Influences of Neck Muscle Strength and Damping on Brain Axonal Injuries Under Traumatic Head Impacts

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Background

Existing Traumatic brain injury (TBI) models lack a unified framework capable of simulating diverse head insults and quantifying the resulting axonal tissue deformation, which is essential for a mechanistic understanding and prediction of diffuse axonal injury across injury scenarios commonly seen in military, sports, recreational activities, and adult falls.

Significance: This study presents a multiscale brain model that unifies a DTI-derived axonal tract model and a validated brain solid model, integrated into a head-neck FE model. Together, this modeling framework can facilitate tissue-level TBI assessment and management for various injury scenarios.

Goal: Evaluate how neck muscle strength and neck damping affect regional brain axonal strain under focal and diffuse military-relevant loading conditions.

Methods

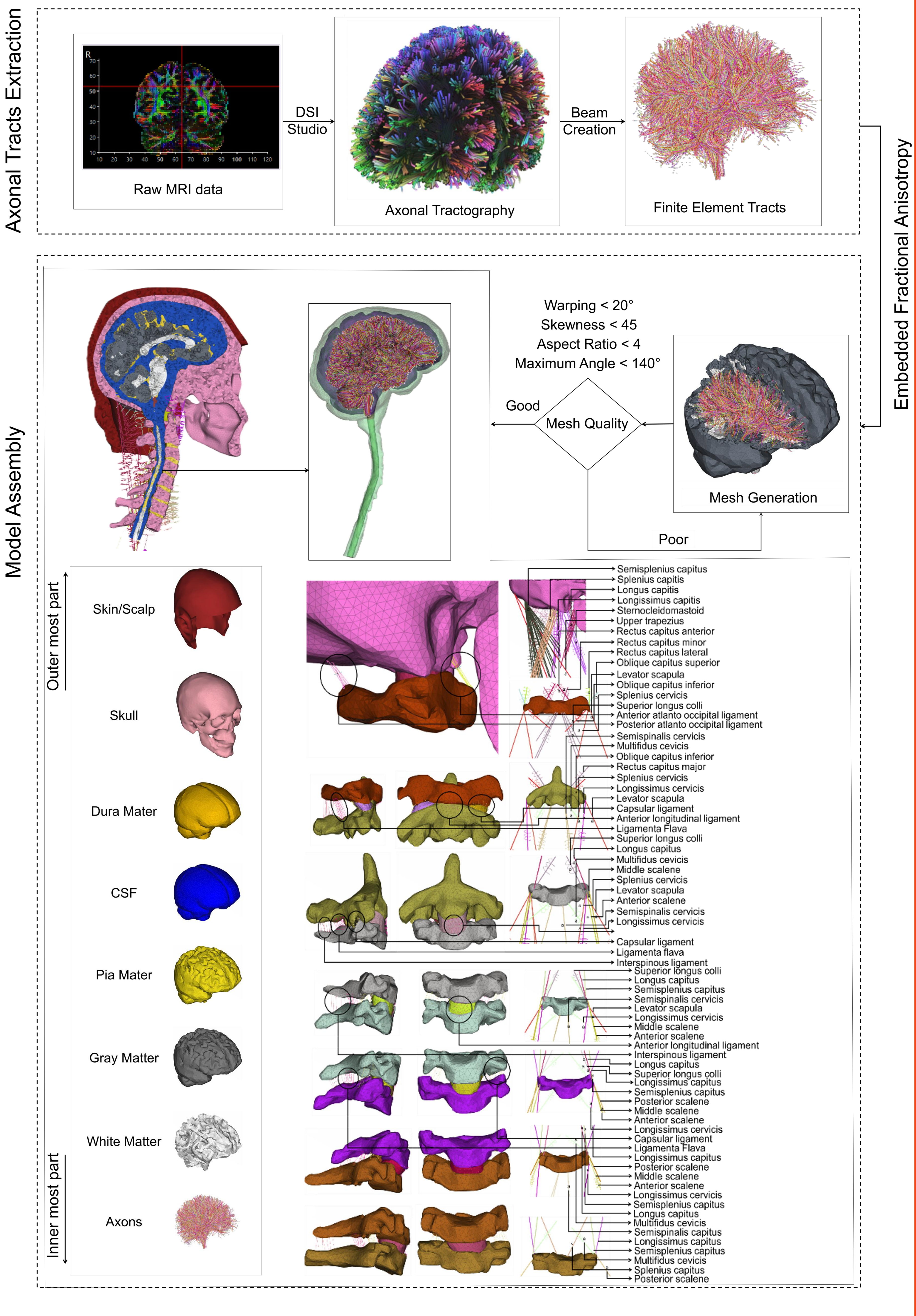

Fig 1: Subject-specific MRI data was used to segment head, brain, and cervical spine structures and generate a detailed head-neck finite element model.

- ❑ A validated MRI-derived head-neck finite element model was used to simulate focal and diffuse impact loading (Fig. 1) [1]. The model included detailed head and cervical anatomy, including the brain, skull, CSF, meninges, cervical vertebrae, intervertebral discs, spinal cord, 42 neck muscles, and 14 ligaments.
- ❑ DTI-based tractography was used to reconstruct white matter fiber pathways (Fig. 1). Two loading conditions were simulated: a 7000 N frontal impact representing focal loading [2] and a 15 g high-acceleration pulse [3] representing diffuse head loading.

Results

- ❑ Increasing neck muscle strength from the 25th to the 95th percentile reduced regional axonal strain by approximately 22% on average across both loading conditions.
- ❑ Increasing neck damping from the 25th to the 95th percentile reduced regional axonal strain by approximately 34% on average, producing greater reductions than muscle strength.

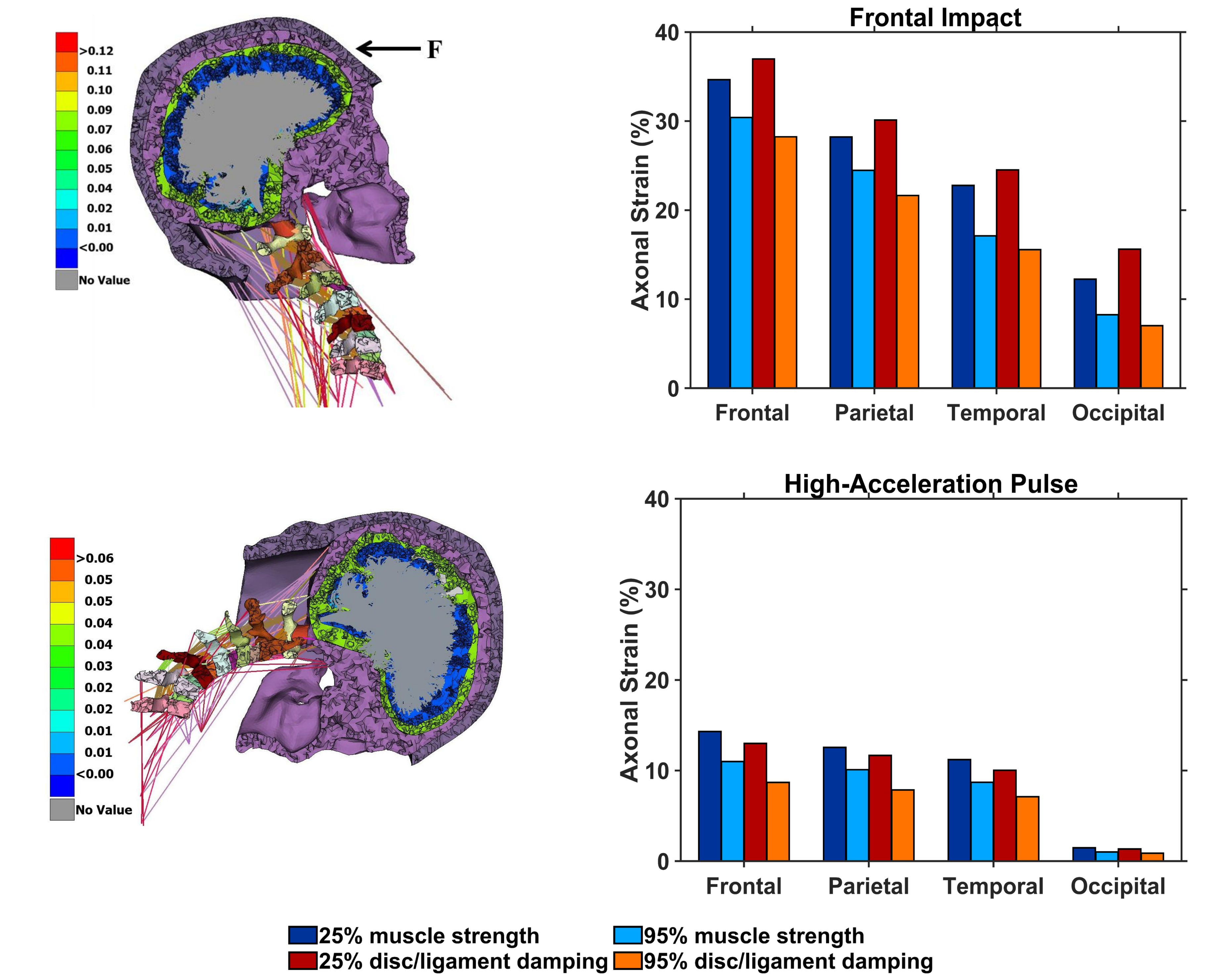

Fig. 2: Regional maximum axonal strain under frontal impact and high-acceleration pulse loading. Increasing neck muscle strength and disc/ligament damping from the 25th to 95th percentile reduced axonal strain across all brain regions, with the largest strains observed in the frontal and parietal regions.

Conclusion

- ❑ Damping from neck soft tissues and neck muscle strength can influence brain injury mechanism
- ❑ This framework can support localized TBI risk assessments, evaluations of head/brain protective devices, and strategies to reduce TBI burden in military-related head insults.

Acknowledgments

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References

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