Duke PRATT SCHOOL of ENGINEERING

Development and validation of a 6YO pediatric neck computational model

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Duke BIOMEDICAL ENGINEERING

Background

- Leading cause of adolescent death is motor vehicle crashes (Fig. 1).
- Neck and back are most prone to injury in motor vehicle crashes.
- Pediatric necks differ in response to accelerations compared with adult necks (Fig. 2).
  - Weaker musculature, smaller size, more porous bone
- Computational modeling provides inexpensive and efficient method of analyzing response to accelerations.
  - Focus generally given to adult neck
- Urgent need for 6YO neck computational model.

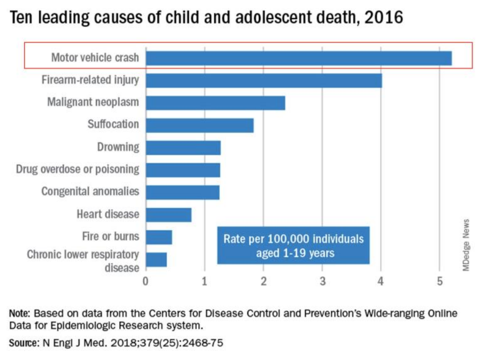


Fig 1. Leading causes of adolescent death table

Fig 2. Comparisons of pediatric (left two panels) and adult (right two panels) radiographs

Materials and Methods

- Developed model corridors as objective metrics for tension, compression, flexion/extension based on literature data
- Included model corridors developed from experiments by the Children's Hospital of Philadelphia (CHOP) and Naval Biodynamics Laboratory (NBDL)
- Designed several initial concepts for neck models (see Iterations) in CAD
- Created meshed models from CAD in LS-PrePost
- Ran CAD designs against corridors and tests to validate optimal performance using MATLAB and LS-DYNA programs
- Performed iterations on material and design features to arrive at final design

Objective Rating Metrics

Models were scored using two calculations:

1. Fraction of curve inside corridor / normalized cross correlation (Tension, compression, flexion, extension, head lag, , head cg, rotation velocity)
2. Extrema location (Flexion, extension, NBDL (z vs x, CGx, CGz), CHOP (EAMx, EAMz, NASX, NASz))

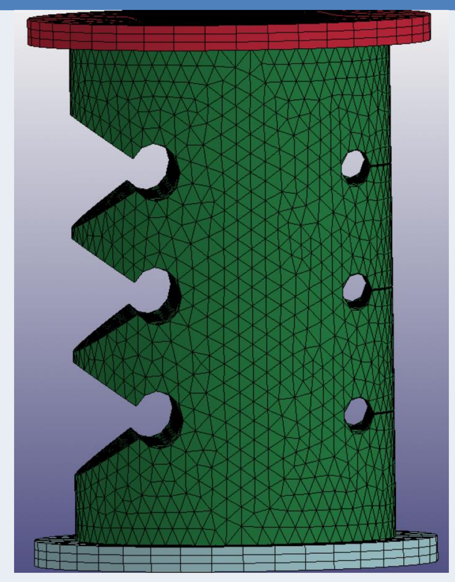
Overall scores were calculated as a weighted average of individual scores

Test	Tension/ Compression		Bending		NBDL		CHOP	
	Tension	0.1	Flexion	0.067	CGx	0.05	EAMx	0.0375
	Compression	0.1	Extension	0.067	CGz	0.05	EAMz	0.0375
			Extension Angle	0.067	Head x vs.z	0.05	NASx	0.0375
					Head Lag	0.15	NASz	0.0375
							Rot. Vel.	0.15
Total Weight		0.2		0.2		0.3		0.3

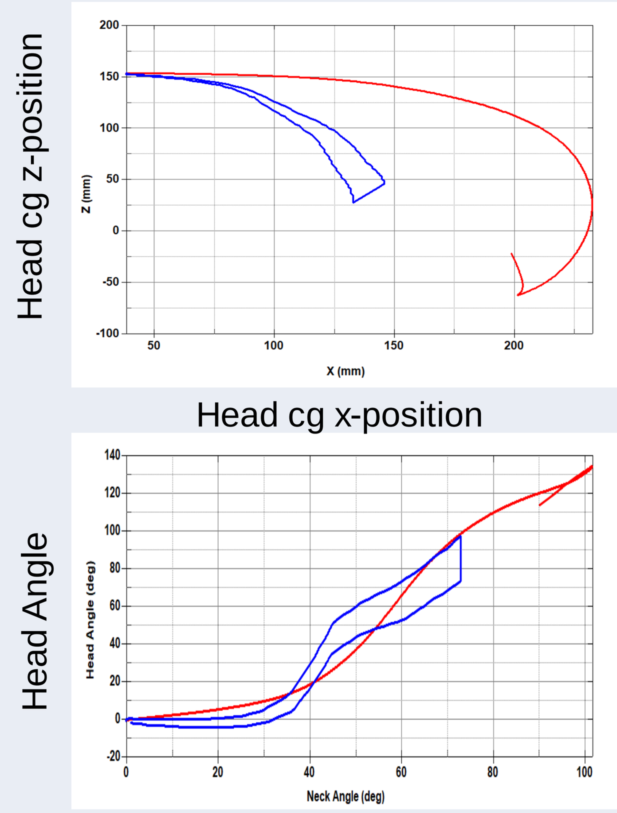
Iterations/Components

In total, we performed 53 iterations to arrive at our final design. Presented here are a few key designs that represent our priorities in design performance.

Hybrid III 6YO Model



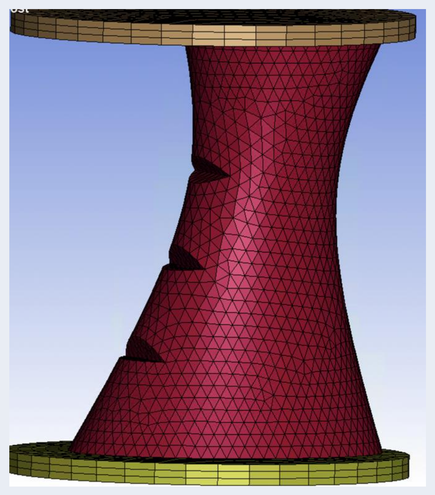
Key Results



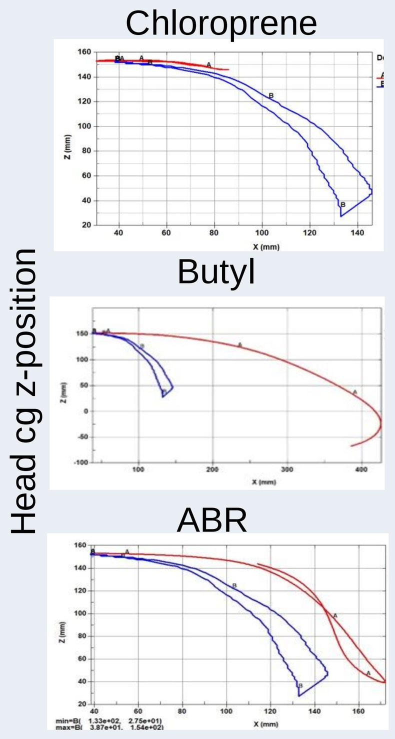
Key Features:
- Material: butyl rubber
- Slits and holes enable varied responses in flexion/extension
- Cylinder enhances uniform tension/compression response
- Current Industry Standard

Conclusion: Hybrid III model fails to accurately predict neck response.

Design A



Key Results



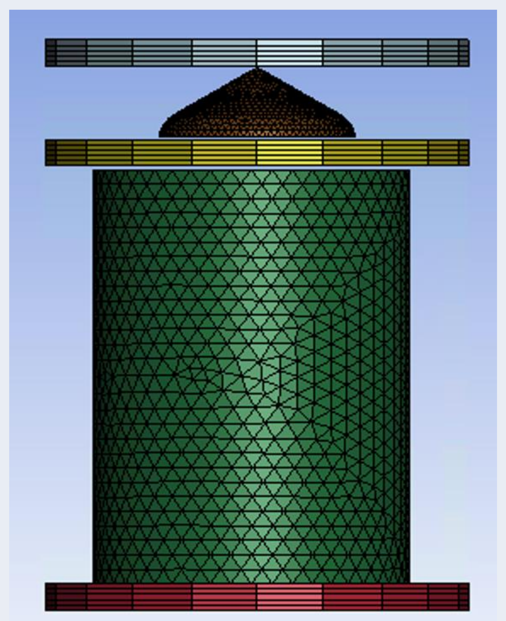
Conclusions
- Butyl rubber (currently used in Hybrid III) is too lax to approximate neck response
- Chloroprene rubber is far too stiff, leaves no room for iteration
- ABR rubber closely mimics neck response

Next Steps
- Decouple different responses (tension/compression, head/neck movement)

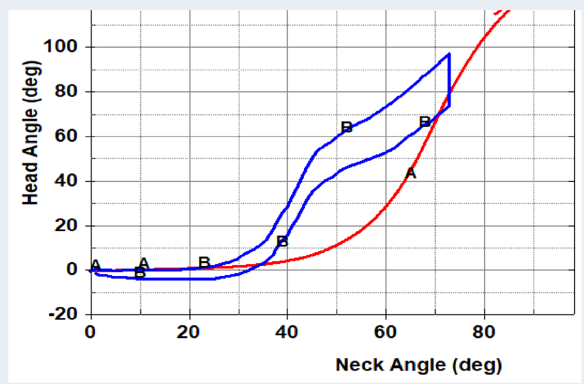
Key Features
- Materials: butyl rubber, chloroprene, ABR rubber
- Goal: Determine optimal material

Conclusion: ABR will be used in future iterations.

Design B



Key Results



Key features
- Revolute joint
- Top plate rubber stopper
- Basic cylinder neck
- Goal: decouple head and neck to delay head rotation

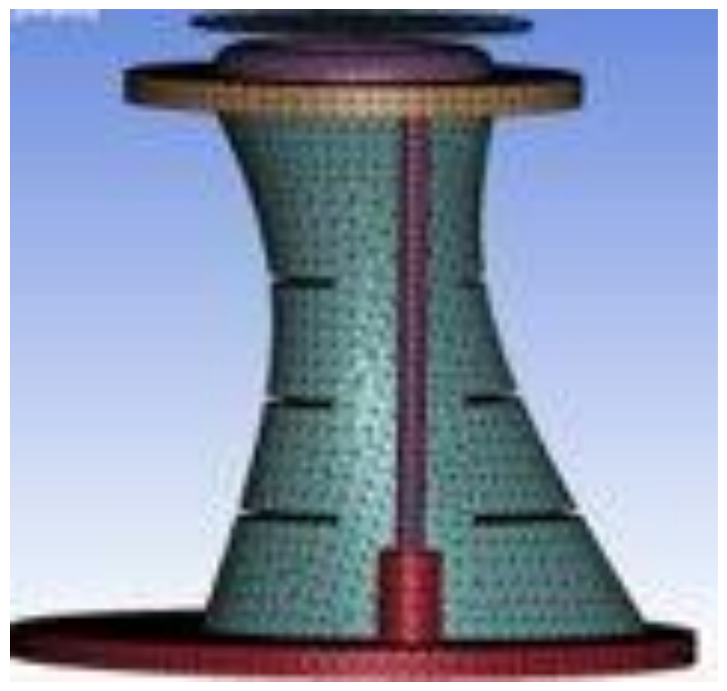
Conclusions
- Revolute joint delays head rotation, improves response in high g-force acceleration

Neck Steps
- Combine revolute joint with tapered, asymmetric neck
- Iterate shape and dimensions of top plate stopper to improve head rotation time and speed

Conclusion: Use of a revolute join improves head-neck decoupling.

Final Design & Results

Test	Score
Tension	99
Compression	99
Flexion	71
Extension	15
Extension Angle	100
NBDLx	100
NBDLz	100
Head lag	18
EAMx	99
EAMz	100
NASx	98
NASz	100
Rot vel	4

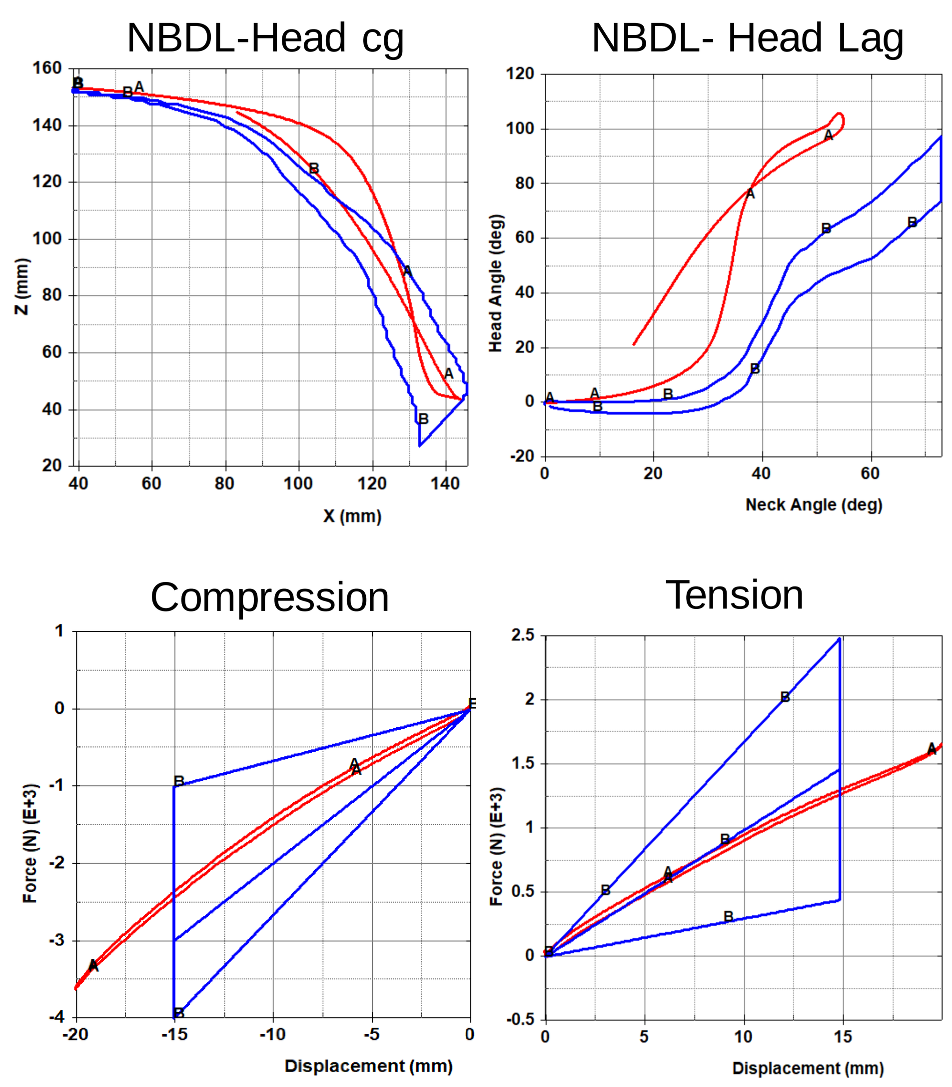


Objective Metric Scores for Hybrid III vs Our Model

Hybrid III	Our Model
20.4	63.8

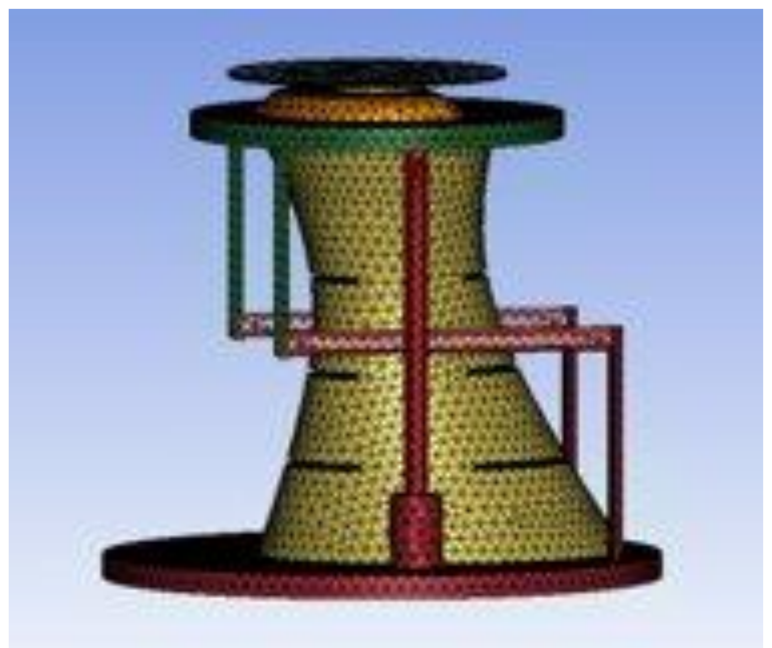
Discussion

- Our model outperforms the industry standard model, Hybrid III.
- Our model shows significant improvements in tensile and compressive responses.
- Our model closely approximates the head-neck response during high acceleration (NBDL) tests.



Future Work

- Further improve head CG response with use of transverse cables (right)
- Iterate top plate bumper dimensions to modulate head rotation timing
- Perfect flexion and extension response
- Remove excessive material from plates



Acknowledgements

We would like to thank Dr. Jason Luck and Josue Nataren Moran for their help and support for the duration of this project.