Injury Threshold of Rectus Capitis Muscles at the Atlanto-occipital Joint

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ABSTRACT

Objective: The objective of this study was to collect muscle stiffness data from the 4 rectus capitis (RC) muscles to better understand their role in stabilizing the atlanto-occipital joint. The passive load displacement properties of these muscles have not been previously reported.

Methods: Rectus capitis muscles were removed from 3 unembalmed head and neck specimens. Passive length-force (stiffness) data were collected by using a servo-controlled hydraulic test machine. Multivariate analysis of variance with Bonferroni correction was used to assess the significance of the differences among passive stiffness within the elastic region of each muscle and the load and strain at the yield points.

Results: Rectus capitis lateralis (RCL) muscles failed at significantly higher levels of load and strain compared with the other 3 pairs of muscles. Passive stiffness of both RCL and RC anterior muscles was significantly higher than the other 2 pairs of muscles.

Conclusion: The anatomic location of the RCL muscles, along with their high levels of passive stiffness, would be expected to facilitate the maintenance of atlanto-occipital joint congruence during normal daily activities. The level at which the RC posterior minor muscles failed could put them at risk of a strain injury during a rear end motor vehicle accident. Diagnostic and treatment protocols that apply forces to the upper cervical spine should be tailored to consider the patient's age, gender, and history of previous injuries to avoid overstretching RC muscles. (J Manipulative Physiol Ther 2017;40:71-76)

Key Indexing Terms: *Atlanto-occipital; Cervical Spine; Force*

INTRODUCTION

External forces that impact the head have the potential to produce nonphysiological motion at the atlanto-occipital (AO) joint and can result in injuries ranging from soft tissue strain to dislocation of the AO joint. Dislocation of the AO junction, although not common, usually results in significant neurologic trauma or death, especially in children. Far more common are acute and chronic symptoms of head and neck pain, which are associated with soft tissue pathologies subsequent to whiplash-type distortions of the upper cervical spine.[1,2] Unfortunately, the source of these chronic symptoms is not clearly understood.

The kinematic response of the AO joint is largely determined by bone and soft tissue structures.[3] The side walls of the AO joint surfaces limit lateral motion of the occiput relative to the atlas. Likewise, the oblique orientation of the AO joint surfaces limits anterior and posterior translation of the occiput relative to the atlas.[4] Posterior translation of the atlas with respect to the axis is constrained by the odontoid process.[5] Anterior translation of the atlas with respect to the axis is constrained by the cruciate ligaments.[6]

The morphology of the AO joint and the stabilizing effect of soft tissue structures, such as ligaments, muscles, and joint capsules, provide the structural stability necessary to limit the amount of posterior translation of the occiput with respect to the atlas to less than 3 mm, a degree of stability that is necessary to protect such structures as the spinal cord from injury during normal daily activities.[7,8] Much has been written about the role of ligamentous structures in preventing excessive motion of the AO joint,[9-11] but little has been reported about the role that rectus capitis (RC) muscles might contribute to stabilizing the AO joint. Part of the reason for this oversight may be not attributing functional significance to these small muscles and the difficulty involved in measuring their biomechanical properties. Computer models are a useful tool for quantifying the response of the upper cervical spine to whiplash-type distortions. Since the utility of such a tool depends on the accuracy of the model; without full knowledge of the biomechanical properties of RC muscles,

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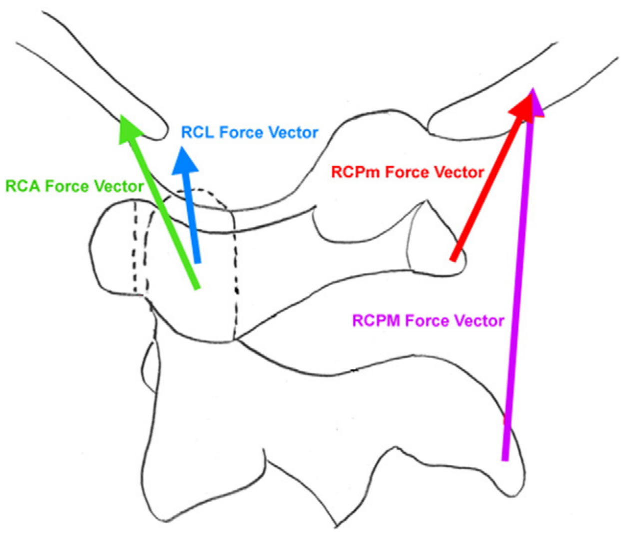

Fig 1. *Sagittal view of the orientation of rectus capitis posterior minor (RCPm), rectus capitis posterior major (RCPM), rectus capitis anterior (RCA), and rectus capitis lateralis (RCL) force vectors.*

the model is inaccurate. To add to the accuracy of a previously published model of the upper cervical spine,[12] passive load displacement (stiffness) data were collected from in vitro preparations of the 4 RC muscles as they were individually stretched to a yield point where muscle fibers began to tear as a result of overstretching.

The RC muscles comprise 4 pairs of muscles (Fig 1). The posterior RC muscles include the RC posterior minor (RCPm) and the RC posterior major (RCPM) muscles.[13] The anterior RC muscles include the RC anterior (RCA) and the RC lateralis (RCL) muscles.[14] Rectus capitis posterior minor muscles arise from the posterior tubercle of the posterior arch of the atlas and insert into the occipital bone inferior to the inferior nuchal line and lateral to the midline. Rectus capitis posterior minor muscles are the only muscles that attach to the posterior arch of the atlas. Rectus capitis posterior major muscles arise from the spinous process of the axis and insert into the lateral part of the inferior nuchal line of the occipital bone. The RCA muscles arise from the lateral process of the atlas and insert into the inferior surface of the basilar process of the occiput. The RCA and RCPm muscles would appear to be antagonists. The RCL muscles arise from the transverse process of the atlas and insert into the jugular process of the occiput.

The passive load displacement characteristics of the RC muscles have not been previously reported. Understanding load displacement characteristics may increase the fidelity of computer models of the upper cervical spine.[12] Therefore, the objective of this study was to quantify the passive load displacement characteristics of RC muscles to increase the utility and fidelity of computer models of the upper cervical spine.

Methods

Length–Force Testing Protocol

Three unembalmed head and neck specimens were obtained from the Anatomical Services Division at the University of Maryland. Donors had given written informed consent during life allowing use of their body for research purposes. Prosection was performed in a room that provided privacy from individuals not associated with the project. To prevent identification of the subjects, no pictures were taken.

A convenience sample of unembalmed head and neck specimens from 3 white females (ages 63, 70, and 85 years) was obtained. The unembalmed specimens were tested because it has been reported that the mechanical properties of cadaveric muscle exhibits a large range in mechanical properties.[15] A prosector proceeded to expose the RCPM and RCPm muscles by first making a midline incision starting at C7 and continuing to the occipital bone. Skin was removed, working from the spinous processes laterally to the mastoid process. Underlying subcutaneous tissue was removed. The trapezius muscle was bisected medially, detached from its superior attachment, and incised medial to lateral from the spinous process of C7 to a point determined to allow ample reflection. The muscle was then reflected laterally, and the underlying fascia was removed. Incisions were made through the splenius capitis at the superior nuchal line of the skull and at C7. The muscle was reflected and removed. The semispinalis capitis muscle was then reflected laterally and removed. A similar approach was used to expose the RCA and RCL muscles.

The left and right RCPm muscles share a common attachment point at the posterior arch of the atlas: the left and right RCPM muscles share a common attachment point at the spinous process of the axis, the left RCA and left RCL muscles share a common attachment point at the left transverse process of the atlas, and the right RCA and right RCL muscles share a common attachment point at the right transverse process of the atlas. Attempting to remove the muscles as separate specimens was not considered practical because that approach would not have left sufficient bone material for the test fixture to grasp without slippage. Consequently, the prosector removed muscles that have common attachments sites as a unit (Fig 2).

Rectus capitis posterior minor and RCPM musculotendinous units were tested without being frozen. Rectus capitis anterior and the RCL musculotendinous units were frozen at –20°C until a time could be scheduled for testing. The biomechanical properties of frozen and unfrozen soft tissues have not been shown to be significantly different.[16] Prior to testing, the specimens were thawed overnight at room temperature (27°C).[17]

A specialized test fixture was fabricated to firmly grasp the attachment points of each muscle to bone and to allow each attachment point to be adjusted in both tilt (Y axis) and rotation (X axis) (Fig 3). The superior attachment point to