COMPRESSIVE MECHANICS OF THE MATURING HUMAN SPINE

David J. Nuckley, Eno M. Yliniemi , Amy M. Cohen, Richard M. Harrington and Randal P. Ching
Applied Biomechanics Laboratory, University of Washington, Seattle, Washington,
e-mail: dnuckley@u.washington.edu, website: http://depts.washington.edu/uwabl/

INTRODUCTION

Child neck injury is a devastating trauma outcome with fatal or life-long debilitating consequences. Although spinal injuries to the pediatric populace account for less than 15% of all spine injuries, their subsequent fatality and spinal cord injury rates eclipse those of the adult population. Despite the devastating socioeconomic sequelae from pediatric neck injuries, the biomechanical characterization of neck properties and injury thresholds remains incomplete, hindering progress on advanced child neck injury prevention strategies.

Therefore, over the past five years our research team has been committed to measuring and documenting mechanical properties and injury tolerance of the cervical spine as a function of developmental age. Due to limited pediatric human tissues, this research has been performed using a baboon model (Papio anubis). A few biomechanical studies have demonstrated a correlation between baboon and human tissues with a scaling ratio of 0.70 : 1.0.[1-3] The current study was designed to understand the compressive properties of human pediatric tissues and relate them to data collected for the baboon model. Thus, we aimed to validate our baboon model and understand the compressive mechanics of the human spine throughout maturation.

METHODS

This research effort involved the biomechanical testing of eleven (11) human cadaver cervical spines across the developmental spectrum (2-to-28 years old). These specimens were dissected into 2-FSU constructs (C3-C5), wired, and embedded in PMMA for compression experimentation (Fig.1). The constructs were preconditioned and tested non-destructively up to 75% body weight in compression using a servohydraulic loading frame (MTS, Eden Praire, MN). Three loading rates were investigated: 0.1, 1.0, and 10-mm/sec and the load-displacement data were collected at 200-Hz. The stiffness was measured as the slope of the linear portion of the load-displacement curve. This protocol mimics the algorithm previously used to test our baboon specimens.[4]

Figure 1: Human Cervical Spine C3-C5 Segments Prepared for Testing. A 5-year old (left) and 18-year old (right) are shown wired on top and embedded in PMMA for testing (bottom).

RESULTS AND DISCUSSION

The human cervical spine compressive stiffness increased with spinal maturation and consistently exhibited greater values throughout development compared to baboon constructs (Fig.2). The baboon data were fit with a 2nd order polynomial growth curve which was then shifted upwards to examine its ability to model the human response. The optimal y-intercept was found using a least-squares iteration method. The human cervical spine stiffness data were found to closely match the shifted baboon growth trajectory (r^2 =0.925).

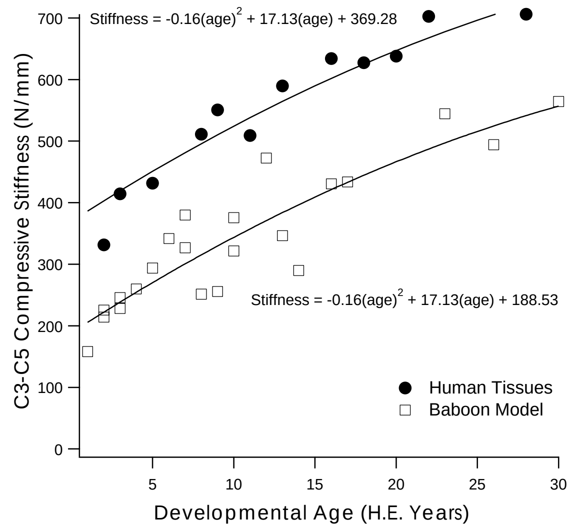

Figure 2: Compressive Stiffness of Human and Baboon C3-C5. Baboon data was fit with a 2nd order polynomial. The human data fits this shifted baboon curve (r^2=0.925).

These human cervical spine biomechanical stiffness data, the first of their kind, demonstrate an increase over baboon spinal stiffness similar to that previously reported in the literature. This relationship provides strong confidence in our baboon model and our ability to scale its spinal mechanics to humans.

CONCLUSIONS

Neck compressive stiffness significantly increased with child development and was found to follow a similar growth trajectory as baboon data. Together, these data facilitate our use of the baboon model for the establishment of child neck safety criteria and the development and analysis of advanced safety systems on playgrounds, for sports, and in automobiles.

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