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Correlation Between Forward Head Posture And Myogenic Temporomandibular Disorder In Addicted Smartphone Users

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Abstract

Background. *Forward head posture (FHP) is common in patients with temporomandibular disorders (TMDs); however, its relationship with pressure pain threshold (PPT) and muscle endurance of masticatory and neck muscles in heavy smartphone users required additional research.*

Purpose. *The purpose of this study is to investigate the correlation between i) FHP and PPT of masticatory and neck extensor muscles and ii) FHP and muscle endurance of masticatory and neck extensor muscles in addicted smartphone users with and without myogenic TMDs.*

Methods. *46 subjects (33 females and 13 males) were divided into 2 groups, Group A: 23 subjects with myogenic TMDs and Group B: 23 subjects without myogenic TMDs based on the presence of trigger points in masticatory and neck muscles according to the myofascial diagnostic criteria and on their smartphone use measured by smartphone addiction scale short version (SAS-SV). FHP was assessed by the craniocervical angle (CVA) and PPT for trigger points of the aforementioned muscles was evaluated using a pressure algometer and muscle endurance was assessed by bite endurance and craniocervical extension tests (CEET).*

Results. *There was no correlation between FHP and PPT of masticatory and neck extensor muscles in both groups. In addition, no correlation was observed between FHP and bite and neck endurance in both groups.*

Conclusion*. In the population of heavy smartphone users, no relationships were observed in patients with and without myogenic TMDs between FHP and PPT and masticatory and neck muscle endurance. Therefore, a longitudinal study to assess these variables and their correlation along specific times with variable posture of mobile phone use in the future may be recommended.*

Study registration*. The protocol registration number at clinicaltrials.gov is NCT06065826.*

Keywords. *Forward head posture; muscle endurance; pressure pain threshold; smartphone addiction; temporomandibular myogenic disorder*

Introduction

The temporomandibular joint (TMJ) and cervical spine are strongly connected anatomically, mechanically, neurophysiologically, and pathologically (1). This explains why TMD patients experience discomfort and dysfunction in the cervical spine and vice versa (2).

The term "temporomandibular disorders" (TMDs) refers to a group of clinical issues involving the temporomandibular joint, the masticatory muscles, and associated tissues (3). The etiology of TMDs is complex and may involve trauma, posture, emotional and psychological variables, parafunctional habits (such as bruxism, object biting, nail or lip biting, clenching teeth, and thumb sucking), and other rheumatic or musculoskeletal illnesses (4). The associated symptoms of the TMDs include pain and sounds in the TMJ, earache, myogenic pain of the masticatory and cervical muscles, limitation of mandibular motion, headache, and tinnitus (4,5).

Assessment of the prevalence of TMDs among university students was the topic of several studies that showed varying degrees of prevalence (6-9). It was 22.6% in India (6), 77.2% in Australia (7), 47.53% in Turkey (8) and 41.4% in Egypt (9). It is worth noting that the prevalence of TMDs is low in developing countries.

Myofascial pain, a subgroup of myogenic TMDs, is defined as pain of muscle origin that is characterized by the presence of myofascial trigger points (MTrPs) (10). It accounts for approximately 45% of all cases that were reported with TMDs (11). MTrP is a hyperirritable spot in a taut band of a skeletal muscle that is tender on palpation and develops either local or referred pain under pressure (12).

Millions of individuals use their smartphones excessively all over the world. Subjects' head and neck postures are affected by this excessive overuse since they stretch their necks downward to look at the screen thus leading to forward head posture (FHP) (13). These adapted postures affect the craniocervical region by reducing lower cervical lordosis, increasing the upper thoracic kyphosis and shortening muscle fibers around the atlantooccipital articulation and overstretches deep cervical flexors and scapular stabilizers and retractor muscles resulting in a shift of the head anteriorly beyond its normal axis (14). Moreover, FHP modifies the position and functions of the mandible, which increases tension in the masticatory muscles and results in TMDs. This may explain the strong correlation between TMDs and FHP (15). Teenagers who use smartphones excessively may have altered craniocervical regions which may induce myogenic TMDs (16).

As a global phenomenon, *smartphone addiction* has become an increasingly common issue that affects people's physical and mental health. By using an easy 10-question tool, the Smartphone Addiction Scale – short version (SAS-sv), people can be screened to measure the level of smartphone screen addiction in both genders (17). Prolonged use of smartphones has been scientifically proven to cause alterations in muscle behavior and neuromuscular proprioception in the head and neck region (16). Changes in head posture influence the development of TMDs due to the altered craniocervical posture that leads to changes in mandible mechanics through different mechanisms (22).

These changes affect the PPT of masticatory muscles and increase its electromyographic activity and masticatory reflexes leading to an increase in TMJ stiffness and pain. It was found that FHP diminishes the value of PPT in patients with TMDs (24); however, such a relationship is not clear among the heavy smartphone user population. The assumption that FHP increases the mechanosensitivity of some cervical tissues and therefore acts as a moderator of the relationship between FHP and neck pain (25), led to a great debate in the literature, with some authors finding an association between FHP and neck pain (26) while others have not observed it (27).

Alteration of head posture in patients with TMDs was found to cause masticatory and neck muscle endurance that had been reduced in patients with TMDs as evidenced by clinical and electromyographic tests (28,29). In Lee's study, heavy smartphone users had stopped neck endurance testing due to pain and muscle fatigue. This was attributed to reduced neck muscle strength in subjects with neck pain (30). However, identifying values of neck endurance in addicted smartphone users suffering from TMDs was very limited in the literature.

Upon reviewing the literature, information about masticatory muscle endurance in subjects with and without TMDs are contradictory. Some investigators found shorter endurance times in patients with myogenic TMD suggesting fatigability in masticatory muscles, a low functional capacity of the jaw motor system, and overuse of the muscles resulting from parafunctional activities (31,32,33). Contrary, Rezaie *et al.* (28) found insignificant differences in masticatory muscle endurance, mouth opening, and neck extension range of motion between TMD patients and healthy subjects. Similarly, submaximal clenching endurance time and amount of work performed before and after treatment were found to be the same in TMD patients and control groups (34).

Many studies have investigated the relationship between FHP and TMJ and how they relate to PPT and neck muscle endurance in both neck and masticatory muscles. However, to the author's knowledge, these relationships were not studied on smartphone addicts with myogenic TMDs. The growing number of smartphone users in the general population may need an assessment of the sequelae of prolonged smartphone use and its possible correlation with several musculoskeletal disorders including TMJ and cervical spine. Identifying these relationships will help therapists and healthcare providers at work or educational entities to conduct regular examinations for smartphone users to early detect TMDs and seek medical attention.

Therefore the purpose of this study was to investigate the relationship between FHP, PPT, and muscle endurance of masticatory and neck muscles in smartphone addicts with and without myogenic TMDs.

Methods

This cross-sectional observational study was conducted at the Physical Therapy Faculty outpatient clinic in the Egyptian Chinese University, between October 2023 and December 2023. This study was conducted following the ethical standards established in the Declaration of Helsinki of 1946 and was approved by the Ethical Committee of the Faculty of Physical Therapy, Cairo University (P.T. REC/012/004030 – Date of approval: September 11, 2022). This study was registered in clinical trial.gov with a protocol ID NCT06065826.

Participants:

Using G-power version 3.1.9.7 for Windows with an effect size of Cohen's d=0.04 with 80% power ($p<0.05$), suggested forty-six participants using correlation testing. Participants with and without myogenic TMDs were chosen for the current investigation based on predefined inclusion and exclusion criteria. The inclusion criteria include age ≥ 18 years and being a heavy smartphone users where the cutoff value for males is 31 and for females is 33 (17). Exclusion criteria include a history of head, neck, or TMJ trauma, congenital or acquired postural deformity, prior neck, spinal, or TMJ surgery, orthodontic treatment, or taking painkillers or anti-inflammatory medications. The flow diagram of this study is shown in Figure 1. Forty-six subjects participated in this study. They were asked to answer SAS-sv and were screened for FHP by measuring the craniovertebral angle being less than 49.9˚ (35). The heavy smartphone user participants who had FHP were divided into two groups, twenty-three participants with myogenic TMDs were assigned to group A (17 females, 6 males), and twenty-three participants without myogenic TMDs were assigned to group B (16 females, 7 males). According to the diagnostic criteria for myofascial pain, the presence of trigger points in the masseter, temporalis, upper trapezius, and C5–C6 articular pillars establish the diagnosis of myogenic TMDs (36). Participants' demographic data, craniovertebral angles, SAS-sv, masticatory, and neck muscles PPT, and endurance were obtained and recorded. All participants provided written informed consent of their approval to participate in this study after explaining to them the study's purpose and procedure.

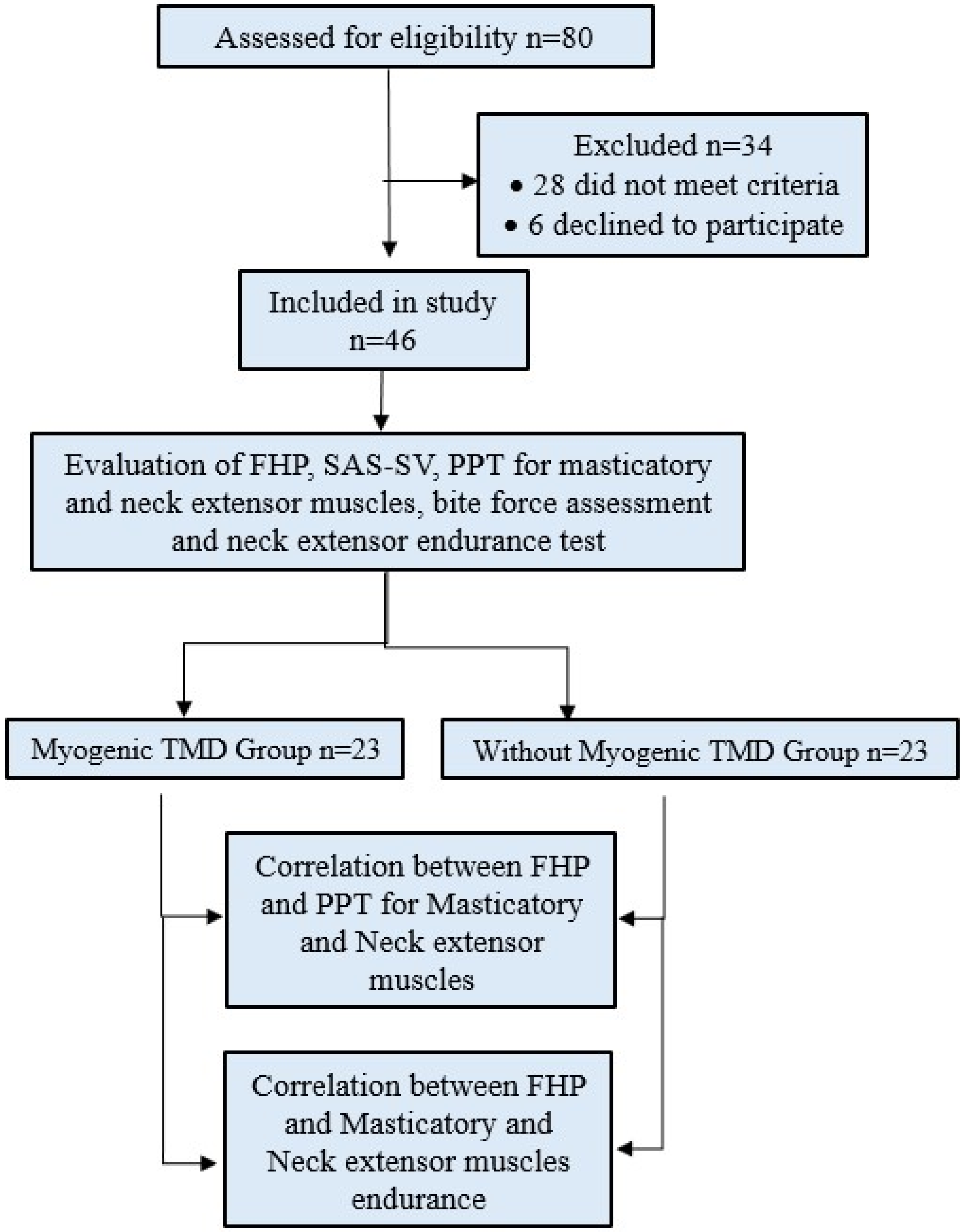

Figure 1: Flowchart of participants

Procedures

Participants filled in data regarding their demographic information and SAS-sv in their datasheet. Myofascial trigger points were assessed by the principal investigator according to the diagnostic criteria of myofascial pain (36). A blind assessor who participated in the study calculated the CVA using the photographic method (35) to detect FHP. The PPT for trigger points in masticatory (37,38) and neck muscles was evaluated by FPX 50 algometer (39). The masticatory muscle endurance was assessed through the bite endurance test using a cell load (40) and neck muscle endurance was assessed through the craniocervical extension test (CEET) using a stopwatch and bubble inclinometer (28).

Assessment

Smartphone addiction assessment

The short version of the Smartphone Addiction Scale (SAS-sv) is a rapid, straightforward, and easy screening instrument for people who are dependent on using smartphones in their daily life. Participants were asked to answer the scale which had ten self-answered items with five domains of evaluation to complete: 1) daily life problem; 2) distance; 3) orientation-cyberspace relationship; 4) overuse; and 5) tolerance. Six response options were available on the scale: strongly disagree (1), disagree in parts (2), disagree (3), agree in parts (4), agree (5), and strongly agree (6). The threshold for smartphone addiction varied by gender; for men, it was 31, whereas for women, it was 33 (17).

Craniovertebral angle (CVA)

The photographic method was used to assess CVA (35). A blind assessor used a mobile camera to take lateral views of the standing subject to measure FHP. The camera was fixed on a tripod at 1.5m away from the subject at the level of their shoulders. Two important landmarks were covered by two adhesive tapes: the tragus of the ear and the 7th cervical spinous process. The subject was asked to stand in front of the grid chart and a hanging plumb line acted as a reference for the horizontal and vertical axes of the photograph. In addition, the subject was asked to perform flexion and extension and return to the neutral position the participant looked forward and then captured the picture. After the photograph was taken and inserted in Kinovea software for analysis, a horizontal line passing through the 7th cervical spinous process was drawn. The angle was measured after drawing a line passing through the tragus and the 7th cervical spinous process. The craniovertebral angle was determined by the software as the angle formed between the horizontal line passing through the 7th cervical spinous process and the line connecting the tragus of the ear and the 7th cervical spinous process. An angle less than 49.9 degrees was considered a decreased CVA (41) (Figure 2). FHP with more than this threshold is considered normal. A mean value was calculated after the procedure was conducted three times.

Figure 2: Craniovertebral angle (CVA) Assessment using Kinovea software

Myofascial trigger points

The subject was seated in a comfortable position. The therapist looked for tender nodules in the taut bands of muscles and pressed them to diagnose myogenic TMD. The therapist's fingers were used to palpate bilaterally on sensitive nodules in taut bands of the masseter, temporalis, upper trapezius, and 1 cm apart from the C5-C6 articular pillars. To ensure that there was a trigger point, it had to fulfill these criteria; taut band and hypersensitive spot (36).

Pressure pain threshold assessment

a. **Masticatory muscles:**

The Pain Test digital algometer (FPX) was used to measure the masseter and temporalis muscles' pressure pain threshold. For the masseter muscle, the subject sat in a relaxed position with an erect trunk and feet on the floor. The masseter and temporalis muscles' bellies were subjected to pressure by the assessor using the rubber tip of a 1 cm^2 algometer. The pressure was increased until the patient complained of pain, maintaining a steady velocity of about 0.5 kg/cm^2. The value displayed on the device in kg/cm^2 was obtained and recorded. Three repetitions of the measurement were made, and a mean value was calculated for statistical analysis (42) (Figure 3).

Figure 3: Masseter muscle PPT (left) and Temporalis muscle PPT (right)

b. **Neck muscles:**

Pain Test digital algometer (FPX) was used to measure the pressure pain threshold for the right and left upper trapezius. The subject was instructed to sit comfortably with their feet flat on the ground and their trunk upright. The midpoint of a line connecting the anterior angle of the acromion and C7 was determined to represent the midpoint of the trapezius, where the rubber tip of the digital algometer was positioned. After that, the pressure pain threshold at C5/C6 articular pillars was obtained while the subject lying prone. That procedure was done by first identifying C7 by repeatedly asking the subject to flex and extend the neck while sitting, then an adhesive sticker was applied on C7. Following that, the patient lay prone where the assessor felt the spinous processes of C7, then palpated C6 and C5 and placed a marker 1 cm laterally from the midway of C6 and C5 spinous processes (39). After three trials of the measurement, a mean value was obtained for further analysis.

Bite endurance assessment

Using an I-load mini bite load cell via the iLoadVUE software helped to measure masticatory muscle endurance. The participant was seated in an upright position, and looking forward on a fixed object. The load was covered with a disposable latex glove for hygienic reasons and was placed under the first molar for measurements. The participant was asked to bite on the first molar as hard and as long as possible until exhaustion (43). Using a stopwatch, time in seconds was recorded. One measurement on each side with a 5-minute interval between both sides and the mean right and left endurance values for recording were taken for analysis (44). Any pain or discomfort felt in the masticatory muscles resulted in the test being stopped (28) (Figure 4).

Figure 4: Bite endurance assessment

Neck muscle endurance assessment

The participant was asked to warm up their neck muscles by repeatedly flexing and extending their neck 3 times slowly. The subject was then instructed to lie facedown on the plinth, with their head and neck left unsupported. A bubble inclinometer was attached to a velcro strap that was fastened around the subject's head. Subjects were instructed to hold their heads in a neutral position for as long as possible while a stopwatch was used to record the time in seconds. The test was terminated when the subject felt pain in the neck or failed to maintain the head in a neutral position and that was identified if the subject's head changed its position for more than 5˚ shown by the inclinometer (19,45).

Statistical analysis:

The unpaired t-test was conducted for the comparison of subject characteristics between groups. Chi-squared test was used for the comparison of sex distribution between groups. Normal distribution of data was checked using the Shapiro-Wilk test. Levene's test for homogeneity of variances was conducted to ensure the homogeneity between groups. Pearson correlation coefficient relation was used to determine the relation between forward head posture and pressure pain threshold and muscle endurance in masticatory and neck muscles in heavy smartphone users with and without myogenic TMDs. The level of significance for all statistical tests was set at $p < 0.05$. All statistical measures were performed through the Statistical Package for Social Sciences (SPSS) version 25 for Windows.

Results

Subject characteristics:

Subjects' characteristics are illustrated in Table I. There was no significant difference between groups in age, weight, height, BMI, SAS-sv, and sex distribution ($p > 0.05$) (Fig. 5).

Table I. Basic characteristics of participants.

	Group A	Group B	*p*-value
	Mean ± SD	**Mean ± SD**	
Age (years)	24.22 ± 6.18	23.35 ± 3.21	0.55
Weight (kg)	69.13 ± 20.36	68.13 ± 14.89	0.85
Height (cm)	167.52 ± 9.65	168.57 ± 10.73	0.73
BMI (kg/m²)	24.26 ± 4.48	23.88 ± 3.85	0.75
SAS-sv	44.78 ± 5.86	44.48 ± 6.50	0.86
Sex, n (%)			
Females	17 (74%)	16 (70%)	0.74

Males	6 (26%)	7 (30%)

SD, standard deviation; *p*-value, level of significance

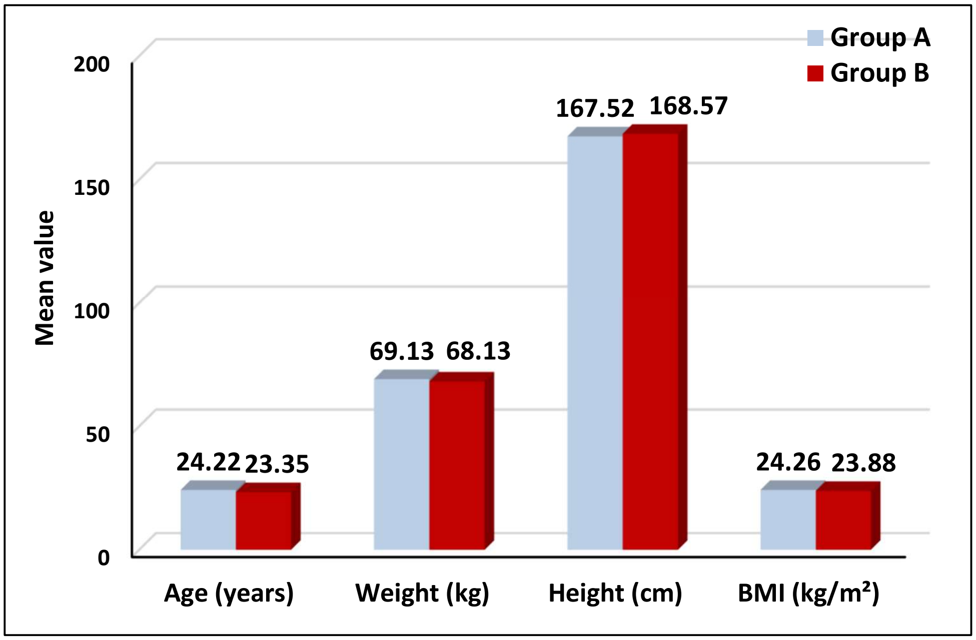

Figure 5: Mean age, weight, height, and BMI of groups A and B.

The correlation between FHP and PPT for masticatory and neck extensor muscles for both groups with and without myogenic TMDs did not show significant results. For the myogenic TMDs group (Group A), the correlation between the FHP (which was assessed by CVA) and PPT of right and left masseter muscles showed weak positive non-significant correlations (r = 0.056, $p = 0.800$) and (r = 0.144, $p = 0.511$), respectively. As for the right and left temporalis muscles, there was also a weak positive non-significant correlation (r = 0.200, $p = 0.360$) and (r = 0.170, $p = 0.439$), respectively. Similarly, the correlations between the CVA and PPT of the right and left C5-C6 articular pillars were weakly positive (r = 0.045, $p = 0.838$) and weakly negative (r = -0.071, $p = 0.746$), respectively, and were not statistically significant. Likewise, the correlation between CVA and PPT of the right and left upper trapezius revealed weak positive non-significant correlations (r = 0.148, $p = 0.500$) and (r = 0.172, $p = 0.433$) respectively (Table II).

Meanwhile, for subjects without myogenic TMDs (Group B), the correlation between CVA and PPT of the right masseter muscle was a weak negative non-significant correlation (r = -0.028, $p = 0.90$), and for the left masseter muscle was a weak positive non-significant correlation (r = 0.151, $p = 0.492$). On the other hand, the correlation between CVA and PPT of right and left temporalis muscles were moderate to weak negative non-significant correlation revealing (r = -0.368, $p = 0.084$) and (r = -0.091, $p = 0.680$), respectively. As for the correlations between CVA and PPT of C5-C6 right and left articular pillars were weak positive non-significant correlations (r = 0.107, $p = 0.628$) and (r = 0.09, $p = 0.682$), respectively. Moreover, the correlations between CVA and PPT of the right and left upper trapezius showed weak negative non-significant correlations (r = -0.012, $p = 0.958$) and (r = -0.080, $p = 0.717$), respectively (Table III).

Table II. Correlation between CVA, PPT, and endurance of masticatory and neck extensor muscles group A:

Variable (unit)	Variable (unit)	r value	*p*-value	Sig
CVA (degrees)	Right bite endurance (sec)	-0.072	0.743	**NS**
	Left bite endurance (sec)	-0.148	0.501	**NS**
	CEET (sec)	0.015	0.945	**NS**
	PPT of right masseter muscle (kg/cm²)	0.056	0.800	**NS**
	PPT of left masseter muscle (kg/cm²)	0.144	0.511	**NS**
	PPT of right temporalis muscle (kg/cm²)	0.200	0.360	**NS**
	PPT of left temporalis muscle (kg/cm²)	0.170	0.439	**NS**
	PPT of C5-C6 right articular pillars (kg/cm²)	0.045	0.838	**NS**
	PPT of C5-C6 left articular pillars (kg/cm²)	-0.071	0.746	**NS**
	PPT of right upper trapezius (kg/cm²)	0.148	0.500	**NS**
	PPT of left upper trapezius (kg/cm²)	0.172	0.433	**NS**

r value: Pearson correlation coefficient *p*-value: Probability value NS: Non-significant

The correlation between FHP and muscle endurance for masticatory and neck extensor muscles was non-significant for both groups. For subjects with myogenic TMDs (Group A), the results revealed that correlations between CVA and right and left bite endurance were weak negative non-significant correlations (r = -0.072, p = 0.743) and (r = -0.148, p = 0.501), respectively. Also, the correlation between CVA and CEET was a weak positive non-significant correlation (r = 0.015, p = 0.945) (Table II).

On the other hand, subjects without myogenic TMDs (Group B) showed that the correlations between CVA and right and left bite endurance were weak negative non-significant associations (r = -0.165, p = 0.451) and (r = -0.285, p = 0.187) respectively; and the correlation between CVA and CEET was a weak positive non-significant correlation (r = 0.149, p = 0.496) (Table III).

Table III. Correlation between CVA, PPT, and endurance of masticatory and neck extensor muscles group B:

Variable (unit)	Variable (unit)	r value	*p*-value	Sig
CVA (degrees)	Right bite endurance (sec)	-0.165	0.451	**NS**
	Left bite endurance (sec)	-0.285	0.187	**NS**
	CEET (sec)	0.149	0.496	**NS**
	PPT of right masseter muscle (kg/cm²)	-0.028	0.900	**NS**
	PPT of left masseter muscle (kg/cm²)	0.151	0.492	**NS**
	PPT of right temporalis muscle (kg/cm²)	-0.368	0.084	**NS**
	PPT of left temporalis muscle (kg/cm²)	-0.091	0.680	**NS**
	PPT of C5-C6 right articular pillars (kg/cm²)	0.107	0.628	**NS**
	PPT of C5-C6 left articular pillars (kg/cm²)	0.090	0.682	**NS**
	PPT of right upper trapezius (kg/cm²)	-0.012	0.958	**NS**
	PPT of left upper trapezius (kg/cm²)	-0.080	0.717	**NS**

r value: Pearson correlation coefficient *p*-value: Probability value NS: Non-significant

Discussion

The study set out to examine the relationship between FHP and PPT and muscle endurance of masticatory and neck extensor muscles in heavy smartphone users with and without myogenic TMDs. The results showed that there was no correlation between FHP and PPT of right and left masticatory and neck extensor muscles in both groups. In addition, no correlation was observed between FHP, bite force, and neck endurance in both groups.

PPT is the minimum force applied that induces pain and discomfort (46). Pain and tenderness in masticatory muscles are common clinical findings in the TMD population (18). Our results revealed that the correlation between FHP (assessed by CVA) and PPT of right and left masseter and temporalis muscles was non-significant in the myogenic TMDs group and on the right masseter and right and left temporalis muscles in the non-myogenic TMDs group. These findings are in general agreement with those of other researchers who investigated the association between FHP and masticatory muscle PPT in TMD patients with and without FHP and found no correlation between FHP and masticatory muscle PPT (47). Patients with and without TMDs may have FHP, thus it is not logical to be implicated as a cause of TMD symptoms (48). Contrary, some investigators believed that FHP can cause excessive masticatory muscle contraction due to anatomical and physiological changes, resulting in TMD symptoms (49,50). The results of the current study could be explained in three ways. Firstly, there is no consensus regarding the definition of FHP, and a variety of angles has been reported between 49° and 53°(51–53) because of that, different CVA measures may have different effects on TMDs and this variation may affect masticatory muscles contraction differently therefore, causing a variation in the degree of TMD symptoms. Secondly, as a compensatory mechanism, masticatory muscles could tolerate pain in the presence of FHP. This fact was present when Pacheco *et al*. found that with more FHP, neck muscle's PPT was better (39). Finally, physiological and psychological factors can be associated with masticatory muscle pain, though we did not study these factors, so an abnormal posture of the head and neck could not only be correlated with masticatory muscle pain (47).

On the other hand, many researchers investigated the association between forward head posture and pressure pain threshold in neck muscles in various patient populations (14, 25, 39, 47, 55). The current research revealed that there were no significant differences between forward head posture and pressure pain threshold for neck extensor muscle. Conversely, Martinez-Merinero *et al.* found a significant increase in mechanosensitivity in the FHP group in all neck muscles except for the upper trapezius and scalenus medius muscles (25). They suggested that FHP could add more compressive forces on the cervical apophyseal joints and more mechanical forces on the neck and shoulder muscles, which could eventually cause nerve sensitization. Likewise, frequent mechanical stress over a prolonged time could enhance the presence of algogenic substances that subsequently lead to tissue hyperalgesia (54).

Moreover, Yao's study found a significant negative correlation between the upper trapezius pressure pain threshold and FHP in patients with TMDs and FHP, i.e. the more FHP the more pain tolerant the trapezius muscle is to pain. They elucidated their findings and related them to the widespread use of mobile phones and gadgets that caused people to adapt to the continuous forward posture since childhood and that prolonged faulty head posture has compensated for the muscle groups in the neck causing an increase in muscle pressure pain threshold (55). Others also revealed there was no correlation between C5-C6 articular pillar PPT and FHP and a negative correlation between trapezius PPT and FHP, i.e. the higher the trapezius PPT, the more the head is protruded forwardly (47). Likewise, a negative correlation between neck muscle PPT and FHP but in non-TMDs participants where the right trapezius showed reduced sensitivity to pain (39). However, based on the previous information, it is possible to interpret the results that our study participants with FHP did not suffer from a severe degree of head protrusion that would trigger the release of inflammatory substances to trigger neck pain and they likely became accustomed to the incorrect head posture and increased their tolerance to muscle pain as a result of their prolonged smartphone use.

Many studies have discussed the relationship between head posture and masticatory bite force measurement (56), muscle activity (57,58), muscle property (59), also muscle fatigue in patients with TMDs (60,61) but to the author's knowledge, there was no previous research linking FHP and masticatory muscle endurance in heavy smartphone users with and without TMDs.

In the previous literature, it was found that the endurance of jaw-closing muscles had been studied indirectly by electromyogram (EMG). Ballenberger *et al.* found that there was a change of masseter EMG activity with different head postures in asymptomatic individuals; however, these postures did not influence EMG activity of the temporalis muscle. That's because a change in a head position would biomechanically change the TMJ position which therefore reduces the masseter muscle lever arm which consequently decreases its activity (57). Similarly, EMG was used to measure muscle fatigue in TMDs patients and was compared to healthy individuals without assessing head posture. They also found reduced muscular activity of the masseter and temporalis muscles in the affected group (60,61). On the contrary, masseter and temporalis muscle activity increases when the head tends to shift anteriorly in TMDs patients because this head posture alters the condyle more posteriorly causing jaw muscle activity to increase and this can generate pain, chronic fatigue syndrome and result in a TMD (58,62). Likewise, the measurement of bite force can provide useful data for the evaluation of jaw muscle function and activity. Similar to our current study, two researchers found no correlation between bite force and head posture in pre-orthodontic children (56).

In contrast, Hellsing and Hagberg found a direct relationship between bite force and head posture; they identified an increase in bite force with head extension posture compared to natural head posture, and that was due to alteration of the hyoid bone position which reflects a change in the muscular interplay between elevators and depressor muscles (63). Furthermore, a Korean study by Wang found that muscle tone and stiffness had increased with a decrease in the CVA, however, the changes were insignificant. Moreover, they found an increase in right masseter stiffness with an increased forward head posture. They explained that a temporary forward head posture in healthy individuals was not to a big extent to cause an explicit change in muscle tone and stiffness. In addition, healthy young male subjects who participated in the study did not suffer from TMD problems and had no abnormal face length as its abnormality is linked to changes in the masticatory muscle tone (59).

Neck extensor muscle endurance has been investigated in many populations with different cervical impairments, such as patients with subclinical neck pain, mechanical neck pain, postural neck pain, disc problems, and FHP. It was agreed that patients with neck involvement have lower neck extensor endurance. However, that was not recognized in the current study, which showed a weak positive nonsignificant correlation between FHP and neck extensors muscle endurance measured by CEET in heavy smartphone users with and without myogenic TMDs.

In parallel to our results, Ghamkhar and Kahlalee found no association between FHP and neck muscle endurance in subjects with and without neck pain, though there was a reduction in neck extensor endurance capacity in the FHP group but it was irrelevant to neck pain. They suggested that this reduction could be related to pain avoidance and kinesphobia which might have affected the time to hold the position during the test (64,65). Moreover, reduced neck muscle endurance in individuals with neck pain is related to poor function of deep neck muscles which function to maintain the cervical spine in an optimal position, meanwhile, a harmful cycle of pain-weakness is being initiated (66). Furthermore, Oliveira and Silva *et al.* found no correlation between FHP and flexor and extensor muscle endurance in patients with neck pain (67).

Contradicting to our results Goodarzi *et al*. investigated the relationship between extensor muscle strength and craniovertebral angle. They showed a negative correlation between the severity of FHP and neck extensor muscle strength. Based on the length-tension relationship, a deviation from the neutral neck position reduces muscle tension, as FHP leads to muscle length alteration which consequently reduces extensor force production by neck muscles (69). That was also supported by Gençosmanoğlu *et al*. who identified a negative relationship between craniocervical muscle performance and TMD severity; however, it was not clinically significant (68). Trunk muscle endurance is also affected by FHP. Salahzadeh *et al.* found that hyperextension of the upper cervical spine i.e. FHP had led to lower trunk muscle endurance and this may likely cause pain and disability in neck musculature and other segments of the spine (21).

Similarly, a study by Rezaie *et al.* revealed a decrease in neck muscle endurance values in TMD patients compared to healthy subjects (28). Their results were similar to *Travell and Simons* who implicated that a functional impairment in the jaw joint would lead to a muscle dysfunction in the neck (70). This was supported scientifically through the physiological and anatomical connections between the temporomandibular and cervical joints (71). Another explanation was related to the neuromuscular pain activation paradigm, which states that the experience of pain inhibits the activation of particular muscle groups that have a predetermined action (72). Individual responses and the complexity of the sensorimotor system impact the changes that take place in the sensorimotor region when pain is present (73). On the other hand, patients with chronic pain have reduced neck muscle endurance, because they suffer from damage to low-threshold motor units which are already fatigued before starting a contraction or they would quickly get fatigued at the beginning of the contraction. Therefore, higher threshold motor units get quickly recruited to compensate for loss of muscular force and mask the myoelectric manifestations of fatigue which in turn produces a lower fatigue index during the neck extensor muscle endurance test (NEMET) (29). Furthermore, due to higher neck extensor fatigability, addicted smartphone medical students have been shown to score lower values on the neck extensor endurance test (19). That was also seen in a study by Hussain *et al.* who investigated the relationship between smartphone addiction and muscle back endurance and they found that the holding time during endurance tests was higher in the non-addicted group (20). The possible contradiction between our results and previous researchers' results may be attributed to the individual variation of the subjects who participated in the study did not complain of neck pain; thus the motor units of the cervical extensor muscles were not severely damaged to induce pain and fatigability of the neck muscles.

Our study has some limitations. Firstly, only the myogenic TMDs were tested revealing no significant correlation between variables, therefore, other types of TMDs, such as intra-articular or mixed TMDs can be included in future research. Second, all participants were smartphone users; however, light users could have participated to compare with heavy users to determine how addiction can be correlated with FHP and the other variables.

CONCLUSION

In the population of heavy smartphone users, no relationships were observed in patients with and without myogenic TMDs between FHP and PPT and masticatory and neck muscle endurance. Therefore, a longitudinal study to assess these variables and their correlation along specific times with variable posture of mobile phone use in the future may be recommended.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

DH: patient physical assessment, outcomes measurement, and writing the initial manuscript. SA: writing – original draft, writing – review & editing. NI: writing – original draft, writing – review & editing. MI: results assessment, writing – original draft, writing – review & editing and a corresponding author.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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