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Effect of Deep Neck Flexor Performance on the Stability of the Cervical Spine in Subject With and Without Neck Pain

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Abstract

This study compared the stability of the cervical spine according to the presence of neck pain and deep neck flexor performance. Thirty subjects with neck pain, and thirty subjects without neck pain were recruited for this study. The Cranio-cervical flexion (CCF) test was applied using a pressure biofeedback unit to classify the subjects into four subgroups; no cervical pain and good deep neck flexor performance (NG group), no cervical pain and poor deep neck flexor performance (NP group), cervical pain and good deep neck flexor performance (PG group), and cervical pain and poor deep neck flexor performance (PP group). The head sway angle was measured using a three-dimensional motion analysis system. A 3-㎏ weight was used for external perturbation with the subject sitting in a chair in the resting and erect head positions with voluntary contraction of the deep neck flexors. A one-way analysis of variance (ANOVA) was performed with a Bonferroni post hoc test. The deep neck flexor performance differed significantly among the four groups ($p<.05$). The NG group had significantly greater deep neck flexor performance than NP and PP groups. The stability of the cervical spine also differed significantly among the four groups in the resting head position ($p<.05$). The head sway angle was significantly smaller in NG group as compared with the other groups. The PP group had the greatest head sway angle in the resting head position. However, there was no significant difference in the stability of the cervical spine among the groups in the erect head position with voluntary contraction of deep neck flexors ($p=.57$). The results of this study suggest that the deep neck flexor performance is important for maintaining the stability of cervical spine from external perturbation.

Key Words: Cranio-cervical flexion test; Deep neck flexor performance; External perturbation; Stability.

Introduction

Neck pain is a common complaint, affects up to 70% of individuals in their lives; it is highly prevalent, and its incidence is increasing (Falla and Farina, 2007; Javanshir et al, 2011). Neck pain is a common condition with substantial personal and financial costs (Jull et al, 2004). Due to the prevalence of cervical pain, effective management is important to relieve symptoms and prevent its recurrence (Jesus et al, 2008).

Spinal instability is considered a major cause of neck pain (Olson and Joder, 2001). Stability is necessary for proper functioning of the kinematics of the spine

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(Panjabi, 1992). The stability of the cervical spine depends on the inherent passive stability of the spinal column and active stability provided by the surrounding muscles. It is estimated that the osteoligamentous system contributes 20% to the stability of the cervical spine, while 80% is provided by the surrounding neck musculature (Panjabi et al, 1998). The ligaments provide stability mainly at end of range postures, while muscles provide dynamic support around the neutral and mid-range postures during activities (Falla, 2004).

The muscles in the cervical region can be classified into two distinct groups according to the relationship of the attachment of the muscles to the axis of motion of the cervical spine (Otis, 2004). The intrinsic muscles of the cervical spine are located close to the axis of motion and provide precise control of motion during movement. The extrinsic muscles of the cervical spine are located farther from the axis of motion and provide power to the motion, but not necessarily precision of motion (Sahrmann, 2011). Although many muscles of the neck contribute to stabilization and protection of the cervical spine, the longus colli and capitis are critical for controlling intervertebral motion and the cervical lordosis; these muscles act as a component of feed-forward postural adjustment (Falla et al, 2004a; 2011; Mayoux-Benhamou et al, 1994). The longus colli is also the principle muscle that supports and controls the cervical curve against the tendency towards buckling of the spine induced by head weight and with the contraction of the powerful extensor muscles (Falla et al, 2004b). Some researchers argue that activation and retraining of the deep neck flexor muscles results in increased stability (Armstrong et al, 2005; Jull et al, 1999). However, it is difficult to measure the activity of deep neck muscles directly using surface and needle electromyography (EMG) in humans (Conley et al, 1995). Therefore, the deep cervical flexor muscles have been investigated using various indirect approaches (Conley et al, 1995; Falla et al, 2003; Vasavada et al, 1998). Of these indirect approaches, the cranio-cervical flexion (CCF) test is a representative method for measuring deep neck flexor performance (Chiu et al, 2005; Fernandez-de-las-Peñas et al, 2007; Jull, 2000).

Some studies have focused on identifying and quantifying deficits in the deep cervical flexor muscles in patients with neck pain disorders (Cagnie et al, 2010a; Falla et al, 2011; Javanshir et al, 2011). Patients with chronic neck pain have cervical spine instability and deficits in isometric cervical and cranio-cervical strength and endurance (Chiu et al, 2005; Falla and Farina, 2007; Roijezon et al, 2011). Some studies have demonstrated that impairment of deep cervical flexor muscle function contributes to chronic neck pain disorders (Jull et al, 2009; Peolsson et al, 2010). Patients with whiplash-associated disorder or insidous-onset neck pain patients showed increased superficial cervical flexor muscle activity during arm movement or the CCF test (Falla et al, 2004b; Jull et al, 2004). Increased activation of the superficial cervical flexors in patients with whiplash-associated disorder and neck pain likely compensates for the dysfunction of the deep cervical flexors (Cagnie et al, 2010b). Weakness of the deep neck flexors in patients with chronic neck pain may contribute to cervical spine instability, increased head sway and poor head stabilization in the presence of postural perturbations (Michaelson et al, 2003). Previous studies have shown that individuals with whiplash-associated disorders have a larger center of pressure displacement amplitude and are more susceptible to sensory perturbations during quiet standing (Côté et al, 2009; Madeleine et al, 2004).

Most studies have compared deep neck flexor performance and cervical stability between subjects with and without neck pain. However, Chiu et al (2005) reported that 20% of the neck pain group had good contractile capacity, while 15% of the asymptomatic group had poor contractile capacity of the deep neck flexors. Therefore, in this study, the subjects were classified into four subgroups according to neck pain and deep neck flexor performance: no cervical pain and good deep neck flexor performance (NG group), no cervical pain and poor deep neck flexor performance (NP group), cervical pain and good deep neck flexor performance (PG group), and cervical pain and poor deep neck flexor performance (PP group). This study compared the stability of the cervical spine during external perturbation among the four groups. It was hypothesized that stability of cervical spine of PP and PG group would be more decreased than NP and NG group during external perturbation.

Methods

Subjects

Thirty subjects without neck pain and thirty subjects with a history of bilateral chronic neck pain participated in this study. The subjects without neck pain (18 males, 12 females) were between 20 and 31 years of age and were included in the past 6 months prior to enrollment of this study and had no history of orthopedic or neurological disorders. The group with neck pain (18 male, 12 female) was between 20 and 26 years of age and had a history of chronic neck pain for longer than 1 year with moderate or severe disability (Neck Disability Index score, 15~34 of NDI). Subjects were excluded if they had undergone cervical spine surgery, had neurological signs, or participated in a neck exercise program in the past 6 months (Table 1). The subjects were recruited from Yonsei University, Korea. Before the study, the principal investigator explained all of the procedures to the subjects, and all of the subjects signed an informed consent form that was approved by the Yonsei University Wonju Campus Human Studies Committee.

Measurement Instruments

Pressure Biofeedback Unit

To measure deep neck flexor performance, a pressure biofeedback unit[1)] was used.

Surface Electromyographic Biofeedback system

To prevent excessive contraction of the sternocleidomastoid (SCM) muscle during the CCF test, EMG biofeedback was used with the Noraxon TeleMyo 2400 system[2)]. The target threshold was measured in the resting position. The threshold amplitude of the SCM was set using the mean of the resting EMG plus two standard deviations (Medina et al, 2008). The EMG biofeedback system provided real-time auditory feedback when the activity of SCM exceeded the target threshold.

3D Motion Analysis System

Head motion was analyzed from the three-dimensional (3D) position coordinates of the body markers using a high-resolution six-camera 3D motion analysis system[3)] with sampling rate of 60 ㎐. Kinematic data were collected and analyzed using Nexus 1.4 software. Reflective markers were placed on the following landmarks: middle of forehead, temporal bone bilaterally, xiphoid process of sternum, and 5 ㎝ superolateral to the xiphoid process bilaterally. The head segment was defined with three head markers and the trunk segment was defined with three

Table 1. General characteristics of subjects (N=60)

Characteristics	Without neck pain group (n_1=30)	Neck pain group (n_2=30)	p
Age (yrs)	23.7±2.3[a]	22.7±1.9	.08
Height (㎝)	166±7.9	168.77±7.5	.32
Weight (㎏)	67.42±7.6	64.85±7.5	.34
Visual analog scale (㎝)		5.46±1.5	
Neck disability index (%)		22.96±6.8	

[a]Mean±standard deviation.

1) Pressure biofeedback unit, Chattanooga Group Inc., Hiexon, U.S.A.
2) Noraxon TeleMyo 2400T, Noraxon Inc., Scottdale, AZ, U.S.A.
3) VICON MX system, Oxford Metrics Ltd., Oxford, U.K.

Figure 1. Location of reflective markers.

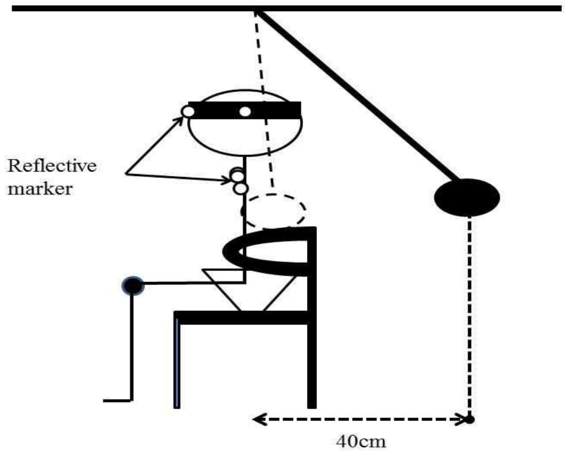

Figure 2. The external perturbation apparatus.

markers on the chest (Figure 1). The head sway angle was computed as the orientation of the head segment relative to the trunk segment. We analyzed the head sway angle in the sagittal plane. The head sway angle was the sum of the maximum flexion and extension angles of the head. The mean head sway angle was determined from three trials.

External Perturbation Apparatus

A 3-㎏ padded ball was used to apply external perturbation at the level of the upper thorax in each subject (Figure 2). The length of the pendulum was adjusted to the height of each subject. The principal investigator dropped the padded ball from 40 ㎝ behind the subject. The subjects wore earplugs and eye patches to eliminate auditory and visual information during the external perturbation.

Procedures

Measuring Deep Neck Flexor Performance

Deep neck flexor performance was measured using the CCF test, as reported by Jull et al (2009). Before the CCF test, the subject was trained in CCF motion. In the first phase of training, the principal investigator taught the subject to perform a slow, and controlled CCF motion in the supine position. The subject concentrated on feeling the back of the head slide in the cranial and caudal directions on the supporting surface to ensure sagittal rotation rather than a retraction movement. Once the correct CCF motion was achieved, the subjects began the second phase of training in which they were trained to hold progressively increasing ranges of CCF using a pressure biofeedback unit. The feedback dial displayed the amount of pressure changes as the cervical lordosis progressively flattened during CCF (Jull et al, 2009). The unit was inflated to a 20 ㎜Hg as the baseline pressure (Chiu et al. 2009). To minimize SCM muscle contraction during CCF, EMG biofeedback was applied. After CCF training, the CCF test was performed. During the test, the subjects were required to perform the gentle nodding motion of CCF, and increase and hold the pressure for 5 seconds without contracting the SCM muscle and avoiding excessive ribcage or lumbar motion. When the SCM activity exceeded a preset target threshold, a tone was heard, and the CCF test was stopped. The principal investigator confirmed pressure gauge while the subjects increase and hold the pressure. When the subject could not hold the increased pressure, the CCF test was terminated. This procedure was repeated three times, and the mean pressure of three trials was recorded.

Chiu et al. (2005) reported that the mean pressure achieved by the control group was 28 ㎜Hg versus 24 ㎜Hg for the subjects in the chronic neck pain group. Therefore, subjects who achieved an increase > 6 ㎜Hg were considered the good deep neck flexor performance group in this study.

Measuring Cervical Spine Stability

To investigate cervical spine stability, an external perturbation apparatus was used. The subjects were asked to sit on a chair with back support. To prevent trunk motion, subject's chest was fixed to the back support with a seat belt. The subjects were asked to wear an eye patch and earplugs and remain relaxed. The pendulum was hung from the ceiling just above the subject's head. The drop distance and weight of padded ball were selected in a pilot study: a 3 ㎏ weight and 40 ㎝ distance behind the back were appropriate for evoking head sway without neck or upper thorax pain. The subjects performed an active neck range of motion exercise to prevent neck injury before the external perturbation. To familiarize with the external perturbation, three external perturbations were performed before the cervical spine stability test.

The cervical spine stability test was performed in two positions: the resting head position and erect head position with voluntary contraction of the deep neck flexors. Three trials were performed for each position. The subjects were asked to maintain their head and neck in a self-selected relaxed position as the resting head position. For the erect head position with voluntary contraction of the deep neck flexors, the subjects were asked to contract the deep neck flexors with a chin tuck. A 3-minute rest was allowed between each trial. The test order was selected randomly.

Statistical Analysis

A one-way analysis of variance (ANOVA) was used to examine the differences in deep neck flexor performance and cervical spine stability among four the subgroups. Post hoc tests to identify the main mean differences were performed using Bonferroni's correction. Statistical significance was set at α=.05. The statistical analyses were performed using SPSS version 18.0 software.

Results

Comparison of deep neck flexor performance among the four groups

Deep neck flexor performance differed significantly

Table 2. Comparison of deep neck flexor performance among four groups (N=60)

Group	Deep neck flexor performance (㎜Hg)	p
NG[b] (n_1=17)	30.86±9.11[a]	<.01
NP[c] (n_2=13)	23.02±3.85	
PG[d] (n_3=12)	27.69±6.12	
PP[e] (n_4=18)	21.64±1.55	

[a]Mean±Standard deviation,, [b]No cervical pain and good deep neck flexor performance, [c]No cervical pain and poor deep neck flexor performance, [d]Cervical pain and good deep neck flexor performance, [e]Cervical pain and poor deep neck flexor performance.

Table 3. Difference of head sway angles among the four groups in each position (N=60)

Position	Head sway angle (°)				p
	NG[b] (n_1=17)	NP[c] (n_2=13)	PG[d] (n_3=12)	PP[e] (n_4=18)	
Resting position	5.43±2.17[a]	7.41±2.79	7.81±2.58	9.71±5.13	<.01
Erect head position	4.21±2.83	5.32±3.07	4.25±1.84	5.58±4.68	.57

[a]Mean±Standard deviation, [b]No cervical pain and good deep neck flexor performance, [c]No cervical pain and poor deep neck flexor performance, [d]Cervical pain and good deep neck flexor performance, [e]Cervical pain and poor deep neck flexor performance.

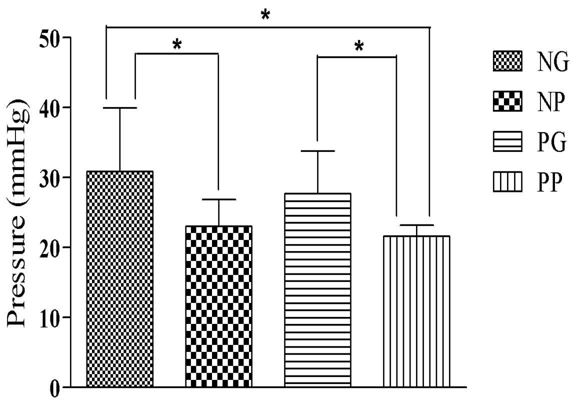

Figure 3. Comparison of deep neck flexor performance among four groups. NG: No cervical pain and good deep neck flexor performance, NP: No cervical pain and poor deep neck flexor performance, PG: Cervical pain and good deep neck flexor performance, PP: Cervical pain and poor deep neck flexor performance (*p<.05).

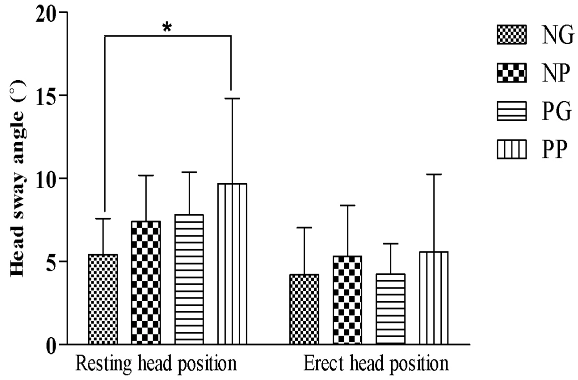

Figure 4. The difference of head sway angles among four groups in each position. NG: No cervical pain and good deep neck flexor performance, NP: No cervical pain and poor deep neck flexor performance, PG: Cervical pain and good deep neck flexor performance, PP: Cervical pain and poor deep neck flexor performance (*p<.05).

among the four groups (p<.01) (Table 2). The NG group had significantly greater deep neck flexor performance than the NP and PP group. The PP group had significantly poorer deep neck flexor performance than the PG group (Figure 3).

Differences in head sway angles among the four groups

The head sway angle differed significantly among the four groups in the resting position (p<.01). There was no significant difference in the head sway angle in the erect head position with voluntary contraction of the deep neck flexors (p=.57) (Table 3). Based on the post hoc tests, the head sway angle of NG group was significantly less than that of the PP group in the resting position (Figure 4).

Discussion

This is the first study to compare the stability of the cervical spine among four groups classified by neck pain and deep neck flexor performance during an external perturbation. Deep neck flexor performance differed significantly among the four groups. The NG group had a significantly higher mean pressure in the CCF test than NP and PP groups, and the PP group had a significantly lower pressure than the PG group. Chiu et al. (2005) reported that 15% of asymptomatic group had poor contractile capacity of the deep neck flexors and 20% of the neck pain group had good contractile capacity. In our study, 13 of 30 subjects without neck pain had poor deep neck flexor performance, and 12 of 30 subjects with neck pain had good deep neck flexor performance. Many studies have suggested that poor deep neck flexor performance contributes to chronic neck pain (Falla, 2004a; 2004b; O'Leary et al, 2011) The pain intensity of the group with neck pain was 5.46 on a visual analog scale (VAS) in our study. This suggests that both neck pain and the performance of the deep neck flexors should be considered when classifying subjects with chronic neck pain for clinical study.

Our study investigated cervical spine stability in resting and erect head positions with voluntary contraction of the deep neck flexors. Cervical spine stability was measured using the head sway angle. The head sway angle of the four groups differed significantly in the resting head position. In the post hoc test, the head sway angle in the resting head position only differed significantly between NG and PP groups. Röijezon et al (2008) reported that the head sway angle increased in subjects with dysfunction of deep neck flexors. The deep cervical flexors contain a high density of muscle spindles and provide dynamic postural stability (Röijezon et al, 2008). Activation of the deep neck flexor muscles can improve the stability and proprioception of the head and neck (Armstrong et al, 2005). Therefore, NG group showed small head sway angle, and the PP group showed great head sway angle.

In this study, the head sway angle in NP and PG group did not differ significantly, and the NP group had a greater head sway angle than the NG group. The PG group had a smaller head sway angle than the PP group and a greater head sway angle as compared with the NG group. These results suggest that neck pain or poor deep neck flexor performance can decrease cervical spine stability, which did support our research hypothesis.

The head sway angle did not differ in the erect head position with voluntary contraction of deep neck flexors among the four groups. All subjects were asked to contract deep neck flexors in the erect sitting position. Stemper et al (2006) also reported that pre-contraction of the neck muscles resulted in a 63% decrease in the maximum head angle in the whiplash test. Therefore, voluntary contraction of the deep neck flexors can compensate for poor deep neck flexor performance resulting from a 3-kg external perturbation. Although the head angle did not differ significantly in the erect head position with voluntary contraction, the NP and PP groups showed greater head sway than NG and PG groups. The cross-sectional area of a muscle affects muscle stiffness (Ryan et al, 2009). Many studies have measured the cross-sectional area of the longus colli muscle to classify subjects with and without neck pain (Chiu et al, 2005; Javanshir et al, 2011; O'Leary et al, 2007). Although we did not measure cross-sectional area of the deep neck flexor muscle directly, the NG and PG groups may have had greater cross-sectional areas than NP and PP groups. We postulate that the difference of cross-sectional area and stiffness of longus colli contributed to the smaller head sway angle in NG and PG groups.

Falla et al (2004b) reported that, in patients with neck pain, the superficial neck flexors were more dominant than the deep neck flexors in the CCF test. The patients with chronic neck pain had a significantly higher EMG amplitude in the superficial neck flexors as compared with symptomatic controls (Fernandez-de-las-Peñas et al, 2007; O'leary et al, 2007). O'leary et al (2011) demonstrated that the intensity of pain and activity of the superficial neck flexors had a significantly strong positive correlation in the CCF test. It is difficult for patients with chronic neck pain to contract the deep neck flexors selectively during the CCF test. Therefore, we used EMG biofeedback to minimize the contraction of the SCM muscle during the CCF test.

Many studies have reported that decreased activity of the deep neck flexors contributes to cervical instability (Falla et al, 2010; Jull et al, 2004; O'Leary et al, 2011). Chiu et al (2007) reported that the neck pain group showed a smaller increase in the mean pressure of the CCF test than the group without neck pain. However, deep neck flexor performance differed significantly between subjects with and without neck pain. Previous studies did not control superficial muscle activation; however, we effectively controlled superficial muscle activation using EMG biofeedback. Therefore, our results suggest that the CCF test should be performed to classify patients with chronic neck pain into subgroups for any clinical study.

This study has some limitations. First, young subjects participated in this study. Therefore, our results cannot be generalized to all populations. Second, we used EMG biofeedback to minimize contraction of the SCM muscles. Contraction of other superficial muscles, such as scalenus, was not controlled during CCF test in this study. Further studies are needed to determine whether long-term deep neck flexor muscle strengthening can increase the stability of the cervical spine with an external perturbation.

Conclusion

This study compared the stability of the cervical spine among four subgroups classified by neck pain and deep neck flexor performance. Deep neck flexor performance differed significantly among the four groups. The stability of cervical spine also differed significantly between the NG and PP groups in the resting head position. However, there was no significant difference in the stability of the cervical spine among groups in the erect head position with voluntary contraction of the deep neck flexors. Our results suggest that deep neck flexor performance is important for maintaining the stability of the cervical spine from external perturbation. Further studies are needed to determine whether long-term deep neck flexor muscle strengthening can increase the stability of the cervical spine with external perturbation.

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