The ratio of change in muscle thickness between superficial and deep cervical flexor muscles during the craniocervical flexion test and a suggestion regarding clinical treatment of patients with musculoskeletal neck pain

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Abstract. [Purpose] The purpose of this study was to identify the imbalance of muscle recruitment in cervical flexor muscles during the craniocervical flexion test by using ultrasonography and to propose the optimal level of pressure in clinical craniocervical flexion exercise for people with neck pain. [Subjects and Methods] A total of 18 students (9 males and 9 females) with neck pain at D University in Gyeongsangbuk-do, South Korea, participated in this study. The change in muscle thickness in superficial and deep cervical flexor muscles during the craniocervical flexion test was measured using ultrasonography. The ratio of muscle thickness changes between superficial and deep muscles during the test were obtained to interpret the imbalance of muscle recruitment in cervical flexor muscles. [Results] The muscle thickness ratio of the sternocleidomastoid muscle/deep cervical flexor muscles according to the incremental pressure showed significant differences between 22 mmHg and 24 mmHg, between 24 mmHg and 28 mmHg, and between 24 mmHg and 30 mmHg, and between 26 mmHg and 28 mmHg. [Conclusion] Ultrasonography can be applied for examination of cervical flexor muscles in clinical environment, and practical suggestion for intervention exercise of craniocervical flexors can be expected on the pressure level between 24 mmHg and 26 mmHg enabling the smallest activation of the sternocleidomastoid muscle.

Key words: Cervical flexor muscle, Ultrasonography, Muscle imbalance

INTRODUCTION

Neck pain and its disability result in a significant burden on individuals and family members, communities, healthcare systems, and businesses1–3). Recently, studies have been conducted in an attempt to identify the disability of deep cervical muscles contributing to stabilization of the cervical spine. A comparison study reported that people with neck pain have reduced activity of deep neck flexor (DCF) muscles with excessive activity of long-lever superficial muscles (e.g., sternocleidomastoid and anterior scalene muscles), resulting in unstable segmental motion in the intervertebral joint during repetitive upper limbs tasks4).

Disability of the DCF muscles in people with neck pain is regarded as a general consideration that a health professional might consider in planning a treatment strategy. In a control trial, Jull et al.5) reported that targeted training of the DCF muscles in people with neck pain demonstrated a greater reduction in score for the Neck Disability Index (NDI) and intensity of neck pain. However, for health professionals, the only feasible assessment method known to detect the activity of the DCF muscles in a clinical setting, due to their location, is electromyographic testing by applying needle or tube insertions, which is not a simplistic approach clinically and legally.

Therefore, in a clinical setting, an easy to apply approach may benefit rehabilitation practices for the imbalance of muscle recruitment in neck flexor muscles due to lack of DCF muscle activity. Ultrasonography is currently receiving attention as a tool for examination of deep layer muscles, but few studies have successfully reported muscle recruitment and neuromuscular responses of DCF muscles using ultrasonography6). The purpose of this study was to identify the imbalance of muscle recruitment in cervical flexor muscles during the Craniocervical Flexion Test (CCFT) using ultrasonography in people with neck pain and to use the findings to further guide explicit exercise management for neck flexor disabilities.

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SUBJECTS AND METHODS

The study subjects were 18 students (9 males) from D University Gyeongbuk Province with a mean age, weight, and height of 21.03 ± 2.67 years, 57.62 ± 12.9 kg, and 168.01 ± 7.61 cm, respectively. Participants were invited to participate in the study if they reported a current neck pain score of 5 points or greater for the NDI (total score is 50 points). Participants were excluded if they reported signs of neurological disorders, visited a health professional, or had experienced whiplash. In accordance with the ethical standards of the Declaration of Helsinki, information on the study was provided to all the subjects, and informed consent was received from them prior to participation in the study.

Real-time ultrasonography images were obtained from the longitudinal cross section of the right deep cervical flexor unit (longus colli and capitis) and right sternocleidomastoid during the CCFT in accordance with the previously established protocol. A 7.5 MHz transducer of a Z.one Ultra Convertible Ultrasound System (ZONARE Medical Systems, Inc., Mountain View, CA, USA) was positioned diagonally against the front of the neck area running along the trachea’s line and 5 cm away from the midline of the cervical spine. The CCFT was performed according to the standard protocol. Subjects were positioned in the supine position with the head and neck in a mid position, and the task required subjects to perform five gradually increasing movements of craniocervical flexion motion adjusted by visual feedback from an air-filled pressure sensor right underneath their neck; the applied pressures were 22, 24, 26, 28, and 30 mmHg.

The images obtained from the trial were transmitted to the NIH ImageJ software (version 1.44 for Windows) and subjected to image analysis process to measure the muscle thicknesses. A four-line grid with a 0.5 cm interval between lines was drawn on each image, and the first line was centered in the middle of each image. The average value for distance estimated from the second, third, and fourth line was designated as the thickness of each muscle. The amount of change in muscle thickness at each pressure level from the reference pressure (20 mmHg) was calculated by the following formula: (muscle thickness at the target pressure − muscle thickness at the reference pressure) / muscle thickness at the reference pressure. The imbalance of muscle recruitment at each pressure level was represented as the ratio of the change in muscle thickness of the sternocleidomastoid muscle (SCM) to the change in muscle thickness in the DCF muscles (imbalance ratio: thickness of SCM/thickness of DCF).

**RESULTS**

The muscle thickness ratio of the SCM/DCF according to the incremental pressure showed significant differences between 22 mmHg and 24 mmHg, between 24 mmHg and 28 mmHg, between 24 mmHg and 30 mmHg, and between 26 mmHg and 28 mmHg (p<0.05). The muscle thickness ratio of the SCM/DCF was smallest at 24 mmHg (Table 1).

**DISCUSSION**

In this study, ultrasonographic assessment of the muscle recruitment in cervical flexor muscles was conducted in people with neck pain. The secondary aim of this study was to determine the clinical applicability of using ultrasonography in evaluating the disability of cervical flexor muscles. Multiple studies have successfully visualized the recruitment pattern of deep cervical muscles in noninvasive and low-cost manners, and the present study highly suggested that ultrasonography could be used for this purpose.

The real values for the thicknesses of the DCF and SCM gradually increased as the pressure increased. Heightened recruitment of the SCM during the CCFT, was observed in the present study, which is consistent with the results of previous studies. Nonetheless, the aim of this study, unlike the previous studies, was to compare the muscle recruitment ratios of the superficial and deep cervical muscles and to suggest the optimal level of pressure for balanced muscle recruitment during the CCFT.

As depicted in Table 1, the greatest imbalance in muscle recruitment between the deep and superficial muscles during the CCFT was revealed at a pressure of 22 mmHg due to considerable thickness changes in the SCM. The second and third greatest imbalances, also due to increased changes in recruitment of the SCM, were 30 mmHg and 28 mmHg, respectively, while the DCF muscles maintained steady amounts of recruitment changes at both of these pressure levels. This finding suggests that health professionals need to take into consideration differences in applied pressures during interventions for patients with a disability of the DCF. As the activation of the SCM during the CCFT is smallest at the pressures of 24 mmHg and 26 mmHg, a recommendation for future research could be to consider these pressures for practical intervention.
for an adequate exercise intervention for DCF training might be established at a pressure level between 24 mmHg and 26 mmHg.

Although this study found great imbalances at pressure levels of 22 mmHg, 28 mmHg, and 30 mmHg, the standard muscle recruitment ratio between deep and superficial cervical muscles was not evaluated in a healthy population. For a comprehensive assessment of the muscle recruitment between symptomatic and non-symptomatic populations, future research needs to consider evaluating both populations with and without pain.

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