

# Neck kinematics and sternocleidomastoid muscle activation during neck rotation in subjects with forward head posture

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**Abstract.** [Purpose] The present study investigated differences in the kinematics of the neck and activation of the sternocleidomastoid (SCM) muscle during neck rotation between subjects with and without forward head posture (FHP). [Subjects and Methods] Twenty-eight subjects participated in the study (14 with FHP, 14 without FHP). Subjects performed neck rotation in two directions, left and right. The kinematics of rotation-lateral flexion movement patterns were recorded using motion analysis. Activity in the bilateral SCM muscles was measured using surface electromyography. Differences in neck kinematics and activation of SCM between the groups were analyzed by independent t-tests. [Results] Maintaining FHP increased the rotation-lateral flexion ratio significantly in both directions. The FHP group had significantly faster onset time for lateral flexion movement in both directions during neck rotation. Regarding the electromyography of the SCM muscles during neck rotation in both directions, the activity values of subjects with FHP were greater than those of subjects without FHP for the contralateral SCM muscles. [Conclusion] FHP can induce changes in movement in the frontal plane and SCM muscle activation during neck rotation. Thus, clinicians should consider movement in the frontal plane as well as in the sagittal plane when assessing and treating patients with forward head posture.

**Key words:** Axial rotation, Cervical movement, Forward head posture

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## INTRODUCTION

Forward head posture (FHP) is a commonly noted abnormal neck posture in students who carry heavy loads or maintain a sitting posture for long periods<sup>1-3</sup>. FHP is defined as the hyperextension of the upper cervical and a forward translation of the cervical vertebrae<sup>4</sup>. FHP increases the compressive loading on tissues in the cervical spine, particularly the facet joints, and stress on the ligaments<sup>4, 5</sup>. Also, FHP can induce neck pain and increase electromyographic activity in the neck muscles<sup>4, 6</sup>. For these reasons, FHP is known to lead not only to neck pain but also to changes in cervical movement patterns<sup>7, 8</sup>.

Alterations in cervical spine movement can provide clinicians with information that assists assessment and treatment and in monitoring the efficacy of rehabilitation programs in FHP populations<sup>1, 9, 10</sup>. In particular, the neck rotation test is often performed for evaluation of cervical spine dysfunction<sup>7</sup>. For the neck rotation test, the subject is asked to maximally rotate the head by turning to one side, left or right, in a sitting position<sup>11</sup>. Comerford and Mottram<sup>11</sup> stated that

generating lateral flexion motion during neck rotation can cause dysfunction and pain in the cervical spine. Thus, to prevent unwanted cervical lateral flexion during cervical rotation, many clinicians and researchers emphasize cervical axial rotation so as not to complicate rotation with other neck motions, such as flexion, extension, and lateral flexion<sup>12, 13</sup>. Cervical axial rotation along the longitudinal axis is considered clinically important for painless neck motion<sup>14</sup>.

For precise cervical axial rotation, it is necessary to properly control the activation of the neck muscles<sup>11, 15, 16</sup>. However, precise neck movements in FHP populations are typically difficult because they have problems with alterations in the length and activation of the neck muscles<sup>8, 17</sup>. The primary problems in FHP are shortening and hyperactivation of the sternocleidomastoid (SCM) muscle<sup>7, 8, 18</sup>. The SCM muscle acts in neck rotation and lateral flexion as well as in neck flexion. However, many previous studies of FHP and SCM muscles have focused largely on movements in the sagittal plane, such as flexion and extension<sup>1, 5, 10</sup>. Also, movements in the frontal plane, which involve hyperactivation of the SCM muscles, have been overlooked in patients with FHP.

Although patients with FHP may be exposed to neck pain caused by hyperactivation of the SCM muscles, to our knowledge, kinematic analysis of lateral flexion movement patterns of subjects with FHP during neck rotation has not been reported. Repeated cervical lateral flexion and translation motions due to FHP posture that occur during cervical rotation in a sitting position or in activities of daily life may

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cause tissue microtrauma, overuse syndrome, mechanical dysfunction, and development of pain in the cervical spine<sup>12, 19</sup>).

For this reason, it is important to understand the kinematics of lateral flexion movement patterns and SCM muscle activation during neck rotation in subjects with FHP. Furthermore, although the neck rotation test is commonly used to evaluate cervical motion in the sagittal plane, there is potential for using this test for evaluating motion in the frontal plane as part of a clinical evaluation for neck problems in subjects with FHP. Thus, the aims of this study were to compare 1) the rotation-lateral flexion ratio, 2) the lateral flexion movement onset time, 3) the rotation and lateral flexion angles, and 4) the muscle activation of SCM between individuals with FHP and controls during neck rotation. We hypothesized that 1) the rotation-lateral flexion ratios would be higher, 2) the lateral flexion movement onset time would be earlier, and 3) the rotation and lateral flexion angle values would be higher during neck rotation in the FHP group; we also hypothesized that 4) the SCM muscles would be more highly activated during maintenance of end-range neck rotation in both directions in the FHP group than in control subjects.

## SUBJECTS AND METHODS

In total, 28 subjects were recruited from university students in Korea (14 control students, 14 FHP students). A cervical postural assessment was conducted to classify subjects into groups. Subjects were recruited into the FHP group if they had a forward translated neck alignment; the FHP group was selected by evaluating the horizontal distance from a vertical line through the lobe of the ear and the acromion process in the sagittal plane ( $FHP \geq 5$  cm)<sup>20</sup>. Additionally, to classify the groups, the cranio-vertebral angle (CVA) was measured in all subjects. The intra-class correlation coefficient (ICC) of the CVA measurement method has been reported to be high ( $ICC = 0.88$ )<sup>21</sup>. Exclusion criteria included past or present spinal canal stenosis, rheumatoid arthritis, and vestibulobasilar insufficiency. Before the experiment, we explained all procedures and the purpose of the study to the subjects in detail. All subjects signed an informed consent form, which was approved by the Inje University College of Health Science Human Studies Committee.

In all sessions, the kinematics were recorded using a three-dimensional ultrasound-based motion analysis system and muscle activity was measured using electromyography. Data collection using the two systems occurred simultaneously so that data were synchronized for a more complete and valid analysis. A three-dimensional ultrasound-based motion analysis system (Zebris CMS20, Zebris Meditechnik GmbH, Isny, Germany) was used to collect kinematic data. Two components of ultrasound markers, one installed on the apex of the head and another attached to the right lateral shoulder, were fixed to accept real time neck motion data via a transducer sensor, which consisted of three microphones. The transducer sensor was placed perpendicular and to the right of the subject at a distance of 1 m. The preferred neck position was set at zero based on the starting position before each test. The kinematic data-sampling rate

was 20 Hz. For measurement of neck movements, the ICC for intra-session test-retest reliability had been previously established as 0.73–0.90, as well as inter-session reliability of 0.43–0.68<sup>22</sup>).

Rotation and the lateral flexion angle of the neck were recorded in real time during neck rotation to identify the ratio of rotation to lateral flexion movements to the ipsilateral or contralateral side. The collected kinematic raw data were converted to ASCII files for analysis. The movement onset time and the motion of the neck were analyzed using Microsoft Excel. The point exceeding a threshold angle of  $1^\circ$  was defined as the onset time of neck movement<sup>23</sup>. All angular data were calculated as absolute values. The mean value of three trials was analyzed to determine onset time and rotation-lateral flexion movement patterns during neck rotation. Finally, the rotation-lateral flexion ratio was calculated as the lateral flexion angle divided by the rotation angle, multiplied by 100.

Electromyographic (EMG) signals from the SCM muscles were recorded and analyzed using a surface electromyography system (MP150, Biopac Systems, Inc., Santa Barbara, CA, USA). Skin preparation at the attachment sites consisted of shaving and cleaning the skin with an alcohol swab. Disposable Ag/AgCl recording electrodes were placed over the SCM muscles. A reference electrode was placed on the C7 spinous process. EMG data were recorded from the SCM muscle (1/3 of the distance from the sternal notch to the mastoid process, parallel and over the muscle belly)<sup>24</sup>. The frequency was set at 1,000 Hz. A band-pass filter (20–450 Hz) and a band-stop filter (60 Hz) were used. Raw data were transformed into the root mean square with a window of 50 ms. For normalization, muscle contraction reference data were collected while the subject performed two maximal voluntary isometric contraction (MVIC) trials over a 5-s period in a manual SCM muscle testing position<sup>4</sup>. A 3-min rest was allowed between MVIC trials. The average value of the middle 3 s of the 5-s trial was used, and the average of two trials was calculated for normalization. During the maintenance phase, the average EMG data from the middle 3 s of the 5-s measurement were used to compare the FHP and control groups.

Subjects were seated on a chair during data collection. Neck and trunk postures were not adjusted, and the usual posture of each subject was maintained throughout the experiment. Subjects were strapped to the chair to minimize compensation by trunk motion during the test. Before the test, each subject was instructed to perform neck rotation in the preferred rotation range in two directions (left and right) randomly to identify end range of motion. Neck rotation end range was defined as maximum range through which each subject could actively rotate his/her cervical spine in each direction. Once end range of motion was established, the neck rotation test was repeated three times in each direction. The initial direction of neck rotation test was randomized, and a 1-min rest was allowed between trials. To minimize differences in vestibular function during the neck rotation, each subject conducted the neck rotation for 6 s (rotation phase) at a speed of  $<15^\circ/s$ <sup>25</sup>) and maintained the end-range position for 5 s (maintenance phase), all timed using a metronome.

Descriptive statistics were calculated for group charac-

**Table 1.** Rotation-lateral flexion movement patterns, mean (SD), during neck rotation to the left and right between two groups

	Direction	Control group (n = 14)	FHP group (n = 14)
Rotation-lateral flexion ratio (%)	Left	10.01 (5.11)	13.46 (10.92) *
	Right	6.43 (3.58)	6.81 (4.80) *
Rotation angle (°)	Left	52.15 (7.12)	62.72 (6.94) *
	Right	51.58 (7.90)	59.45 (7.35) *
Lateral flexion angle (°)	Left	3.39 (1.95)	6.22 (3.01) *
	Right	3.46 (2.55)	7.97 (6.21) *
Lateral flexion onset time (s)	Left	1.68 (0.79)	1.04 (0.45) *
	Right	1.54 (0.75)	0.88 (0.39) *

FHP: forward head posture; SD: standard deviation

\* $p < 0.05$

teristics and group differences were assessed. Differences in the rotation-lateral flexion ratio, rotation angle, lateral flexion angle, SCM activation, and subject demographic in each direction between subjects with and without FHP was evaluated using independent t-tests. The SPSS statistical package (ver. 18.0, SPSS, Chicago, IL, USA) was used for all statistical analyses and a  $p$ -value  $\leq 0.05$  was considered to indicate statistical significance.

## RESULTS

Subjects in the two groups were of similar age, height, and weight ( $p > 0.05$ ). The forward head distance was significantly increased in the FHP group compared with the control group ( $p < 0.05$ ).

The results of the kinematic analyses are presented in Table 1, all of which were significantly different between the FHP and control groups ( $p < 0.05$ ). The rotation-lateral flexion ratio was higher in both directions in the FHP group than that in the control group. At end range neck rotation, the FHP group showed rotation angle was greater by approximately 8–10 degrees than the control group, respectively. Also, lateral flexion angle in FHP group was greater by 3–4 degrees than in control group. In addition, the onset of lateral flexion movement during neck rotation of all directions in the FHP group occurred up to about one second earlier than in control group ( $p < 0.05$ ).

With regard to electromyography of the SCM muscles during neck rotation in both directions, the activity in the contralateral SCM muscles was greater in subjects with than in those without FHP ( $p < 0.05$ ) (Table 2).

## DISCUSSION

Many researchers emphasize correct neck motion to minimize dysfunction in the adjacent structures of the cervical spine<sup>17, 26</sup>. Although FHP is a common physical finding in persons with malalignment of the neck, to our knowledge, there have not been any publications investigating variations in neck kinematics in FHP during neck rotation<sup>3, 27, 28</sup>. Here, we investigated rotation-lateral flexion movement patterns and SCM activation during neck rotation in FHP and control

**Table 2.** Muscle activation as a percentage of the maximum voluntary isometric contraction (%MVIC) during neck rotation to the left and right between the two groups (n = 28)

Direction	Muscle	Muscle activation (%MVIC)	
		Control group Mean (SD)	FHP group Mean (SD)
Left rotation	Left SCM	2.88 (1.35)	3.52 (2.08)
	Right SCM	16.90 (7.74)	29.21 (14.69) *
Right rotation	Left SCM	18.29 (6.38)	34.78 (21.48) *
	Right SCM	4.39 (2.17)	3.32 (1.69)

FHP: forward head posture; SD: standard deviation

\* $p < 0.05$

subjects.

Our data suggest differences in the rotation-lateral flexion movement patterns and activation of SCM muscles between the FHP and control groups during neck rotation. The data showed relatively less axial neck rotation in the FHP group than in the control group. This may be because long-duration FHP maintenance induces alterations in cervical motor control and muscle imbalance of the neck muscles, such as the SCM. Altered activation of the SCM may induce abnormal kinematics during neck rotation. Faulty alignment, neck muscle imbalances, and alteration of motor control of the cervical spine have been reported to contribute to neck movements<sup>5, 6, 8, 18</sup>. Also, no other axial neck rotation could induce repetitive translation motion in the transverse plane in the cervical spine as often as neck rotation, and translation motion can induce cervical instability<sup>12</sup>) and spinal disorders<sup>31</sup>).

The SCM muscles of subjects with FHP showed greater imbalance between the left and right muscles compared with the control group. This may be because the SCM muscles in the FHP group are hyperactive during neck motion due to changes in the condition of the neck muscles caused by maintaining a faulty posture such as FHP. The muscle imbalance induced by FHP can result in decreased muscular efficiency and increased activation of the additional muscles needed to maintain neck and head posture<sup>29</sup>). As a result, subjects with FHP used contralateral SCM muscles to a greater extent during neck rotation than did the control subjects.

These kinematics and EMG data show that subjects with FHP have different pattern of neck movement and SCM activation than those without FHP. These aspects may indicate that global muscles, such as the SCM, are being used instead of local muscles during neck rotation. Global muscles are known to function as musculature for multi-segmental joints, and they generate large movements rather than precise movements<sup>7, 8, 17</sup>). Thus, excessive activation of SCM-controlled lateral flexion during neck rotation occurred significantly more in people with FHP than in control subjects. Although statistical significance does not necessarily imply clinical significance, clinicians may recognize the clinical implications of these findings for preventing neck problems in FHP patients.

Our data indicate the importance of neck rotation tests in those with FHP. Neck rotation tests can be used to as-

ness movement of the cervical spine<sup>7, 11</sup>). However, many clinicians overlook motion in the frontal plane and examine only movement in the sagittal plane in FHP<sup>1, 32, 33</sup>). Repeated non-axial neck rotation can induce cervical instability and disorder. Thus, it should be recommended that clinicians examine lateral flexion in the frontal plane when assessing and treating patients with FHP.

In this study, the angle of rotation in the FHP group was significantly higher than that in the control group. However, a previous study demonstrated that subjects with FHP had a decreased range of motion of neck rotation compared with the control group<sup>30</sup>); this differs from our findings. It is possible that the subjects with FHP in this study may have compensated for the decreased range of neck motion by lateral flexion the neck.

This study has several limitations. First, we calculated all angular data as absolute values. This may have resulted in our overlooking differences in the direction of lateral flexion movements during preferred neck rotation. In future research, the direction of lateral flexion movement generated during neck rotation should be identified and considered within the interpretation of the results. Second, our results cannot be generalized to other age groups because all subjects were university students. Finally, we did not measure EMG activity in the intrinsic neck rotator muscles.

Our results demonstrate that neck rotation in subjects with FHP is characterized by lateral flexion in addition to axial rotation compared with subjects without FHP. The clinical importance of this study lies in its confirmation of often-overlooked neck movement in the frontal plane and the provision of baseline data for future clinical interventions concerning lateral flexion in subjects with FHP. Additionally, significant differences in activation patterns of the SCM muscles were noted in individuals with FHP, specifically with increased recruitment on the contralateral side during movement. Assessment of neck rotation movement in patients with FHP should take into consideration lateral flexion in the frontal plane and contralateral SCM activation.

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