한국전문물리치료학회지 2015년 22권 4호 44-50
Phys Ther Korea 2015;22(4):44-50

ISSN (Print) 1225-8962, ISSN (Online) 2287-982X
http://dx.doi.org/10.12674/ptk.2015.22.4.044

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

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Abstract

This study compared the effects of the initial head position (i.e., a HHP versus a relaxed head position) of subjects with and without a FHP on the thickness of the deep and superficial neck flexor muscles during CCF. The study recruited 6 subjects with a FHP and 10 subjects without a FHP. The subjects performed CCF in two different head positions: a HHP, with the head aligned so that the forehead and chin formed a horizontal line, and a relaxed head position (RHP), with the head aligned in a self-selected comfortable position. During the CCF exercise, the thickness of the longus colli (LCo) and the thickness of the sternocleidomastoid (SCM) were recorded using ultrasonography. The thickness of each muscle was measured by Image J software. The statistical analysis was performed with a two-way mixed-model analysis of variance. The thickness of the SCM differed significantly ($p<.05$) between the subjects with and without FHP. According to a post hoc independent t-test, the change in thickness of the SCM increased significantly during CCF in the subjects with FHP while adopting a HHP compared to that in the subjects without FHP. The change in thickness of the SCM was not significantly different between the two positions in subjects without FHP, and there was no significant change in thickness of the LCo muscle during the CCF exercise according to the initial position in both subjects with and without FHP. The results suggest that CCF should be performed in RHP to minimize contraction of the SCM in subjects with a FHP.

Key Words: Cranio-cervical flexion; Deep neck flexor; Initial head position; Superficial neck flexor.

Introduction

The prevalence of a forward head posture (FHP) has increased due to the increased numbers of people today who sit at a desk for extended periods (Yip et al, 2008). With a FHP, the head is in an anterior position in relation to the plumb line, which is vertical to a horizontal line through the center of gravity of the body (Griegel-Morris et al, 1992). A FHP is one of the most common types of poor head posture in patients with neck disorders (Yip et al, 2008). Johnson (1998) suggested that a prolonged FHP might increase pressure on the posterior cranio-cervical structure. Subjects with a FHP show an in-

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creased degree of upper cervical extension in comparison to that of the lower cervical spine. Other effects of a FHP are shortness of the suboccipital extensors, superior obliques, inferior obliques, and rectus capitis (Page et al, 2010; Sahrmann, 2010). Ishida et al (2015) demonstrated that the muscle thickness of the longus colli (LCo) of subjects with a FHP was reduced compared to that of subjects without a FHP.

Cranio-cervical flexion (CCF) exercise aims to activate the deep cervical flexor muscles (DCFMs). DCFMs consist of LCo, which provide support to the cervical curve, segments, and longus capitis (LC) works in synergy with the LCo in CCF (Gong et al, 2012; Jull et al, 2004b). In CCF exercise, a pressure biofeedback unit (PBU) is used to monitor cranio-cervical movement caused by progressive flattening of the cervical lordosis (Mayoux-Benhamou et al, 1997). The exercise is composed of five progressive stages from a baseline pressure of 20 ㎜Hg to 22, 24, 26, 28, and 30 ㎜Hg. According to previous studies, the electromyography activity (Falla et al, 2003) and the change in the thickness (Jesus et al, 2008) of the DCFM increased when the stage of the PBU was increased during CCF. However, many studies have shown that the superficial cervical flexor muscles (SCFMs), such as the sternocleidomastoid (SCM) and anterior scalene, of subjects with neck pain were overactivated during CCF (Falla et al, 2004; Jull et al, 2004b; Jull et al, 2008). Jull et al (2004b) suggested that the increased activity of the SCFMs during CCF could be to compensate for the poor activation of the LCo. To prevent such compensatory movements during CCF, the activity of the SCFMs should be monitored (Falla et al, 2004; Jull et al, 2004b; Jull et al, 2008).

In previous studies (Jesus et al, 2008; Jull et al, 2008; Lluch et al, 2013), the head and neck were placed in a horizontal position before CCF exercise, with the subject's forehead and chin in a horizontal position and in a midposition. However, subjects with a FHP usually have posterior neck extensor muscles tightness and lengthened DCFMs (Sahrmann, 2010). When a subject with a FHP performs CCF exercise in a horizontal head position (HHP), the subject requires more torque than does a subject without a FHP. Such torque is difficult in FHP subjects because of changes in the length-tension curve of the DCFMs. The change may result in greater activity of the SCFMs during CCF exercise with a FHP. Therefore, the purpose of this study was to determine the effects of the initial head position on the thickness of the LCo (DCFM) and SCM (SCFM) during CCF exercise in subjects with and without a FHP. It was hypothesized that a HHP would increase the change in thickness of the SCM during CCF exercise in subjects with a FHP.

Methods

Subjects

Sixteen volunteers (12 males, 4 females) aged 18∼30 years were recruited from Yonsei University students (Table 1). The inclusion criteria were young age (18∼30 years) and the presence or not of a FHP. A FHP was defined as a cranio-vertebral angle of 40.3°∼47.5° (Subjects with FHP). No FHP was defined as a cranio-vertebral angle of 49.2°∼

Table 1. General characteristics of the subjects (N=16)

Characteristics	With FHP[a] (n_1=6)	Without FHP (n_2=10)
Age (year)	23.8±2.0[b]	22.2±1.3
Height (㎝)	177.2±4.4	170.6±8.4
Weight (㎝)	84.8±9.0	67.2±6.8
Cranio-vertebral angle (°)	43.3±3.0	52.5±3.1

[a]forward head posture, [b]mean±standard deviation.

55.8° (Subjects without FHP) (Cheung Lau et al, 2009). The exclusion criteria included a history of fracture injury at the cervical and shoulder region or vertebral column, scoliosis, severe thoracic kyphosis, spasmodic torticollis, rheumatic disease, temporomandibular joint dysfunction, neurological motion disorders or back pain, or loss of standing balanced. All the subjects signed written informed consent forms, and the study was approved by the Institutional Review Board of Yonsei University Wonju Campus (approval number: 1041849-201510-BM-068-01).

Instruments

2D analysis (Image J): Measurement of FHP

Image J imaging software (U.S. National Institutes of Health, Maryland, USA) was used to measure the FHP angle, which is the angle between a line drawn from the tragus of the ear to the seventh cervical (C7) spinous process and a horizontal line from the bottom. First, adhesive reflexive markers were placed over the C7 spinous process (i.e., the midpoint of the most prominent point and tragus of the left ear). The subjects were asked to stand, face forward, and then extend and flex their neck three times until they were in a comfortable position (Yip et al, 2008).

Ultrasound

Ultrasound images of the LCo and SCM were recorded using the Accuvix A30 Ultrasound (Medison Co. Ltd., Seoul, Korea) system. The transducer (7.5-㎒) was placed to the right of the neck about 5 ㎝ from thyroid cartilage and parallel to the direction of the trachea. In this position, the LCo and SCM, right carotid artery, vertebral lamina, and boundary of the SCM (benchmark) could be visualized clearly on the left side of the ultrasonography image (Jesus-Moraleida et al, 2011).

Procedure

The subjects were positioned in a supine position, with their knees bent (hips 45° flexion, knees 90° flexion), and their arms crossed on their chests. Before the CCF exercise, the subject's head and neck were placed in the two initial head positions (Figure 1). In this study, HHP and relaxed head position (RHP) are used as initial head positions. The two terms are explained below.

-HHP: In a supine position, the subject's forehead and chin were horizontal by anterior gliding of the head in the frontal-axis measured using a hand-made smartphone based measurement tool.

-RHP: In a supine position, the subject performed the CCF five times. After the CCF, the subject's head was maintained in a comfortable position.

A PBU (Healience, Seoul, Korea) was placed suboccipitally and inflated to a baseline pressure of 20 ㎜Hg. The PBU is a sensitive apparatus for recording increases in pressure with cervical nodding. A manometer provided visible feedback on the pressure.

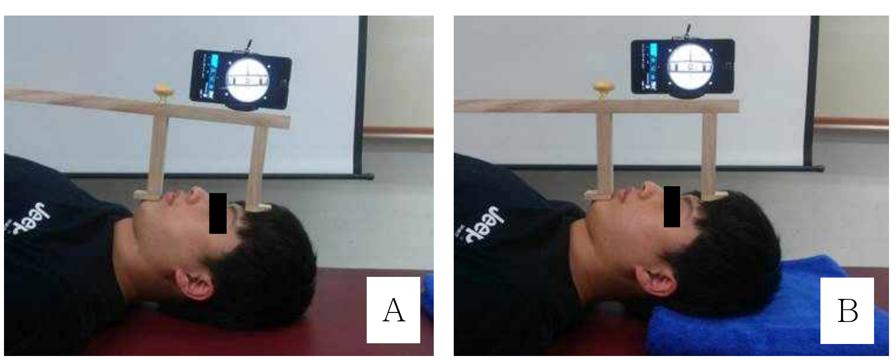

Figure 1. Two initial positions (A: relaxed head position, B: neutral head position).

To familiarize the subjects with the CCF exercise, the subjects were shown how to perform the exercise from the two initial positions. They then performed the exercise for 5 min. During this exercise period, the examiner verbally discouraged neck retraction to minimize superficial muscle contraction. As the subjects performed the CCF, the pressure was increased from a baseline pressure of 20 ㎜Hg to a maximum of 30 ㎜Hg for 10 sec, with a 2-min rest between trials. Ultrasonography images were obtained both in the resting position and when the exercises were performed at pressures up to 30 ㎜Hg (Jesus et al, 2008).

Data management

To determine the thickness of the LCo and SCM, three lines (broken lines in Figure 2) of equal length were drawn from the midline of the ultrasound image to the right side (edge) of the image. The thickness of the LCo muscle was calculated from the inferior of the carotid boundary to the superior of the echogenic vertebral lamina. The thickness of the SCM was calculated from the superficial to deep boundaries of the SCM. The thickness of each muscle was calculated by using the average of the three dash lines. The changes in the muscle thickness during the CCF exercise were expressed as a proportion of the muscle thickness at rest (Jesus et al, 2008).

Statistical analysis

Statistical analyses were conducted using SPSS ver. 21.0 (SPSS Inc., Chicago, IL, USA). After a normal distribution was examined using the Kolmogorov-Smirnov Z-test, a two-way mixed-model analysis of variance (ANOVA) was used to compare the between-group (with FHP vs without FHP) difference in the muscle thickness (SCM/LCo) when the exercise was performed at the different positions (HHP/RHP). When a significant difference was found, post hoc independent t-tests were performed. An paired t-test was used to compare the between head position difference in the muscle thickness (SCM/LCo) in each group. The level of statistical significance (α) was chosen as .05.

Results

The two-way ANOVA showed that there was a significant difference ($F=19.797$, $p<.001$) between subjects with and without FHP in the change in thickness of the SCM and there was no significant difference between group in the change in thickness of the LCo ($p=.814$). A summary table for the two-way analysis of variance is presented in Table 2. The results of the post hoc independent t-tests demonstrated that the thickness of the SCM was

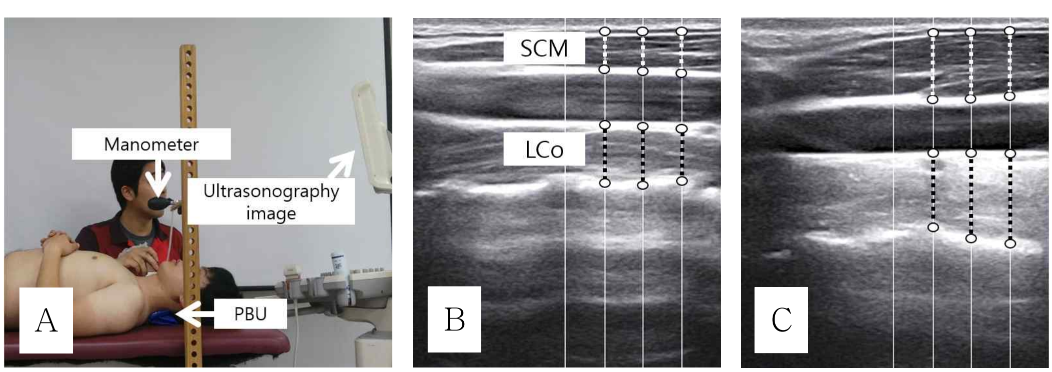

Figure 2. PBU measurements using a hand-held manometer and ultrasonography recordings (A: measurement setting, B: ultrasonography image in the resting position while adopting a HHP, C: ultrasonography image while performing CCF at a pressure of 30 ㎜Hg, PBU: pressure biofeedback unit, SCM: sternocleidomastoid, LCo: longus colli).

Table 2. Summary table for the two-way analysis of variance

	Muscle	Sum of squares	df	Mean square	F	p
Group	SCM[a]	.249	1	.249	19.797	<.001*
	LCo[b]	.001	1	.001	.056	0.814

[a]sternocleidomastoid, [b]longus colli, *statistically significant at the level of p<.012.

Table 3. Between-group comparison of the change in the muscle thickness at the different positions

Muscle	Position	With FHP[a]	Without FHP	T	p
SCM[b]	RHP[c]	1.18±.13[d]	1.10±.09	1.589	.134
	HHP[e]	1.36±.10	1.08±.13	4.534	<.001
LCo[f]	RHP	1.15±.09	1.11±.13	.539	.598
	HHP	1.14±.08	1.15±.19	-.108	.916

[a]forward head posture, [b]sternocleidomastoid, [c]relaxed head position, [d]mean±standard deviation, [e]horizontal head position, [f]longus colli, *statistically significant at the level of p<.05.

Table 4. Between-initial head position comparison of the change in the muscle thickness at the different groups

Muscle	Position	RHP[a]	HHP[b]	T	p
With FHP[c]	SCM[d]	1.18±.13[e]	1.36±.10	-5.384	<.001*
	LCo[f]	1.15±.09	1.14±.08	.150	.887
Without FHP	SCM	1.10±.09	1.08±.13	.700	.502
	LCo	1.11±.13	1.15±.19	-.920	.381

[a]relaxed head position, [b]horizontal head position, [c]forward head posture, [d]sternocleidomastoid, [e]mean±standard deviation, [f]longus colli, *statistically significant at the level of p<.05.

significantly increased (p<.001) in the subjects with FHP in the HHP compared to that of the subjects without FHP (Table 3). There was no significant between-group difference in the change in thickness of the LCo muscle during the CCF exercise in the HHP (p=.916). A paired t-test showed that there was no significant difference except for change in thickness of the SCM between initial head positions in the Table 4.

Discussion

This is the first study to compare the change in thickness of the LCo and SCM during CCF exercise at two initial positions in subjects with and without FHP. The study suggests that for subjects with a FHP, CCF exercise in a RHP is more effective than CCF exercise in a HHP for minimizing changes in the thickness of the SCM. The results of this study showed that the change in thickness of the SCM during CCF exercise in a HHP significantly increased in the subjects with FHP compared to that of the subject without FHP (Table 3). There are various possible explanations for this findings.

First, muscular adaptations in a FHP include shortness of the suboccipital muscles (extensors, superior/inferior oblique, and rectus capitis) because of the increased degree of upper cervical extension (Sahrmann, 2010). The shortness of the suboccipital extensor muscles may lead to more torque of the LCo and LC during CCF because the suboccipital extensor muscles are activated during cranio-cervical extension (Neumann, 2010). Therefore, subjects with a FHP may require more torque of the LCo and LC during CCF. Second, a FHP is a biodynamical posture in which the suboccipital flexors, such as the LCo and LC, are elongated (Sahrmann, 2010). In a

FHP, the length of the LCo and LC muscles may increase beyond physiological limits but not beyond the normal range of motion. Changes in the length-tension curve result in "stretch weakness" (Kendall et al, 2005). When a subject with a FHP is placed in a HHP, the LCo and LC is shortened. This condition may lead to compensative movement because subjects with a FHP cannot make maximal torque of the LCo in the shortened range position. As a result, the SCM is overactivated during CCF in a HHP by subjects with a FHP. Third, in a FHP, the SCM is overactivated, and the LCo is underused (Ishida et al, 2015). Adopting a FHP for extended intervals may result in overactivation of the SCM and underactivation of the LCo during CCF. The activation of the SCM and LCo may also be altered by a prolonged FHP caused by sitting at a desk in front of a computer for long periods on a daily basis. It is similar to the changed pattern of muscle recruitment observed between the DCFMs and SCFMs in young subjects with neck pain (Jull et al, 2004a; Uthaikhup and Jull, 2009).

The results of this study suggest that CCF in a RHP is effective for preventing compensative movement with a FHP. Previous studies used electromyography for monitoring the recruitment of the SCM (Kwon et al, 2011) and a force measuring apparatus for monitoring neck retraction (Falla et al, 2003). These methods are complex and time consuming and so are difficult to apply in the clinical setting. The modified head positions (HHP and RHP) adopted in the present study may offer a convenient and effective measurement method of CCF exercise for FHPs.

The present study has some limitations. First, it included only young subjects. Therefore, the results cannot be generalized to the overall population. Second, the study included only subjects without pain. Thus, the results have limited applications to patients with neck pain. A further study is necessary to determine the effect of the initial head position on the thickness of the neck flexor muscles during CCF exercise in subjects with neck pain.

Conclusion

This is the first study to compare the change in thickness of the LCo and SCM among subjects with and without a FHP. The change in thickness of the SCM significantly increased in the subjects with FHP compared to that of the subjects without FHP during the CCF exercise with a HHP, and this change was significantly greater in the subjects with FHP. The results suggest that the initial head position is important for minimizing superficial muscle activity during CCF exercise in subjects with a FHP. Future studies are needed to determine whether long-term CCF exercise in different positions (RHP and HHP) can minimize changes in thickness of the SCFM. Therefore, individual with FHP should select RHP during performing CCF exercise for minimizing superficial muscle activity.

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This article was received October 8, 2015, was reviewed October 8, 2015, and was accepted November 8, 2015.