Validation of a Custom Head Fixture for Pediatric Cervical Spine Strength and Stiffness Assessment

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Objective: Pediatric cervical spine injuries (CSI) account for roughly 10% of all CSI across all age groups[1–3]. Anatomical differences in children may account for this increased vulnerability to CSI[1,4]. The broad objective of this research is to quantify biomechanical responses of the cervical spine (c-spine) in children 5–7 years old to aid and improve the biofidelity of pediatric human body models (HBM) and anthropomorphic test devices (ATD). However, this task is not possible without the development of a custom fixture that allows the quantification of c-spine biomechanics. This study is focused on the validation of a custom head fixture to quantify c-spine biomechanics.

Methods: A custom head fixture was designed and machined as an attachment to a Biodex Isokinetic Dynamometer, to be used to quantify c-spine strength and stiffness of pediatric volunteers. Validation of the fixture was performed in two phases, Phase I: mechanical validation and Phase II: volunteer validation. Phase I assessed artifact interference, adequate load distribution, and repeatability. The variables were assessed by comparing outputs of the fixture to outputs of a geometrically similar manufacturer provided attachment. For this phase, the fixture was tested in 'worst-case' test scenarios. These scenarios involved testing at a higher speed and a larger range of motion than the volunteer protocol.

Phase II focused on fixture validation with an adult cohort and evaluated the effects of attachment fit and measurement accuracy. Effects of attachment fit were evaluated for user self-selected loose and snug helmet fits. Measurement accuracy was determined by comparing measurement outputs to data available in literature[5,6]. Prior to testing, surface electromyography (sEMG) were placed bilaterally on the sternocleidomastoid and trapezius muscles. For both validations, isometric strength measurements were collected at 0° and ±30° in the anterior-posterior (AP) and lateral directions and used to calculate maximum voluntary isometric contractions. Stiffness measurements were quantified passively at 5°/s (with no effort) and dynamically at 30°/s (with maximum effort). Subject's efforts during testing were quantified using sEMG.

Results: Phase I results demonstrate that during 'worst-case' scenarios the fixture only showed artifact interference at end of motion for all directions. Repeatable measurements showed negligible peak torque differences on measurements regardless of chosen equipment sensitivity.

Two female volunteers have participated in Phase II thus far. Three additional subjects are scheduled to complete this phase of validation. Current results demonstrate that a snug helmet fit resulted in less relative motion of the head in both the lateral and AP directions. Preliminarily, a snug fitting helmet resulted in slightly higher, but negligible, peak torques. Helmet fit did not result in any major differences on muscle activation.

Conclusions: The custom head fixture produces consistent and repeatable data outputs. While there is a little more volunteer data to collect, if these trends remain the fixture is ready to be used to quantify pediatric c-spine strength and stiffness. With these new data, we will help bridge the gap of knowledge in the pediatric biomechanics field and begin to improve the biofidelity of the current pediatric HBMs and ATDs.

References

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