Quantified Segmental Geometry and Curvature of Women-Specific Neck Muscles: Upright MRI Study

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I. INTRODUCTION

Recent studies have shown that spine geometries of seated men and women are different [1, 2]. Specifically, in women, forward angulation of the cervicothoracic junction and lordotic curvature of the neck are lesser, while the sacrum slope and lordosis of the lumbosacral spine are greater than men. Biomechanical studies have shown that geometry/posture influences injuries, injury mechanisms, and injury tolerances [2]. In other words, the load carrying capacity of the human vertebral column is dependent on posture and region of the spine. Another factor that influences internal load-sharing is the stability offered by the surrounding musculature. While automotive occupants do not wear headgear, riders of two-wheelers wear protective devices. Prolonged use of these devices induces morphometric alterations in the paraspinal musculature and may lead to pain [3-5]. Military personnel wear dedicated helmets and head-mounted devices, known as head supported mass, HSM, for prolonged periods of time and for routine operational activities. The extracranial mass places additional demand on the head-neck complex including the musculature and the osteoligamentous column. Increased prevalence of neck pain and spondylosis is attributed to the prolonged use of HSM [6, 7]. The overall aims of this study are to determine the effects of HSM on musculature and spine loads. Specifically, the present investigation was designed to quantify morphometric alterations in cervical flexor/extensor muscles, specifically the sternocleidomastoid and multifidus, at segment-specific levels and cervical curvature with HSM using upright Magnetic Resonance Imaging (MRI).

II. METHODS

The study was approved by the Institutional Review Board of the Medical College of Wisconsin and the United States Department of Defense. Young healthy female volunteers were recruited. Demographic factors such as age, stature, total body mass, head length, and head circumference were recorded. The subjects were donned with a military helmet. T1 and T2-weighted MRIs were obtained in a neutral sitting position in an upright scanner. All scans were done at the beginning of the day. The mass of the head was calculated based on the head circumference of the specific subject and according to literature [8]. The subjects were instructed to wear the helmet for four continuous hours and were monitored during this period for maintaining the posture. Upright MRIs were obtained for the second time in the sitting position after four hours of helmet wear, while the subejctes wore the HSM. Cross-sectional areas of the bilateral sternocleidomastoid and multifidus muscles from C2 to C7 levels were obtained by neurosurgeons specializing in complex spine surgery (authors, HC and JB). Cervical lordosis was measured as the angle between the superior endplate of C3 and superior endplate of T1 vertebral bodies. Intersegmental angles were also obtained. Intra- and inter-observer data were accommodated in the design of the experiment (DOE).

III. INITIAL FINDINGS

The mean and standard deviation data on the age, stature, total body mass, head circumference, and body mass index (BMI) of the five female subjects were: 34 ± 4 years, 1.7 ± 0.1 m, 75 ± 3 kg, 55 ± 1 cm, and 27.3 ± 4.1 kg/m^2. All subjects completed the full scanning protocol without exception. Paired data (pre- and post continuous wear MRIs) were used to determine changes in the curvature and area for the two bilateral muscle types. Using the pre-MRI scans as the base, prolonged wear of the HSM produced increased curvature, i.e., greater lordosis of up to 20 degrees and level-specific changes in the areas of both muscles (Figure 1).The areas of the multifidus muscles demonstrated greater alterations than the areas of the sternocleidomastoid muscles (Figure 2).

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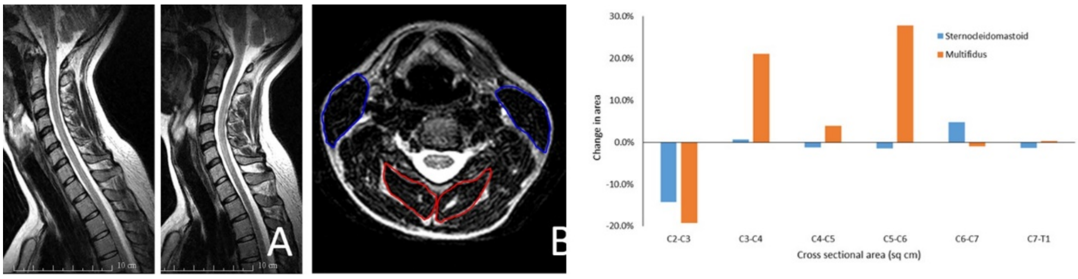

Figure 1: A) T2-weighted upright sagittal MRI of the cervical spine in a female volunteer before and after four hours of continuous helmet wear; B) T2-weighted axial MRI of the same subject with sternocleidomastoid (shown in blue) and multifidus (shown in red). Bar chart shows changes in the cross-sectional areas in the two muscles.

IV. DISCUSSION

The images were obtained in the neutral position, i.e., the Frankfort plane of the head was horizontal, and the thorax was upright. A common reason for increased cervical lordosis in the automotive seated posture is that the thorax rolls forward over time. The exact location and orientation of the head with respect to T1, orientation of T1, and thorax alignment are important. Increased lordotic curvature is attributed to the extracranial loading due to HSM. The increase in the multifidus muscle properties in the mid-cervical column and general decrease in the sternocleidomastoid properties, mostly notably at the axis are also due to the prolonged use of the HSM, although the use was limited to four hours. Morphological musculature changes found in this preliminary study support increased cervical lordosis theory considering their local anatomy with respect to the spine and balancing roles. Although fiber lengths were not measured, changes in cross-sectional areas may indicate flexor elongation and mid-cervical extensor shortening. While eccentric and concentric contractions were not delineated, it is likely that flexors and extensors activate to sustain the increase in the weight of the head due to HSM use, and recognizing that the effect of the added HSM is greater in females, it is expected that as muscles fatigue, the osteoligamentous structures may experience increased loads, further enhancing the degree of lordosis. While the basic anatomy and structural components of men and women are similar from structural and postural perspectives, differences exist [9]. Literature indicates that in females, the facet joint is significantly ($p<0.05$) thinner, cartilage gap is larger, cartilage is thinner, C2 depth is smaller, facet angles at C2, C3 and C6 are lower, and vertebra width, disc-facet depth and cervical column height are shorter in sitting height-matched group of people, and vertebral dimensions are smaller in the head circumference-matched group [10-12]. While these data are reported , MRI-supported quantifiable data are sparse in clinical and bioengineering literatures. Human Body Models (HBMs) and head-neck complex models have the flexibility to include posture and segment-specific cervical musculature data, and this study, albeit preliminary, provides important level-specific regional muscle and posture-related results. As the current DOE accommodates scanning of male subjects, the present initial female-only quantitative data on spinal level-specific muscle geometry and curvature at all subaxial levels can be used as an initial dataset for HBM and other models. Incorporation of these data will provide more realistic segmental forces and moments, and other stress analysis-based variables for injury prediction and load-sharing (re)distribution under defense operational environments, contact/noncontact-induced loadings such as vertical, rear, and frontal impacts. Muscle changes and cervical lordosis from the use of HSM affect local segmental spine loads.

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