Bilateral Asymmetry of Semispinalis Capitis Muscle Thickness and Neck Motion during Prone Neck Extension in Subjects with Unilateral Posterior Neck Pain

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Abstract. [Purpose] This study compared the bilateral thicknesses of the semispinalis capitis muscle and neck motions between subjects with and without unilateral posterior neck pain (UPNP). [Subjects] The study recruited 20 young subjects with UPNP at the end-range of neck extension and 20 age- and sex-matched subjects without neck pain as a control group. [Methods] The bilateral thicknesses of the semispinalis capitis in a relaxed prone position were measured bilaterally using ultrasonography. A three-dimensional motion-analysis system was used to measure the asymmetry of neck motions at 45° of prone neck extension. [Results] We found that the asymmetry of the semispinalis capitis muscle was greater in the UPNP group than in the controls. Neck rotation to the painful side and lateral bending to the non-painful side were greater in the UPNP group at 45° of prone neck extension than in the controls. [Conclusion] Asymmetric thickness of the semispinalis capitis muscles might be the cause of asymmetric neck motions in subjects with UPNP.

Key words: Asymmetry, Muscle thickness, Neck motion

INTRODUCTION

The cervical paraspinal muscles play an important role in neck extension, maintaining the lordotic curve of the cervical spine1). The cervical paraspinal muscles also contribute to proprioception of head and neck movements2), and postural balance while standing3). To improve the performance of the cervical paraspinal muscles, neck extension exercises in the sitting or prone position are often advocated in the management of patients with mechanical neck pain4). Neck extension exercises are effective at increasing the size of the cervical paraspinal muscles in patients with mechanical neck pain5).

The size of the cervical paraspinal muscles is measured when evaluating muscle function and provides a basis for therapeutic interventions in patients with chronic neck pain6–8). Measuring the size of the cervical paraspinal muscles is considered an objective method of estimating indirect strength9–11). Ultrasonography is commonly used to assess muscle size, including the atrophy and symmetry of the cervical paraspinal muscles11, 12). A previous study suggested that an obscure outline of the fascial layer in ultrasound images was a diagnostic feature of muscle atrophy12). However, the cervical muscle is smaller than the lumbar spine, and the lateral boundary of the deep posterior neck muscle is ambiguous. Therefore, ultrasonography is valid for measuring the thickness, but not the width or cross-sectional area, of the cervical multifidus and semispinalis capitis muscles12, 13). Previous studies have demonstrated that bilateral symmetry is seen in ultrasound images of the posterior neck muscles of healthy subjects and patients with bilateral neck pain7, 11).

Asymmetry of the paraspinal muscles has been reported in unilateral spinal pain14). In patients with unilateral back pain, a reduction in muscle cross-sectional area, i.e., atrophy of the multifidus or psoas major, ipsilateral to the side of pain has been demonstrated15–17). Unless the atrophic multifidus muscle is worked with specific exercises, the decreased muscle size will not recover in patients with unilateral back pain18). In addition to the lumbar paraspinal muscles, asymmetry of the cervical paraspinal muscles has been demonstrated in patients with unilateral posterior neck pain (UPNP)19). The semispinalis capitis muscle was smaller on the painful side than on the non-painful side in ultrasound images of patients with UPNP or migraine13, 19, 20).

Although a previous study found that semispinalis capitis thickness was asymmetrical in patients with UPNP19), no study has determined whether the asymmetric thickness of the semispinalis capitis influences neck motion during prone neck extension in subjects with UPNP. Therefore, we
compared the bilateral thicknesses of the cervical paraspinal muscles in the relaxed prone position, and neck motions while performing prone neck extension between a UPNP and control groups. We hypothesized that there would be greater asymmetry of muscle thickness and neck motions in subjects with UPNP than in the control group subjects.

SUBJECTS AND METHODS

This study recruited 20 subjects with UPNP from among graduate students of Yonsei University, Korea (Table 1). The inclusion criteria for selecting subjects with UPNP were that the subjects had UPNP at the end-range of active neck extension and passive neck extension with rotation to one side in the sitting position21, 22). The peak intensity of the UPNP in this study exceeded 50 mm on a 100-mm visual analogue scale (VAS) when performing active neck extension and passive neck extension with rotation in the sitting position. The average pain intensity of the neck exceeded 30 mm VAS during the past 6 weeks23). Subjects with bilateral posterior neck pain or those who were unable to perform prone neck extension to 45° due to UPNP, migraine, or dizziness were excluded.

Twenty age-, sex-, and weight-matched healthy subjects were recruited as a control group from among graduate students of Yonsei University. Inclusion criteria for selecting control subjects were the ability to perform prone neck extension to 45° and no history of past or present neck pain, migraine, neurological, or orthopedic problems. Before this study, the principal investigator explained all of the procedures to the subjects in detail. All subjects signed an informed consent form approved by the Yonsei University Faculty of Health Sciences Human Ethics Committee.

To measure the bilateral thicknesses of the semispinalis capitis muscles, each subject was scanned by a SonoAce X4 ultrasound scanner with a 7.5-MHz linear array transducer. The subjects were asked to assume a relaxed prone position with a pillow under their chest and abdomen to maintain a straight lumbar and thoracic spine. To enable them to breathe during the ultrasonographic measurement, we placed a doughnut-shaped air cushion with a hole for the nose and mouth under the subject’s head. The head and neck were positioned neutrally when viewing the subject from the side13). The subject’s arms were placed symmetrically on the table at 90° of shoulder abduction. After applying warm gel to both sides of C3, the ultrasound probe was positioned with its long axis in the transverse plane. The spinous process of the C3 vertebra was identified as the midline and the probe was moved laterally so that the vertebral lamina and separating fascia were clearly visible. The image was then frozen on the monitor. The thicknesses of both semispinalis capitis muscles were measured at the greatest depth from the dorsal to the ventral boundary of the muscle15). The intra-rater reliability of the ultrasound measurement of the posterior neck muscles was previously shown to be high; the intraclass correlation coefficient for the semispinalis capitis was 0.98–0.9911).

A three-dimensional ultrasonic motion-analysis system (CMS-HS) (Zebris Medizintechnik, Isny, Germany) was used to measure concurrent neck rotation and lateral bending during prone neck extension24). A triple-active marker was fixed to the back of the subject’s head with a specially designed headband. The transducer sensor was placed above the back of the head to measure the concurrent neck motions during prone neck extension. Before recording the concurrent neck motions, the head and neck in the prone position were calibrated to zero as reference positions relative to a neutral head position. The neutral head position was defined as the position without rotation, lateral flexion, or exaggerated cervical lordosis4). The sampling rate was 20 Hz. A belt was fastened around the upper thoracic region to prevent thoracic extension while performing prone neck extension. The subjects were asked to perform prone neck extension comfortably to 45° with their eyes open and to maintain this position for 5 seconds. A fixed target bar was placed at the level of 45° of prone neck extension. The subjects were instructed to perform prone neck extension while viewing the bar in front of their face until their head touched the target bar. Neck motion data were recorded while the subjects held 45° of prone neck extension. Data of the middle 3 seconds of the 5-second measurement were used in the analysis25). The mean value of three trials was calculated to determine the range of concurrent neck motions at the targeted angle of active prone neck extension.

The independent t-tests was performed to compare the difference in the bilateral thicknesses of the semispinalis capitis muscles in the relaxed prone position, and neck motions during prone neck extension between the UPNP and control groups. The paired t-test was used to compare the thicknesses of the painful and non-painful sides of the semispinalis capitis muscles within the subjects with UPNP. Statistical significance was accepted for values of p < 0.05. Data are expressed as the mean and standard deviation (SD). Statistical analyses were performed using SPSS 12.0.1 software (SPSS, Chicago, IL).

RESULTS

The mean difference in the bilateral muscle thicknesses of the semispinalis capitis muscle was significantly greater in subjects with UPNP (p<0.05) (Table 2). Within the UPNP group, the muscle thickness on the painful side was significantly smaller than that on the non-painful side (0.46 ± 0.12 vs. 0.58 ± 0.12 cm; p<0.05).

The range of neck rotation toward the painful side and lateral bending toward the non-painful side at 45° of prone neck extension were significantly greater in the UPNP group than in the control group (p<0.05) (Table 3).

DISCUSSION

This study investigated whether asymmetric thickness of the semispinalis capitis influences neck motion during prone neck extension in subjects with UPNP. We demonstrated that subjects with UPNP had asymmetric thicknesses of the semispinalis capitis and performed asymmetrical neck motions, including neck lateral bending and rotation during prone neck extension. To our knowledge, this is the first
study to show that subjects with UPNP have an asymmetrical movement pattern during active prone neck extension, as well as asymmetrical thickness of the semispinalis capitis.

Consistent with previous results, the bilateral asymmetry of the semispinalis capitis thickness was greater in the UPNP group than in the control group. The marked bilateral asymmetry of the posterior neck muscle thickness may indicate pathology in the neck. Pain-related fear of neck movement is a possible reason for the asymmetry of the muscle thickness. Hodges demonstrated that pain due to lumbar injury in a porcine model induced a rapid reduction in the muscle size and atrophy of the lumbar multifidus. Danneels suggested that low back pain inhibits the trunk muscles in patients with UPNP. The results of this study can indicate pathology in the neck. According to Feipel, the direction of coupled rotation and lateral bending is ipsilateral in the lower cervical spine and contralateral in the upper cervical spine. Contralateral coupling in the upper cervical levels is necessary to maintain the head in an erect position. In our study, subjects with UPNP carefully performed prone neck extension with an erect head along the straight line in front of their face. Maintaining the head in an erect position may result in contralateral coupling between neck rotation and lateral bending in the upper cervical spine during prone neck extension.

However, unilateral contraction of the semispinalis capitis induces neck extension with ipsilateral lateral bending. In addition to unilateral contraction of the semispinalis capitis muscle, concurrent lateral bending during prone neck extension occurred toward the hypertrophic semispinalis capitis (non-painful) side of subjects with UPNP. It is possible that the semispinalis capitis on the hypertrophic side is more likely to be activated than the atrophic side via reflex inhibition, resulting in lateral neck bending toward the hypertrophic side during prone neck extension in the UPNP group. The concurrent neck rotation toward the side opposite that of lateral bending may be induced by the biomechanical properties of the neck. According to Feipel, the direction of coupled rotation and lateral bending is ipsilateral in the lower cervical spine and contralateral in the upper cervical spine. Contralateral coupling in the upper cervical levels is necessary to maintain the head in an erect position. In our study, subjects with UPNP carefully performed prone neck extension with an erect head along the straight line in front of their face. Maintaining the head in an erect position may result in contralateral coupling between neck rotation and lateral bending in the upper cervical spine during prone neck extension.

It remains to be determined whether the asymmetry of muscle thicknesses while resting and neck motion during prone neck extension causes UPNP or if the UPNP triggers the asymmetry. Due to the cross-sectional design of the current study, causation could not be determined. A longitudinal study is needed to clarify the cause and effect relationship between UPNP and the asymmetry of muscle thicknesses and neck motions. However, it is clear that prone neck extension exercises should be performed symmetrically with minimal motion in both the transverse and frontal planes with the symmetrical use of the bilateral semispinalis capitis muscles in patients with UPNP. The results of this study can be applied to the management of patients with UPNP for the

### Table 1. Descriptive data of the participants

<table>
<thead>
<tr>
<th>Parameter</th>
<th>UPNP group (N=20)</th>
<th>Control group (N=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (male/female)</td>
<td>10/10</td>
<td>10/10</td>
</tr>
<tr>
<td>Age (years)</td>
<td>23.4 ± 1.9</td>
<td>23.4 ± 2.1</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>66.8 ± 8.4</td>
<td>65.5 ± 9.4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>173.4 ± 5.8</td>
<td>172.8 ± 6.9</td>
</tr>
<tr>
<td>Visual analog scale (mm)</td>
<td>60.5 ± 7.7</td>
<td>None</td>
</tr>
</tbody>
</table>

### Table 2. Comparison of mean percentage difference of thickness between bilateral semispinalis capitis in each group

<table>
<thead>
<tr>
<th>Muscle</th>
<th>UPNP group (N=20)</th>
<th>Control group (N=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semispinalis capitis</td>
<td>26.78 ± 15.18 a</td>
<td>2.57 ± 2.97 a</td>
</tr>
</tbody>
</table>

<sup>a p<0.05</sup>

### Table 3. Comparison of range of neck motion between the two groups during prone neck extension

<table>
<thead>
<tr>
<th>Motion</th>
<th>UPNP group (N=20)</th>
<th>Control group (N=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck rotation</td>
<td>3.95 ± 4.13 *(Non-painful side)</td>
<td>1.51 ± 2.95 a</td>
</tr>
<tr>
<td>Neck lateral bending</td>
<td>−4.36 ± 5.61 *(Painful side)</td>
<td>−1.22 ± 2.67 a</td>
</tr>
</tbody>
</table>

<sup>a p<0.05</sup>
selective activation of the atrophied semispinalis capitis and to minimize asymmetric neck motions during prone neck extension exercise.

This study had several limitations. First, our subjects were young; therefore, we cannot generalize our results to other populations. Second, we could not measure the real-time change in the thickness of the semispinalis capitis using ultrasonography when performing prone neck extension. Ultrasonography is useful for measuring muscle size during muscle contraction. However, we could not obtain clear ultrasonographic images because the skin over the semispinalis capitis shifted with the concurrent lateral bending and rotation of the neck in the UPNP group. Further studies are needed to measure real-time changes in the posterior neck muscle thickness during prone neck extension with a specialized jig to stabilize the probe in the UPNP group. Future studies should also use visual feedback with ultrasonography to examine the effects of activating the atrophied semispinalis capitis on the increase in muscle size and symmetrical neck motion during prone neck extension in subjects with UPNP.

In conclusion, the UPNP group showed greater bilateral asymmetry of the semispinalis capitis muscles and neck motions during prone neck extension than the control group. Asymmetric thickness of the semispinalis capitis muscles might induce asymmetric neck motions in subjects with UPNP. The asymmetric thickness of the semispinalis capitis muscles and asymmetric neck motions while performing prone neck extension have been used as a rationale for cervical stabilization exercises in individuals with UPNP. We suggest that clinicians treat individuals with UPNP with selective training of the atrophied semispinalis capitis and minimization of asymmetric neck motions during prone neck extension.

REFERENCES