

Methods for Assessing Passive Cervical Spine Flexion in Human Volunteers

Jami Saffioti BS², Jennifer Kadlowec PhD², Thomas Seacrist MBE¹, Sriram Balasubramanian PhD¹, Robert Sterner PhD², Kristy Arbogast PhD^{1,3}, Matthew Maltese MS¹

¹The Children's Hospital of Philadelphia, ²Rowan University, ³University of Pennsylvania School of Medicine

BACKGROUND

Head trauma is the most frequent injury sustained by children in car accidents, and the neck plays a key role in governing head kinematics during the crash. Pediatric anthropomorphic test devices (ATDs) are useful for the assessment of head injury in frontal car crashes, yet the pediatric ATD neck is a size-scaled model of the adult ATD neck, with no consideration for the tissue and morphological changes during human development. The primary objective of this study is to compare the passive cervical spine flexion of children in specific age groups with adults. The data will help guide the development and validation of pediatric cervical spine computational models.

METHODS

- Subjects with restrained torsos and lower extremities were exposed to a 1G inertial load in the posterior-to-anterior direction, such that the head-neck complex flexes when the subject relaxes their neck musculature.
- Electromyography with audio feedback was used to coach the subjects to relax their neck musculature (paraspinal, sternocleidomastoid, and trapezius muscle groups).
- A multicamera 3-D target tracking system was employed to capture the motion of specific landmarks on the head (Frankfort Plane), thoracic spine (T1 and T4), and torso (acromion processes, manubrium, and xiphoid process).
- The head vs. spine angle (i.e. neck flexion) was computed using two vectors in the sagittal plane – the vector through the Nasion and the midpoint between the left and right External Auditory Meadus (EAM), and the vector through T1 and T4.

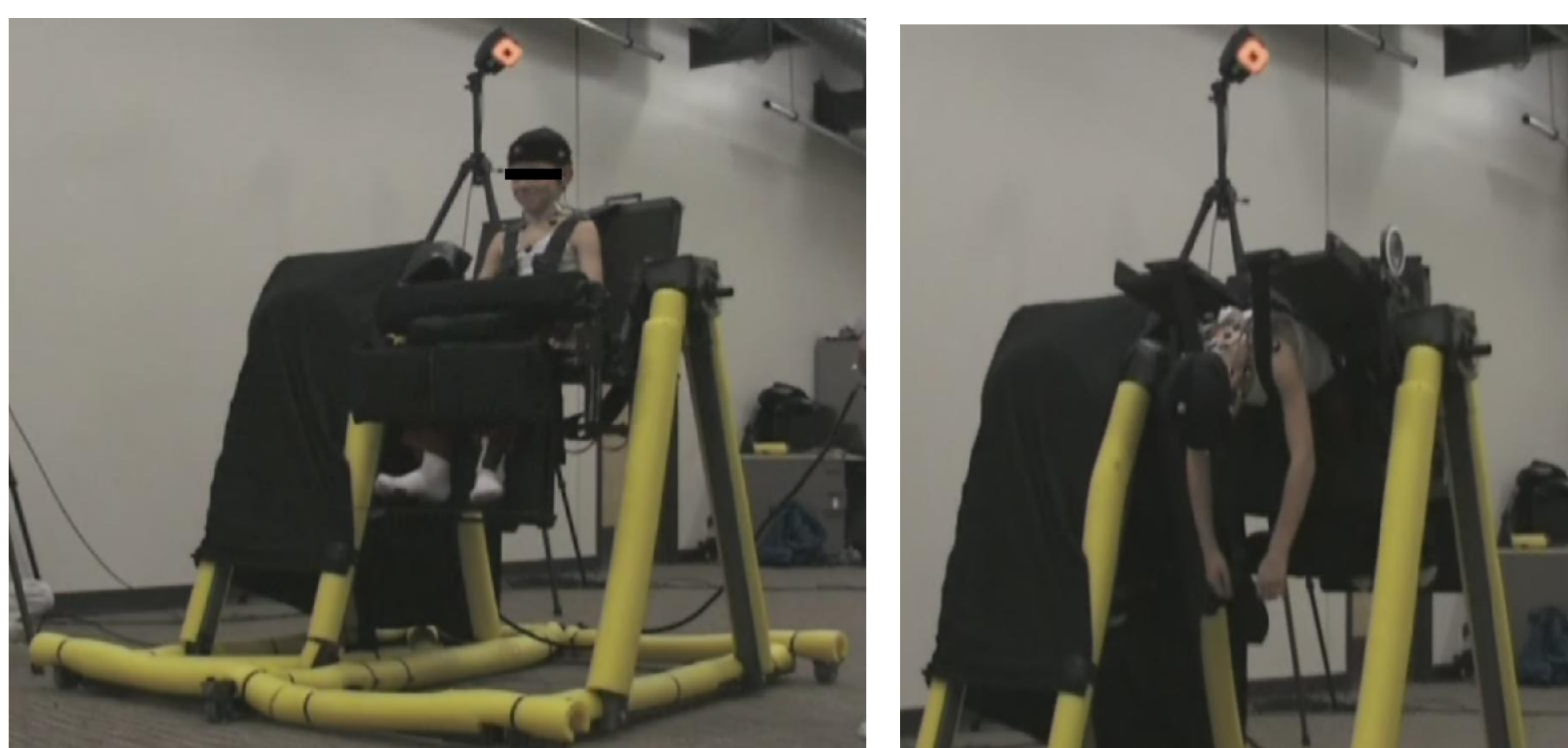


Figure 1. Pediatric subject seated in test apparatus (left) and rotated 90° with the head experiencing 1g inertial load (right).

RESULTS

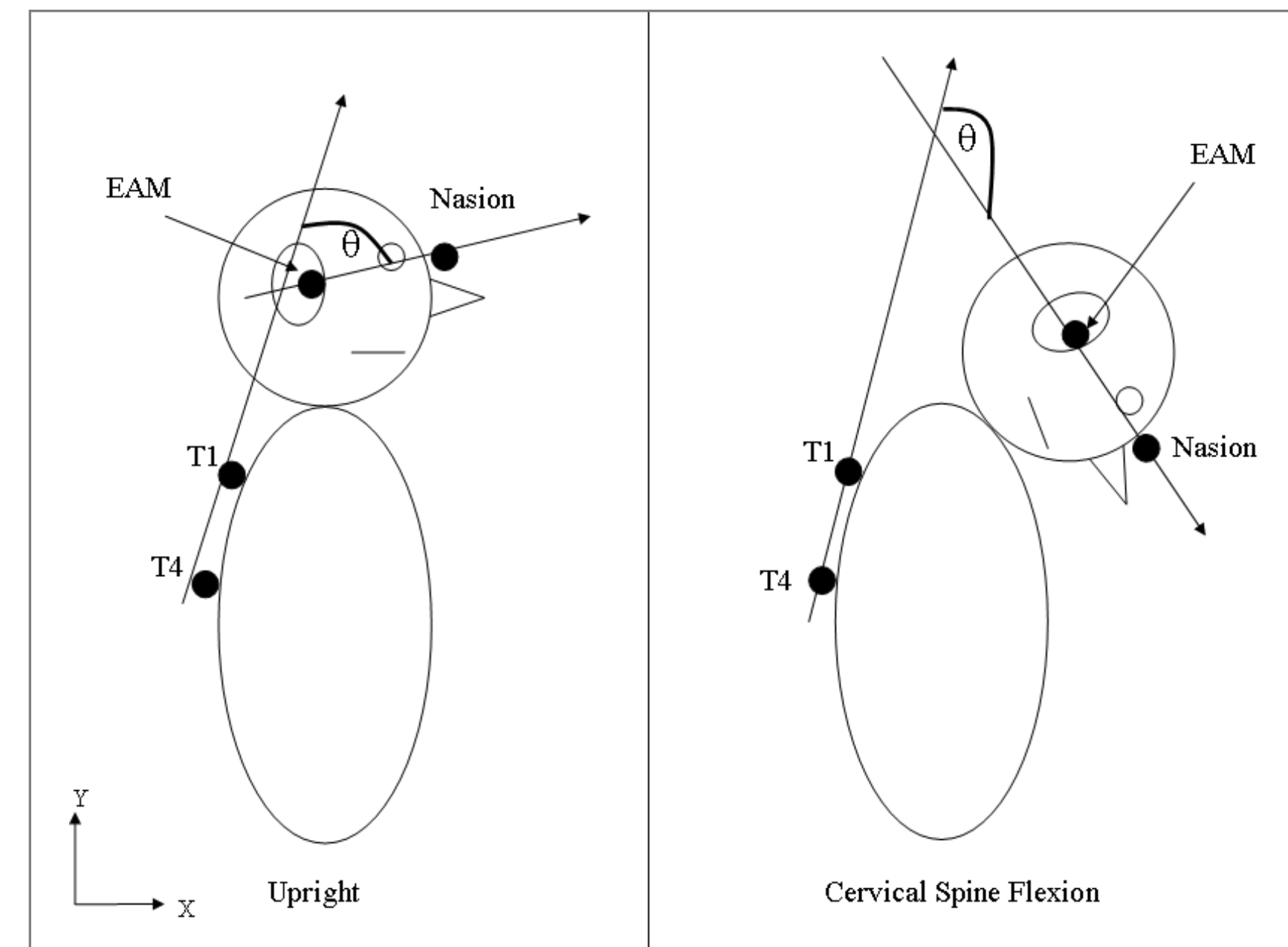


Figure 2. Method for calculating neck flexion angle. Reflective markers were placed along the Frankfort Plane (Nasion and EAM) and spine (T1 and T4).

Table 1. Subject characteristics. Head-to-Neck Ratio is the dimension ratio of the head to the neck. Neck slenderness is the neck length divided by the neck girth.

Subjects	Age	Gender	Height	Mass	Head-to-Neck Ratio			Neck Slenderness
	yrs	M/F	cm	kg	Width	Depth	Girth	
Pediatric	7	F	123	24.5	1.71	1.87	1.72	0.48
	8	F	127	21.9	1.69	2.50	2.04	0.54
	9	M	131	24.5	1.84	2.47	2.11	0.45
	9	M	134	26.8	1.67	2.16	1.87	0.42
	10	F	156	56.8	1.52	2.18	1.75	0.52
	10	M	140	29.1	1.54	2.46	1.88	0.54
12	F	135.5	39.1	1.53	2.38	1.93	0.58	
Average	9.3	M=3 F=4	135.2	31.8	1.64	2.29	1.90	0.51
Adult	20	M	170.5	72.3	1.27	1.80	1.47	0.49
	20	M	174	65.9	1.47	1.91	1.59	0.42
	21	M	176	59.1	1.48	1.93	1.56	0.50
	22	M	171	71.6	1.39	1.79	1.54	0.43
	22	F	170	56.8	1.52	2.26	1.83	0.63
	24	F	155	55.9	1.64	2.12	1.84	0.40
26	M	173	66.8	1.41	1.82	1.57	0.56	
Average	22.1	M=5 F=2	169.9	64.1	1.45	1.95	1.63	0.49

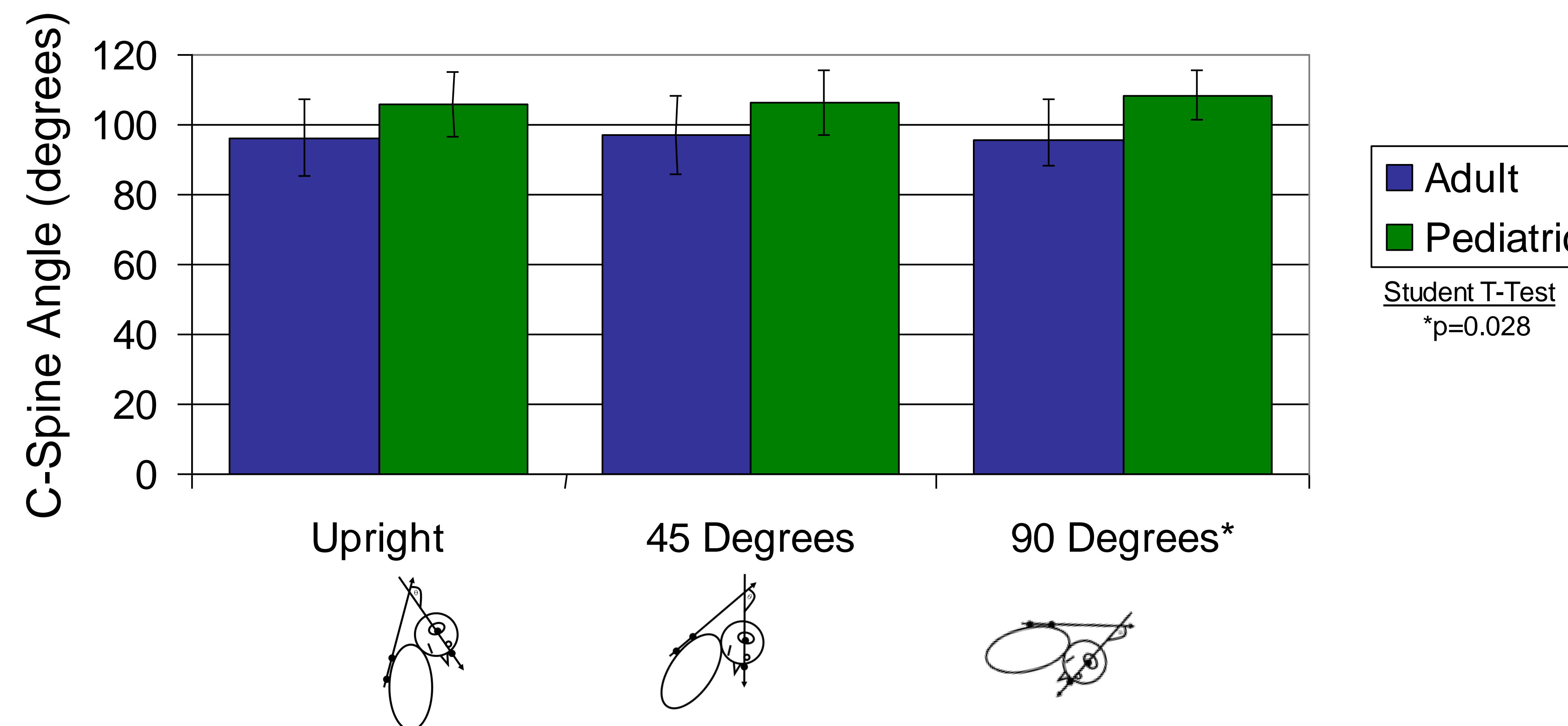


Figure 3. Average head vs. spine flexion angle of adult (n=7, age=20-23) and pediatric (n=7, age=7-12) subjects seated upright, and rotated to spine angles 45 and 90 degrees from upright. A statistically significant increase (*p<0.028) in cervical spine flexion was found in children when compared to adults using separate mixed effects linear regression models accounting for repeated measures.

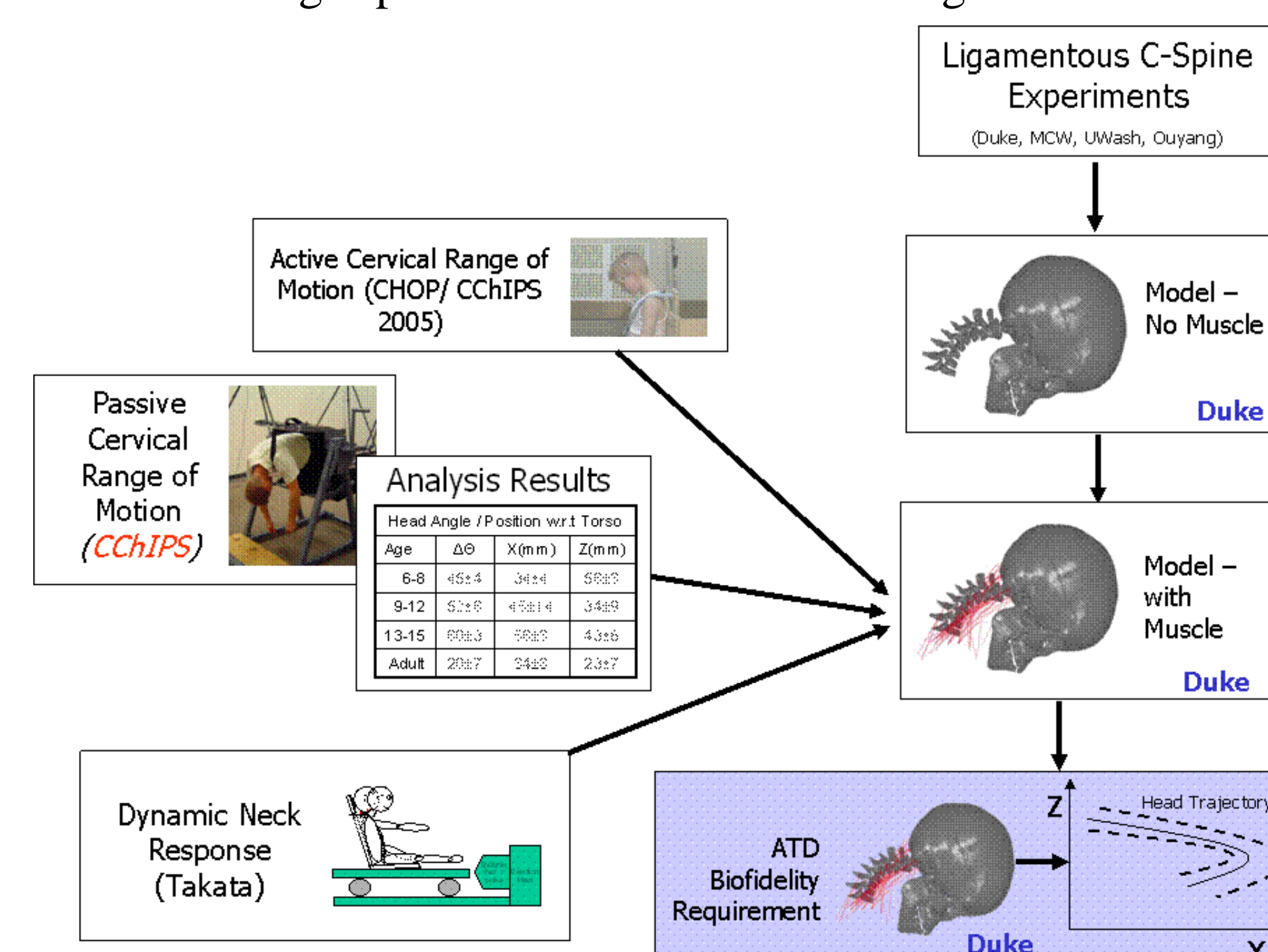


Figure 4. Cervical spine flexion data in coordination with Duke neck model.

RESULTS

- Pediatric subjects experienced significantly greater cervical spine flexion angles at 90° rotation (difference=-12.99, p=0.028).
- Pediatric subjects had larger head-to-neck width (p=0.01), depth (p<0.01), and circumference (p<0.01) ratios when compared with adults.

DISCUSSION

- Segmental cervical spine mobility decreases with age (Kasai et al (1996)).
- Larger head-to-neck ratio could produce greater deformation of passive muscle and ligament structures.
- Existing data does not clarify exactly where the flexion is occurring.

LONG TERM GOAL

Whole and functional spinal unit PMHS cervical-spine experimental data are available in the literature. However these protocols lack quantification of muscle response. Our goal is to assess the ligamentous cervical flexion in the presence of passive muscle activity, and to contribute these data as a validation set for pediatric and adult cervical-spine computational models being developed at Duke University.

FUTURE WORK

- Future research will break subjects into four groups (ages 6-8, 9-12, 20-30, 31-40 years) to study changes throughout maturation.
- The investigation will also incorporate improved measurements of C-Spine curvature to better understand the location of C-Spine flexion.

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