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Comparison of Craniovertebral Angle and Muscle Properties after Smartphone Use in Healthy Individuals with and without Forward Head Posture

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Abstract

Purpose : Forward head posture (FHP) is one of the most common postural malalignment of the cranio-cervical region. Previous studies have reported that FHP might affect both temporomandibular joint (TMJ) and cervical muscles, but still remains unclear. The purpose of this study was to compare the changes of craniovertebral angle (CVA) and muscle properties after smartphone use in healthy individuals with and without FHP.

Methods : Fifteen healthy individuals aged 18 to 22 years were included. CVA was evaluated using Dartfish motion analysis, and the subjects were divided into two groups according to their CVA: a FHP group (n = 7, CVA less than 48 °) and a control group (n = 8, CVA more than 48 °). MyotonPro was used to measure muscle properties of masseter, digastric and sternocleidomastoid muscles (SCM). Each subject underwent 15-minutes of smartphone task (web browsing or video watching) in relaxed sitting posture. CVA and muscles properties were assessed both before and after the smartphone task.

Results : There were significant changes in post measurements of CVA between the groups. Masseter muscle showed significant differences in pre and post measurements of all muscle properties, and digastric muscle showed significance only in muscle tone. Amount of changes (post-pre), however, showed no significant difference in this study.

Conclusion : 15-minutes of smartphone task did not affect CVA and muscle properties of masseter, digastric and SCM in both groups, however, there were significant changes in pre and post measurements of CVA and some muscle properties of masseter and digastric muscles. Therefore, CVA, masseter and digastric muscles might be significantly changed in a heavy duration of smartphone usage more than 15-minutes. Further studies are needed regarding duration of smartphone task, assessments in other various TMJ muscle groups, and participants with pathological FHP conditions.

Key Words : forward head posture, muscle properties, smartphone, temporomandibular joint

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Ⅰ. Introduction

Forward head posture (FHP) has become one of the most common postural malalignments of the cranio-cervical region since the use of digital devices became widespread (Berolo et al., 2011). The changes in cervical alignments induced by FHP, which exaggerates the extension of the upper cervical spine (C1~C2) and flexion of the lower cervical spine (C3~C7) in the sagittal plane, also increase the loads on cervical intervertebral discs and joints (Patwardhan et al., 2015). The loads applied on the cervical spine in neutral head posture was 4.5–5.4 ㎏ and increased up to 27.2 ㎏ as the head tilts forward (Hansraj, 2014). Moreover, increased loads on the cervical spine might alter the stresses and strains on various anatomical structures, which become more vulnerable to fatigue, cervical pain, headaches, and other musculoskeletal disorders (Armijo-Olivo et al., 2011; Lau et al., 2010). Therefore, it is common practice to assess sagittal FHP in clinical settings (Nam et al., 2013). Photogrammetry is an indirect evaluation technique to quantify FHP by recording the reference points and measurement angles on a photographic image (Mani et al., 2017; Talati et al., 2018). Various measurement angles have been used in different studies (Fig 1A), with craniovertebral angle (CVA) considered as the most commonly used one among them (Talati et al., 2018). This postural assessment method is reliable (Nam et al., 2013) and capable of classifying the severity of FHP into normal, slight, moderate, and severe (Mani et al., 2017).

Head posture and cervical alignments are closely linked to other adjacent joints through kinematic chains formed by myofascial structures (Salkar et al., 2015; Szczygiel et al., 2019). The muscle and ligament connections between cranio-cervical region and temporomandibular joint (TMJ) form a complex functional structure called the cranio-cervico-mandibular system (Carini et al., 2017). In relation to these anatomical connections, FHP might alter the tension of masticatory muscles and other supporting tissues, consequently redirecting the mandibular position (Salkar et al., 2015) and moving the mandibular condyle to a higher and more posterior region of the mandibular fossa than in neutral head posture (Faulin et al., 2015). Poor head posture might also affect muscle characteristics due to the altered anatomical attachment point of masticatory muscles, but the evidence for this are limited. In previous study, the subjects with FHP had higher right side masseter muscle stiffness, however their results showed significance only in the unilateral right side and no significance in other masticatory muscles (Wang, 2019). In addition, several studies have reported a close interrelationship between FHP and TMJ (Di Giacomo et al., 2018; La Touche et al., 2011; Salkar et al., 2015). They stated that poor head and shoulder angles show a high correlation with developing TMJ disorders (Di Giacomo et al., 2018), and found that patients with TMJ disorder have a tendency to develop cervical malalignments (La Touche et al., 2011). In contrast, Armijo-Olivo et al. (2011) found small cranio-cervical postural differences between TMJ disorder and healthy groups that were not clinically significant.

Even though these various studies were reported as described above, the association between head position and TMJ disorder is still unclear. It is clinically important to reveal both TMJ and cervical muscle groups related to FHP, and to prevent the secondary musculoskeletal problems due to FHP. Thus, the aim of current study was to compare the changes of CVA and muscle properties of both TMJ and cervical muscles after smartphone use in healthy individuals with and without FHP. We hypothesized that smartphone usage worsen FHP, and also show changes in muscle properties.

Ⅱ. Methods

1. Subjects

Twenty healthy young volunteers aged 18 to 22 years entered the study. The exclusion criteria were a history of any neurological or musculoskeletal problems in the cervical spine and TMJ within the previous three months, visual or vestibular problems, and medicine taken in the last 24 hours. Five volunteers were ruled out based on exclusion criteria and remaining fifteen healthy subjects matched the criteria were included in this study (Fig 1B). The subjects were divided into two groups according to their CVA: the FHP group (n=7, CVA<48 °) and the control group (n=8, CVA≥48 °) (Shaghayegh Fard et al., 2016). All subjects were provided written consents after the experimental procedure was fully explained to them prior to participation, and the rights and safety of each subject were protected. This study was approved by the Institutional Review Board of the College of Health and Welfare, Woosong University (approval No. 1041549-210413-SB-118).

2. Instrumentations

1) CVA and Dartfish motion analysis

The CVA of each subject was calculated using Dartfish motion analysis software (Dartfish TeamPro, Dartfish, Switzerland). CVA is an angle formed by a horizontal line passing through the C7 vertebra and a line from this vertebra to the tragus of the ear (Fig 2A). Park et al. (2015) reported that the CVA measured to evaluate FHP in previous studies showed excellent test-retest reliability (ICC=.88~.98). Preliminary evidence has shown correlations between functional cervical disability and CVA (Kim & Kim, 2016) and suggested that CVA is a predictive factor of pain in the cervical vertebral region (Kim et al., 2018). A smaller CVA (< 48 °) indicated a greater FHP (Ahmadi et al., 2016). Therefore, subjects in the current study with a CVA less than 48 ° were defined as the FHP group and those with a CVA more than 48 ° were defined as the control group.

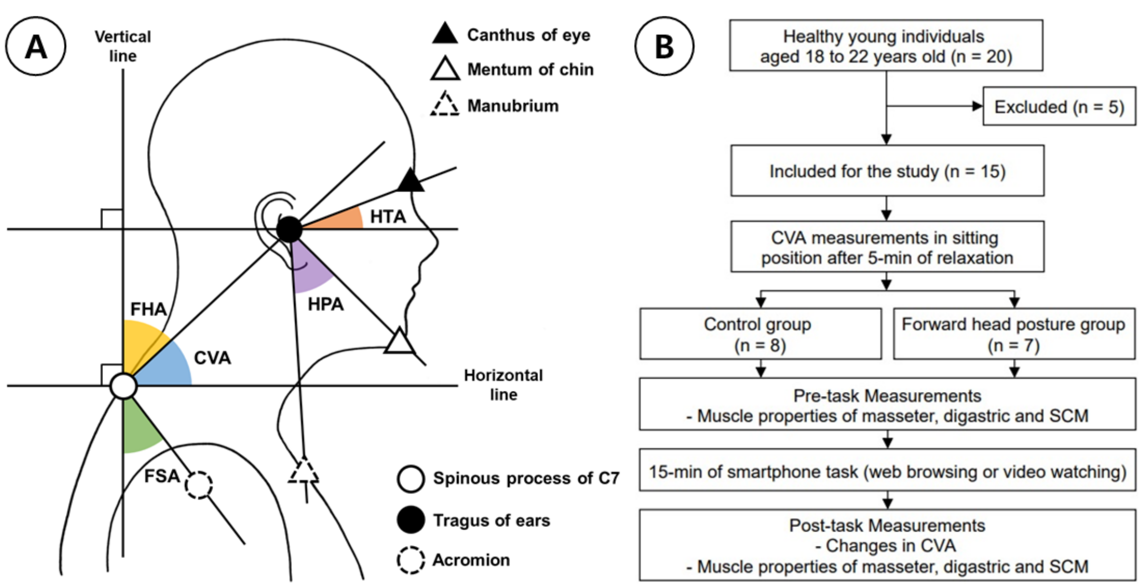

Fig 1. Experimental Design; (A) Diagnostic angles to evaluate the FHP used in previous studies. (B) Experimental flowchart of present study. FHP; forward head posture, CVA; craniovertebral angle, FHA; forward head angle, FSA; forward shoulder angle, HPA; head position angle, HTA; head tilt angle, SCM; sternocleidomastoid muscle

2) MyotonPro

Muscle properties (muscle tone, stiffness, and elasticity) were measured by MyotonPRO (Myoton®PRO, Myoton AS, Estonia). MyotonPRO has been shown to have excellent within-session intra-rater reliability (ICC=.94~.99) and inter-rater reliability (ICC=.92~.95) in young individuals (Agyapong-Badu et al., 2013). Muscle properties, such as muscle tone, stiffness, and elasticity, represent the functional condition of the muscle (Chung et al., 2013). Muscle tone is the passive tension that derives from the intrinsic viscoelastic properties of muscle that is not being voluntarily contracted. Muscle elasticity is the capacity of muscle to return to its original form after an applied load is removed, while muscle stiffness is the ability of muscle to resist deformation induced by external forces.

3. Procedures

The general information data of each subject at the beginning was recorded. Subjects were dressed in T-shirts to minimize CVA measurement errors. Prior to the measurements, they were asked to take a relaxed sitting posture on a stool. A smartphone camera (iPhone 8, Apple, USA) in a fixed location (tripod with a height of 103 ㎝ and a distance of 50 ㎝ away from the stool) was used to record the subjects' sitting posture in the sagittal plane during the entire experimental procedure (Fig 2B). Subjects were divided into FHP group or control group according to the measured CVA of their sitting posture after 5-minutes of relaxation. The calculation of CVA using Dartfish software was carried out by the same researcher in this study. Pre-task measurements of muscle properties of the right side masseter, digastric, and sternocleidomastoid muscle (SCM). To measure muscle properties, the probe of MyotonPRO was placed vertically to the midpoint of each muscle belly being assessed according to their anatomical attachments as follows: 1) The assessment position of the SCM was the muscle belly at the midpoint of attachments between clavicular head and mastoid process of the TMJ (Yeo et al., 2020). 2) Masseter muscle was measured at the marked point of the muscle belly, 3 ㎝ above the mandible angle, that bulges during contraction (Song et al., 2021). 3) Digastric muscle was measured at the point of anterior muscle belly, 2.5-3.0 ㎝ inferolateral from the mental protuberance when subjects slightly extend their cervical

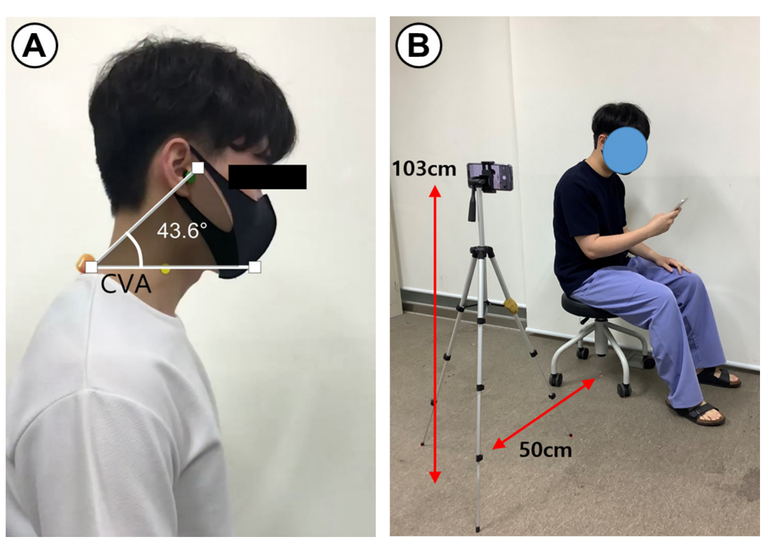

Fig 2. Experimental instruments; (A) CVA measurement using Dartfish motion analysis, (B) Video recording in sitting position

spine in the sitting position (Mukai et al., 2011), The average value of three trials and two trials were used as data of the muscle properties, respectively. Afterward, the 15-minutes of smartphone task (web browsing or video watching) in a quiet laboratory space was given to both groups. Post-task measurements of muscle properties were conducted by the same researcher right after the task. The changes of CVA after the given task in both groups were also evaluated by Dartfish motion analysis.

4. Statistical analysis

Statistical data were analyzed using a non-parametric method. The pre, post measurements and amount of changes (post-pre) in CVA and muscle properties between the FHP and control groups were analyzed using the Mann-Whitney U test. IBM SPSS Statistics ver. 25 (SPSS, IBP Corp., Armonk, NY, USA) was used to perform all data analysis. The level of statistical significance was set at .05.

Ⅲ. Results

1. General characteristics of subjects

The general characteristics of each group are shown in Table 1; no significant differences were found between the general characteristics of the FHP and control groups.

Table 1. General characteristics of subjects (n=15)

	Control (n=8)	FHP Group (n=7)
Age (years)	20.38±1.41	20.43±1.62
Height (㎝)	164.38±6.41	164.09±10.96
Weight (㎏)	61.63±12.59	58.86±16.15

Values are presented as mean ± standard deviation. FHP; forward head posture

2. Changes in CVA after smartphone task

Changes in CVA after the experimental task between groups are shown in Table 2. There were significant differences observed between both groups in pre measurements (p=.001) and post measurements of CVA (p=.049). However, the amount of changes (post-pre) in CVA did not show significant difference between two groups.

Table 2. Comparison of changes in CVA

	Control	FHP Group	z	*p*
Pre	53.71±4.81	44.31±4.01	-3.243	.001
Post	48.26±8.45	40.07±4.76	-1.967	.049
Post-pre	-5.45±6.40	-4.24±2.26	-.637	.524

Values are presented as mean ± standard deviation. FHP; forward head posture, CVA; craniovertebral angle

3. Changes in muscle properties of TMJ muscles

Changes in muscle properties of the masseter muscle are shown in Table 3. There were significant differences in both pre and post measurements of muscle properties of the masseter muscle between the FHP and control groups: muscle tone (pre: p=.008, post: p=.049), stiffness (pre: p=.015, post: p=.028), and elasticity (pre: p=.015, post: p=.011). No significant differences were found in the amount of changes (post-pre) in muscle properties of masseter muscle between groups.

Changes in muscle properties of the digastric muscle are shown in Table 4. Significant differences were found in both pre and post measurements of muscle tone of the digastric muscle between the groups (pre: p=.037, post: p=.024). There were also significant differences in pre measurements of stiffness (p=.003) and elasticity (p=.013) between both groups. However, the amount of changes (post-pre) in digastric muscle did not show significant differences between groups.

Table 3. Comparison of changes in masseter muscle properties

		Control	FHP Group	z	*p*
Masseter tone	Pre	12.60±1.00	14.97±1.73	-2.664	.008
	Post	12.98±1.22	14.65±1.25	-1.971	.049
	Post-pre	.38±.61	-.32±1.01	-1.504	.132
Masseter stiffness	Pre	219.12±28.49	275.35±37.23	-2.430	.015
	Post	230.37±37.42	286.71±36.17	-2.199	.028
	Post-pre	11.25±16.77	11.35±24.32	-.290	.772
Masseter elasticity	Pre	1.41±.20	1.66±.10	-2.432	.015
	Post	1.46±.21	1.71±.09	-2.548	.011
	Post-pre	.04±.07	.05±.06	-.116	.907

Values are presented as mean ± standard deviation. FHP; forward head posture

Table 4. Comparison of changes in digastric muscle properties

		Control	FHP Group	z	*p*
Digastric tone	Pre	12.18±1.03	13.46±1.09	-2.083	.037
	Post	12.44±1.37	14.10±1.21	-2.259	.024
	Post-pre	.25±.74	.63±.48	-.927	.354
Digastric stiffness	Pre	171.06±12.97	238.64±55.31	-3.009	.003
	Post	189.50±27.62	236.92±68.34	-1.389	.165
	Post-pre	18.43±.26.28	-1.71±32.62	-.812	.417
Digastric elasticity	Pre	1.10±.07	1.30±.19	-2.493	.013
	Post	1,19±.10	1.28±.16	-1.102	.270
	Post-pre	.08±.04	-.02±.16	-1.739	.082

Values are presented as mean ± standard deviation. FHP; forward head posture

4. Changes in muscle properties of SCM

No significant differences were found in muscle properties of the SCM between the groups (Table 5). Also, the amount of changes (post-pre) in muscle properties of SCM did not altered significantly between groups.

Table 5. Comparison of changes in SCM properties

		Control	FHP Group	z	*p*
SCM tone	Pre	13.40±.99	13.75±1.04	-.812	.417
	Post	13.38±.92	13.62±.91	-.232	.816
	Post-pre	-.01±.69	-.121±.58	-.349	.727
SCM stiffness	Pre	186.68±23.38	205.85±32.39	-1.100	.271
	Post	194.00±23.12	204.64±28.07	-.579	.562
	Post-pre	7.31±15.51	-1.21±9.83	-1.157	.247
SCM elasticity	Pre	1.14±.12	1.17±.12	-.347	.728
	Post	1.22±.14	1.18±.09	-.580	.562
	Post-pre	.08±.11	.01±.09	-1.100	.271

Values are presented as mean ± standard deviation. FHP; forward head posture, SCM; sternocleidomastoid muscle

Ⅳ. Discussion

Prolonged abnormal posture, such as looking at the monitor positioned below eye level, is well known to worsen FHP (Sun et al., 2014). It is known that FHP could induce the mechanical stress on musculoskeletal structure of shoulder, thoracic, particularly TMJ. Therefore, we demonstrated the changes of CVA and muscle properties of both TMJ and cervical muscles after smartphone use in healthy young individuals with and without FHP.

In the current study, the subjects with FHP showed the significant differences of CVA in both pre and post measurement compared to control group (pre: p=.001, post: p=.049). However, the amount of changes in CVA were not significantly different between the groups after 15-minutes of smartphone usage. Although, temporary smartphone usage lasted only 15-minutes did not change the CVA, the heavy duration of smartphone usage could exacerbate the head and cervical posture. Jung et al. (2016) reported that prolonged smartphone usage might negatively affect CVA, and that the heavy duration of smartphone usage (more than 4 hours per day) has more negative effects than light duration does (less than 4 hours per day). Cervical muscles, which contain higher muscle spindle densities compared to other body muscles, play an important role in providing afferent proprioceptive information to control posture (Ha & Sung, 2020). It was reported that postural changes were not affected by duration of usage, but rather by how subjects use and adapt their posture to this use (Alshahrani et al., 2018). Besides, Ha and Sung (2020) reported a decrease in cervical proprioception due to temporary FHP induced by smartphone viewing. The amount of changes (post-pre) in the present study did not show significant differences, therefore, we assumed that temporary smartphone usage will decrease cervical proprioception regardless of head posture. Lee et al. (2014) found out a decrease in cervical proprioception in individuals with FHP, however, CVA changes in the current study showed larger alteration in the control group; specifically, the amount of CVA changes in the FHP group and control group were 4.24 ° and 5.45 °, respectively. Although the FHP group showed a smaller change in CVA compared to the control group, Hansraj (2014) has revealed that the amount of forces applied to the cervical spine increases when more cervical flexion and head tilt occur. Therefore, changes in head weights and the stress in the cervical spine and tissues might be larger in the FHP group than in the control group.

The surface electromyography used to investigate muscle activation in dynamic conditions, however, hard to detect changes in mechanical properties of static muscles (Mutlu & Ozdincler, 2015). Therefore, it is a effective way to measure muscle properties using MyotonPro to identify differences between abnormal and normal static posture. Wang (2019) assumed that temporary postural changes in healthy individuals with normal CVA may not affect the muscle properties of TMJ muscles. They also stated that results might be different with poor head posture.

The results of current study revealed significant differences in some muscles properties of the masseter and digastric muscles. Although the amount of changes (post-pre) in these muscle properties did not show significance in the present study, FHP induced by smartphone usage more than 15-minutes might have influences on muscle properties. However, no significant differences were found in SCM in the results of this study. Hence, we assumed two possible explanations for our results in SCM. 1) Smartphone usage lasting 15-minutes might be too short to change the muscle properties of SCM. 2) SCM also creates rotational movements in the transverse plane; therefore, it is insufficient in terms of anatomical characteristics of SCM to evaluate the head posture only in a sagittal plane such as CVA without evaluating the head posture in the horizontal plane. Faulin et al. (2015) mentioned about possibility of head tilt and rotation due to head protrusion in frontal and transverse plane when evaluating head postures. In further research, it is necessary to consider horizontal planes other than sagittal planes, and studies on cervical muscle properties other than SCM will be needed. In addition, it is necessary to determine what each item of muscle property means.

Ⅴ. Conclusion

FHP induced by 15-minutes of temporary smartphone task did not affect CVA and muscle properties of masseter, digastric and SCM regardless of the head posture. However, there were significant changes in pre and post measurements of CVA and some muscle properties of masseter and digastric muscles between groups. We assumed that 15-minutes of smartphone task was insufficient duration to observe significance, therefore, CVA, masseter and digastric muscles might be significantly changed in a heavy duration of smartphone usage. Further studies are needed regarding experimental task duration, assessments in other various TMJ muscle groups, interrelationship between FHP and TMJ muscles, and participants with pathological FHP conditions.

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