한국전문물리치료학회지 2018년 25권 2호 62-70 ISSN (Print) 1225-8962, ISSN (Online) 2287-982X
Phys Ther Korea 2018;25(2):62-70 https://doi.org/10.12674/ptk.2018.25.2.062

Comparison of the Cross-Sectional Area of Longus Colli and Muscle Activity of Sternocleidomastoid in Subjects With Forward Head Posture on the Two Craniocervical Flexion Methods

Min-chan Son[1,2], BPT, PT, Ui-jae Hwang[1,2], PhD, PT, Sung-hoon Jung[1,2], PhD, PT, Sun-hee Ahn[1,2], MSc, PT, Hyun-a Kim[1,2], MSc, PT, Oh-yun Kwon[1,3,4], PhD, PT

[1]Kinetic Ergocise Based on Movement Analysis Laboratory
[2]Dept. of Physical Therapy, The Graduate School, Yonsei University
[3]Dept. of Physical Therapy, College of Health Science, Yonsei University
[4]Dept. of Ergonomic Therapy, The Graduate School of Health and Environment, Yonsei University

Abstract

Background: The craniocervical flexion (CCF) exercise is one of the effective exercise in correcting forward head posture (FHP). However, some people with FHP achieve CCF with compensatory movements, for example, low cervical flexion using superficial neck flexors such as the sternocleidomastoid (SCM) muscle. No study has yet investigated whether a dual-pressure biofeedback unit (D-PBU) method to prevent low cervical flexion would be helpful in performing pure CCF movement.

Objects: The purpose of this study was to compare the effects of the CCF using D-PBU method and the traditional CCF method on the cross-sectional area (CSA) of the longus colli muscle (LCM) and the activity of SCM muscle in subjects with FHP.

Methods: Twenty-four FHP subjects (male: 16, female: 8) were recruited for this study. All subjects performed CCF using two different methods: the traditional CCF method and the CCF using D-PBU method. The CSA of the LCM was measured via ultrasound, and surface electromyography was used to measure SCM muscle activity.

Results: The change in CSA of the LCM was significantly larger during the CCF using D-PBU method (1.28±.09) compared with the traditional CCF method (1.19±.08) ($p<.05$). The SCM muscle activity using the CCF using D-PBU method (2.01±1.97 %MVIC) was significantly lower than when using the traditional CCF method (2.79±2.32 %MVIC) ($p<.05$).

Conclusion: The CCF using D-PBU method can be recommended for increasing LCM activation and decreasing SCM muscle activity during CCF movement in subjects with FHP.

Key Words: Craniocervical flexion; Cross-sectional area; Dual-pressure biofeedback unit; Forward head posture; Muscle activity.

Introduction

Forward head posture (FHP) is defined as a protraction of the head anterior to the trunk in the sagittal plane (Silva et al, 2009). FHP usually involve shortened cervical spine extensors (suboccipital extensors, rectus capitis, superior obliques, and inferior obliques) and lengthened intrinsic cervical flexors [the longus colli muscle (LCM) and the longus capitis muscle] (Sahrmann, 2010; Jung et al, 2015). FHP also involves an extended middle cervical spine, and a flexed lower cervical spine (Harman et al, 2005). It is related to deep cervical flexor weakness(Griegel-Moris et al, 1992).

Craniocervical flexion (CCF) exercise is one of the effective training methods to strengthen the deep

Corresponding author: Oh-yun Kwon kwonoy@yonsei.ac.kr

cervical flexor muscles such as the LCM and longus capitis muscle in the upper cervical region, giving support to the cervical segments, and curve, rather than the superficial cervical flexor muscles like the sternocleidomastoid (SCM) muscle and anterior scalene muscle (Jull et al, 2004; Jull et al, 2009). However, poor activation of the LCM can affect the increased activation of the SCM during CCF exercise (Jull et al, 2004). Sahrmann (2010) showed that subjects with FHP using an extrinsic muscles such as the SCM cause excessive cervical vertebrae anterior translation rather than sagittal rotation, which occurs via intrinsic cervical muscles such as the LCM. Therefore, many studies (Falla et al, 2004; Jull et al, 2004; Jull et al, 2008) have used CCF, encouraging the action of the LCM and monitoring SCM activities.

A CCF test can be used as an indirect measurement of LCM contraction ability and be used to evaluate an individual's ability to perform and maintain precise upper cervical flexion without mid or lower cervical spine flexion (Chiu et al, 2005; Mayoux-Benhamou, 1997). CCF is associated with the interrelated action of the LCM and longus capitis muscle to support and stabilize the lordosis of the cervical spine (Jull et al, 1999). However, some subjects with neck disorders perform CCF by retracting the cervical spine, using superficial neck flexors such as the SCM instead of pure CCF movement through deep neck flexors contraction (Chiu et al, 2005: Jull et al, 2000). This usage is related to uncontrolled movement such as upper cervical flexion with excessive low cervical flexion during the CCF movement (Comerford and Mottram, 2012).

Many studies have shown the importance of identifying control impairments such as excessive low cervical flexion during cervical flexion and of diagnosis based on the impairment of movement in the cervical spine (Caldwell et al, 2007; Comerford and Mottram, 2012; Sahrmann, 2002). Comerford, and Mottram (2012) suggested that the upper cervical area can flex without low cervical flexion for the correction of the cervical flexion. In previous studies, a pressure biofeedback unit (PBU) was used to control craniocervical movement at the upper cervical region during CCF (Jung et al, 2015). During CCF, compensatory movements like retracting the cervical spine, performed by superficial muscles, were controlled just by the researcher (Falla et al, 2004; Jull et al, 2009). However, there are no studies using the objective apparatus that have investigated cervical movement during CCF both in the upper cervical region and lower cervical region by restricting low cervical flexion. So, this study suggests adding one more PBU under the lower cervical region to restrain low cervical flexion during CCF.

The purpose of this study was to confirm the effects in subjects with FHP of using CCF using dual-PBU (CCF using D-PBU) method compared with the traditional CCF method using one PBU on a cross-sectional area (CSA) of the LCM and the activity of the SCM muscle. We hypothesized that the CSA of the LCM would be larger and that the activity of the SCM muscle would be lower when using the CCF using D-PBU method than when using the traditional CCF method.

Methods

Subjects

Twenty-four volunteers (16 males, 8 females) aged 20∼30 years at Yonsei University in Wonju participated in this study. The characteristics of the subjects are shown in Table 1. The inclusion criteria included (1) a young age (20∼30 years) and (2) the presence of FHP, where FHP was defined as having

Table 1. Characteristics of the subjects (N=24)

Characteristics	Mean±SD[a]
Age (year)	22.8±1.9
Height (㎝)	170.9±6.9
Weight (㎏)	69.9±11
Cranio-vertebral angle (°)	46.3±2.6

[a]mean±standard deviation.

a craniovertebral angle less than 50° (Ruvio et al, 2017). The craniovertebral angle is a crossed angle between the line from the tragus of the ear to spinous process of the C7 vertebra and a horizontal line of the C7 spinous process in the sagittal plane (Yip et al, 2008). The reflective markers were an attached C7 spinous process and the tragus of the ear. Subjects were asked to flex and extend their necks three times until the head was in a comfortable position (Yip et al, 2008). The head and neck posture were recorded using a digital camera (Samsung, Seoul, Korea). To confirm subjects with FHP, Image J imaging software (U.S. National Institutes of Health, Maryland, USA) was used to measure the craniovertebral angle. Exclusion criteria included (1) being unable to achieve 30 ㎜Hg in upper cervical region through CCF (2) having a previous history of shoulder and neck surgery. All participants signed informed consent forms, and this study was approved by the Yonsei University Wonju Institutional Review Board (approval number: 1041849-201710-BM-123-01).

Instrumentations and data processing

The Myson U6 (Medison, Seoul, Korea) was used to record the image of the LCM. To measure the size of the LCM, a linear transducer (5-12 ㎒) was placed 2 ㎝ below the thyroid cartilage, perpendicular to the neck. To increase reliability, the examiner marked the location of the transducer with a marker. In this position, the outlines of the LCM can be visualized by the vertebrae body (inferiorly and medially), retropharyngeal space (superiorly), and carotid artery (laterally). The CSA of the LCM was calculated from the outlines linking the vertebrae body, the retropharyngeal space, and the carotid artery (Janvanshir K, 2011). The change in the LCM CSA during each CCF methods were shown as a proportion of the LCM CSA at starting position (ending position/starting position) (Jung et al, 2015).

The activation of the SCM muscle was measured by EMG (Noraxon Telemyo 2400T, Noraxon, Scottsdale, AZ, USA). The electrodes for the SCM were placed 2 ㎝ from each electrode, parallel to the SCM muscle fibers, and were attached around the middle part between the clavicle and the mastoid process (Criswell, 2010). A Myoresearcher XP Master Edition (Noraxon Inc., Scottsdale, USA) was used to collect signals. A band-pass filter applied between 20 ㎐ and 450 ㎐ to filter the raw signals. Root mean squares were calculated using 50 ㎳. The data were recorded at a 1000 ㎐ sampling rate.

To normalize the EMG signals of the SCM, maximum voluntary isometric contraction (MVIC) was used. To obtain the SCM MVIC data, the standard manual muscle-test position was used. Each subject was asked to lie supine, and turn their face toward the non-tested side, with lateral flexion against resistance in the opposite direction above the temporal region, applied by the examiner (Kendall et al, 2005). The MVIC data was collected three times for five seconds, with a three minutes rest between muscle contractions. To calculate the mean value, the data from the middle three seconds of each trial were used. The EMG data of SCM was expressed as a percentage of the MVIC. The data of SCM activity was collected when PBU pressure of upper cervical region achieved 30 ㎜Hg.

A PBU (Pressure biofeedback unit, Healience, Seoul, Korea) is a sensitive apparatus showing pressure increases in cervical nodding. Visible feedback on the pressure is provided by a manometer (Jung et al, 2015). In this study, PBUs were used to control the movement and measure the pressure of the upper cervical region and the lower cervical region when performing traditional CCF method and CCF using D-PBU method. The data of PBU in the lower cervical region was collected when PBU pressure of upper cervical region achieved 30 ㎜Hg.

Procedure

Prior to the measurement, the order of the trials was randomized to remove any order effects, based on a random number generating process using Microsoft Excel ver. 2010 (Microsoft Corporation,

Figure 1. Craniocervical flexion using dual-pressure biofeedback unit (CCF using D-PBU) method (A: starting position, B: ending position).

Washington, US). The traditional CCF and CCF using D-PBU methods were used for the intervention. Before the intervention, subjects were given ten minutes of practice time to acclimatize to the traditional CCF method and the CCF using D-PBU method. Each method was performed two times, with a resting time of 30 seconds. There was also a five minutes resting time between interventions to prevent carry-over effects. The average value of two trials was used to analyze the data. The other researcher was blinded to the experimental circumstances during variables analysis.

The starting position of the traditional CCF method is a supine crook lying, with the subject lying with neutral neck position where towels are used to make the line of face horizontal with the surface. One pressure sensor is located in the upper cervical region, with a pressure of 20 ㎜Hg (Jull et al, 2008). The other pressure is placed in the lower cervical region, with a pressure of 40 ㎜Hg. The ultrasound image was recorded in starting position. The subjects performed CCF until the upper cervical region pressure was 30 ㎜Hg (Jung et al, 2015), ignoring lower cervical region pressure. The subjects maintained both the starting and ending positions for five seconds. The examiner recorded the EMG data, the ultrasound image, and the PBU data of lower cervical region both for the starting position and when the PBU pressure of upper cervical region achieved 30 ㎜Hg.

The process of the CCF using D-PBU method is similar to the traditional CCF method, except that one more PBU controlling low cervical flexion movement is added in the lower cervical region. The starting position for the CCF using D-PBU method is the same as for the traditional CCF method. However, subjects are asked to maintain a lower cervical region pressure of 40 ㎜Hg as much as possible to prevent low cervical flexion, until they achieve 30 ㎜Hg pressure in the upper cervical region with the PBU during CCF. The problem with CCF is excessive low cervical flexion rather than upper cervical flexion (Comerford and Mottram, 2012). For the pure CCF, PBU at the lower cervical region was used to control the low cervical flexion during CCF. The data were recorded both in the starting position and when the upper cervical region pressure achieved 30 ㎜Hg, in the same way as for the traditional CCF method (Figure 1).

Statistical analysis

For determine relative reliability in two trials, 95% confidence intervals (CIs) intra-class correlation coefficients (ICCs) was used. Standard errors of the measurement (SEM) was calculated to confirm the precision of measurement in the same unit (Kim et al, 2017a).

To analyze the data, the Statistical Package for Social Science version 23 (SPSS Inc., Chicago, IL,

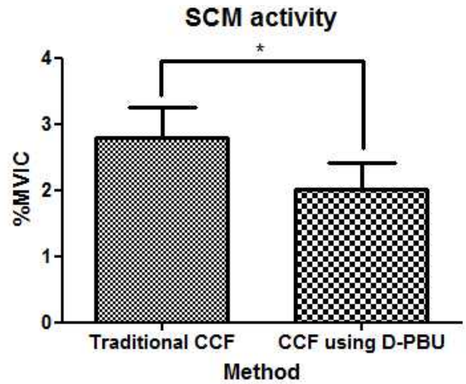

Figure 2. A comparison of SCM activity using two different methods. *p<.05, (SCM: sternocleidomastoid, MVIC: maximum voluntary contraction, CCF: craniocervical flexion, D-PBU: dual-pressure biofeedback unit).

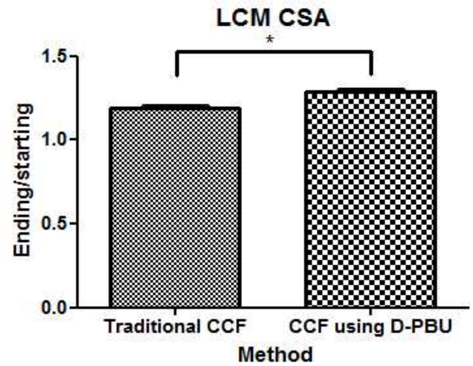

Figure 3. A comparison of LCM CSA (ending position/starting position) using two different methods. *p<.05, (LCM: longus colli muscle, CSA: cross-sectional area, CCF: craniocervical flexion, D-PBU: dual-pressure biofeedback unit).

USA) was used. The Kolmogorov-Smirnov test was used to identify the normal distribution of the data. The data from this study are shown as a mean±standard deviation. The difference in muscle activity, muscle CSA, and PBU data between the two methods was compared by a paired t-test. The significance level (α) was set at .05 to confirm statistical significance.

Results

The intra-rater reliability of measurements for 24 participants is reported in Table 2. The results of ICC were very high in all measurements (ICC>.92). The SCM muscle activity was 2.79±2.32 %MVIC and 2.01±1.97 %MVIC, respectively, for the traditional CCF method and the CCF using D-PBU method. The SCM muscle activity using the CCF using D-PBU method was significantly lower than that for the traditional CCF method (t=3.988, p=.001) (Figure 2). The change in the LCM CSA (ending position/starting position) was 1.19±.08 and 1.28±.09, respectively, for the traditional CCF method and the CCF using D-PBU method. The change of LCM CSA in the CCF using D-PBU method was significantly larger than that for the traditional CCF method (t=-6.849, p<.001) (Figure 3). The pressure of the PBU in the lower cervical region was 44.15±6.59 ㎜Hg, and 40.25±.78 ㎜Hg, respectively, for the traditional CCF method and the CCF using D-PBU method. The pressure for the traditional CCF method using the PBU under the lower cervical region was significantly increased compared with that for the CCF using D-PBU method (t=2.987, p=.007) (figure 4).

Table 2. Intra-rater reliability of measurements (N=24)

Measurements	ICC[a] (95% CI[b])	SEM[c]
SCM[d] activity with traditional CCF[e]	.94 (.87-.98)	.81
SCM activity with CCF using D-PBU[f]	.92 (.81-.96)	.75
LCM[g] CSA[h] in resting	.97 (.93-.99)	.02
LCM CSA with traditional CCF	.97 (.93-.99)	.02
LCM CSA with CCF using D-PBU	.96 (.91-.98)	.2

[a]intraclass correlation coefficient, [b]confidence interval, [c]standard error of the mean, [d]sternocleidomastoid, [e]traditional craniocervical flexion, [f]craniocervical flexion using dual-pressure biofeedback unit, [g]longus colli muscle, [h]cross-sectional area.

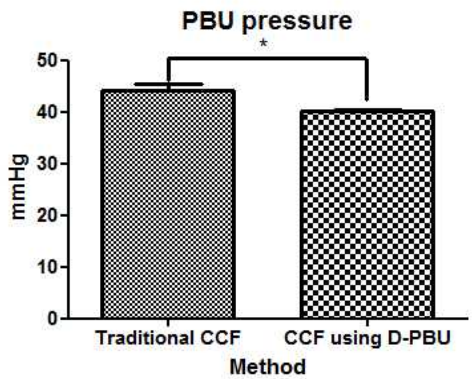

Figure 4. A comparison of PBU pressure in the lower cervical region using two different method. *p<.05, (PBU: pressure biofeedback unit, CCF: craniocervical flexion, D-PBU: dual-pressure biofeedback unit).

Discussion

Previous studies showed that accurate CCF can be performed with the LCM and longus capitis rather than superficial neck flexors such as SCM (Falla et al, 2004; Jull et al, 2008; Jung et al, 2015). Therefore, this study compared the CSA of the LCM, the muscle activity of the SCM, and the PBU pressure between the traditional CCF method and the CCF using D-PBU method in subjects with FHP. The results showed that the CSA of the LCM was significantly larger and the muscle activity of SCM was significantly lower using the CCF using D-PBU method compared with the traditional CCF method. The traditional CCF method also had a significantly increased pressure of the PBU under the lower cervical region compared with that of the CCF using D-PBU method.

The LCM plays an important role in stabilizing the cervical spine and controlling neck posture (Mayoux-Benhamou et al, 1994). FHP is associated with a weakness of the deep cervical flexor muscles, such as the LCM (Griegel-Moris et al, 1992). It is important to correct FHP through exercise (Harman et al, 2005). Jull et al (2009) showed that performing CCF exercise using one PBU in the upper cervical region is an effective method of activating deep cervical muscles such as the LCM. In this study, CCF using one PBU and D-PBU was compared, to detect which methods would be most effective in activating the LCM. The results showed that the CSAs proportion of LCM were 1.19±.08 and 1.28±.09, respectively, when using the traditional CCF method and CCF using D-PBU method. This means that it is more effective to use the CCF using D-PBU method than to use the traditional CCF method to activate the LCM.

The CCF movement involves the action of the LCM and longus capitis, not the action of the SCM and scalenes (Falla et al, 2003). The purpose of CCF tests has been to assess synergistic anatomical action of deep cervical muscles such as the LCM and the longus capitis muscle, rather than SCM and the anterior scalene muscles (Jull et al, 2004). These tests have shown that pure CCF does not involve the retraction of the cervical spine by superficial muscles (Chiu et al, 2005). Therefore, many studies have supervised the muscle activity of SCM by observation or palpation during CCF (Fernández-de-las-Peñas et al, 2007; Falla et al, 2003; Jull et al, 2008). To more precisely control the compensation motion by superficial muscles such as the SCM, in this study, we added one more PBU under the lower cervical region, unlike the configuration in the traditional CCF method. The resulting data (traditional CCF method: 2.79±2.32 %MVIC; CCF using D-PBU method: 2.01±1.97 %MVIC) demonstrated that the CCF using D-PBU method activated SCM less than the traditional CCF method. This means that the activity of the SCM would be restricted using the CCF using D-PBU method through obstructing low cervical region flexion or retraction by maintaining a lower cervical region pressure of PBU 40 ㎜Hg.

In this study, the new CCF using D-PBU method, using one more PBU at the lower cervical region, showed more ideal results in terms of performing pure CCF movement than did the traditional CCF method. The pressure of the PBU was significantly increased in the traditional CCF method compared to that with the CCF using D-PBU method (traditional CCF method: 44.15±6.59 ㎜Hg; CCF using D-PBU method: 40.25±.78 ㎜Hg). Some studies used biofeedback for controlling muscles, strengthening the target muscles, and decreasing compensation (Koh et al, 2016; Roy et al, 2010). For example, Kim et al (2017b) used a PBU to decrease compensation movement. Noh et al (2014) also used CCF using D-PBU to control the pelvic rotation angle during an active straight leg raise and confirmed that the pelvic rotation angle was significantly lower with D-PBU than with a single PBU. In this study, using the CCF using D-PBU method not only maintained lower cervical stabilization through restricting SCM activation during CCF, but it also allowed unsupervised training by self-monitoring through the lower cervical region pressure of the PBU.

There are some limitations in this study to be considered. First, this study investigated the immediate effects of the CCF using D-PBU method and not the long-term effects. Therefore, the long-term effects of the CCF using D-PBU method will also need to be studied. Second, the subjects of this study were only young adults with FHP, so it is difficult to generalize these results to the overall population. Third, this study investigated only FHP subjects. Further studies are necessary to investigate the effects of the CCF using D-PBU method in subjects with other neck disorders.

Conclusion

In this study, we compared the effects of the CCF using D-PBU method and the tradtional CCF method on the CSA of the LCM and the muscle activity of SCM in subjects with FHP. The results showed that CCF using D-PBU method produced more increased LCM activation and lower SCM muscle activity than traditional CCF method. These results suggest that the CCF using D-PBU method can provide more benefits than the traditional CCF method in subjects with FHP.

References

Caldwell C, Sahrmann S, Van Dillen L. Use of a movement system impairment diagnosis for physical therapy in the management of a patient with shoulder pain. J Orthop Sports Phys Ther. 2007;37(9):551 - 563. https://doi.org/10.2519/jospt.2007.2283

Chiu TT, Law EY, Chiu TH. Performance of the craniocervical flexion test in subjects with and without chronic neck pain. J Ortho Sports Phys Ther. 2005;35(9):567-571. https://doi.org/10.2519/jospt.2005.35.9.567

Comerford M, Mottram S. Kinetic Control: The management of uncontrolled movement. 1st ed. Sydney, N.S.W, Elsevier churchil livingstone, 2012:219-291.

Criswell E. Cram's Introduction to Surface Electromyography. 2nd ed. Sudbury, Massachusetts, Jones and Bartlett Publishers, 2010:279-282.

Falla D, Jull G, Dall'Alba P, et al. An electromyographic analysis of deep cervical flexor muscles in performance of craniocervical flexion. Phys Ther. 2003;83(10):899-906.

Falla DL, Jull GA, Hodges PW. Patients with neck pain demonstrate reduced electromyographic activity of the deep cervical flexor muscles during performance of the craniocervical flexion test. Spine (Phila Pa 1976). 2004;29(19):2108-2114.

Fernández-de-las-Peñas C, Pérez-de-Heredia M, Molero-Sánchez A, et al. Performance of the craniocervical flexion test, forward head posture, and headache clinical parameters in patients with chronic tension-type headache: A pilot study. J orthop Sports Phys Ther. 2007;37(2):33-39. https://doi.org/10.2519/jospt.2007.2401

Griegel-Morris P, Larson K, Mueller-Klaus K, et al. Incidence of common postural abnormalities in the cervical, shoulder, and thoracic regions and their association with pain in two age groups of healthy subjects. Phys Ther. 1992;72(6):425-431.

Harman K, Hubley-Kozey CL, Butler H. Effectiveness of an exercise program to improve forward head posture in normal adults: A randomized, controlled 10-week trial. J Man Manip Ther. 2005;13(3):163-176.

Janvanshir K, Mohseni-Bandpei MA, Rezasoltani A, et al. Ultrasonography of longus colli muscle: A reliability study on healthy subjects and patients with chronic neck pain. J Bodyw Mov Ther. 2011;15(1):50-56. https:/doi.org/10.1016/j.jbmt.2009.07.005

Jull G, Barrett C, Magee R, et al. Further clinical clarification of the muscle dysfunction in cervical headache. Cephalalgia. 1999;19(3):179-185. https://doi.org/10.1046/j.1468-2982.1999.1903179.x

Jull GA. Deep cervical flexor muscle dysfunction in whiplash. J Musculoskelet Pain. 2000;8:143-154.

Jull G, Kristjansson E, Dall'Alba P. Impairment in the cervical flexors: A comparison of whiplash and insidious onset neck pain patients. Man Ther. 2004;9(2):89-94. https://doi.or/10.1016/S1356-689X(03)00086-9

Jull GA, O'Leary SP, Falla DL. Clinical assessment of the deep cervical flexor muscles: The craniocervical flexion test. J Manipulative Physio Ther. 2008;31(7):525-533. https://doi.org/10.1016/j.jmpt.2008.08.003

Jull GA, Falla D, Vicenzino B, et al. The effect of therapeutic exercise on activation of the deep cervical flexor muscles in people with chronic neck pain. Man Ther. 2009;14(6):696-701. https://doi.org/10.1016/j.math.2009.05.004

Jung SH, Kwon OY, Choi KH, et al. Comparison of the thickness of the neck flexor muscles of subjects with and without a forward head posture on the two initial head positions during cranio-cervical flexion exercise. Phys Ther Kor. 2015;22(4):44-50. https://doi.org/10.12674/ptk.2015.22.4.044

Kim HA, Hwang UJ, Jung SH, et al. Comparison of shoulder strength in males with and without myofascial trigger points in the upper trapezius. 2017a;49:134-138. https://doi.org/10.1016/j.clinbiomech.2017.09.001

Kim HA, Hwang UJ, Jung SH, et al. Effect of horizontal adduction force on infraspinatus and deltoid activities during the side-lying wiper exercise using pressure biofeedback. Phys Ther Kor. 2017b;24(4):77-83. https://doi.org/10.12674/ptk.2017.24.4.077

Koh EK, Park KN, Jung DY. Effect of feedback techniques for lower back pain on gluteus maximus and oblique abdominal muscle activity and angle of pelvic rotation during the clam exercise. Phys Ther Sport. 2016;22:6-10. https://doi.org/10.1016/j.ptsp.2016.04.004

Mayoux-Benhamou MA1, Revel M, Vallée C, et al. Longus colli has a postural function on cervical curvature. Surg Radiol Anat. 1994;16(4):367-371.

Mayoux-Benhamou MA, Revel M, Vallee C. Selective electromyography of dorsal neck muscles in humans. Exp Brain Res. 1997;113(2):353-360.

Noh KH, Kim JW, Kim GM, et al. The influence of dual pressure biofeedback units on pelvic rotation and abdominal muscle activity during the active straight leg raise in women with chronic lower back pain. J Phys Ther Sci. 2014;26(5):717-719. https://doi.org/10.1589/jpts.26.717

Peterson-Kendall F, Kendall-McCreary E, Geise-Provance P, et al. Muscles Testing and Function With Posture and Pain. 5th ed. Baltimore: MD, Lippincott Williams and Wilkins, 2005:156.

Roy JS, Moffet H, McFadyen BJ. The effects of unsupervised movement training with visual feedback on upper limb kinematic in persons with shoulder impingement syndrome. J Electromyogr Kinesiol. 2010;20(5):939-946. https://doi.org/10.1016/j.jelekin.2009.10.005

Ruivo RM, Pezarat-Correia P, Carita AI. Effects of a resistance and stretching training program on forward head and protracted shoulder posture in adolescents. J Manipulative Physiol Ther. 2017;40(1):1-10. http://dx.doi.org/10.1016/j.jmpt.2016.10.005

Sahrmann S. Diagnosis and treatment of movement impairment syndromes. 1 ed. St Louis, Mosby, 2002:5-8.

Sahrmann S. Movement System Impairment Syndromes of the Extremities, Cervical and Thoracic Spines. 1 ed. St Louis, Mosby, 2010:51-86.

Silva AG, Punt TD, Sharples P, et al. Head posture and neck pain of chronic nontraumatic origin: A comparison between patients and pain-free persons. Arch Phys Med Rehabil. 2009;90(4):669-674. https://doi.org/10.1016/j.apmr.2008.10.018

Yip CH, Chiu TT, Poon AT. The relationship between head posture and severity and disability of patients with neck pain. Man Ther. 2008;13(2):148-154. https://doi.org/10.1016/j.math.2006.11.002

This article was received April 3, 2018, was reviewed April 3, 2018, and was accepted May 6, 2018.