Correlation between Cranio-Vertebral Angle and Muscle Activity According to Body Movements in Forward Head Posture

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Abstract: - The purpose of this study is to determine the correlation between FHP and how it may affect muscle activity during raising the arm and loss of body balance, 40 young people participated. All subjects will have their cranio-vertebral angle (CVA) and muscle activity of the serratus anterior (SA), upper trapezius (UT), and lower trapezius (LT), static balance index, and central pressure excursion index (CPEI) measured. Muscle activity was measured using TeleMyo 2400(Noraxon U.S.A., Inc., Scottsdale, AZ, USA), and static balance indicators and CPEI were measured using the MatscanVersaTek system (Tekscan Inc., MA). Spearman correlation analysis was used to determine the correlation between variables. CVA and SA, UT, and LT all showed significant correlation, positive correlation with SA(r=0.429/p=0.006) and LT(r=0.377/p=0.017), and negative correlation with UT(r=-0.473/p=0.007) (Table 2). CVA showed a moderate level of negative correlation with AREA(r=0.-0.420 /p=0.007) and L-R distance(r=-0.508 /p=0.000) among balance indicators, and did not show a significant correlation with CPEI (Table 3). In people with more severe FHP, SA, and LT muscle activity tended to be lower, UT muscle activity tended to be higher, and static balance ability was lower. According to the results of this study, FHP can have a negative effect on various factors of the body, such as arm movement and static balance, suggesting that establishing correct posture is necessary to prevent secondary physical problems.

Key-Words: - Forward head posture, Cranio-vertebral angle, Muscle activity, Static balance, Electromyography, Serratus anterior, Upper trapezius, Lower trapezius.

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1 Introduction

A forward head posture is defined as a posture in which the head is positioned excessively forward beyond a vertical reference line, [1]. FHP causes various side effects such as neck pain, kyphosis, reduced mobility of the spine, rounder shoulder, etc, [2], [3], [4]. In particular, FHP is often observed in people who are spending a long time in a sitting position, [5]. prolonged sitting can also lead to weakness in the trunk, and because the muscles around the neck muscles are connected to the trunk, it can affect overall musculoskeletal functions by causing changes in the posture of the trunk or even the tilt of the pelvis, [6].

The FHP is the most common cervical postural deviation occurring in the sagittal plane. Forward movement of the head and neck due to a prolonged flexed head position can cause sagittal postural defects of the cervical spine. The head moved forward increases the mechanical load, which can adversely affect muscle imbalance, functional impairment, and head posture control, [7], [8]. FHP can cause posture defects on the sagittal plane, which can reduce the ability to control the posture of the head making it difficult to maintain balance, [2]. This is supported by a few studies that people who have lost the ability to adjust their heads have a reduced balance ability, [9], [10], [11]. And FHP can change the position of the scapula. The movement of the scapula is essential for body movements such as raising the arm. A person who has changed the position of the scapula due to FHP can experience pain, and the functional movement of the arm can be adversely affected by the imbalance of the muscles around the scapula, [12], [13], [14].

Cranio-vertebral angle (CVA) is the most widely known measurement method used to determine how forward the head is tilted in a person in FHP, [15]. Studies have shown that abnormal forward head postures and increased kyphosis postures lead to an imbalance in related muscles, providing a framework for body movement and increasing imbalance in the spine and surrounding soft tissues that maintain body posture against gravity, [13], [16]. The numbers that quantify CVA are objective indicators that can express the degree of FHP and can be used to identify the correlation between body imbalance and loss of balance caused by FHP, [17].

As mentioned earlier, FHP creates a rounded shoulder posture, which can affect the activation of muscles around the scapula, [2]. Depending on the degree of FHP, it can be assumed that it is related to body movements such as raising the arm, [14]. This is because the movement of fully raising the arm (180° flexion or abduction of shoulder) requires 60° upward rotation of the scapulothoracic joint, [18]. The muscles around the scapula that affect upward rotation include the serratus anterior, upper trapezius, and lower trapezius, and these are muscles that can be affected by the non-ideal position of the scapula in FHP or the resulting rounded shoulder posture, [12]. According to scapulohumeral rhythm, upward rotation of the scapulothoracic joint rarely occurs during the initial 30-degree raising of the arm, [19]. During the subsequent arm-raising movement, it has been revealed that the movement of the shoulder joint (flexion or abduction) and the upward rotation of the scapulothoracic joint move at a ratio of 2:1, [18].

Surface EMG (sEMG) is a beneficial device that can measure the muscle activity of superficial muscles, [19]. A few research results show that CVA affects muscle activity depending on its degree. In these studies, EMG equipment is useful in providing numerical data on muscle activity, so it is widely used as a research device for muscle activity. However, studies on CVA and muscle activity mainly involve muscles around the neck, and there are not many studies that measure muscle activity related to movements in other parts of the body, [20], [21]. In the case of people who show more severe FHP due to a smaller CVA angle, there is a change in the muscle activity around the scapula. Since the movement of the scapulothoracic joint is an essential element in the movement of raising the arm, it can be affected by the CVA. The primary upward rotators of the scapulothoracic joint are the serratus anterior, upper trapezius, and lower trapezius. There have been several studies measuring the activity of these muscles during raising the arm or in people with FHP, [12], [22], [23].

Serratus anterior is a muscle that greatly contributes to the upward rotation of the scapulothoracic joint, [23]. According to previous research results, during shoulder joint abduction of more than 140 degrees, the muscle activity of the serratus anterior was much higher than that of the upper trapezius or lower trapezius, [23]. This fact may be a factor to be considered in the design of this study to measure EMG while raising the arm.

In previous studies, there were studies on various side effects on the body by FHP, but there have been few studies investigating the correlation between FHP and the activity of muscles around the scapula during raising the arm and the body's balance ability. Therefore, the purpose of this study is to find out through correlation how physical imbalance caused by FHP affects muscle activities for arm movement and static balance ability and to consider the causes.

2 Methods

2.1 Subjects

The subjects were 40 adults in their 20s living in Daegu, South Korea. The subjects were excluded from the study, including those who suffered back pain or had been treated for back pain six months before the study, those with abdominal or spinal surgery, nervous or cognitive disorders, trunks, and back pain stabilization exercises. All subjects were informed of the purpose of the study, the method, content, and procedures of the experiment, and those who agreed to participate in the experiment were selected as subjects. The study is approved by the Bioethics Committee (YNC IRB/2021-R-0005-001).

2.2 Measurement Tools and Measurement Methods

2.2.1 Cranio-vertebral Angle

For CVA measurement, the digital camera (Canon 650D, Canon, Japan) was fixed and mounted at a distance of 1m, and the side of the subject was photographed, for accurate measurement of CVA, a plumb line suspended from the ceiling was allowed to descend directly next to the subject. Subjects were instructed to stand comfortably with both arms relaxed on the side of the trunk and maintain a natural head posture. CVA was defined as the angle between the horizontal line and the line from the spinous process of the seventh cervical vertebra to the ear tragus. The CV angle means that the smaller the angle, the greater the flexion of the lower cervical spine (Figure 1).

Fig. 1: Measurement method for cranio-vertal angle

2.2.2 Muscle Activities

Surface electromyography (sEMG) was measured using TeleMyo 2400 (Noraxon U.S.A., Inc., Scottsdale, AZ, USA) to collect data on muscle activity. EMG signal data were converted to digital signals using the software MyoResearch XP 1.07 (Noraxon U.S.A., Inc., Scottsdale, AZ, USA) for statistical analysis, and a notch filter of 60 Hz was used. the raw EMG signal was sampled at 1000Hz and the signal was full-wave rectified. And band-pass filtering in the 30-500 Hz was performed. EMG amplitudes were analyzed by Root Mean Square (RMS) and the collected EMG data were calculated as percentages of RVC (%RVC).

sEMG of the upper trapezius (UT), lower trapezius (LT), and serratus anterior (SA) were measured while raising the arm. After a preliminary description of the test procedure to the subject, the skin around the electrode area was shaved and polished then cleaned with alcohol to lower the skin impedance. And the electrode was securely attached. The EMG electrode locations for each muscle were as follows. (1) UT: The midpoint of an imaginary line connecting the spinous process of the 7th cervical vertebrae and the posterior sides of the scapular acromion. (2) LT: The point 5cm inferomedial from the root of the spine of the scapula (3) SA: The point of the muscle located in front of the latissimus dorsi under the axillary and parallel to the inferior angle of the scapula, [23].

Participants were instructed to take measurements while standing in a comfortable position and looking straight ahead. Since previous research has shown that after the shoulder joint is flexed to 140 degrees, muscle activity in LT becomes smaller and UT becomes larger, EMG was measured at a flexion angle of 140 degrees to minimize this effect, [23]. Participants were instructed to hold a 1kg dumbbell and perform the exercise at a comfortable speed using their dominant arm. A stop sign was given when they reached 140 degrees using a goniometer, and EMG data was collected after stopping. Care was taken not to rotate the torso while lifting the arms. EMG data were collected for 5 seconds while maintaining the posture to obtain the RMS value for the intermediate 3-second interval. This was repeatedly measured three times to obtain the RVC value through the average value.

2.2.3 Static Balance

A MatscanVersaTek System (Tekscan Inc., MA) was used to measure static balance and center pressure excursion index (CPEI). Matscan components consisted of an HR mat, cuff, USB, and two hubs. The HR mat is 0.18mm thick and contains 2288 sensors, [24], [25]. The analysis was performed using the Tekscan program, and static balance was measured for 30 seconds at 30 frames per second in one leg standing with the hip and knee joints flexion at 90 degrees, [26]. The measured static balance values were the total area(Area) where the body sway occurred, the total distance(Total distance), the maximum distance anterior and posterior(A-P distance), and the maximum distance left and right(L-R distance).

CPEI had the HR mat walk in a comfortable walking condition. CPEI was the measured value of the distance between the line connecting the points starting from the heel and passing to the tip of the toe and the actually moved COP excursion path, divided by the foot width, and converted into a percentage and converted into data, [27]. Matscan is a valid and reliable screening tool for measuring sway and COP excursion, [25].

2.3 Statistical Analyses

SPSS 22.0 (IBM, Chicago, IL, USA) was used for all statistical analyses. The Shapiro-Wilk test was used to test the normality of all variables, but the normality test was not satisfied. Accordingly, Spearman correlation analysis was used to determine the correlation between CVA and muscle activities and between CVA and balance indicators. The statistical significance level was set to 0.05.

3 Results

A total of 40 subjects participated in the experiment, and the average and standard deviation for general characteristics such as age, height, weight, CVA, muscle activities, Area, Total distance, A-P distance, L-R distance, and CPEI of the subjects are shown in Table 1.

Table 1. Means ± SDs of general characteristics and cranio-vertebral angle, muscle activity, balance indicators, CPEI of subjects

Total participants (n=40)	
Age(year)	22.28 ± 2.72
Weight(kg)	58.20 ± 10.29
Height(cm)	164.38 ± 6.06
Cranio-vertebral angle (°)	53.92 ± 4.42
Serratus anterior(%RVC)	91.01± 3.52
Upper trapezius(%RVC)	135.34±3.72
Lower trapezius(%RVC)	83.29±1.90
Area(cm^2)	5.01 ± 1.48
Total distance(cm)	117.66 ± 28.45
A-P distance(cm)	3.88 ± 0.69
L-R distance(cm)	3.16 ± 0.58
Center pressure excursion index(%)	17.54 ± 9.42

Table 2. Correlation between cranio-vertebral angle and muscle activities during shoulder flexion

	CVA		Area		Total distance		A-P distance	
	r	p-value	r	p-value	r	p-value	r	p-value
CVA	1							
SA	0.429	0.006**	1					
UT	-0.473	0.002**	-0.333	0.036*	1			
LT	0.377	0.017*	0.323	0.042*	-0.203	0.208	1	

*CVA: cranio-vertebral angle, SA: serratus anterior, UT: upper trapezius, LT: lower trapezius * p<0.05, ** p<0.01*
** CVA showed a moderate positive correlation with SA.*
** CVA showed a moderate negative correlation with UT.*
** CVA showed a weak positive correlation with LT.*

Table 3. Correlation between cranio-vertebral angle, balance indicators, CPEI of subjects

	CVA		Area		Total distance		A-P distance		L-R distance		CPEI	
	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
CVA	1											
Area	-0.420	0.007**	1									
Total Distance	-0.198	0.219	0.496	0.001**	1							
A-P Distance	-0.230	0.154	0.790	0.000**	0.437	0.005**	1					
L-R Distance	-0.508	0.001**	0.698	0.000**	0.548	0.000**	0.353	0.025*	1			
CPEI	-0.151	0.353	0.111	0.496	0.097	0.553	-0.045	0.781	0.238	0.139	1	

CVA: cranio-vertebral angle, CPEI: center pressure excursion index
** p<0.05, ** p<0.01*
** CVA showed a moderate negative correlation with Area.*
** CVA showed a moderate negative correlation with L-R Distance.*

As a result of the experiment on the correlation between CVA and muscle activities during shoulder flexion, CVA and SA, UT, and LT all showed significant correlation, positive correlation with SA(r=0.429/p=0.006) and LT(r=0.377/p=0.017), and negative correlation with UT(r=-0.473/p=0.007) (Table 2).

As a result of the experiment on the correlation between CVA and balance indicator, CVA and Area, L-R distance showed a significant correlation, negative correlation with Area (r=-0.420/p=0.007) and negative correlation with L-R distance (r=-0.508 /p=0.000) (Table 3).

4 Discussion

In this study, we tried to find out how much FHP affects muscle activities for arm movement and static balance ability. It is generally known that the smaller the CVA angle, the more severe the FHP. As a result of this study, CVA showed a moderate positive correlation with SA and a weak positive correlation with LT. This means that the more severe the FHP, the lower the SA and LT muscle activity. In addition, CVA showed a moderate negative correlation with UT, meaning that the more severe the FHP, the higher the muscle activity of UT. Regarding static balance, CVA showed a moderate negative correlation with L-R distance and AREA among the static balance indicators, meaning that people with smaller CVA angles experienced greater body sway when maintaining static balance. This means that people with more severe FHP have poorer static balance abilities.

Upward rotation of the scapulothoracic joint is essential during the movement of raising the arm above the head (Whether it is shoulder flexion or abduction). While fully raising the arm, the scapulothoracic joint must be upward rotated by about 60 degrees, and the muscles involved in upward rotation are SA, UT, and LT, [28]. Typically, as FHP is more severe, a round shoulder posture also develops, and this non-ideal posture causes a change in the position of the scapula. In the FHP, the scapula is protracted, rotated downward, tilted forward, and rotated internally. This position of the scapula will inevitably affect muscle activity by causing changes in the length of the SA, UT, and LT muscles around the scapula, [23], [28].

The results of this study showed that the activity of UT was higher in people with more severe FHP(smaller CVA angles). UT is known to be an upward rotator of the scapulothoracic joint and antagonist of the levator scapula muscle. In one previous study, it was mentioned that people with severe FHP always have increased tension in the levator scapula muscle, so muscle activity of UT is increased as acting as an antagonist to offset the increased tension of FHP. Also in that study, it was said that the role of the upward rotator was added while raising the arm, resulting in higher activity of UT, [29]. In another study, in the case of FHP, the torque of cervical spine flexion due to gravity may increase, and there was also a view that the muscle activity of UT would increase because the cervical extensors must show more activity to counteract this imbalance, [30].

The results of this study showed that people with more severe FHP showed weaker SA and LT muscle activity. One of the clinical assumptions associated with these weakened muscle activities is that non-ideal changes in scapula position increase the passive length of the muscle. Because SA and LT become lengthened at FHP, it appears that they bring biomechanical disadvantages from the perspective of the length-tension relationship and muscle activity also decreases, [30]. In addition, it is known that during upward rotation of the scapulothoracic joint, UT and LT act as a couple of forces to cause movement. In this study, a tendency for UT activity to increase during arm flexion in people with FHP was found. So when there is increased UT activity during upward rotation of the scapula, the involvement of LT, which is involved as a pair force, may be relatively become smaller, [28].

SA contributes to the 3D stereoscopic movement of the scapula during arm raising. It contributes to upward rotation along with UT and LT, but can also cause lateral rotation and posterior tilt of the scapula, [31]. Therefore, in addition to pain caused by hyperactivation of UT, people with FHP may also experience muscle imbalance problems caused by the inactivity of SA. Less activated SA causes internal rotation and anterior tilt of the scapula, which accelerates the shortening of the pectoralis minor muscle, which can entrench the round shoulder posture. In addition, raising the arm while anterior tilt of the scapula leaning forward can put pressure on the tissue in the space under the acromion of the scapula, which can lead to additional problems such as impingement syndrome, [28].

There have not been many studies in which the forward head posture or CVA angle directly affects the balance ability, but various studies have found evidence that it can indirectly affect it. First of all, posture with increased CVA, such as the forward head posture, can affect not only the imbalance of the muscles around the neck but also the muscle condition of the trunk. Prolonged sitting posture and excessive use of computers or smartphones are among the main factors that cause increased CVA, and a number of studies have revealed the relationship between these factors and the trunk muscle, [7], [8], [32], [33].

Trunk muscle endurance may be a major factor influencing the decrease in balance, [34]. Prolonged sitting posture that causes an FHP eventually leads to a decrease in physical activity and a decrease in muscle activity to maintain the posture, which can lead to a decrease in endurance of the core muscle strength that maintains the posture in the long run, [22], [35]. In particular, it has been reported that trunk extensor fatigue has an effect on increasing the postural sway of static balance, [36]. It has already been shown by several studies that weakness in trunk muscles or core muscles can lead to a decrease in balance, [34], [37], [38], [39]. There may be various reasons for the decrease in balance ability of a person with a smaller CVA angle, among which a decrease in trunk muscle endurance due to prolonged sitting posture may be the main factor.

The percentage value calculated by CPEI indicates that the smaller the number, the more inward the foot arch collapses, which is often used as an indicator to measure the degree of flat feet, [24], [25]. Static balance can be greatly influenced by the feet touching the ground. In this study, CPIE values were also checked to determine whether the degree of the arch of the foot, which varies from person to person, affected the balance. The value of CPEI did not show a significant relationship with CVA or any other balance indicators. This means that the decrease in balance ability in subjects who showed a smaller CVA angle was not due to at least problems such as the arch of the foot. At least, according to the results of this study, the decrease in balance ability could be interpreted as being caused by the degree of the CVA rather than the foot. Similarly, there are several studies that strengthen the core is more important than the leg or foot to enhance static balance ability, [40], [41], [42].

5 Conclusion

In this study, we investigated the correlation between CVA and muscle activities during raising the arm and static balance to determine the causes of these results. In our finding, people with more severe FHP(those with smaller CVA) tended to develop an imbalance in muscle activity while raising their arms and decreased balance ability. In general, many researchers focused and investigated only on pain or the muscles around the neck in research on FHP. However, our findings contributed to confirming that people with FHP can be adversely affected by balance or body movement. The balance of the muscles around the scapula reduces the efficiency of the arm-raising motion, can cause pain, and can also lead to secondary dysfunction such as impingement syndrome. Our findings suggest that it can be beneficial for people with FHP to suppress UT and strengthen SA or LT when raising their arms. Furthermore, our results found that the more severe the FHP, the greater sway can occur in a static standing position. These results may serve as a reference for future studies on the association between FHP and elderly falls. This study has limitations in that the subjects were young, the sample number was small, and the relationship between CVA and other direct body imbalance factors was not considered. In the future, there is a need to further investigate this relationship so that it can serve as basic data for improving posture and balance in CVA patients such as FHP.

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Conflict of Interest

The authors have no conflicts of interest to declare.