CHILD MOVEMENTS IN SWERVING MANEUVERS

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PRE-CRASH MANEUVERS

- 80% of crashes involve some form of pre-crash maneuver (Seacrist et al. 2018).
- Active safety and automated vehicle features may expose the occupant to a greater variety of pre-crash dynamics not yet understood.
- Pre-crash maneuvers generated by lateral vehicle acceleration (e.g. evasive swerving or lateral vehicle skidding) less studied than emergency braking (Holt et al. 2017).
- Pre-crash maneuvers generated by lateral vehicle acceleration have the potential to influence occupant restraints and injury risk associated with crashes (e.g. Bohman et al 2011)

OBJECTIVE

AIM 1: To investigate the effect of occupant age on in-vehicle simulated evasive swerving maneuver (i.e. slalom).

- **Slalom→** lateral accelerations that may precede either a planar or rollover crash
- **Rear seating→** common with pediatric passengers, rideshare services and in driverless technology.
- **Human volunteers→** ATDs have no neuromuscular control, nor were they designed to achieve biofidelic responses in LATE events.
- **Children→** different neuromuscular control, and bracing behavior, important to study age differences

AIM 2: To examine the contribution of the booster seat motion to children occupant motion on in-vehicle simulated evasive swerving maneuver.

PARTICIPANTS

Booster Children (6-8) — n = 7

Age (years)	7.1 ± 0.9
Seated Height (cm)	64.9 ± 5.1
Weight (kg)	27.9 ± 6.1

Children (9-12) — n = 7

Age (years)	11.6 ± 0.8
Seated Height (cm)	76.7 ± 6.2
Weight (kg)	47.8 ± 12.8

Teens (13-17) — n = 8

Age (years)	15.1 ± 1.2
Seated Height (cm)	84.8 ± 5.3
Weight (kg)	60.3 ± 8.2

Adults (18-45) — n = 9

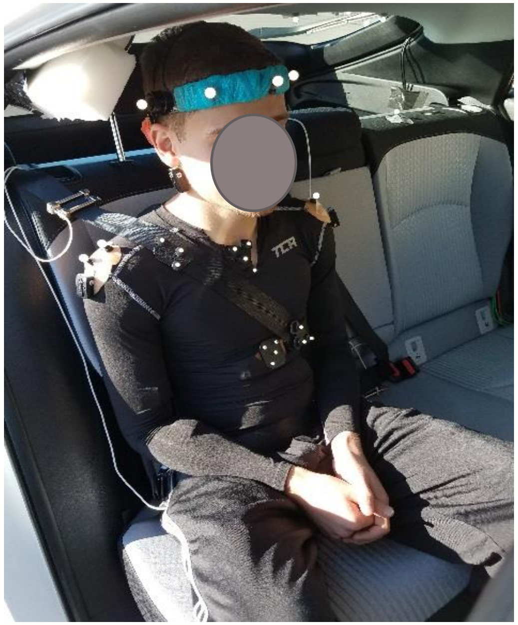
Age (years)	23.8 ± 4.8
Seated Height (cm)	88.1 ± 4.1
Weight (kg)	70.5 ± 10.5

MOTION CAPTURE SYSTEM

The right rear seat position was instrumented with an **8-infrared camera 3D motion capture system** (Optitrack Prime 13, 200Hz, NaturalPoint, Inc.)

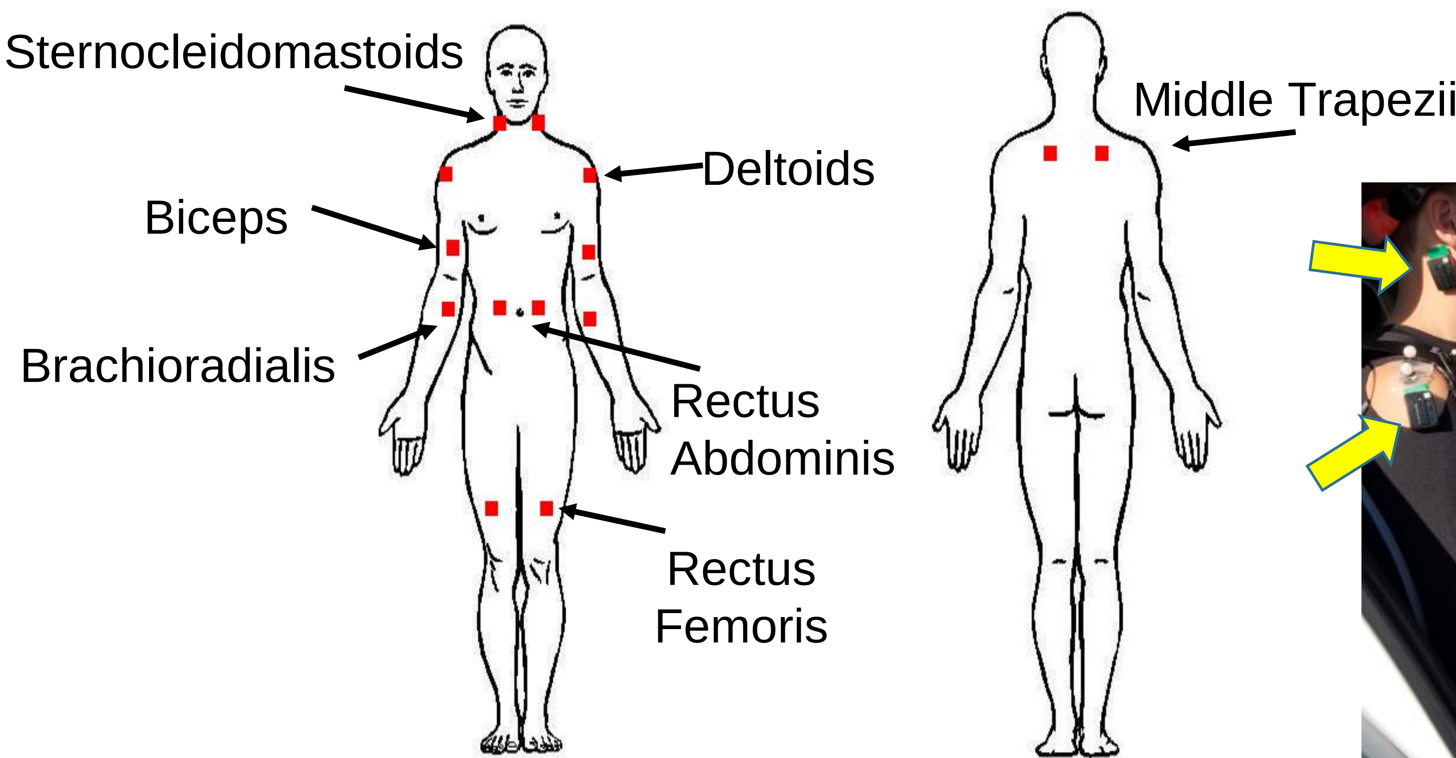
Photo-reflective markers placed:

1) Participants' head (on a tightly fitted head piece) and sternum (suprasternal notch)
2) Seat belt, vehicle roof, right rear seat, and booster seat



ELECTROMYOGRAPHY

Electromyography (EMG, Trigno EMG Wireless Delsys, Inc., 2000 Hz) sensors placed on bilateral muscles likely involved in bracing behaviors.



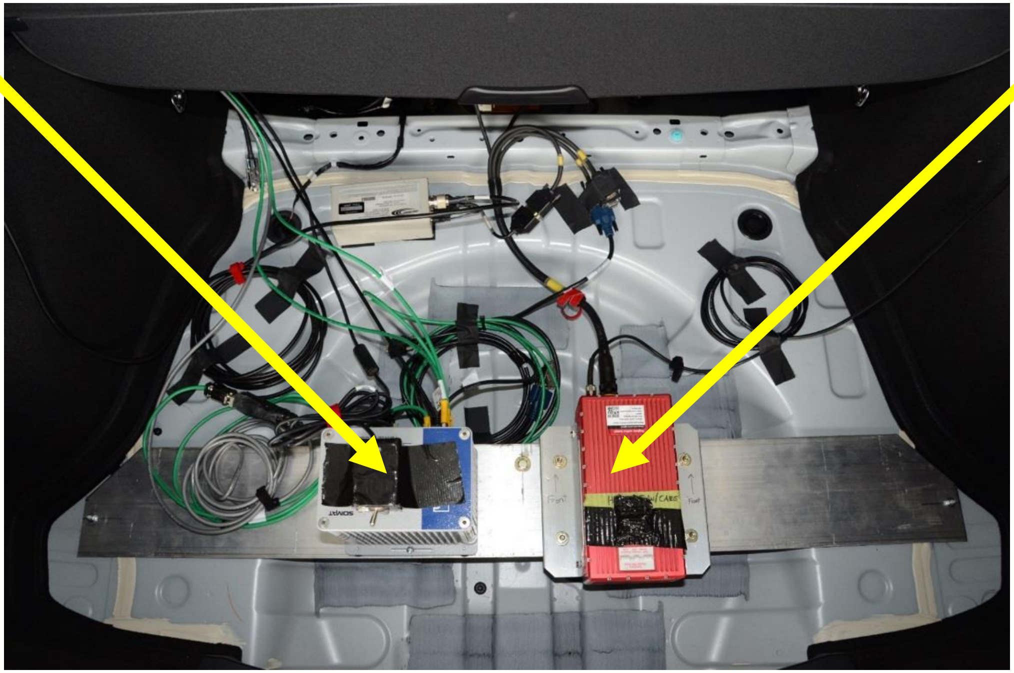
SEAT-BELT LOAD CELLS

- 3 **seatbelt load cells** (16kN, Measurements Specialties, Inc. 2000 Hz) placed on shoulder belt and at each side of the lap belt to characterize seatbelt reaction loads.
- Data acquisition was synchronized with 3.3 V trigger generated by the camera system and recorded by the EMG and eDAQ systems.

VEHICLE INSTRUMENTATION

Data acquisition system (Somat eDAQlite HBM, 200 Hz) connected to Oxford RT 3003 and Seat-belt load cells.

Inertial and GPS Navigation system (Oxford RT 3003, Oxford Technical Solutions Ltd.) to measure vehicle dynamics (i.e. motion, position, and orientation).



VEHICLE DYNAMICS

- On-road vehicle dynamics were tested without passengers with a recent model year sedan at the Transportation Research Center Inc. (TRC, East Liberty, Ohio)

- A professional driver performed the maneuvers aimed to establish repeatability of the acceleration targets and appropriateness for human subjects.

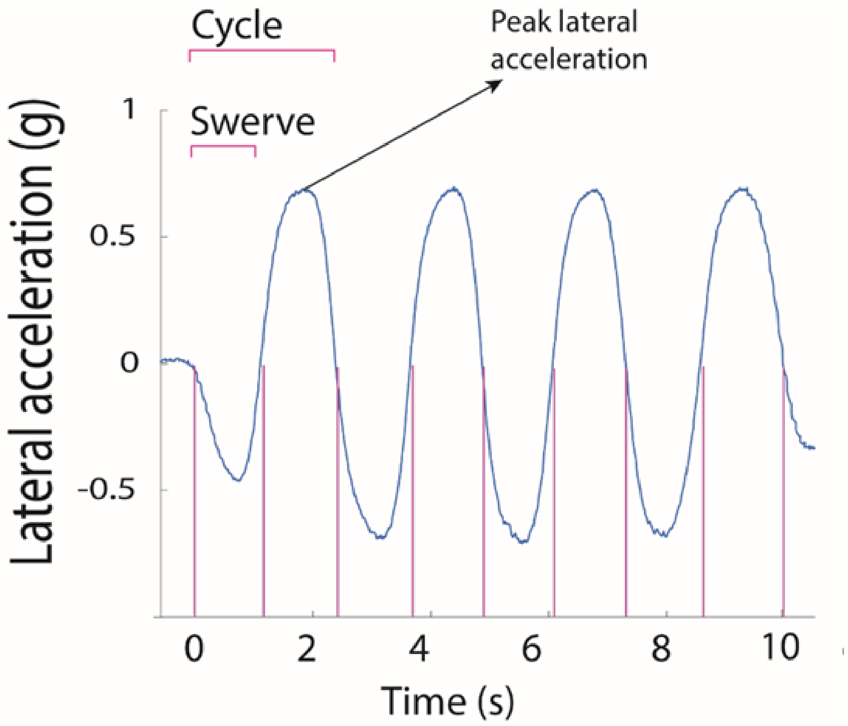
- Target acceleration for each maneuver was based on previous literature (e.g. Kirschbachler et al 2014, Stockman et al 2013, Kim et al 2013)

EVASIVE SWERVING SIMULATION

Slalom:

- Moving between 8 cones placed 20 meters apart
- Speed of 65 km/h with cruise control
- Average peak lateral acceleration of ~0.75 g

OUTCOME MEASURES



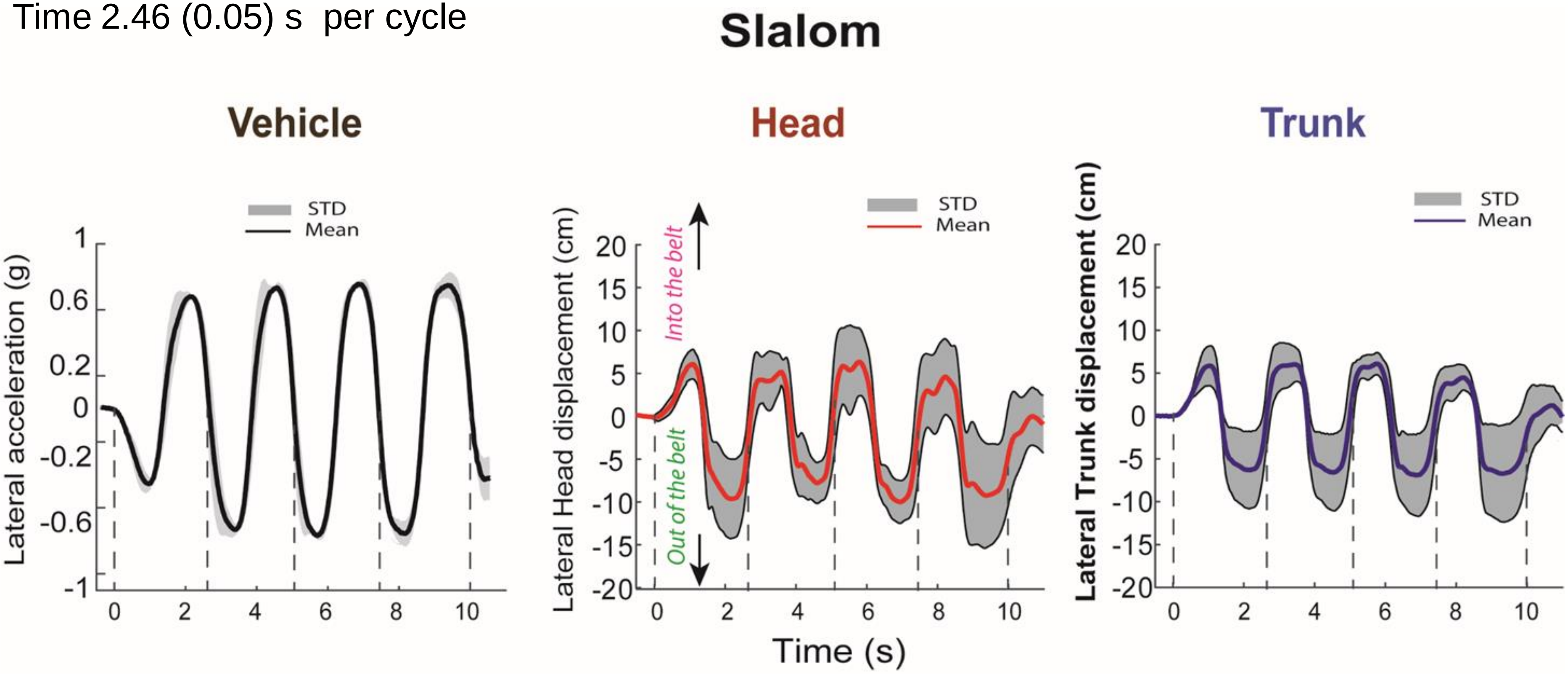
- **Peak head and trunk excursions** for each swerve into-the-belt (outboard) and out-of-the-belt (inboard).
  - Raw and normalized by seated height
- **Mean EMG** over the duration of each swerve for each muscle.
- **Mean seat-belt loads** (shoulder belt, left and right lap belt) over the duration of each swerve.

Statistical analysis:

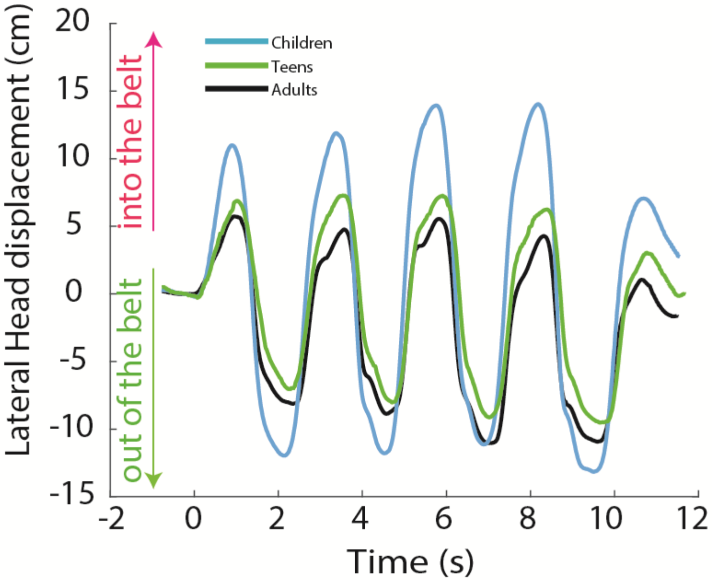
- Mixed 3-ways ANOVAs: age (children, teens, adults), cycle (1-4) and repetition (1 vs. 2).

TIME SERIES: KINEMATICS

Peak 0.73 (0.006) g
Time 2.46 (0.05) s per cycle



AIM 1: EFFECT OF AGE ON PEAK HEAD EXCURSION (NON- BOOSTER OCCUPANTS)



Peak Head (cm)	Children	Teens	Adults	ANOVA	Post-Hoc Test
out of the belt	12.9 (6.05)	9.4 (5.8)	12.3 (4.2)	p=0.25	
normalized	0.2 (0.08)	0.1 (0.06)	0.1 (0.05)	p=0.19	
into the belt	13.6(8.3)	7.9 (4.1)	6.1 (3.8)	***p<0.03****	***Children> Adults p<0.03****
normalized	0.2 (0.1)	0.1 (0.05)	0.1 (0.04)	***p=0.007****	***Children> Adults, Teens p<0.04****

Children (9-12 y.o.) showed greater peak head excursion than adults and teens when moving into the belt p<0.04* (in both raw and normalized data)

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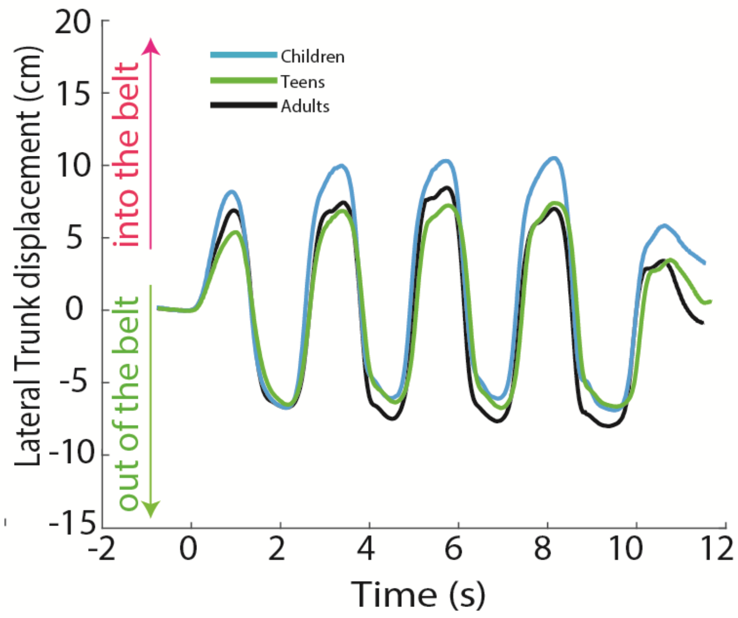
AIM 1: EFFECT OF AGE ON PEAK TRUNK EXCURSION (NON- BOOSTER OCCUPANTS)



Peak Trunk (cm)	Children	Teens	Adults	ANOVA	Post-Hoc Test
out of the belt	6.7 (3.11)	6.7 (2.8)	7.9 (2.5)	p=0.41	
normalized	0.09 (0.04)	0.08 (0.04)	0.09 (0.03)	p=0.78	
into the belt	10.1 (4.7)	7.1 (2.14)	7.8 (2.5)	p=0.11	
normalized	0.1 (0.06)	0.08 (0.03)	0.09 (0.03)	*p<0.02**	*Children> Adults, Teens (p<0.05*)*

Children (9-12 y.o.) showed greater peak trunk excursion than adults and teens when moving into the belt p<0.02* (normalized data only)

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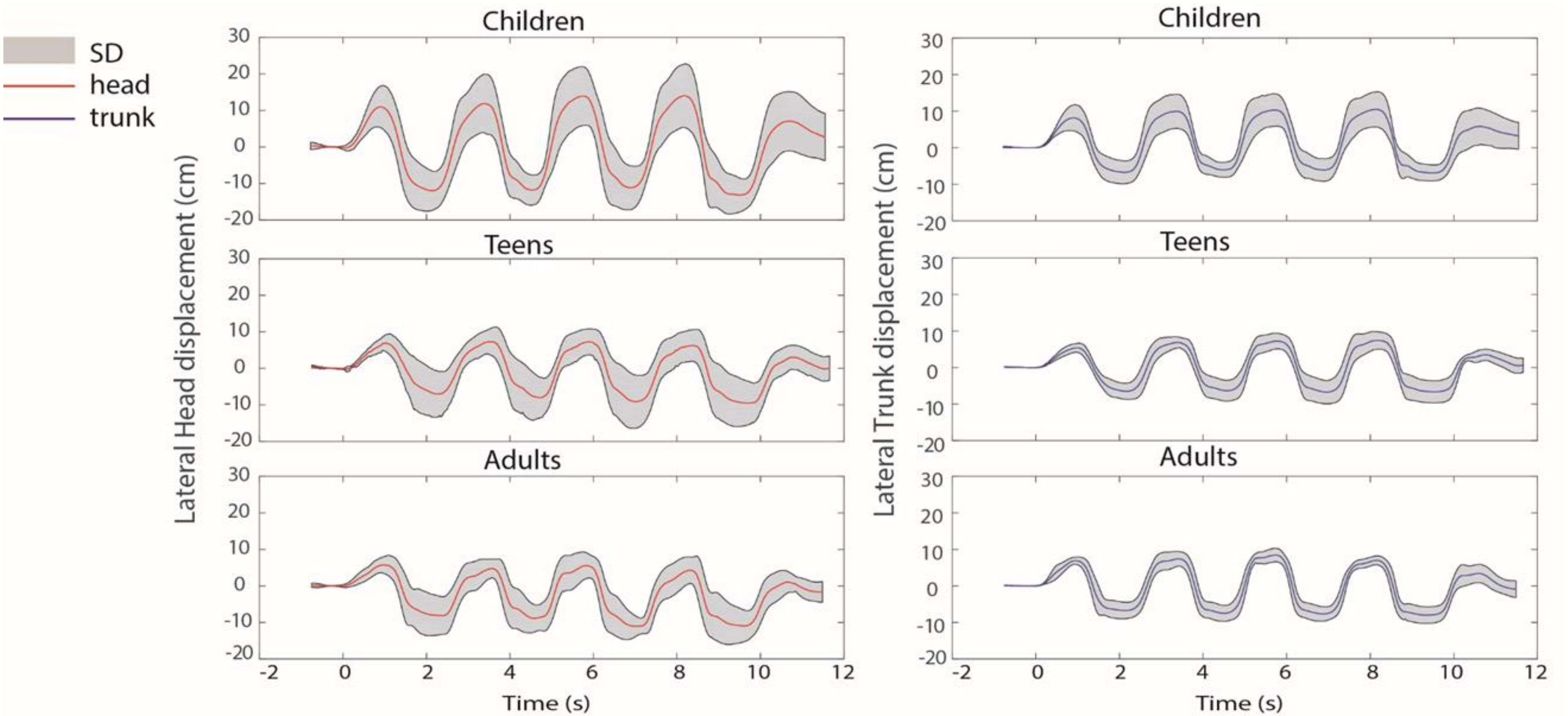
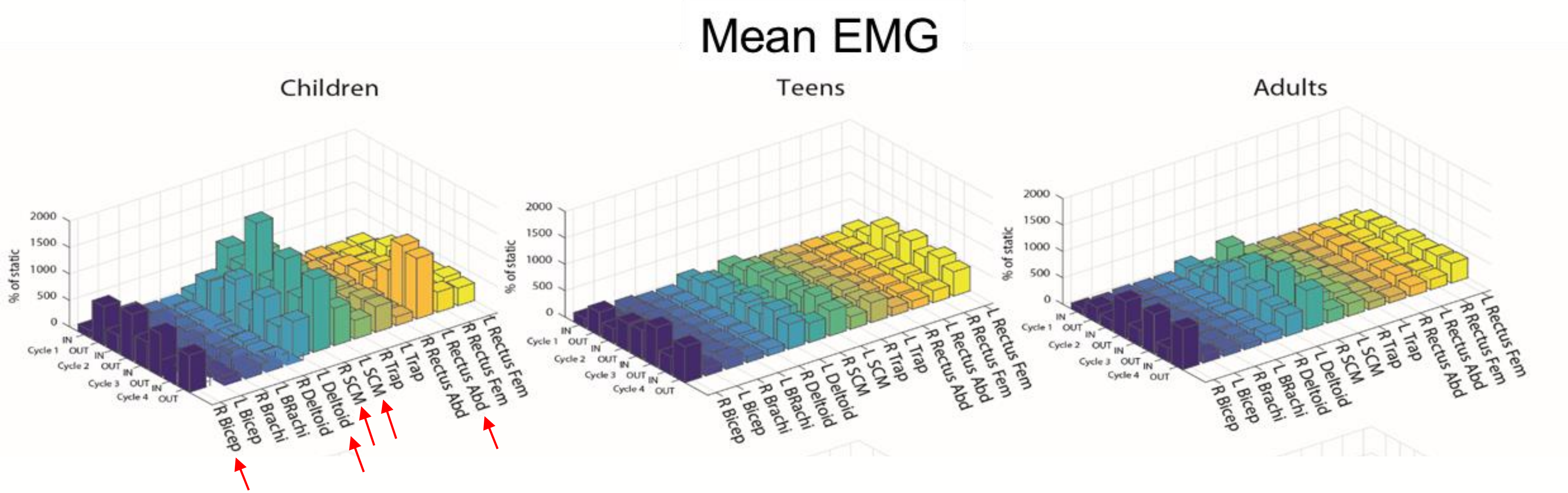
AIM 1: EFFECT OF AGE ON PEAK HEAD AND TRUNK EXCURSIONS

(NON- BOOSTER OCCUPANTS)

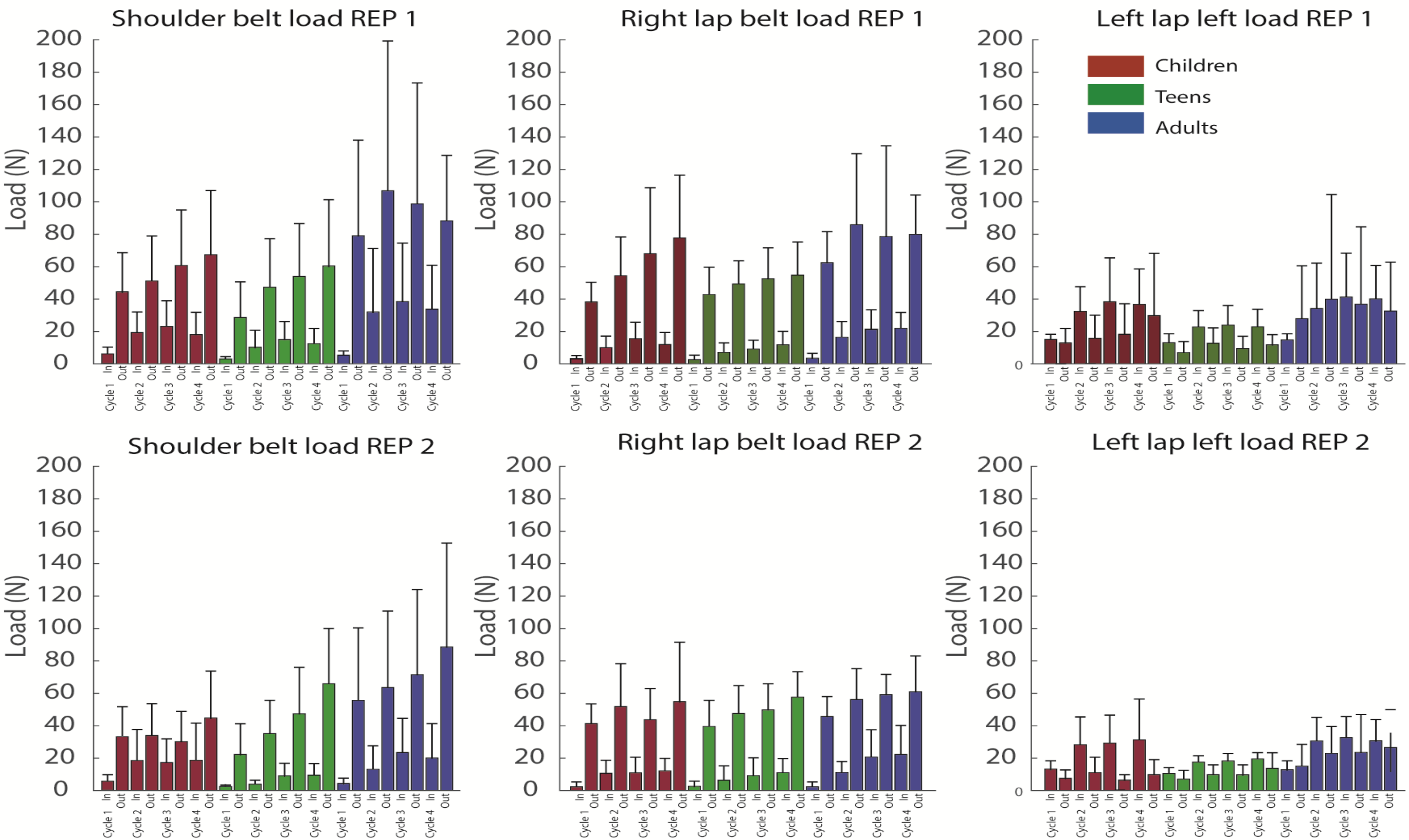


AIM 1: EFFECT OF AGE ON MUSCLE ACTIVITY (NON- BOOSTER OCCUPANTS)

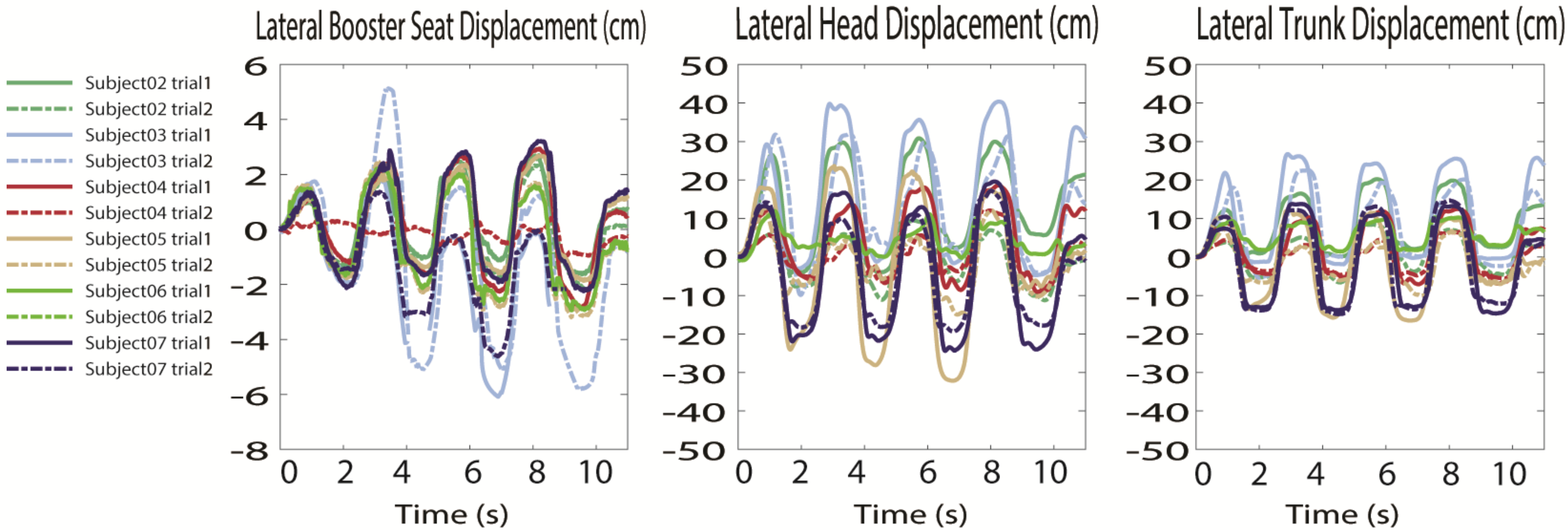


AIM 1: EFFECT OF AGE ON KINETICS

(NON- BOOSTER OCCUPANTS)



AIM 2: BOOSTER SEATED CHILDREN KINEMATICS

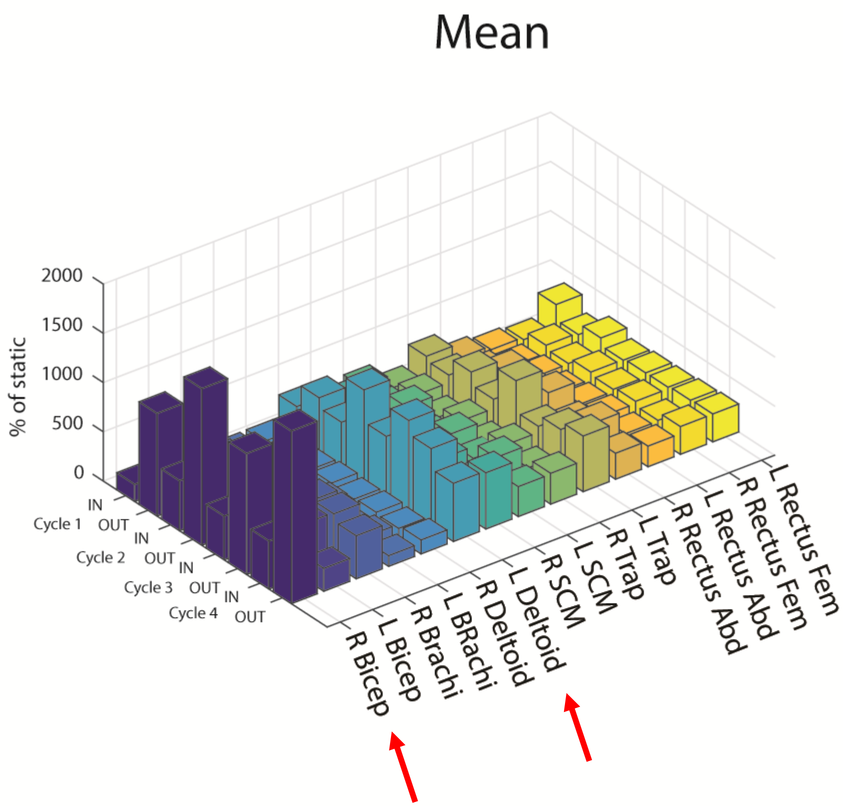


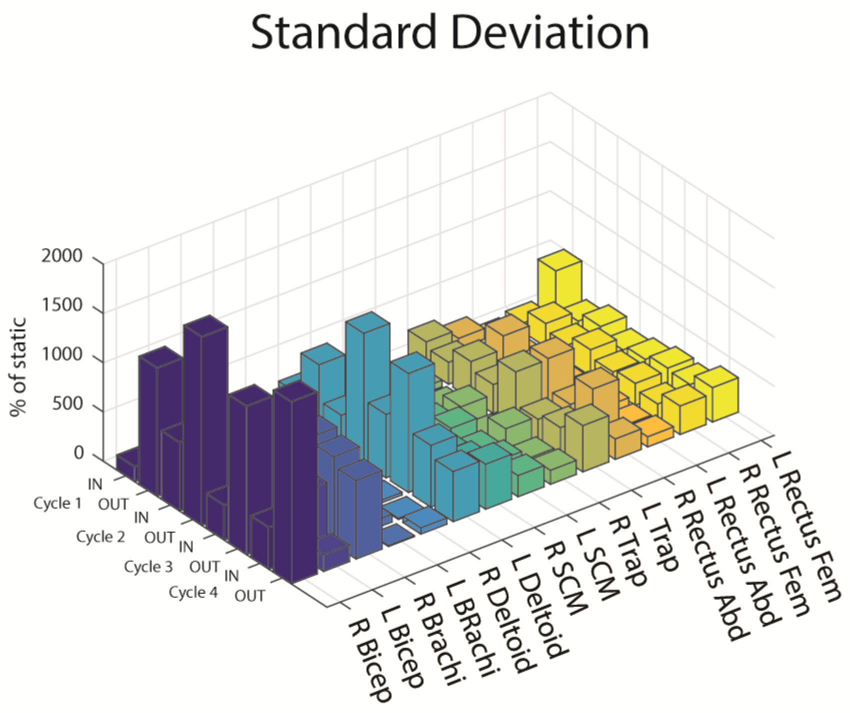
Booster seat lateral displacement:

- 1.2 -2.9 cm → 9% - 35% of head and trunk displacement and increased with cycle

Lateral head and trunk excursion decreased with cycles

AIM 2: BOOSTER SEATED CHILDREN MUSCLE ACTIVITY





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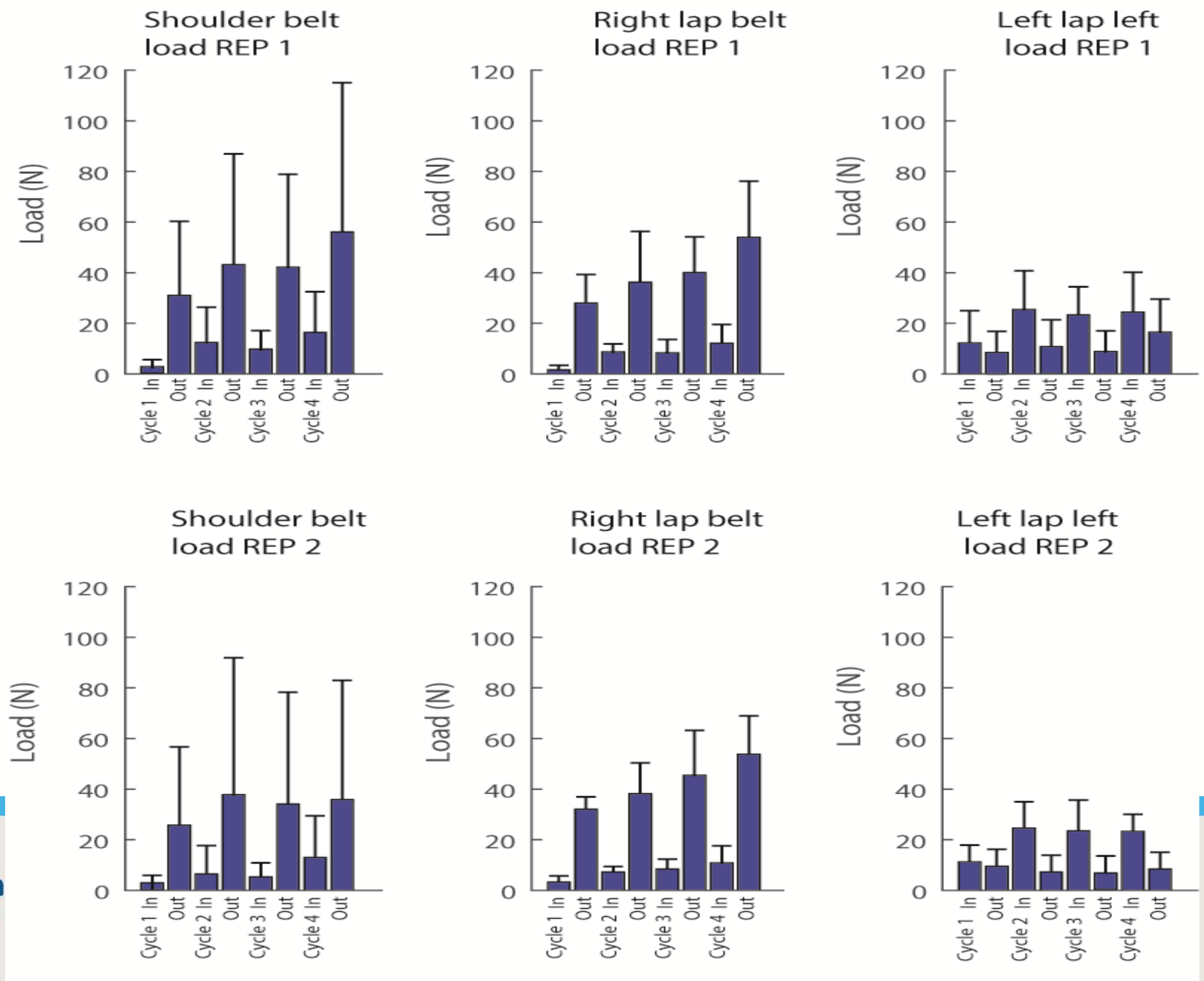
AIM 2: BOOSTER SEATED CHILDREN KINETICS



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CONCLUSIONS

- **Children → different neuromuscular control of head and trunk motion:**
  - Into the belt→ non booster children show similar muscle activation but greater head and trunk motion than adults and teens.
  - Out of the belt→ greater neck and right arm muscle activation to achieve similar head and trunk motion than adults and teens.
  - Booster children→ increased arm muscle activation over neck muscle activation
  - Booster motion→ may have contributed to head and trunk excursion
- **Neuromuscular control changed with time→ participants fine-tuned their strategy to control motion along the duration of the maneuver.**
  - Out of the belt→ some muscles show less activation over time (e.g. SCM, deltoids) and belt load increased with cycles
  - Occupant may have saved energy and relied more on the belt in the later cycles.

LIMITATIONS

- Instrumentation and test site limited naturalistic environment, and the participants were aware of which maneuver they were going to experience
  - Unaware of timing
  - Startle-like muscle activation suggests naïve responses

- "Into the belt" motion also means "into the door trim and roof line of the vehicle": since teens and adults were taller than children, their motion may have been more influenced by the vehicle geometry than the children's motion.

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THANK YOU!

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