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RESEARCH ARTICLE

An isolated contraction of the Obliquus Capitis Inferior and Rectus Capitis Posterior Major demonstrated with Musculoskeletal Ultrasound Imaging

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Abstract

Study design: A quasi-experimental study design

Background: The motion of the suboccipital region is controlled by several groups of the smaller and larger muscle group, and these might play a role in the development of cervicogenic headache. Abnormal muscle tone can lead to abnormal movement patterns resulting in altered proprioceptive information from the mechanoreceptors in this region. Thus, abnormal muscle tone will contribute to cervical dysfunction and might result in pain, joint irritation, and poor functioning of the neck. At the same time , unilateral contraction of the suboccipital muscles could lead to rotation of the atlas. This could result in a significant translation of the spinal cord toward the side of rotation within the dural sack. This homolateral shift of the spinal cord could then lead to dural tension and possibly contribute to cervicogenic headaches.

Methods: A convenience sample of 25 healthy subjects were recruited for this study. Musculoskeletal ultrasound imaging was used to measure the diameter of the Obliquus Capitis Inferior and the Rectus Capitis Posterior Major immediately following an isometric contraction into head extension and rotation.

Outcomes: An isometric-induced contraction resulted in a significant change in the diameter of the obliquus capitis inferior and contralateral rectus capitis posterior major and, thus, could affect the position of atlas in the atlantoaxial joint.

Discussion: The effect of an isometric-induced contraction of the obliquus capitis inferior and contralateral rectus capitis posterior major in a subgroup of asymptomatic individuals was measured using musculoskeletal ultrasound imaging. The results of this study indicate that the diameter of both muscles significantly changed with the isometric contraction. This study's findings support that suboccipital muscles can contract in isolation and, thus effect the position of atlas.

Keywords: Obliquus Capitis Inferior, Rectus Capitis Posterior Major, Atlas positional default, Cervicogenic Headache, Musculoskeletal Ultrasound Imaging

Level of evidence: Therapy, level 3

Introduction

Approximately half of the adult population experience headaches. Headaches can have a significant socio-economic impact resulting in decreased productivity and possible sick days. Many of those experiencing headaches will have an origination in the cervical spine.[1,2] These headaches have been identified as cervicogenic headaches (CGH).[4] The International Headache Society has defined CGH as a "headache caused by a disorder of the cervical spine and its component bony, disc and/ or soft tissue elements, usually but not invariably accompanied by neck pain."[4] The CGH typically results in pain on one side of the head and face. The incidence of CGH is about 15% of all headaches.[3] The exact causation of CGH remains elusive. Despite this, individuals with CGH traditionally have been treated with pharmacological and non-pharmacological interventions. Considering uncertainty about the underlying mechanism of current management strategies and their long-term effects must be called into question.

A possible relationship between headaches and the functioning of the upper cervical spine has been established.[1,2] This relationship originates in the fact that there is a direct anatomical connection between the trigeminal nerve and the C1-C3 spinal nerves at the trigeminocervical nucleus. Besides these neurogenic pathways, musculoskeletal dysfunctions have been identified in subjects with CGH.[1,2] These dysfunctions include joint stiffness, atlas positional fault, occipital paresthesia, and muscle weakness.[3] The upper cervical spine is a very complex anatomical region. This region's movement depends on the spatial orientation shape of articular surfaces, the stabilizing ligaments, and the muscles controlling the region. Mid and lower cervical spine intervertebral motion is similar; however, this motion dramatically varies in the upper cervical region (Occiput-C3).[7] The atlas can rotate about 40-45 degrees in the atlantoaxial (AA) joint, contributing more than 50% of the total cervical spine rotation.[19] The integrity of the AA segment is maintained by several ligaments, and the suboccipital musculature directly controls the motion in the AA joints.

Rotational movement of the atlas relative to the axis in the AA joints results from co-contraction of the homolateral obliquus capitis inferior and superior muscles. It has been demonstrated that continued co-contraction of the homolateral obliquus capitis inferior and superior muscles will cause and maintain a rotation positional default of the atlas.[16,17] Such atlas rotational positional fault will lead to movement restrictions and/ or pain with movement. This positional default of the atlas was previously demonstrated by Sillevis and Swanick[7] using a method of musculoskeletal ultrasound imaging. Additionally, Sillevis et al identified a significant correlation between the presence of a rotatory default position of the atlas and subjects with neck pain and headaches when evaluating radiographs of subjects with CGH. Therefore, this positional default could cause additional nociceptive and thus contribute to the development or maintenance of CGH.[7,35] Additionally, in the upper cervical region, fascial connections (myodural bridges) between the Rectus Capitis Posterior Major (RCM), Rectus Capitis Posterior Minor, and Obliquus Capitis Inferior (OCI), the nuchal ligament, and the dura have been demonstrated.[10,1113] The myodural bridges between the obliquus capitis inferior muscles and the dura can result in a unilateral mechanical compression of the C2 nerve root. This compression could be a contributing factor to the development of CGH.[13,36,37] Between the C1 and C2 vertebra arches, the myodural bridges join the meningovertebral ligaments to span the epidural space and insert into the dura. The significance of this implies that muscle tone could directly affect the positioning of the dura in the spinal canal and, thus, might have a causative role in the development of cervicogenic headaches.

Sillevis and Hogg[3] demonstrated that a rotation of the atlas resulted in a significant translation of the spinal cord toward the side of rotation within the dural sack. It was postulated that this homolateral shift of the spinal cord could lead to dural tension. Jansen[4] confirmed the contribution of cervical neural tension to CGH. He identified that the subject's CGH was relieved after freeing the dura from compression by cervical dorsal laminectomy. Even though the cervical dura does not have a rich innervation of nociceptive fibers, the cranial dura does.[20] Witten et al[21] demonstrated the contributing role of the cranial dura in the development of headaches. As the International Headache Society identified, subjects with CGH typically report headaches that initiate in the upper cervical spine and refer to the head.[4] The notion that the upper cervical spine muscles can be a causative factor to develop dural tensioning is further supported by the findings of Noseda et al[23]. They demonstrated the presence of cervicovascular neurons in the posterior dura overlying the cerebellum. These neurons can contribute to the development of sensitization and pain in this region.

The motion of the suboccipital region is controlled by several groups of the smaller and larger muscle group, and these might play a role in the development of CGH. Abnormal muscle tone can lead to abnormal movement patterns resulting in altered proprioceptive information from the mechanoreceptors in this region.[12] The upper cervical spine contains an exceptionally high density of mechanoreceptors.[12] Abnormal muscle tone will contribute to cervical dysfunction and might result in pain, joint irritation, and poor functioning of the neck. Another contributing factor to CGH might be the upper cervical spine's ongoing challenge due to gravitational compressive forces. While upright, the upper cervical spine muscles must maintain the head in the upright position. This need for muscle control commonly leads to increased muscle tone in the suboccipital cervical spine and, therefore, the development of trigger points.[5] It has been previously identified that suboccipital trigger points can refer pain in the head and face. [5]

Musculoskeletal ultrasound imaging (MSK US) allows real-time dynamic visualization of the suboccipital muscle tissues. The development of high-resolution ultrasound transducers has improved the visualization of soft tissues and bony structures, thus increasing diagnostic values.[11,12] MSK US allows for a noninvasive safe imaging technique.[6,7] The validity and reliability of MSK US to assess the musculoskeletal system have been previously demonstrated.[18-22] Good inter-tester reliability of MSK US to evaluate soft tissue and bone has been demonstrated.[8]The inter-tester reliability, sensitivity, and specificity of MSK US compared to Magnetic Resonance Imaging range from moderate to good. [23]

Considering the importance of the role of the suboccipital muscles in the creation and maintenance of the positional relationship of the atlas in the atlantoaxial joint and the development of CGH, it was the aim of this study to identify if the homolateral OCI and RCM muscles can be contracted in isolation measured by MSK US.

Material and Methods

Subjects

This quasi-experimental study used a method of convenience sampling with a within-subject repeated measure. G*power, version 3.1, was used to perform a priori power analysis assuming a normal distribution of data in combination with a power of 0.80 and a medium effect size of 0.60. The minimum number of required subjects was 25. For this study, a total of 25 subjects were recruited. All available subjects were screened for the eligibility criteria. To participate, all subjects had to be between the ages of 18 and 65 and be able to read English, so proper written consent could be given. Additional exclusion criteria included any recent or current neck trauma, previous cervical fractures or surgeries, and current physical therapy treatment for neck pain. This study received institutional review board (IRB) approval from Florida Gulf Coast University. All subjects provided written consent before participating in the study.

Study Protocol

The MSK US Philips Lumify, manufactured by Philips Healthcare, was used by the principal investigator to measure the length of the muscle belly of both the OCI and RCM muscles directly. The primary investigator has been using MSK US since 2021 and has completed specific MSK US training with a clinician certified in using MSK US. During the measurement phase, the subjects were comfortably seated on a stool in front of a treatment table (Figure 1). Before any measurement, palpation was used to identify the spinous process of C2 so the MSK US probe could be properly placed to achieve correct and consistent visualization of the OCI and RCM muscles. The probe position for the OCI muscle is displayed in Figure 1. While in full cervical flexion, the subject was given a force to head in extension/ rotation and was expected to resist this isometrically (Figure 2). Real-time MSK US imaging was used to measure muscle diameter length directly (Figures 3 & 4). This was repeated for the RCM muscle.

Figure 1: *Probe placement to capture the right OCI at rest.*

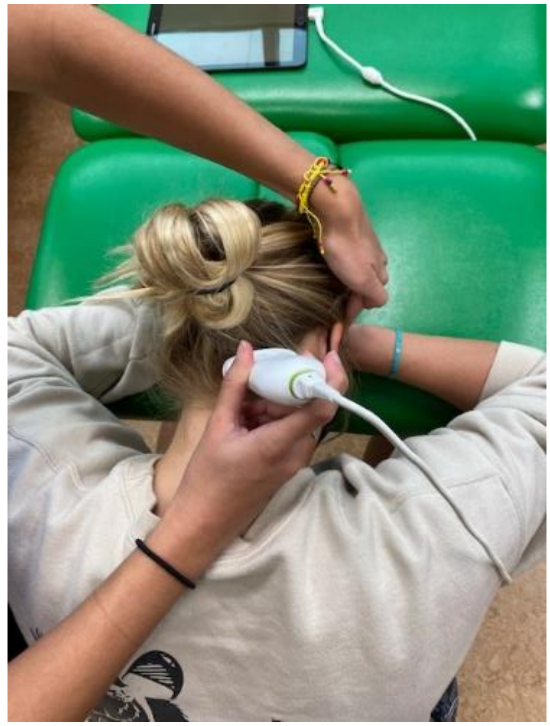

Figure 2: *Probe placement with isometric contraction of cervical rotation to capture the right OCI when contracted.*

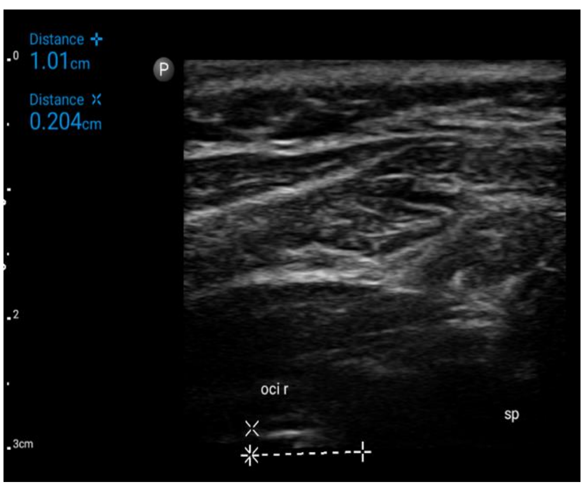

Figure 3: *R OCI at rest (oci r) with Spinous Process of C2 as a bony landmark (sp).*

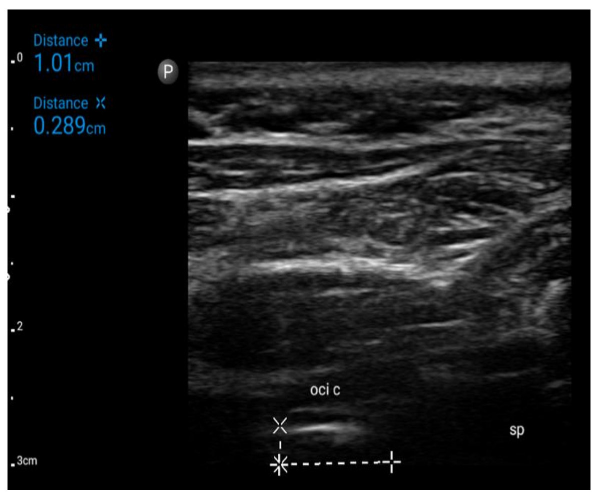

Figure 4: *R OCI during an isometric contraction (oci c) with Spinous Process of C2 as a bony landmark (sp).*

Statistical Analysis

Statistical analyses were performed using the SPSS, version 28.0, statistical software package from IBM. All data were analyzed using a confidence interval of 95% and a significance level of 0.05.

Results

Twenty-five subjects completed the measurement and interventional protocol. The subject population had an age range from 22 to 32 years of age, with a mean age of 26.5. There were 15 female and 10 male subjects. The data were analyzed for normal distribution using the Sharpo-Wilk test of normality, and all data were normally distributed with $p>0.05$; for that reason, the assumption for parametric statistics was satisfied, and the paired *t*-test was used to compare the muscle with the OCI and RCM muscles in rest to the diameter during isometric contraction.

The mean width of the OCI at rest was .230 centimeters (cm) with a standard deviation (SD) of .06 cm, and the mean width of the OCI during an isometric contraction was .267 cm with an SD of .059 cm. The mean width of the RCM at rest was .231 cm with an SD of .055 cm, and the mean width of the RCM during an isometric contraction was .274 cm with an SD of .057 cm. Cohen's *d* was used to calculate the effect size. For the OCI at rest, this was 3.740 and 4.512 during a contraction. The effect size for the RCM at rest was 4.217 and 4.836 during contraction. The paired *t*-test was used to determine the difference in OCI resting muscle diameter compared to contracted diameter. There was a significant difference for the OCI with $p<0.001$. The paired *t*-test was used to determine the difference in RCM resting muscle diameter compared to contracted diameter. There was a significant difference in the OCI with $p<0.001$.

Discussion

Cervicogenic headache disorders with an incidence of about 15% of all headaches.[3] Although the exact mechanism remains elusive, cervicogenic headaches appear to be caused by dysfunction in the upper cervical spine.[9,10] During the rotation of the upper cervical spine the suboccipital muscles, as part of the complex neuromuscular control mechanism will create motion of the atlas relative to the axis, and thus turning of the head.[11] Additionally, this motion is governed by the shape and orientation of the articular structures and the location of the strong transverse ligament allowing the atlas to rotate around the dens. Based on the orientation and attachments of the obliquus capitis inferior muscle, unilateral contractions create this rotation of the atlas relative to the axis is. [12] Sillevis et al[11] demonstrated that a maintained rotation of atlas correlates with the presence and intensity of CGH. The mobility and/ or position of the atlas appears to play a central role in the development and maintenance of CGH.[12] The suboccipital muscles have direct control of the atlas and axis through the suboccipital muscles.[9] Both the OCI and the RCM muscles contribute to the rotation and, thus, the position of the atlas.[13-15] Mulligan defined the altered position between bones as a "positional fault".[12] Unopposed maintained OCI muscle tonicity will result in movement restrictions and possible pain with head movement causing nociceptive afferent input and, therefore, contribute to the development of CGH.[16] It has been previously proposed that prolonged unilateral muscle hypertonicity of the OCI muscle can lead to a positional default of atlas in the sagittal and transverse planes. This rotated position can be visualized with the open mouth radiograph and has been correlated with the development and maintenance of CGH.[17-19]

Additionally, myodural connections between the suboccipital muscles and the dura have been identified.[3,16,20,21] These collagenous connections between the dura and the OCI muscle could result in the compression of the unilateral C2 nerve root. This increased and prolonged muscle tone might be a contributing factor for the development of CGH.[3,22,23] The presence of increased muscle tone in the suboccipital muscles and the presence of myofascial tripper points in these muscles in subjects with headaches have been previously demonstrated.[5] Therefore, this study aimed to determine if a muscle specific isometric contraction of the OCI and RCM could be achieved as demonstrated by a selective cross-sectional muscle diameter change.

This study's subjects were positioned with the neck in maximal flexion to isolate movement in the upper cervical spine. The effect of maximum neck flexion has been previously validated when using the cervical flexion-rotation test (FRT). Maximum forward bend position result in maximal facet motion, and thus only rotation of the atlas in the atlantoaxial joint can occur. The reliability of the FRT in those with cervicogenic headaches was demonstrated by Hall et al[24]. The FRT has a high sensitivity (90-91%), specificity (88-90%), and overall diagnostic accuracy (91%), supporting the fact that this position isolates atlas rotation.[24,25] In this maximum flexed position, the subjects in our study were given an isometric resisted force in the flexion and contra-lateral rotation direction. The subjects were asked to resist this force resulting a suboccipital extension and rotation, further causing activation and contraction of the OCI and RCM muscles.

Our results demonstrated that both the OCI and RCM muscles showed significant change in width from the resting condition to the muscle-contracted condition. On average, the OCI mean in the resting state was 19.6 millimeters (mm), and during contraction, the diameter increased to 23.0 mm. The RCM mean in the resting state was 21.5 mm, and during contraction, the diameter increased to 24.7mm. This finding indicates that the OCI and the RCM muscles can be contracted in isolation using a submaximal isometric force in flexion and contralateral rotation. This finding concurs with Chen et al[26], who demonstrated significant diameter changes of suboccipital muscles upon isometric rotational resistive forces to the head. Our findings agree with the findings of Lin et al[27], who demonstrated that submaximal resisted isometric contraction in extension resulted in a significant diameter change of the suboccipital muscles, including the RCM.

The results of this study indicate that both the OCM and RCM can be contracted in isolation. This has significant consequences for those managing individuals with upper neck pain and CGH.[9] The role of the atlas and the position relative to the axis seems to correlate with neck pain and headaches.[15] It has been demonstrated that the positional default of atlas plays a role in the development and maintenance of CGH. Therefore, it seems plausible to assume that isometric muscle contractions directed to the head can be utilized to change the relative atlas position in the atlantoaxial joint. Exercise regimes that focus the OCI and RCM muscles could result in muscle strengthening and, thus, potentially normalize atlas position in the atlantoaxial joint and potentially reduce the incidence of CGH.[28] Additionally, the collagenous connections between the suboccipital muscles and the dura could play a cardinal role in maintaining upper cervical dysfunction and pain.[3,29] Being able to isolate the contraction of those suboccipital muscles, such as the OCI and the RCM, might have a direct effect on dural tension via the myodural bridges. [3,29]

This study used MSK US to measure the OCI and RCM muscle diameter under two different testing positions. MSK US is a noninvasive and safe imaging technique. However, the image's quality greatly depends on the examiner's experience.[30,31] It has been previously demonstrated that reliable images can be obtained with minimal training. It could have been a limitation that MSK US images are limited to the probe size. It is known that the muscles can vary in size and shape. The MSK US image used in this study was based on the location of the OCI and RCM. It is possible that the location of the probe did not capture the exact same location during contraction. This could have had an impact on the study results. Only one clinician obtained the MSK US images, and one rater measured the muscle length. Based on this, the measurement protocol could have resulted in type I and II errors. Despite this, the investigator was trained and experienced enough to recreate images in this study based on the anatomical landmarks and should have been able to produce valid MSK US images.

The subjects in this study were asymptomatic healthy individuals between the ages of 22-32 without any history of cervical trauma and who had no neck pain at the time of this study. This should not have impacted the upper cervical spine response to force in our subjects and, thus, should not negatively impact the results.

Conclusion

This study measured the effect of an isometric-induced contraction of the obliquus capitis inferior and contralateral rectus capitis posterior major in a subgroup of asymptomatic individuals using musculoskeletal ultrasound imaging. The results of this study indicate that the diameter of both muscles significantly changed with the isometric contraction. This study's findings support that suboccipital muscles can contract in isolation. Further research is necessary to explore those suboccipital muscles that can best be trained during upper cervical stabilization exercises to avoid atlas movement and dural tension.

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Conflict of Interests

The authors disclose no conflict of interest.

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