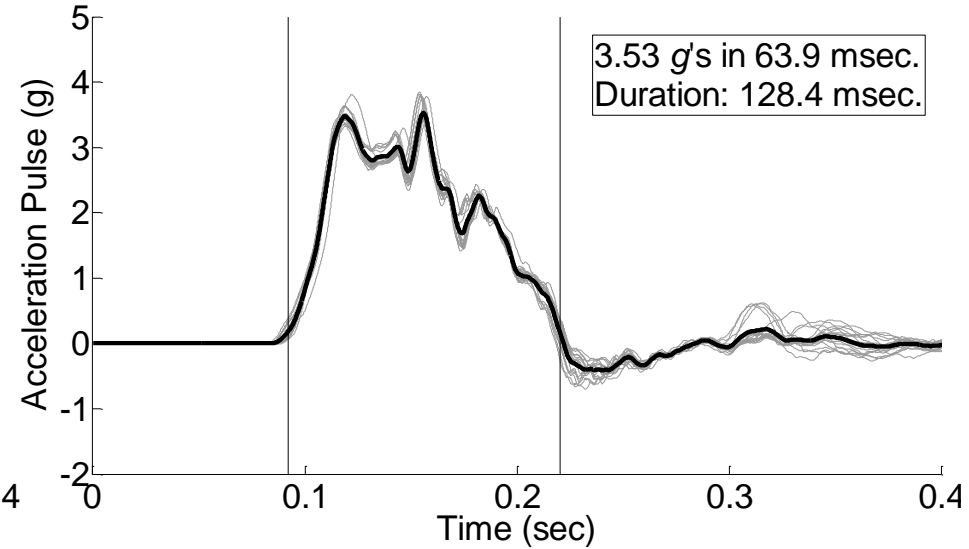


Results: Acceleration Pulse

Hybrid III 6 Yr Old



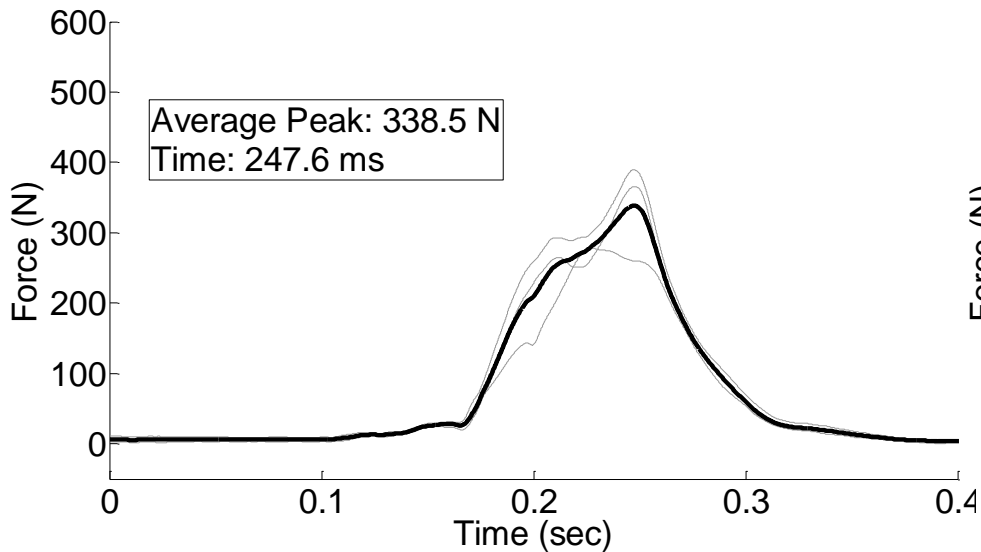
Pediatric Volunteers



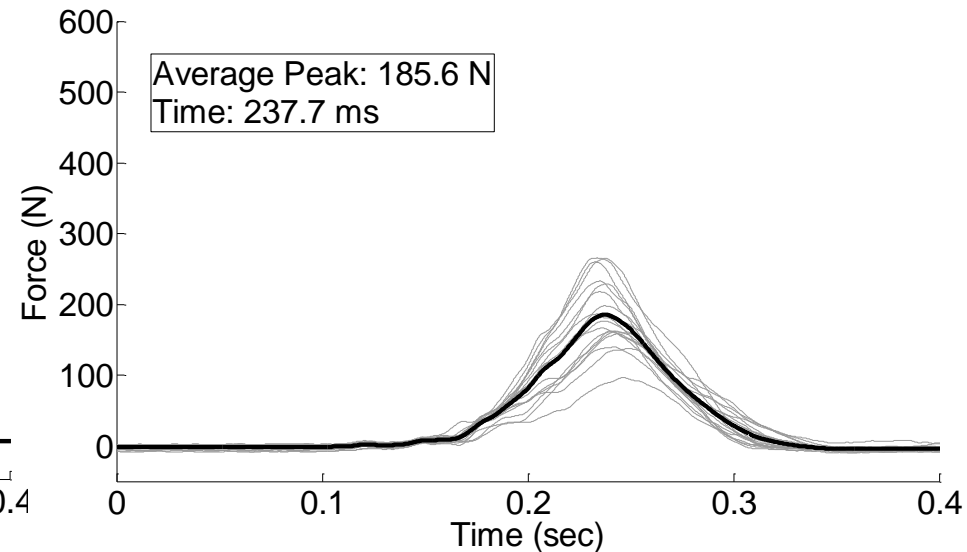
3% difference in ΔV

Results: Shoulder Belt Load

Hybrid III 6 Yr Old



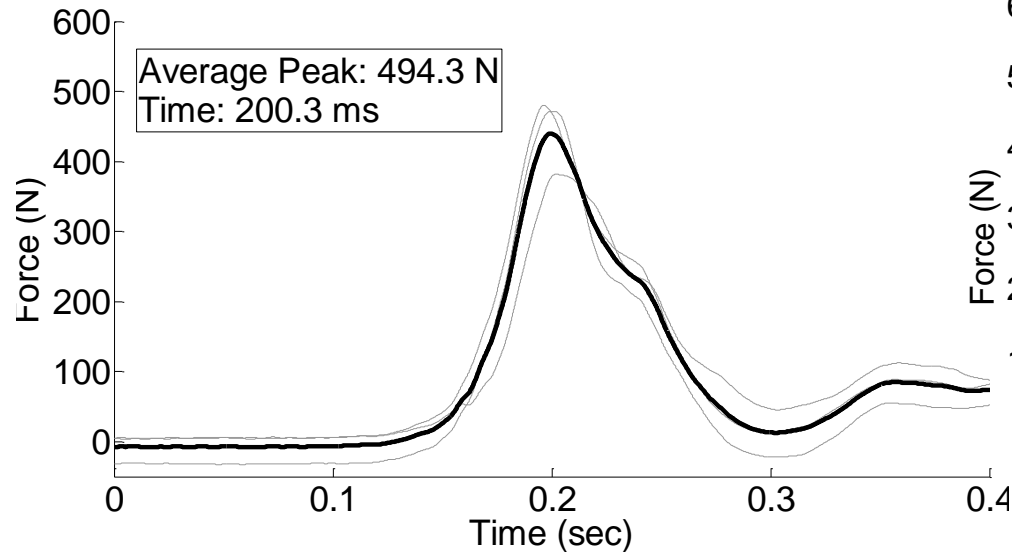
Pediatric Volunteers



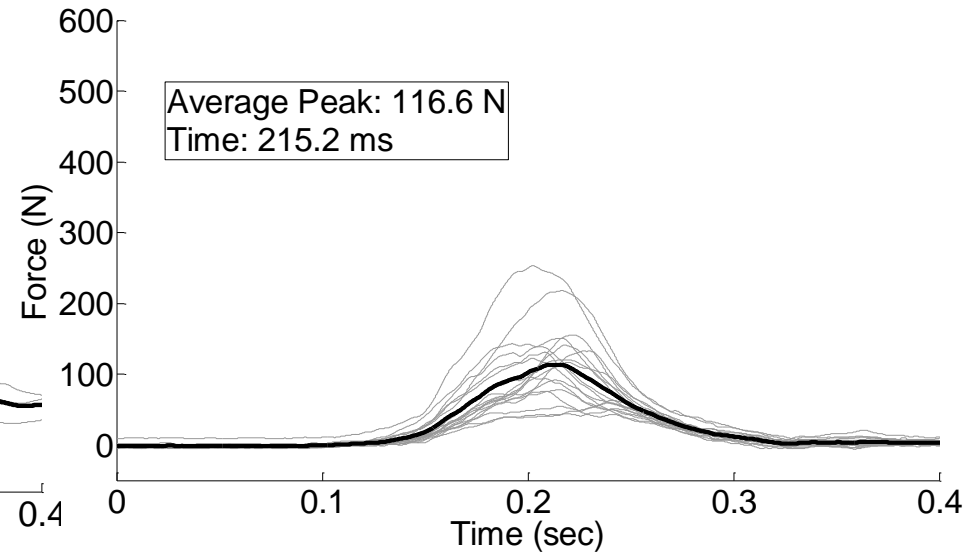
- ATD shoulder belt load 83% greater than PV avg
- ATD shoulder belt load 30% greater than PV max
- ATD max load occurs 10 ms later than PV

Results: Lap Belt Load (Left)

Hybrid III 6 Yr Old



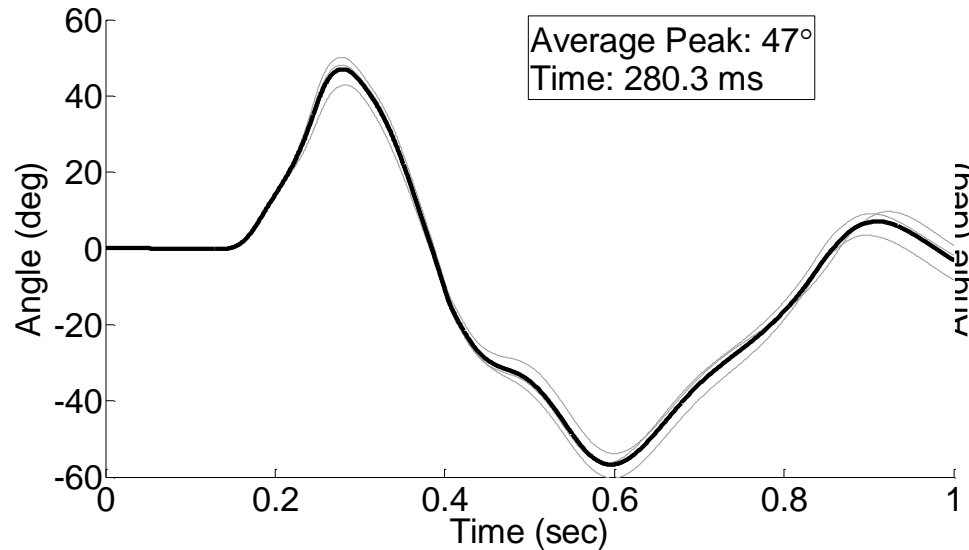
Pediatric Volunteers



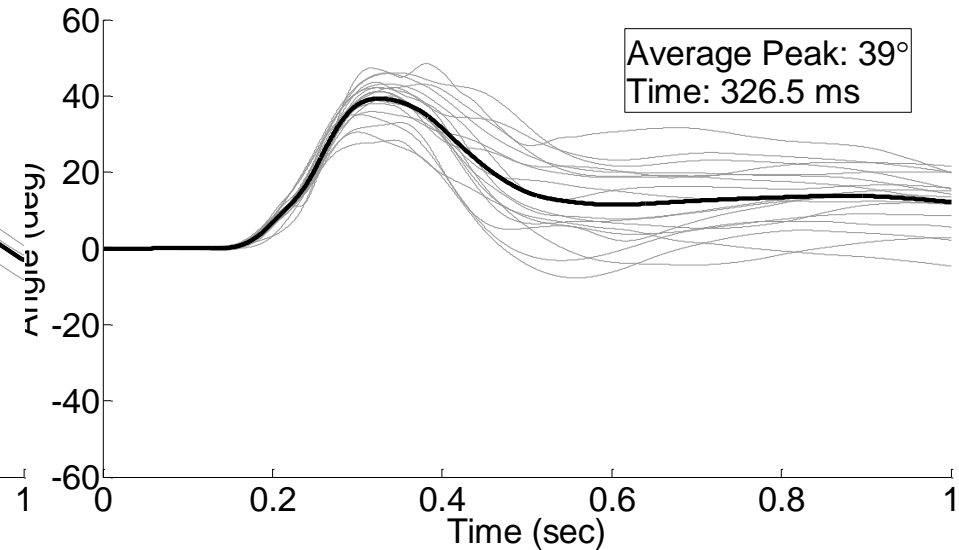
- ATD left lap belt load 264% greater than PV avg
- ATD left lap belt load 76% greater than PV max
- ATD max load occurs 15 ms earlier than PV

Results: Head Rotation (Relative to Initial Position)

Hybrid III 6 Yr Old



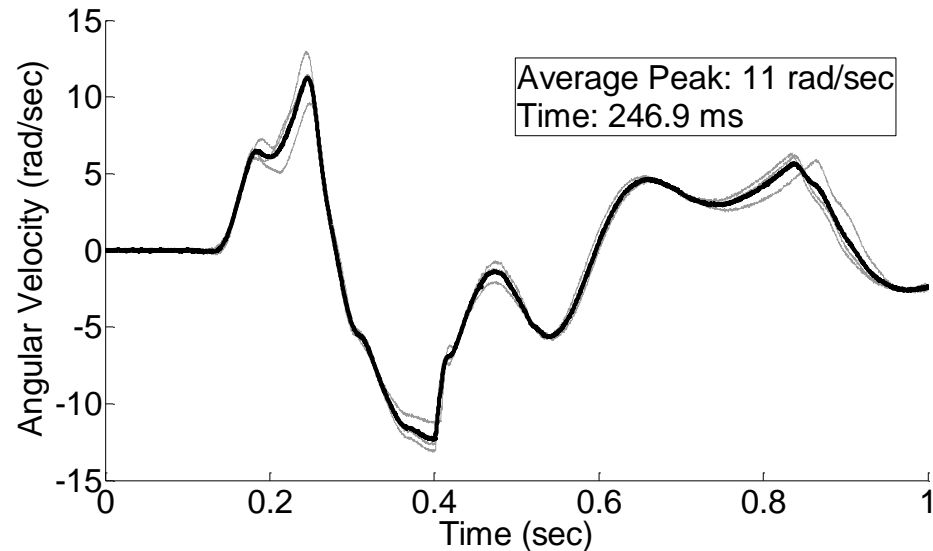
Pediatric Volunteers



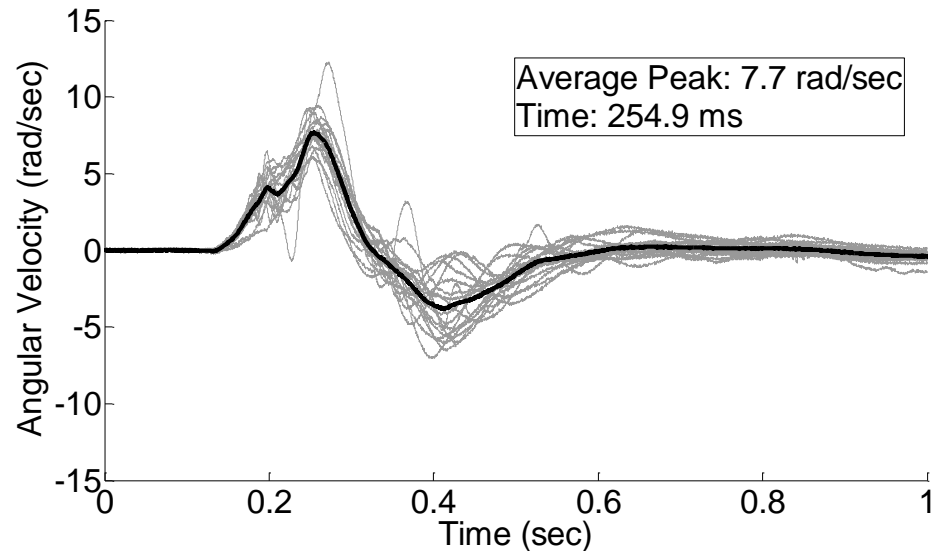
- ATD max forward rotation 18% greater than PV
- ATD max rotation occurs 46 ms earlier than PV

Results: Head Angular Velocity

Hybrid III 6 Yr Old



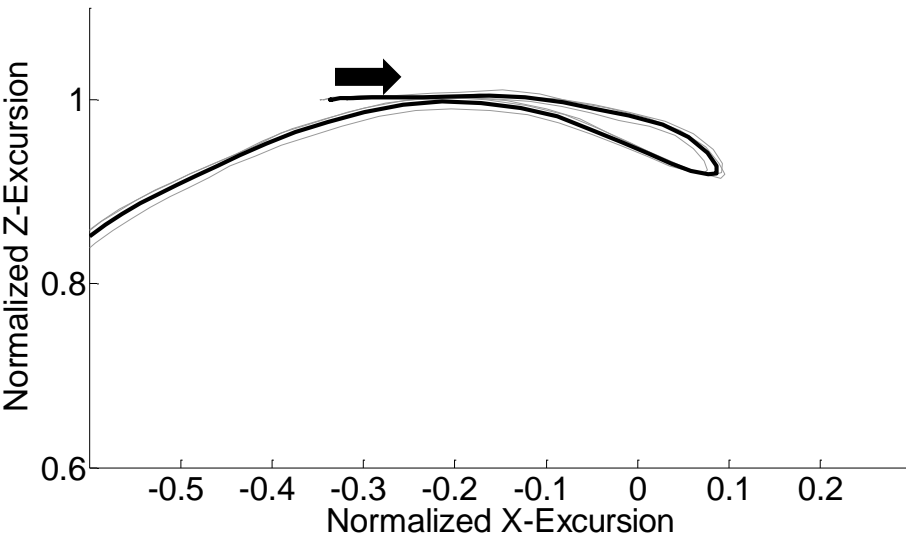
Pediatric Volunteers



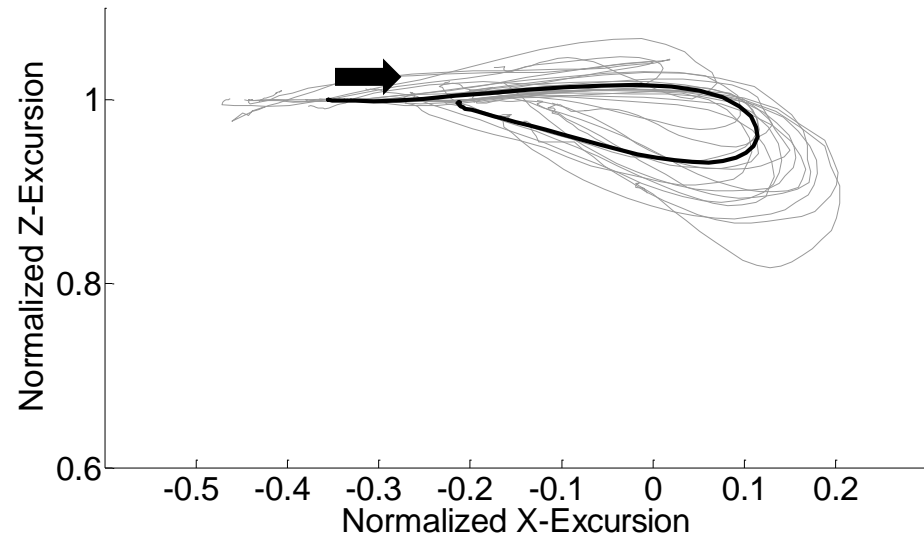
- ATD max angular velocity 41% greater than PV
- ATD max angular velocity occurs 8 ms earlier than PV

Results: Head Top

Hybrid III 6 Yr Old



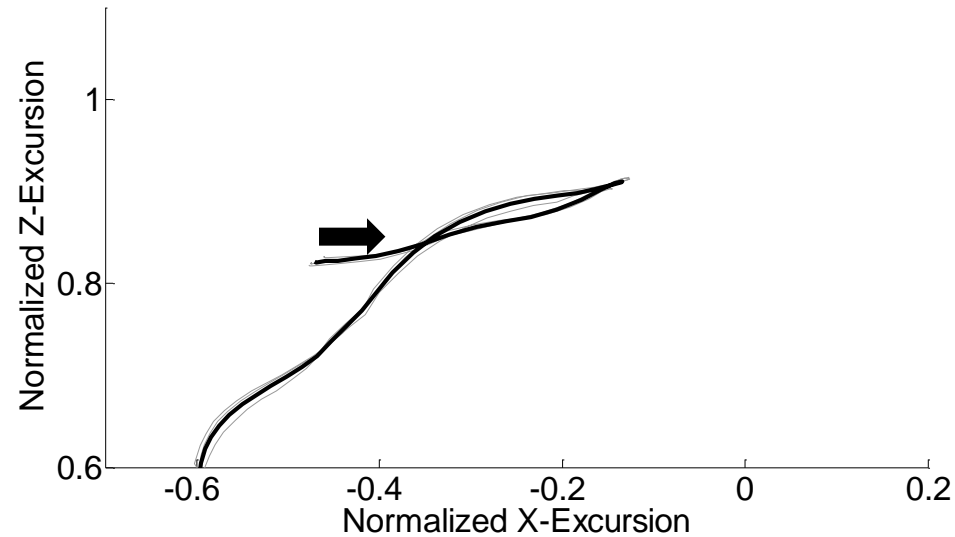
Pediatric Volunteers



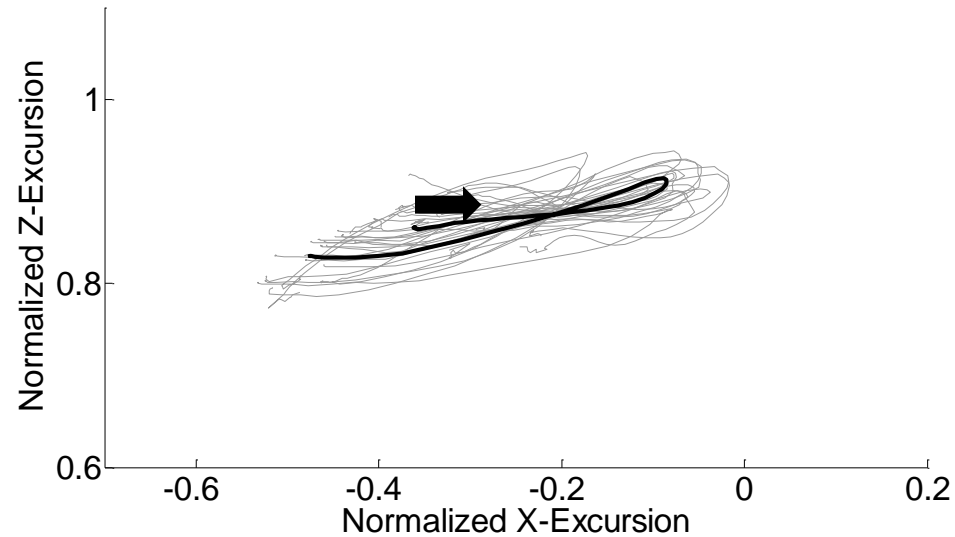
Subject	Max excursion, Δx (avg \pm SD)
Hybrid III	0.42 \pm 0.02 ↓11%
PV	0.48 \pm 0.03

Results: Opisthocranion

Hybrid III 6 Yr Old



Pediatric Volunteers

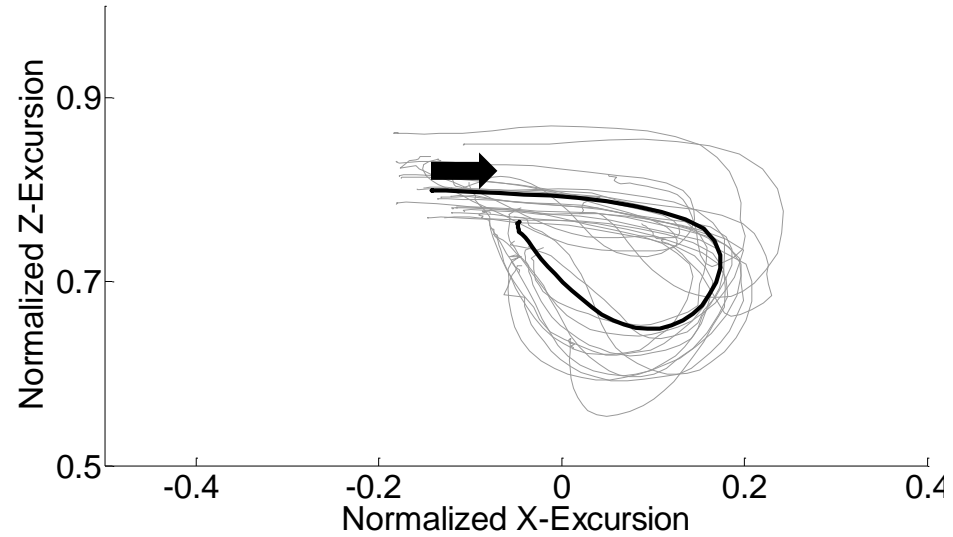
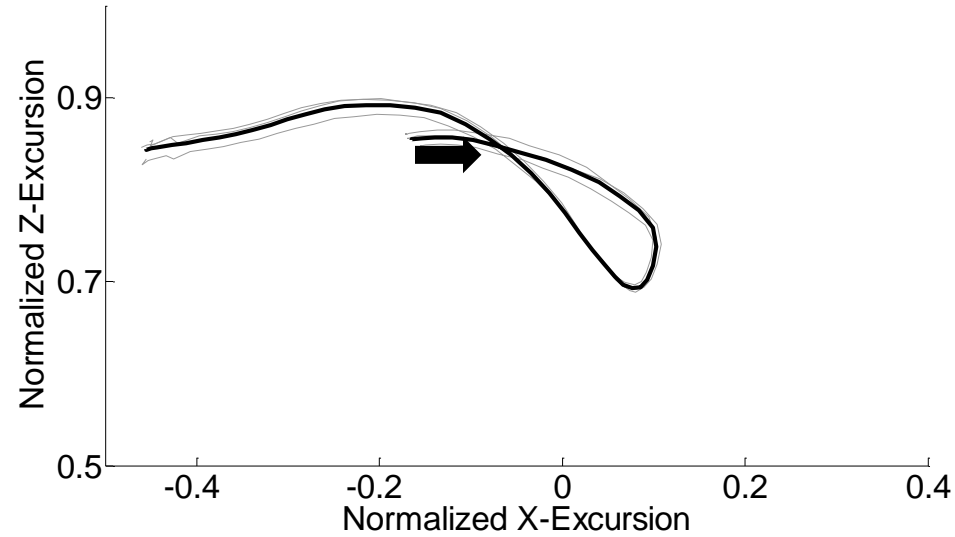


Subject	Max excursion, Δx (avg \pm SD)
Hybrid III	0.34 \pm 0.02 ↓15%
PV	0.40 \pm 0.03

Results: Nasion

Hybrid III 6 Yr Old

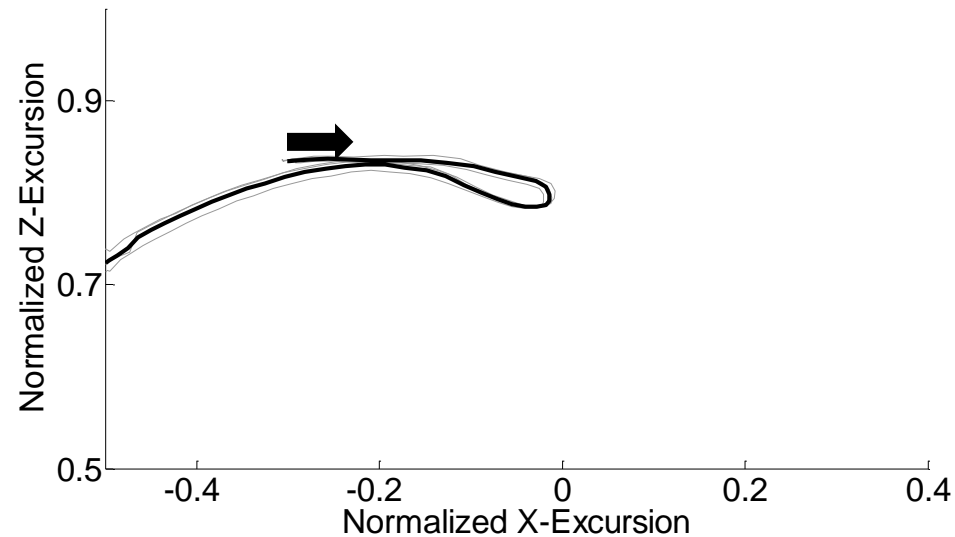
Pediatric Volunteers



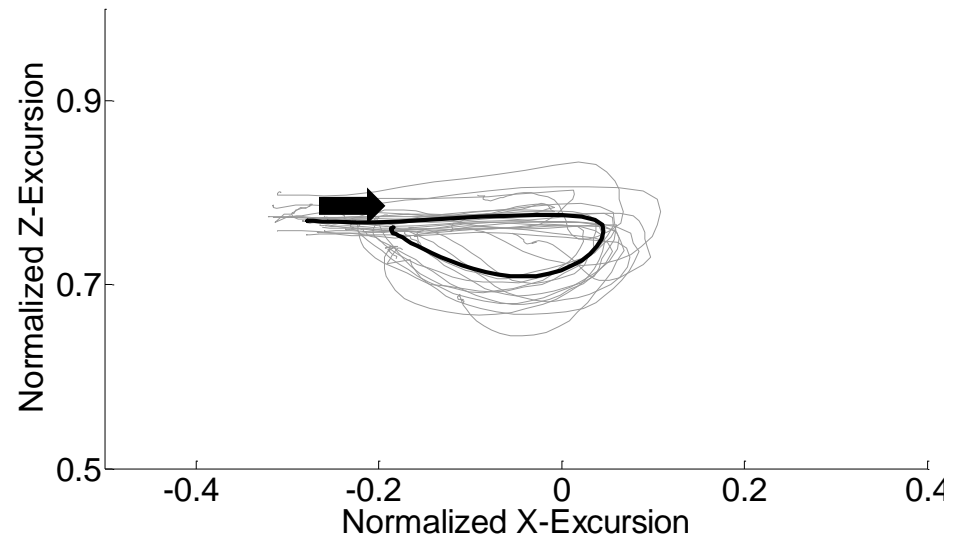
Subject	Max excursion, Δx (avg \pm SD)
Hybrid III	0.27 \pm 0.01 ↓17%
PV	0.32 \pm 0.02

Results: EAM (midpoint)

Hybrid III 6 Yr Old



Pediatric Volunteers

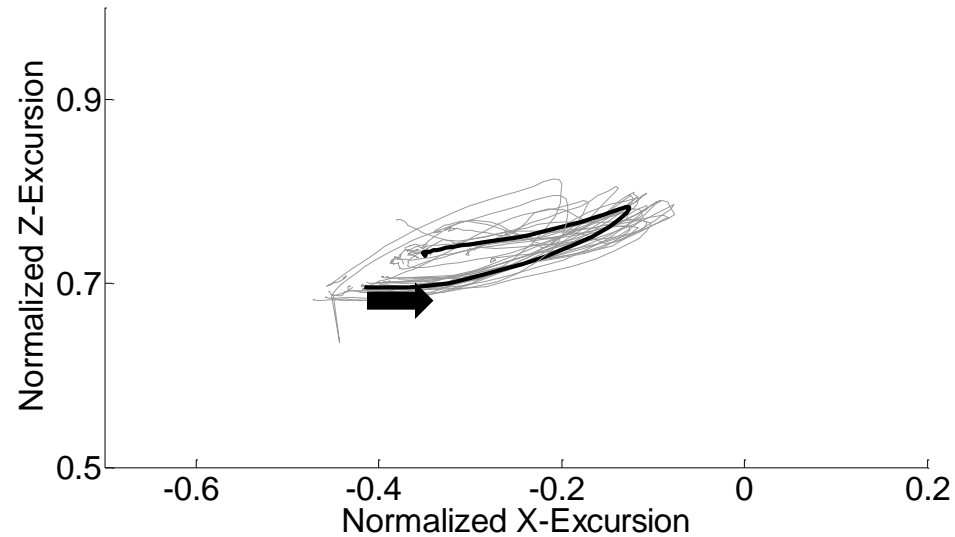
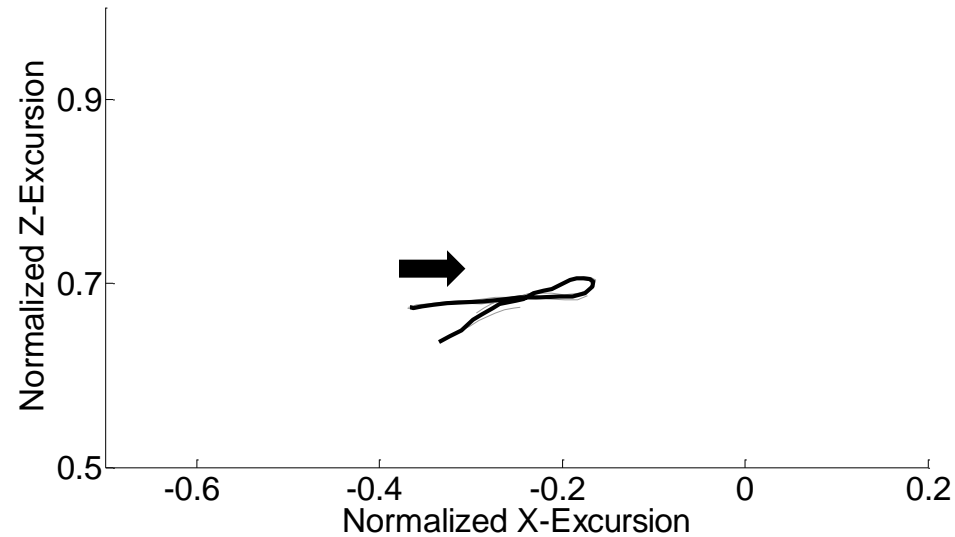


Subject	Max excursion, Δx (avg \pm SD)
Hybrid III	0.30 \pm 0.02 ↓9%
PV	0.33 \pm 0.02

Results: C4

Hybrid III 6 Yr Old

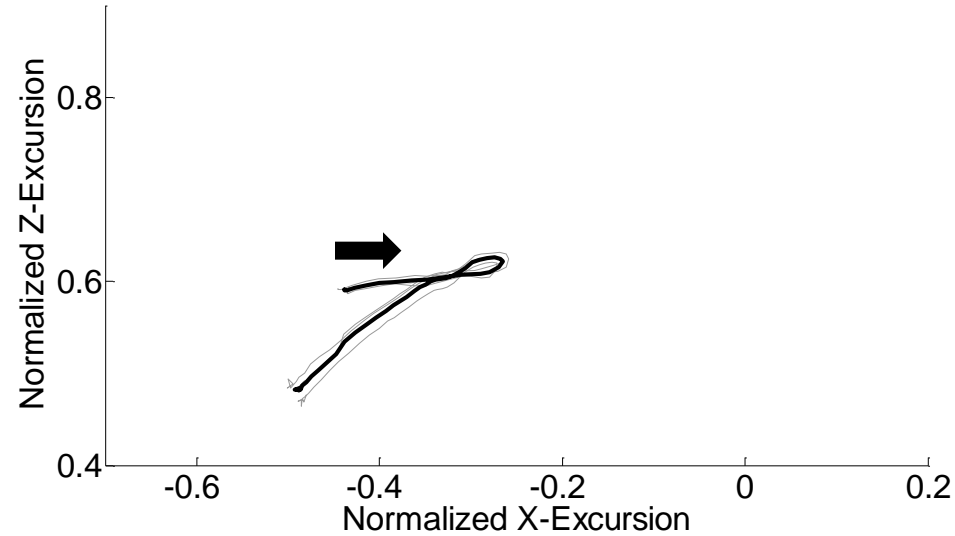
Pediatric Volunteers



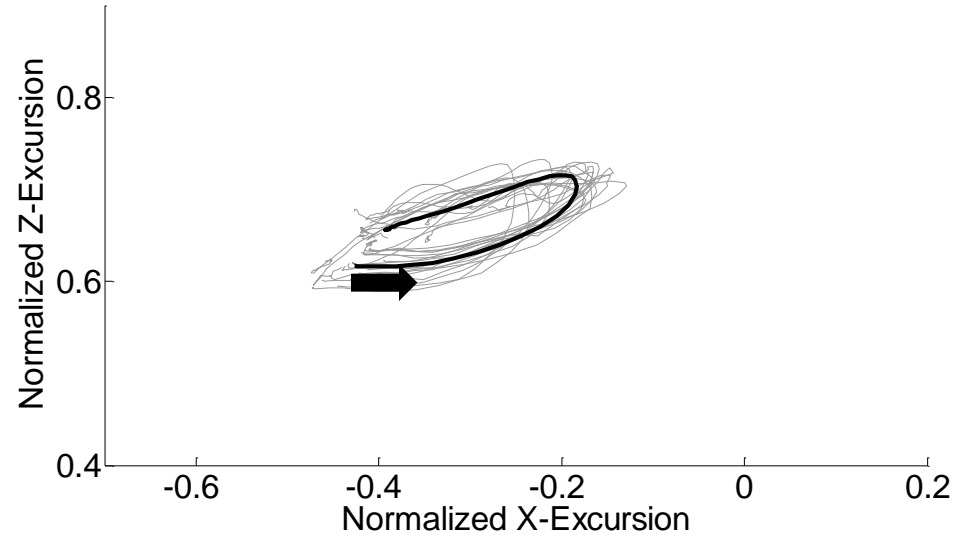
Subject	Max excursion, Δx (avg \pm SD)
Hybrid III	0.20 \pm 0.01 ↓25%
PV	0.27 \pm 0.02

Results: T1

Hybrid III 6 Yr Old



Pediatric Volunteers

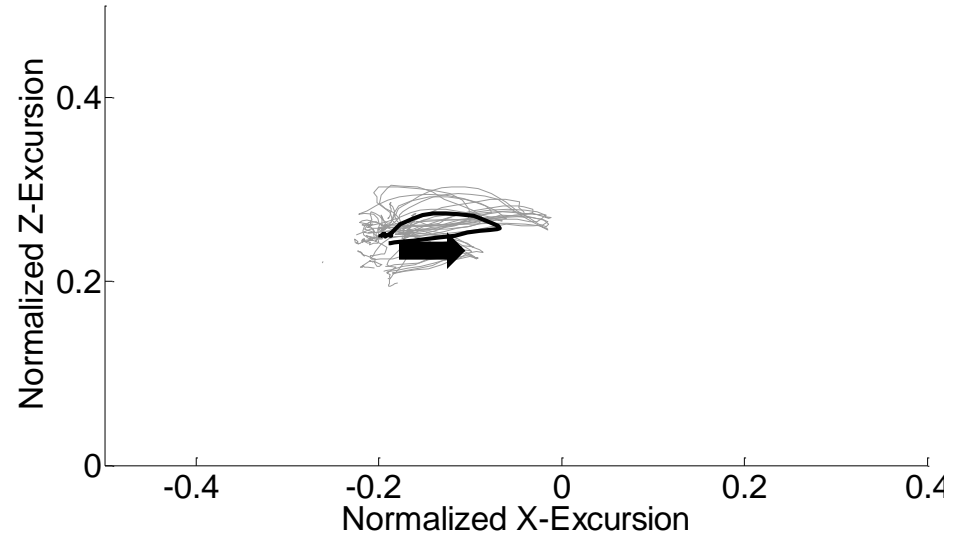
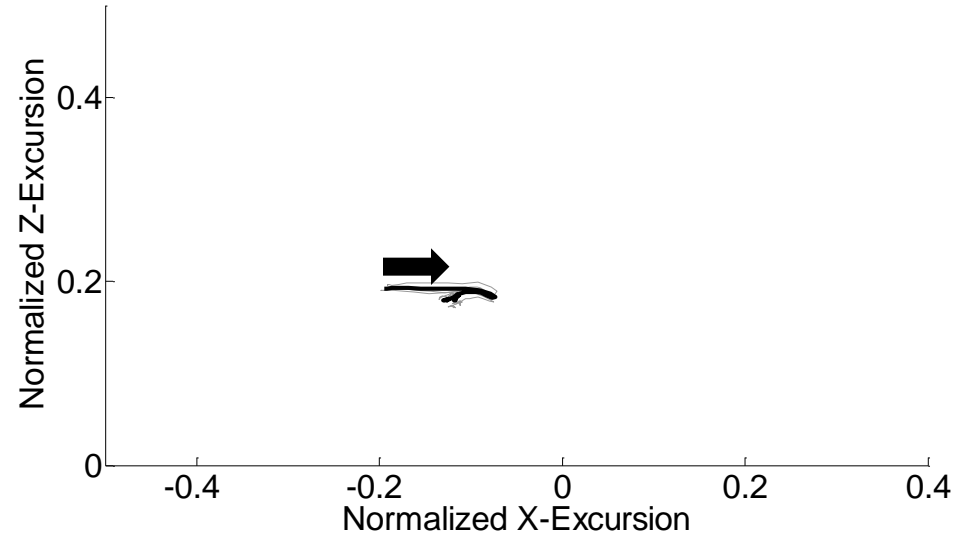


Subject	Max excursion, Δx (avg \pm SD)
Hybrid III	0.17 ± 0.01 ↓30%
PV	0.25 ± 0.02

Results: Iliac Crest (Left)

Hybrid III 6 Yr Old

Pediatric Volunteers



Subject	Max excursion, Δx (avg \pm SD)
Hybrid III	0.12 \pm 0.00 ↓4%
PV	0.13 \pm 0.03

Limitations

- Projection onto sagittal plane - $< 7\%$ error
- ATD-human differences evaluated for a single crash condition
 - May not be the same in higher loading environments
- Volunteer data compared to a single ATD
 - Q-series 6 year old may show different results

Discussion

- Decreased forward head and spine excursion of ATD may be attributed to rigidity of ATD spine
- Increased angular velocity of the ATD head may result in increased loads in the upper neck
 - ATD demonstrates greater head rotation than the volunteers
- ATD rebound greater than volunteers likely due to absence of muscle response
- Future work will examine differences in cervical spine loads and moments between humans and ATD

Summary of Findings

- At low speeds, Hybrid III 6 year old demonstrates reduced forward excursion of head and spine by 9-30% compared to the pediatric volunteer
 - Not due to differences in forward excursion of the pelvis
- Hybrid III exhibited increased head angular velocity and increased head rotation
 - Resulted in quicker time to max rotation
- ATD shoulder belt load $\sim 2x$ greater and later than volunteers
- ATD lap belt load $\sim 4x$ greater and earlier than volunteers

Acknowledgements

- All pediatric volunteers
- Mike Beebe, Denton ATD, Inc.
 - Use of Hybrid III 6 Yr Old
- Takata Corporation
 - Collaboration and financial support

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For a more detailed discussion of other research on pediatric ATD biofidelity,

Please see our 2010 CPS Issue Report at:

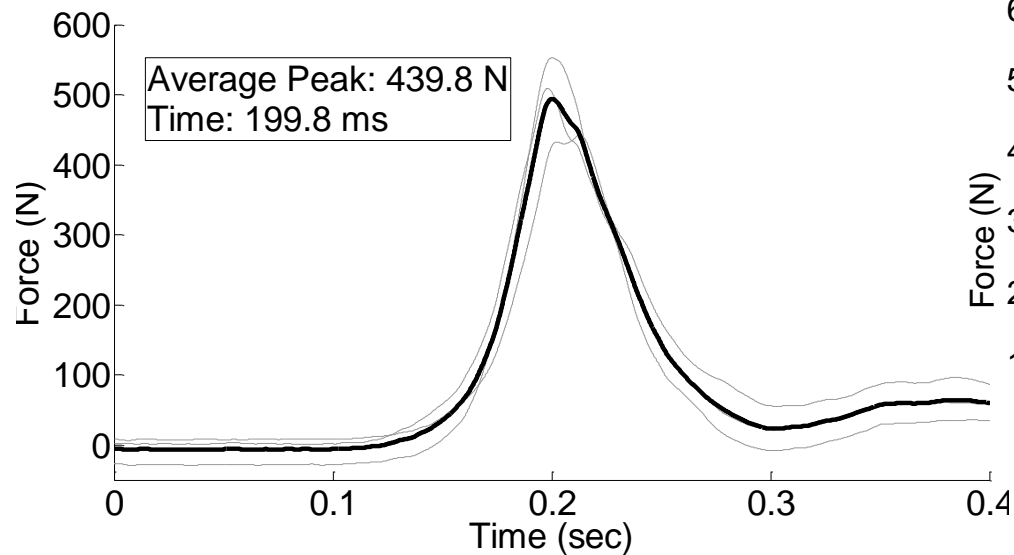
www.chop.edu/injury



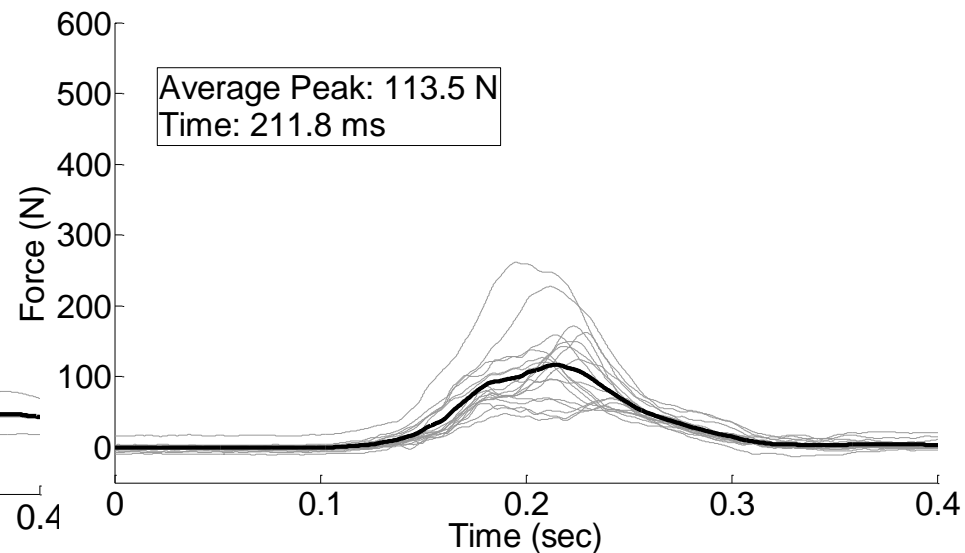
Results:

Lap Belt Load (Right)

Hybrid III 6 Yr Old



Pediatric Volunteers

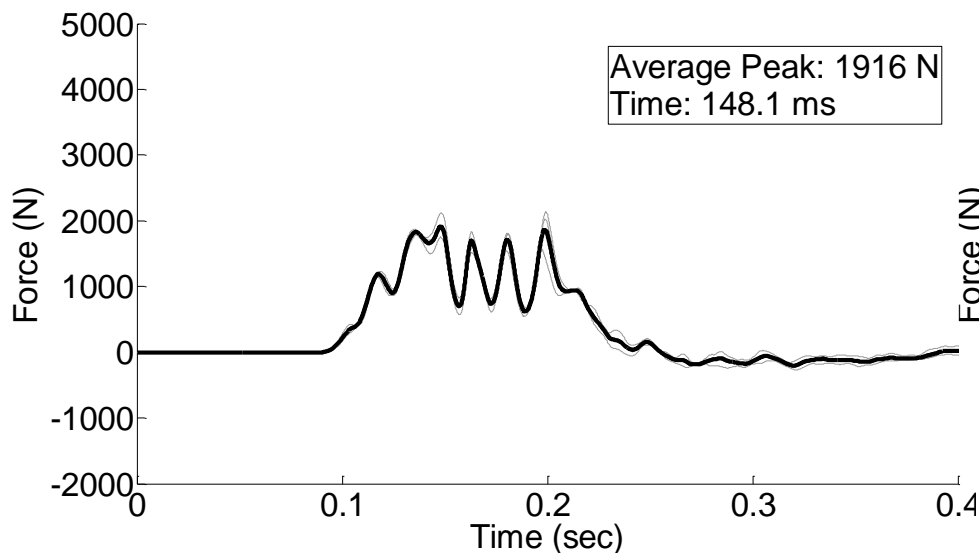


- ATD right lap belt load 287% greater than PV avg
- ATD right lap belt load 92% greater than PV max
- ATD max load occurs 12 ms earlier than PV

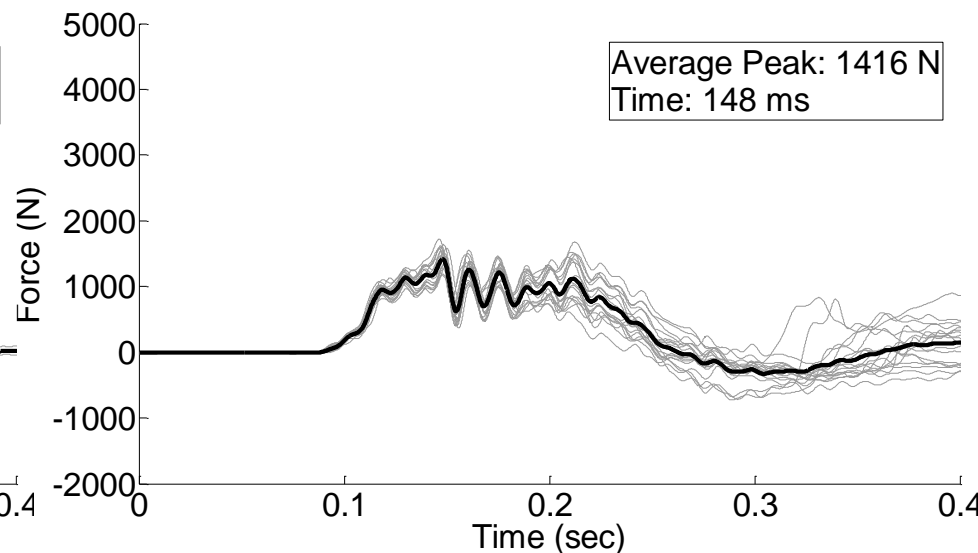
Results:

Foot Rest Loads (Z-Axis)

Hybrid III 6 Yr Old



Pediatric Volunteers

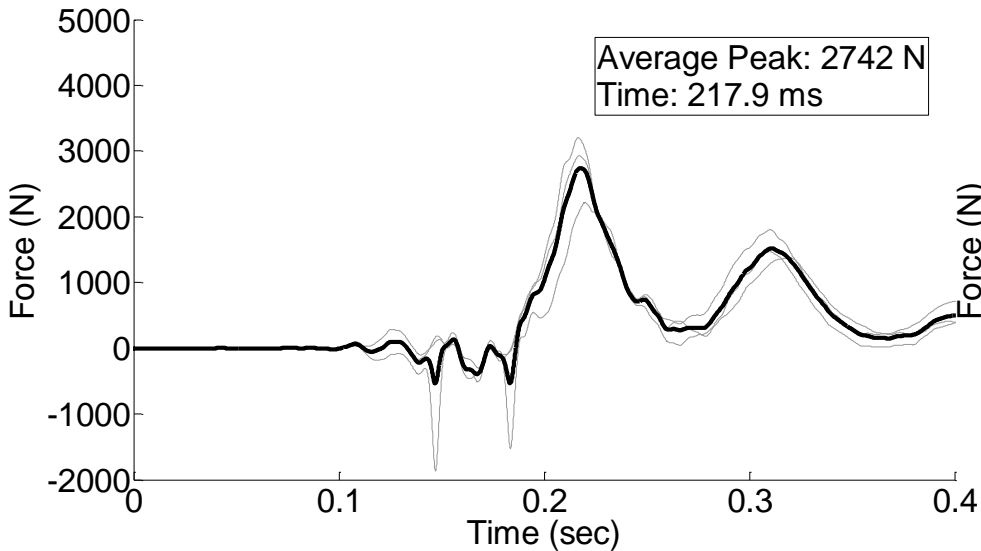


- ATD foot rest load 34% greater than PV avg

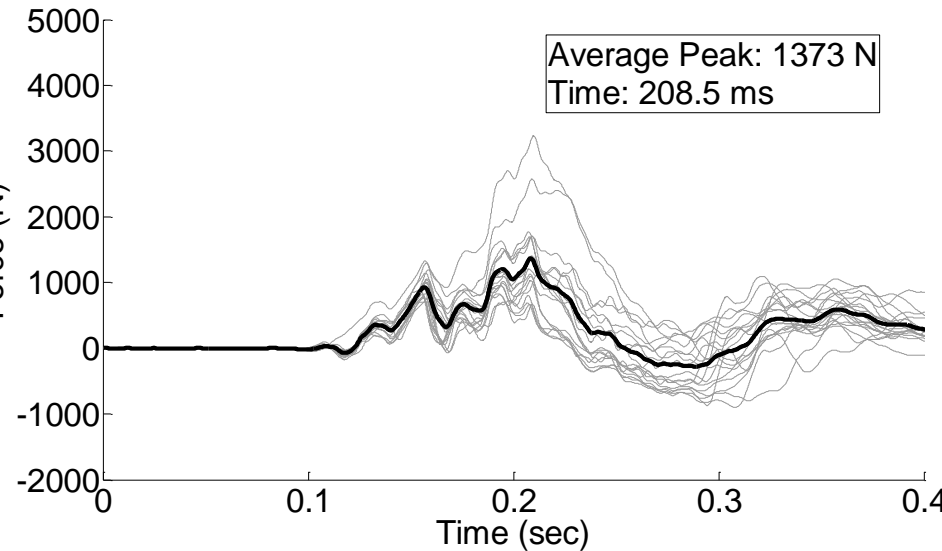
Results:

Seat Pan Loads (Z-Axis)

Hybrid III 6 Yr Old



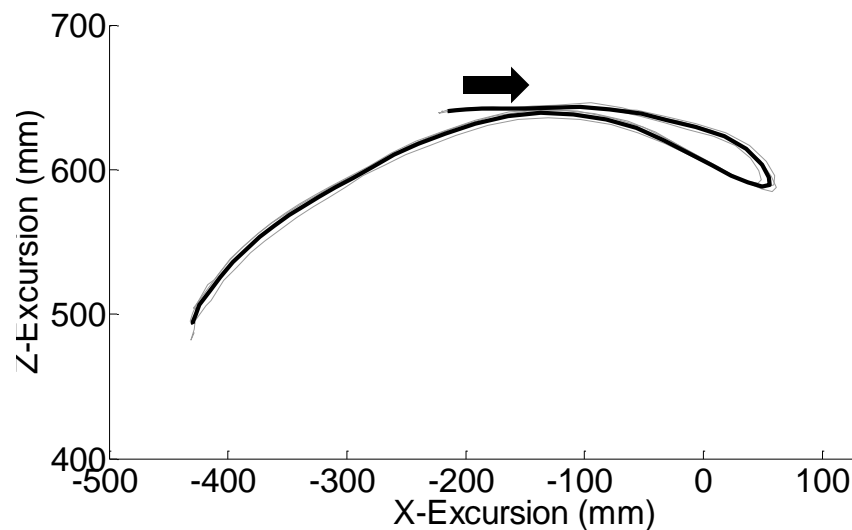
Pediatric Volunteers



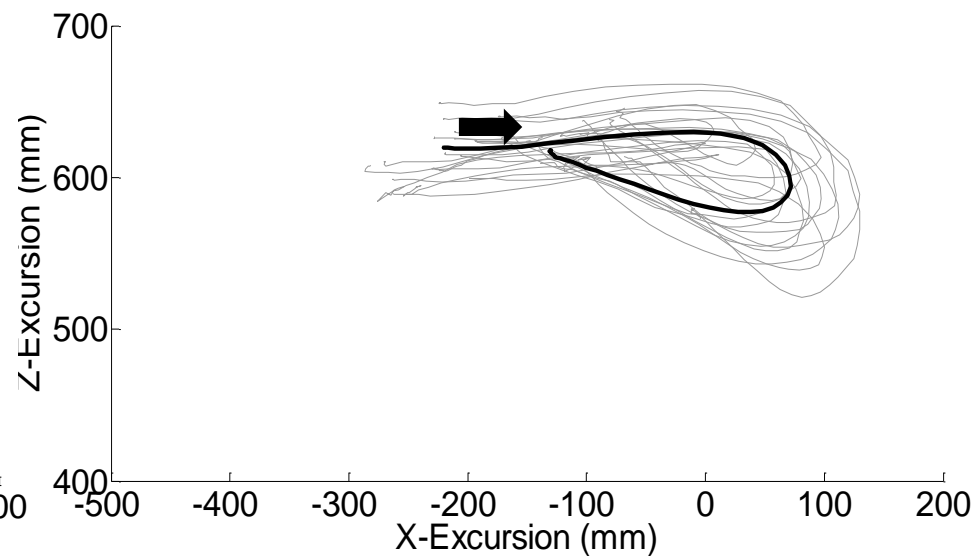
- ATD seat pan load 89% greater than PV avg
- ATD max load occurs ~10 ms later than PV

Results: Head Top

Hybrid III 6 Yr Old



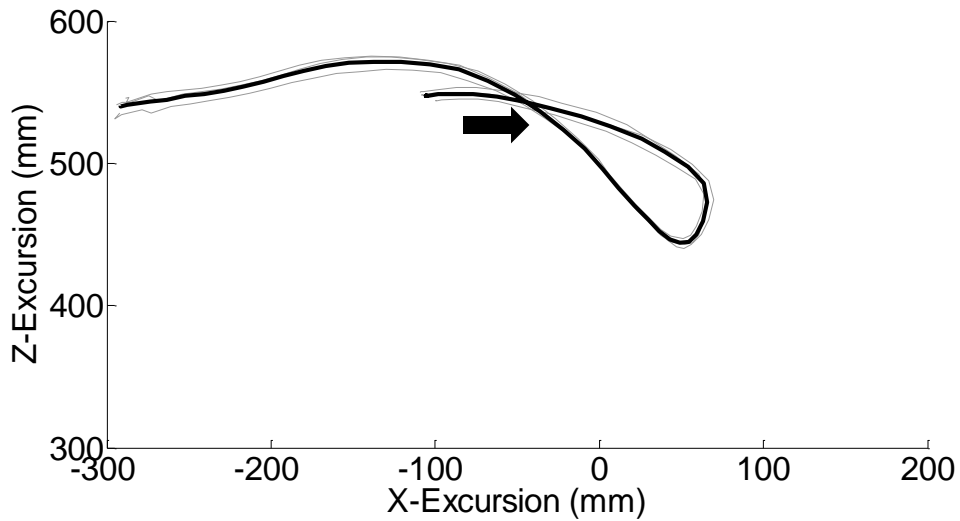
Pediatric Volunteers



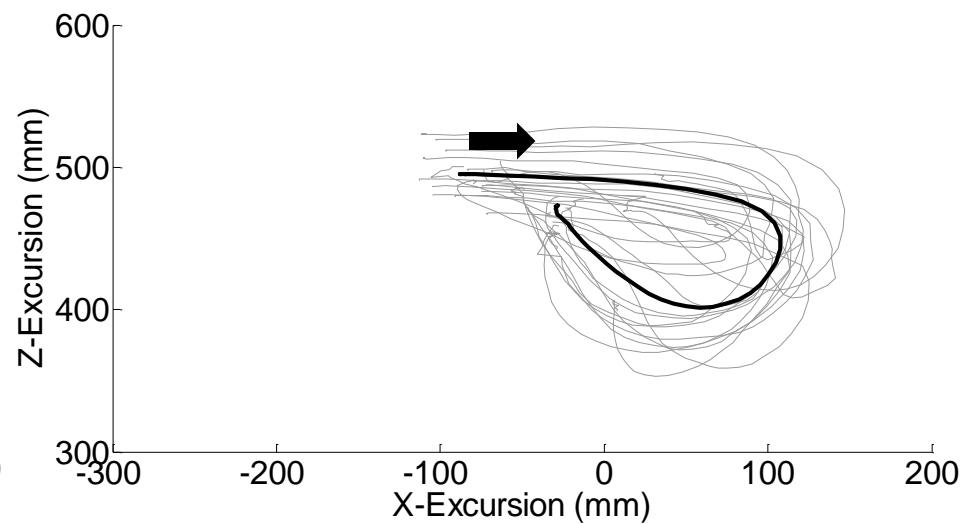
Subject	Max excursion, Δx (avg \pm SD)
Hybrid III	271.8 \pm 13.4 mm
PV	295.0 \pm 21.0 mm

Results: Nasion

Hybrid III 6 Yr Old



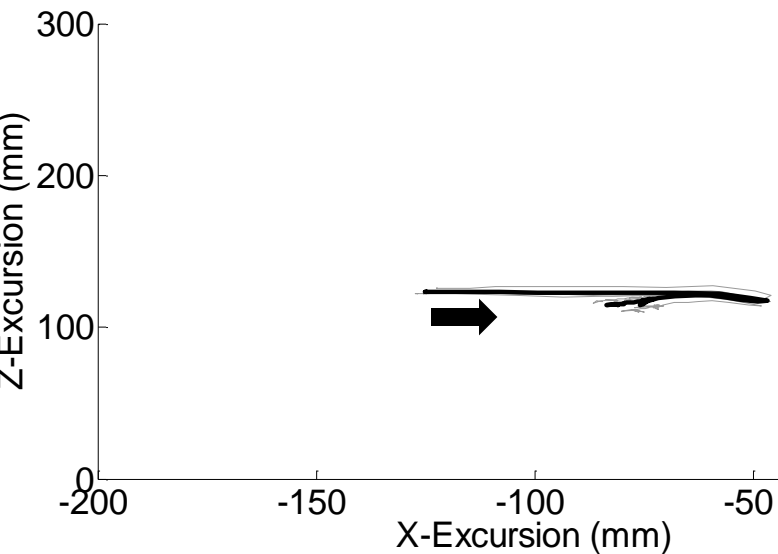
Pediatric Volunteers



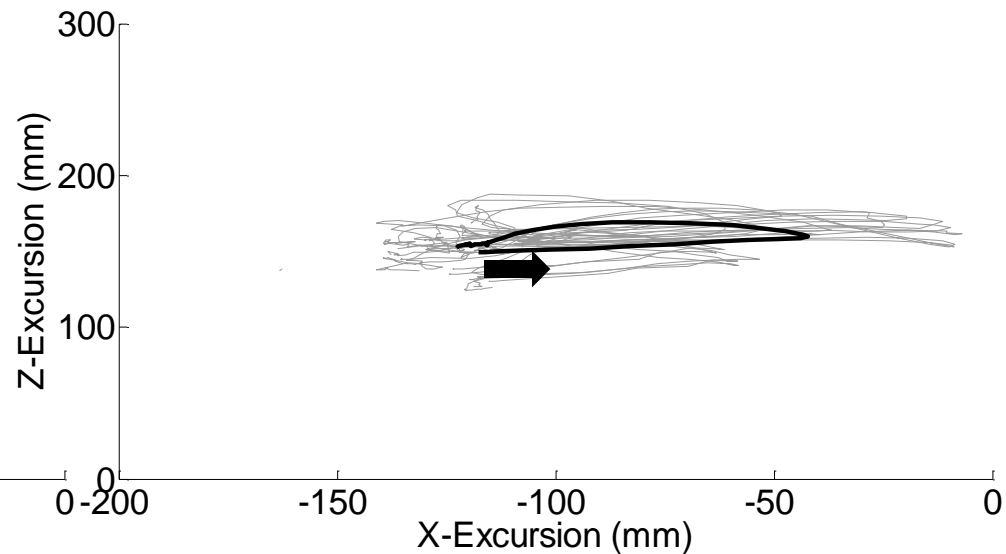
Subject	Max excursion, Δx (avg \pm SD)
Hybrid III	171.7 \pm 6.4 mm
PV	220.6 \pm 21.0 mm

Results: Iliac Crest (Left)

Hybrid III 6 Yr Old

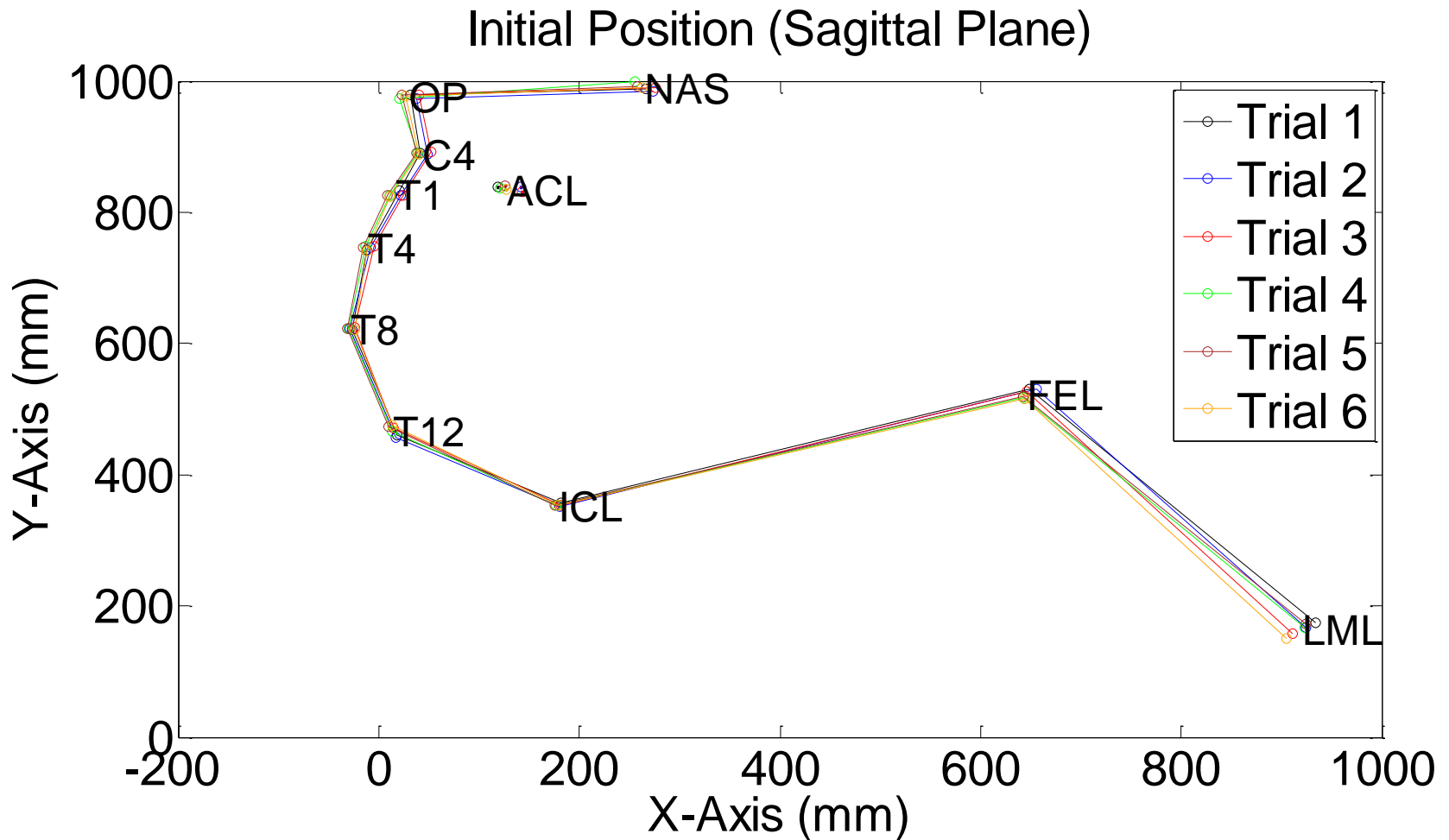


Pediatric Volunteers



Subject	Max excursion, Δx (avg \pm SD)
Hybrid III	78.3 \pm 1.2 mm
PV	78.7 \pm 16.4 mm

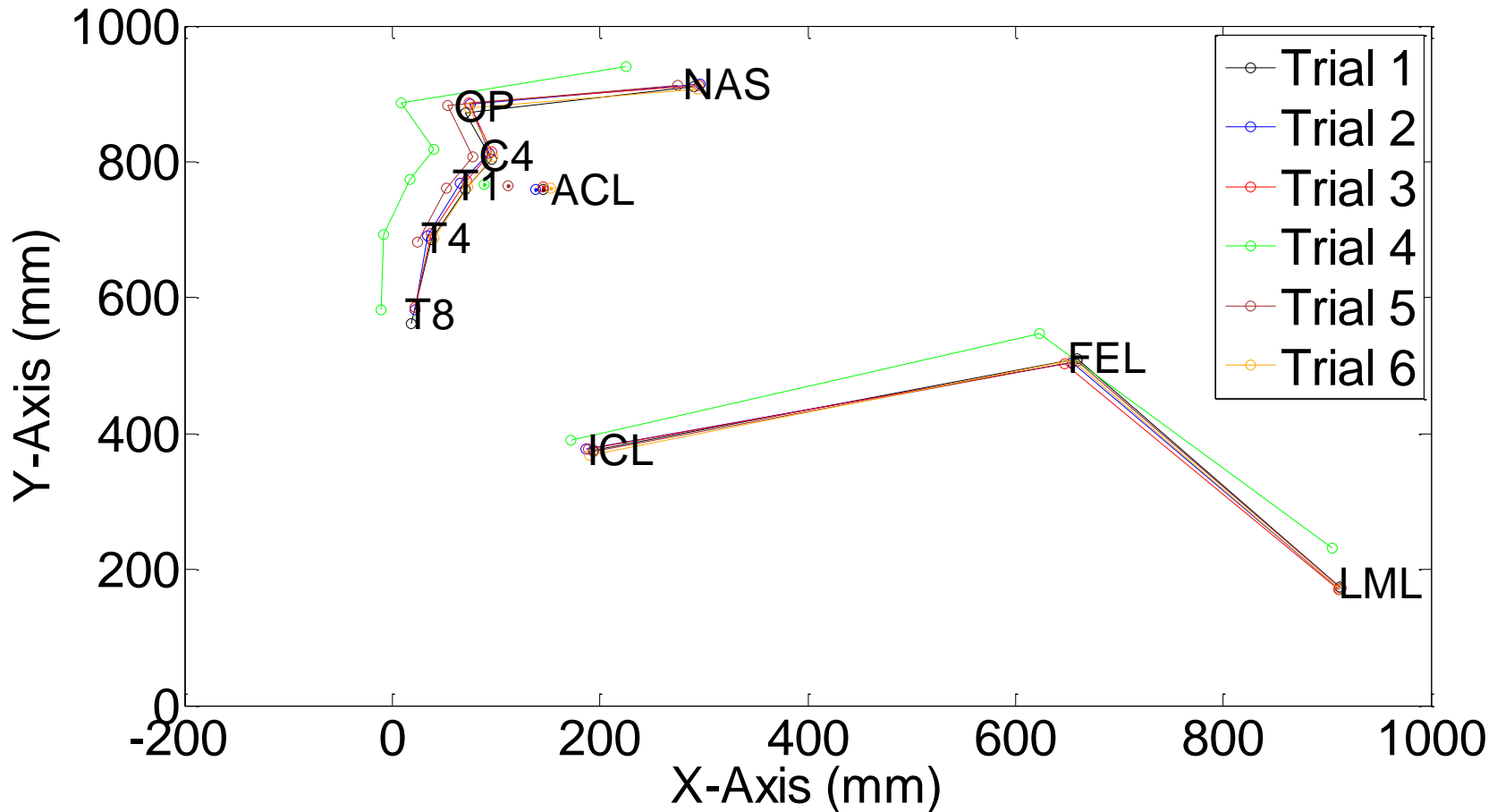
Initial Position – Optimal Alignment



Avg $SD_x=9.5\text{mm}$
Avg $SD_y=8.4\text{mm}$
Avg $SD_z=7.1\text{mm}$

Initial Position - Suboptimal

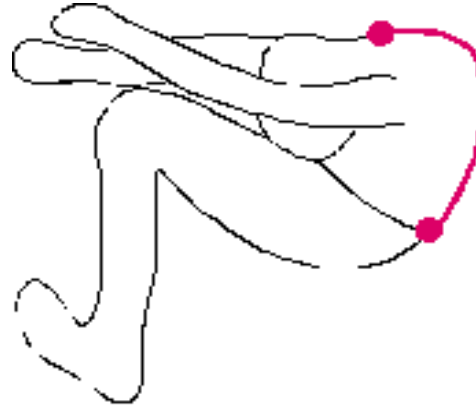
Initial Position (Sagittal Plane)



Avg $SD_x = 9.5\text{mm}$
Avg $SD_y = 8.4\text{mm}$
Avg $SD_z = 7.1\text{mm}$

Evidence that Spinal Kinematics Differ between Pediatric ATD and PMHS

10 Year Old PMHS

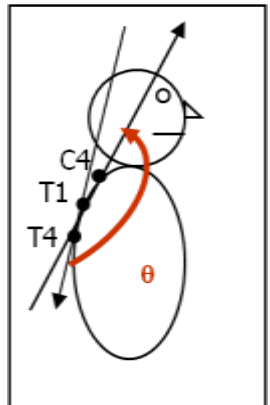
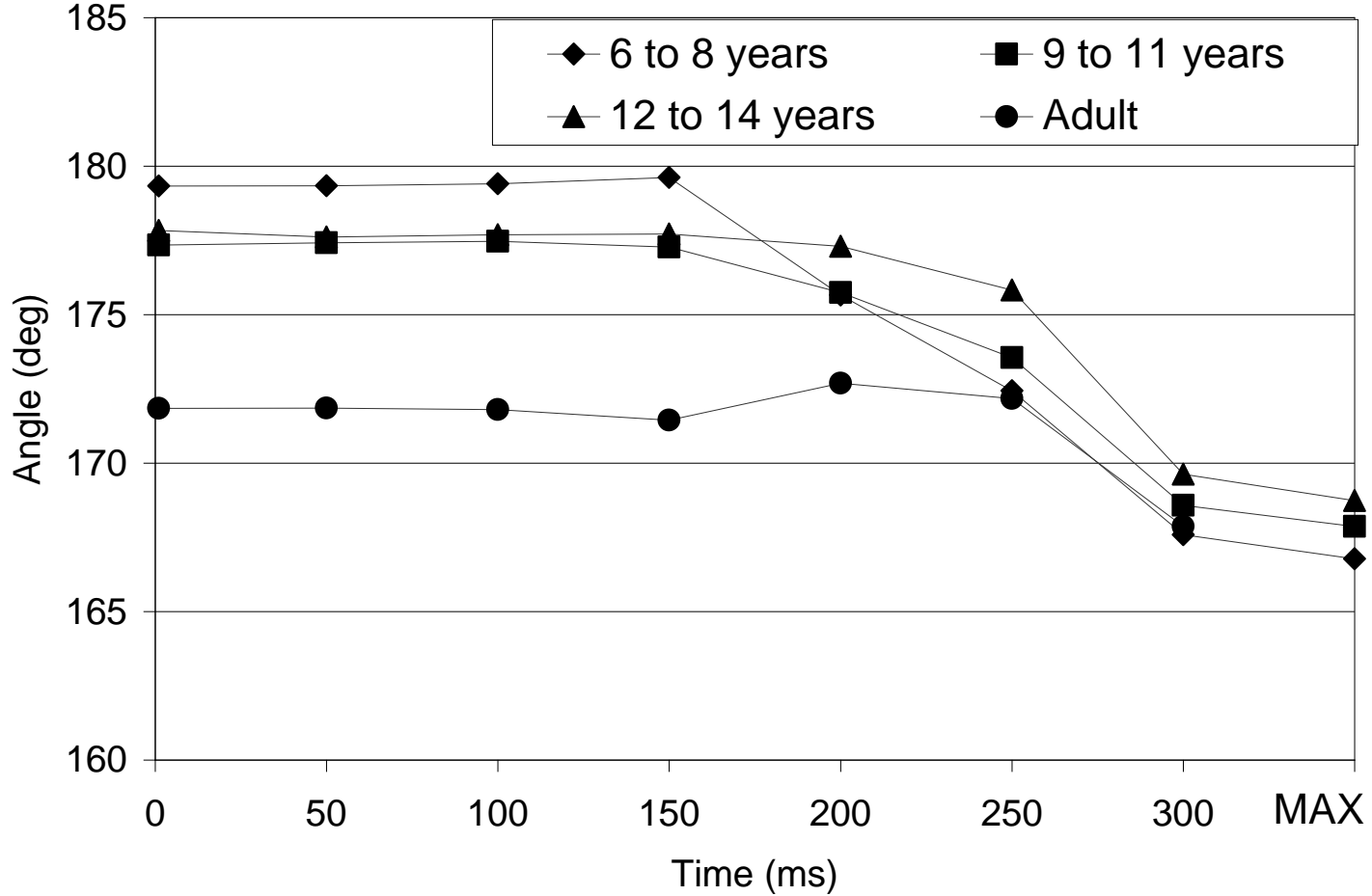


Hybrid III 6 Yr Old

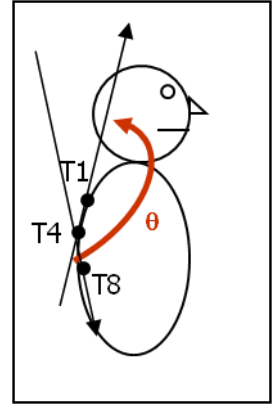
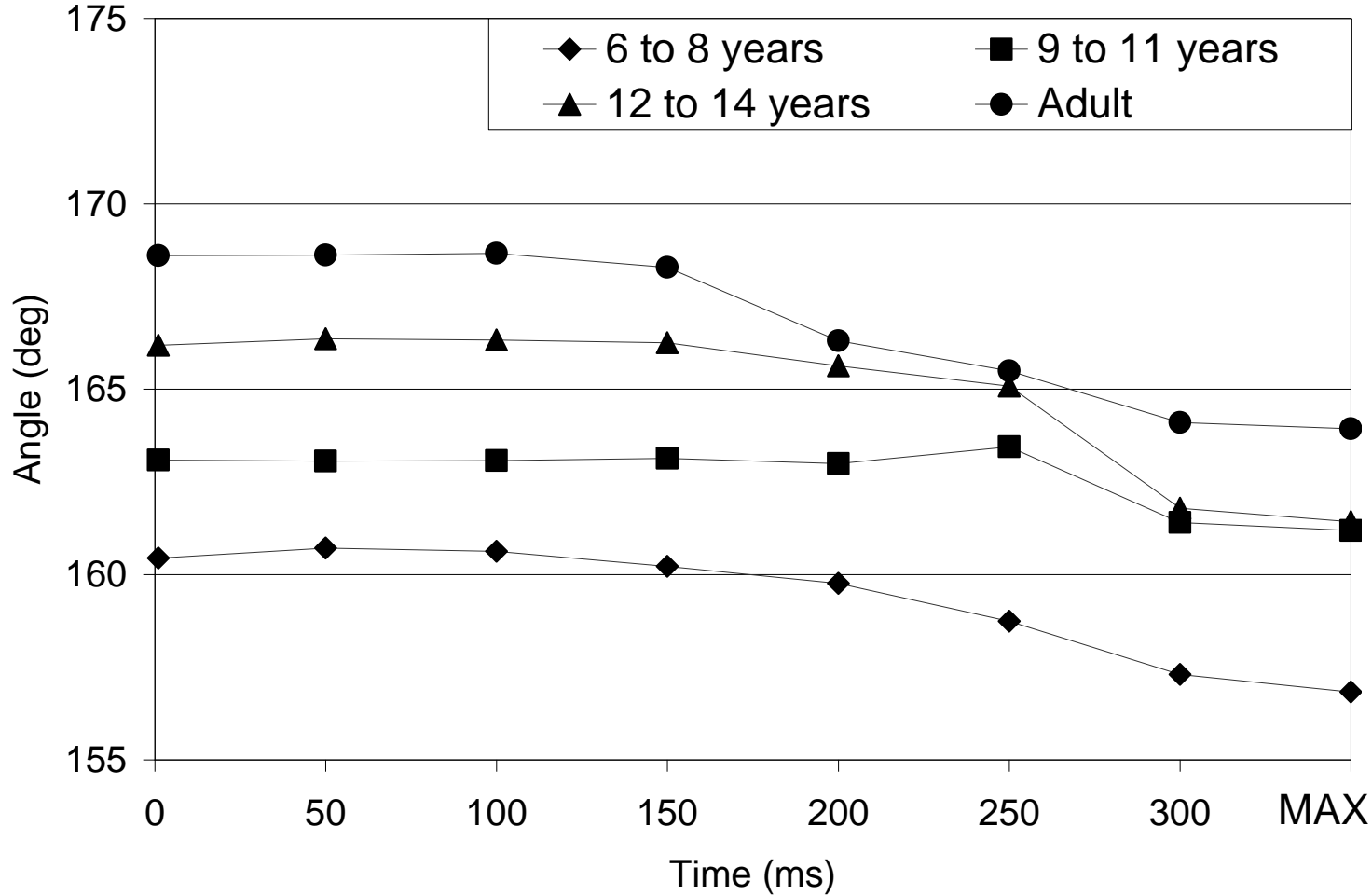


Sherwood 2003

Time History – Upper Thoracic Angle

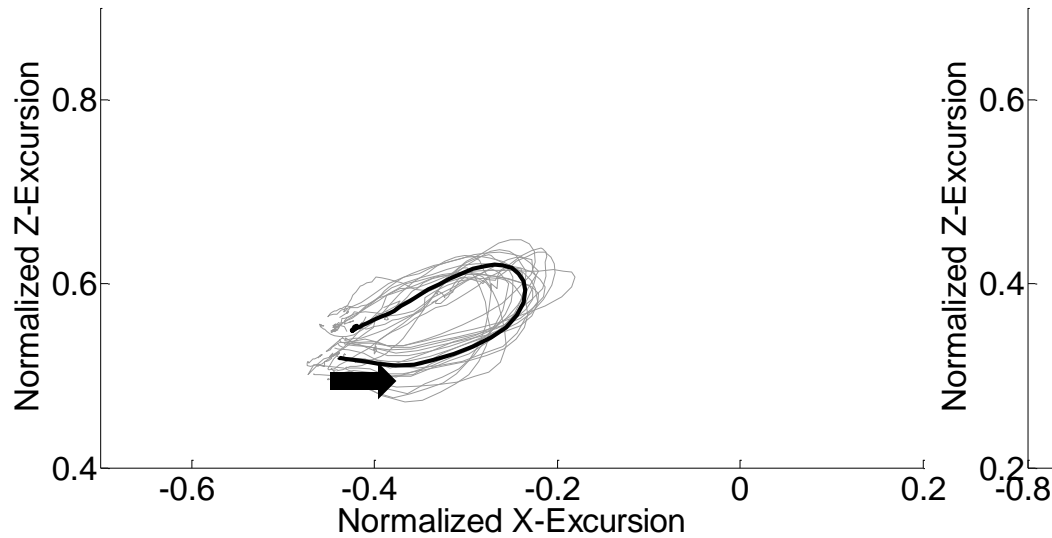


Time History – Lower Thoracic Angle



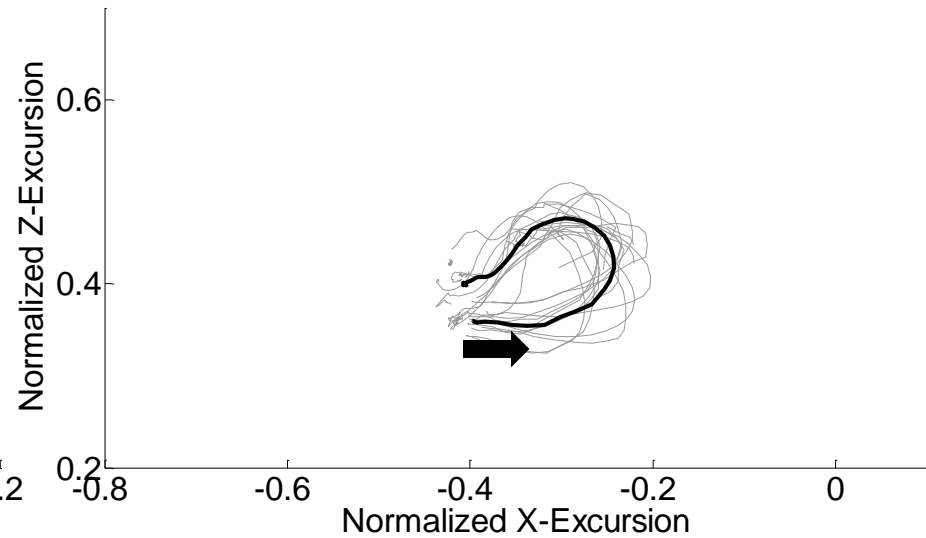
Results: T4 and T8

Pediatric Volunteers T4



$$\Delta X = 0.20 \pm 0.02$$

Pediatric Volunteers T8



$$\Delta X = 0.16 \pm 0.02$$