The Efficacy of a Motocross Neck Brace in Reducing Injury

Deepak Sathyanarayan[1], Roger Nightingale[2], Colin Ballantyne[3], Matthew B. Panzer[1]

[1]University of Virginia, Charlottesville, VA; [2]Duke University, Durham, NC; [3]Alpinestars Europe, Inc., Asolo Italy

Introduction

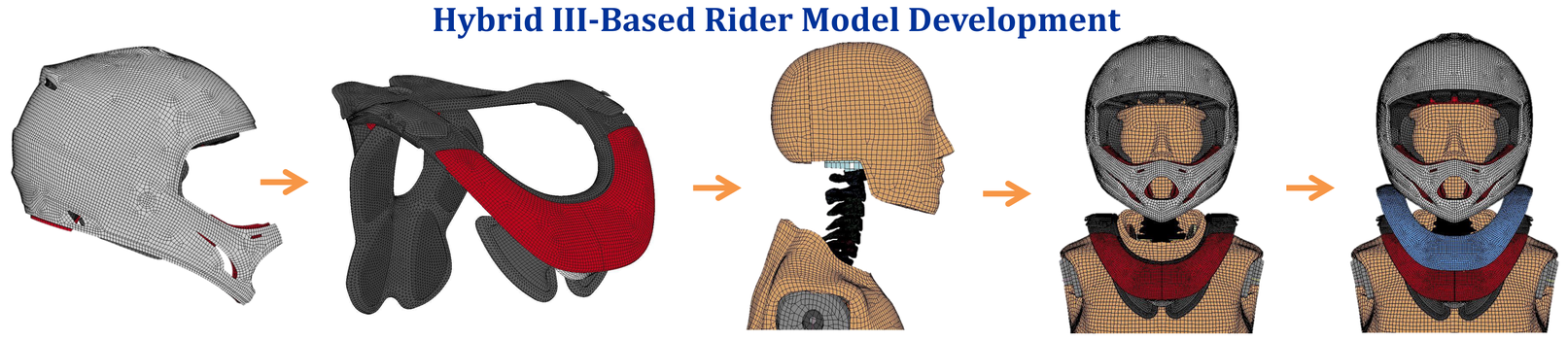
- Cervical spine fracture account for nearly 10% of all injuries to motocross riders in a crash [1].
- Neck braces have been designed and marketed as a countermeasure for neck injury during an impact. However, there is little biomechanical research that would support claims that cervical spine injuries can be reduced when equipped with a neck brace.
- Finite Element (FE) methods can be used to assess baseline neck injury risk, as well as efficacy of neck braces in reducing cervical spine injury over a range of impact conditions.

Objectives

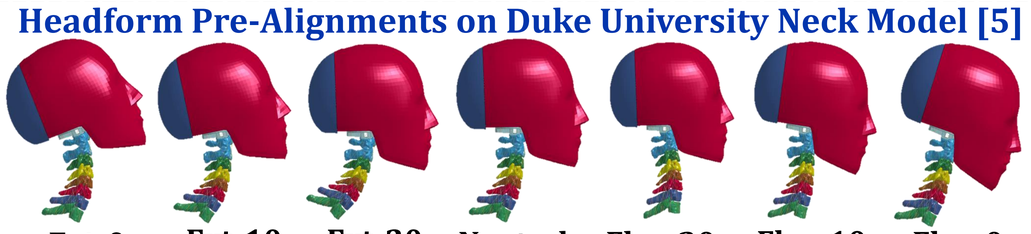
1. Develop and validate an integrated FE model of production motocross helmet and neck brace.
2. Investigate neck brace efficacy in reducing cervical spine injury following helmeted head impact.
3. Identify and address limitations in current neck brace designs by investigating modified designs for improved neck injury performance.
4. Conduct parametric shoulder and torso compliance analysis on modified brace design.

Methods

Hybrid III-Based Rider Model Development

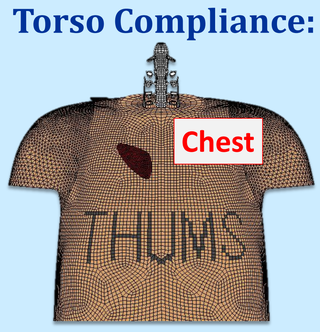


Headform Pre-Alignments on Duke University Neck Model [5]



Ext_0	Ext_10	Ext_20	Neutral	Flex_20	Flex_10	Flex_0
T1: 0°	T1: 10 °	T1: 20 °	T1: 0 °	T1: -20 °	T1: -10 °	T1: 0 °
O-C2: -20°	O-C2: -10°	O-C2: 0°	O-C2: 0°	O-C2: 0°	O-C2: 10°	O-C2: 20°

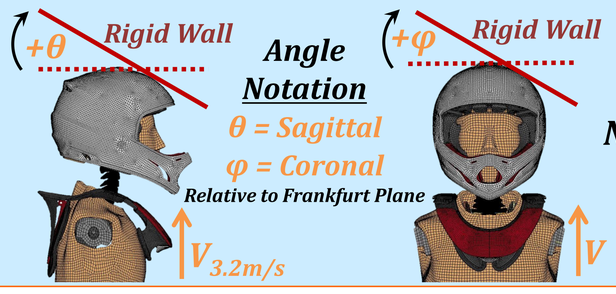
Torso Compliance: *THUMS V4.0_Ped*



Compliant Regions

- Chest
- Shoulder
- Upper Back
- Lower Back

Headform Impact Angles



Neck Injury Criteria (Nijc)

$$Nijc = \max\left[\frac{Fz(t)}{Fz_{critical}} + \frac{My(t)}{My_{critical}}\right]$$

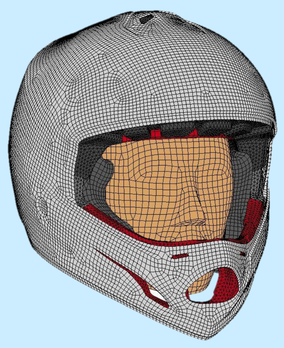
- *Nijc > 1.0 at any point in time indicates cervical spine injury.*

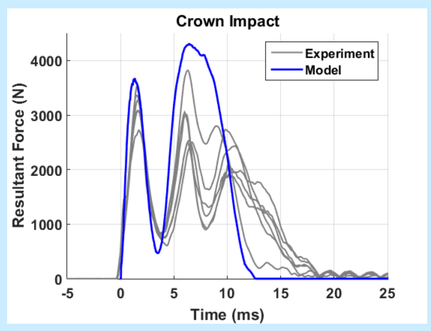
Critical Values	Joint	
Parameter	O-C2	C7-T1
Tension	2520 N	2700 N
Compression	3050 N	3050 N
Flexion	39 Nm	24.2 Nm
Extension	49.5 Nm	28.6 Nm
References	2, 4, 5	3, 6

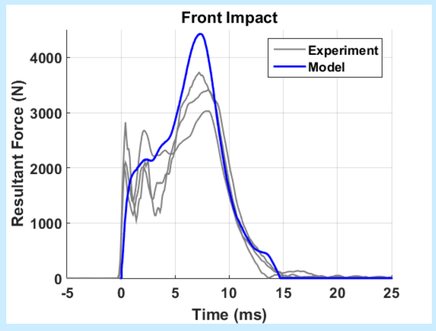
Results

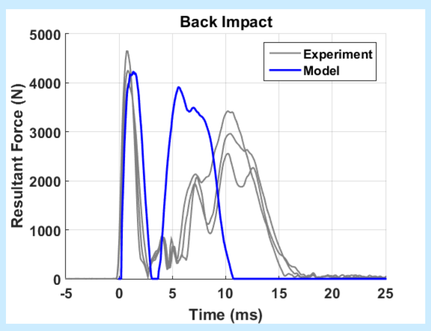
Phase 1

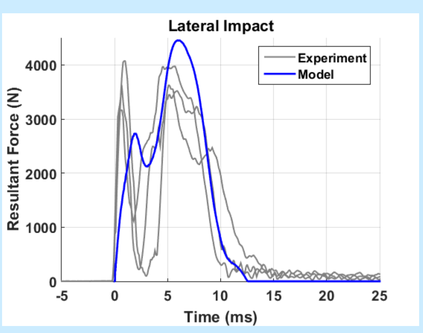
Helmeted-Headform Drop Tests *With 3.2 m/s Impact*





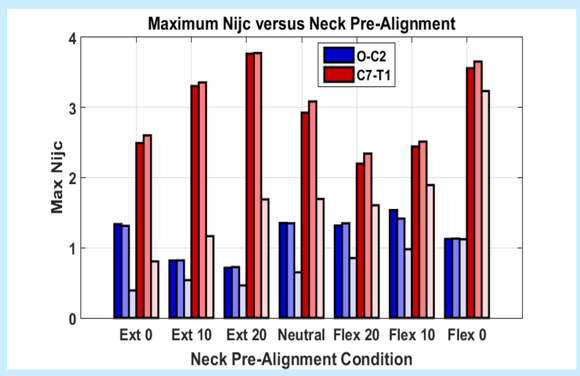


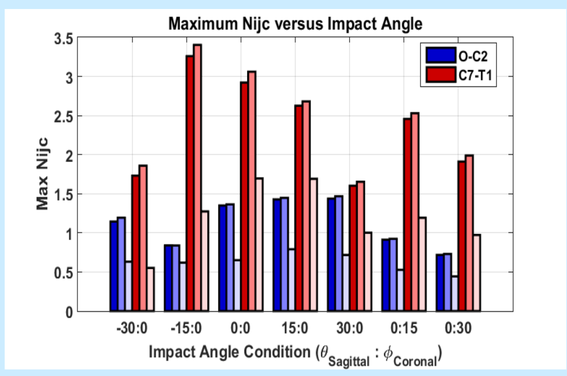




Phase 2

Helmeted-Rider Impact Models *With Modified Neck Brace*

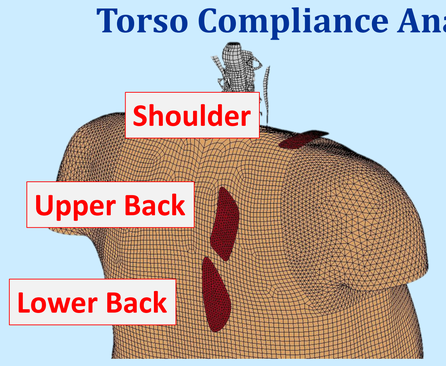




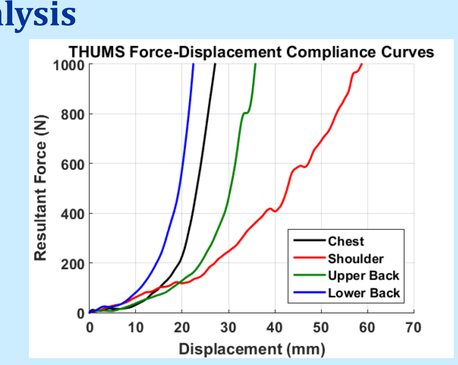
Dark = No Brace ***Moderate = Production Brace*** ***Light = Modified Brace***

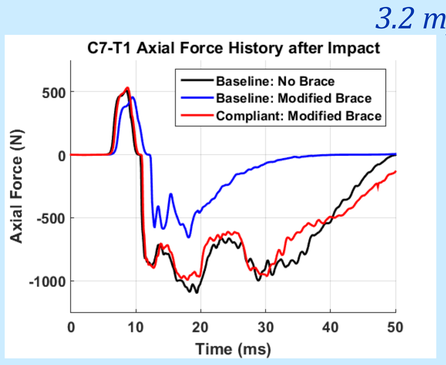
Phase 3

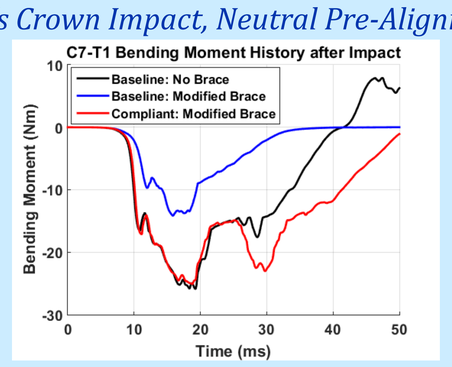
Torso Compliance Analysis

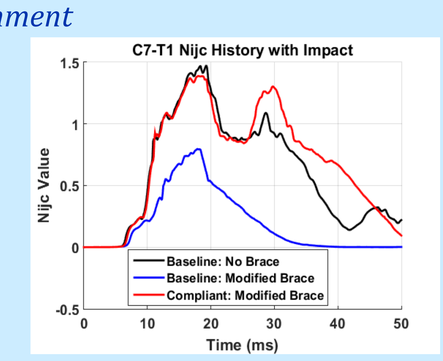


3.2 m/s Crown Impact, Neutral Pre-Alignment









Discussion

- From the impact conditions tested, substantial neck injury risk (Nijc > 1) was predicted for all non-brace extension and flexion cases at C7-T1 within 10ms of impact, as well as instances of O-C2 injury in all neutral and flexion cases.
- No risk reduction for compression-related injuries was observed with production neck brace implementation relative to no brace controls. Lack of improvement was attributed to the standoff distance between the brace and the helmet (~50mm) being greater than the amount of neck compression at the time of injury.
- Standoff reduction, as in the modified neck brace, showed moderate decreases in injury risk in most impact cases relative to the no brace controls by promoting brace-to-helmet interaction and distributing the impact force to the rider's shoulders and torso.
- Parametric torso compliance results indicated that shoulder compliance reduced any benefit of a fully-engaged neck brace, however more biofidelic shoulder and torso compliance models must be developed for accurate predictions of cervical spine loading and torso deformations during impact.

Acknowledgements

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References

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University of Virginia – Center for Applied Biomechanics

Deepak Sathyanarayan
ds7rs@virginia.edu