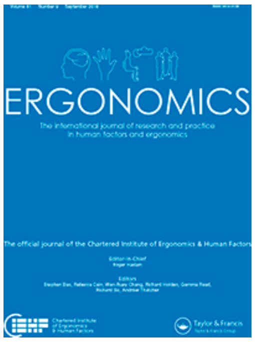


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# Effect of Neck Flexion Angles on Neck Muscle Activity among Smartphone Users With and Without Neck Pain

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This study examined the differences in neck muscle activity at various neck flexion angles in smartphone users with and without neck pain. Forty-four participants performed texting tasks for 1 minute and 30 seconds. Neck muscle activity and pain in the neck were measured at different neck flexion angles. There was a difference in neck muscle activity for each of the neck flexion angles; the Cervical Erector Spinae (CES) muscle activity increased while the Upper Trapezius (UT) muscle activity decreased when at increased neck flexion angles. At neck flexion angle of $0^o$-$15^o$, the activity of both CES and UT muscles were acceptably low. Smartphone users with neck pain had slightly higher muscle activity levels than smartphone users without neck pain. In conclusion, smartphone users should consider adopting neck flexion angles between 0-15 degrees during smartphone use as there is an association between this neck flexion angle range and reduced CES muscle activity.

**Practitioner Summary:** This study demonstrated that both smartphone users with and without neck pain should try to keep their neck flexion angle between $0^o$-$15^o$ when using their smartphone. This would reduce neck muscle activity and the risk of developing neck disorders associated with smartphone use.

**Keywords:** Neck flexion angle, neck muscle activity, smartphone users

## 1. Introduction

In our digital society, there are 3.4 billion smartphone users worldwide (Ericsson 2015). Thailand is nineteenth of the top twenty-five countries in terms of global smartphone use (eMarketer 2014). The age group of smartphone users varies, ranging from students to workers to elderly people (Han et al. 2012). University students in their 20s, in particular, use smartphones more than any other age group (Lee and Seo 2014). Smartphone usage can encourage awkward postures. A previous study in Thailand (Namwongsa et al. 2018) found that the majority of smartphone users who reported musculoskeletal disorders maintained a flexed neck posture (82.74%) when using a smartphone.

A neck flexion posture, which is the most common posture smartphone users adopt when looking at their smartphone visual display terminals for extended periods, potentially provides risk for musculoskeletal problems (Kang et al. 2012, Lee et al. 2015, Park et al. 2015). Prolonged use of smartphones could induce changes in the cervical spine posture and in proprioception (Kim et al. 2013). Heavy smartphone use might produce considerable stress on the cervical spine, thus changing the cervical curve (Park et al. 2015). Smartphone users commonly maintain head flexion of $33^o$-$45^o$ from vertical when using a smartphone (Lee et al. 2015). A study by Ning et al. (2015) also demonstrated that smartphone users maintained significantly more neck flexion when operating a smartphone ($44.7^o$). The weight on the spine dramatically increases when flexing the head forward at varying degrees; an adult head weighs 10 to 12 pounds in the neutral position. As the head tilts forward the forces on the neck surge to 27 pounds at $15^o$, 40 pounds at 30 $^o$, 49 pounds at $45^o$ and 60 pounds at $60^o$ (Hansraj 2014). The visual display terminal, which has a small screen, requires users to bend their neck more, thereby also increasing the activity of the shoulder muscles (Straker et al. 2008). This means that when using a small screen, there is increased muscle activity required to stabilize the neck in the more flexed position. To keep the neck balanced, the extensor muscles are activated, thereby increasing the load placed on the cervical erector spinae and the trapezius muscles (Greig et al. 2005).

Xie et al. (2016) conducted a study on the activity of three proximal postural muscles (cervical erector spinae, upper trapezius, and lower trapezius) and four bilateral distal muscles (extensor carpi radialis, extensor digitorum, flexor digitorum superficialis, and abductor pollicis brevis) in smartphone touchscreen use by young people with and without chronic neck–shoulder pain. It was reported that young people with neck–shoulder pain showed altered motor control consisting of higher muscle activity in the cervical erector spinae and upper trapezius muscle when performing texting and typing tasks. Generally, unilateral texting was associated with higher muscle load when compared with bilateral texting, especially in the forearm muscles. Compared with computer typing, smartphone texting was associated with higher activity in neck extensor and thumb muscles but lower activity in upper and lower trapezius as well as wrist extensors (Xie et al. 2016). However, in this study they examined differences in muscle activity between young people (aged 23.9±3.2) with and without neck-shoulder pain and they focused only on texting (with both hands and with only one hand) compared with computer typing. But the investigators were not particularly concerned about different neck flexion angles, which may in fact affect muscle activity because the load taken by the spine dramatically increases when flexing the head forward at varying degrees (Hansraj 2014).

To resist the greater flexor moment related to the flexed neck posture when using a smartphone keypad touchscreen, higher extensor moment is needed, most likely accounting for the increased cervical erector spinae activity during bilateral texting (Xie et al. 2016). Consistent with this hypothesis, minor damage accumulated in the neck due to chronic posture and sudden muscular contraction can further lead to deconditioning of muscles that are not commonly being utilized, thereby inducing mechanical dysfunction and chronic pain

(Boyd-Clark et al. 2002). Neck muscle behavior might be altered in patients with neck pain whereby patients display reduced activation of the deep cervical extensors as well as less defined activation patterns (Schomacher and Falla 2013). Patients therefore support their neck by increasing activity in the superficial extensor muscles, which increases the load placed on the cervical erector spinae and the trapezius muscles (Greig et al. 2005).

The current study sought to investigate the neck muscle activity at various neck flexion angles during smartphone use, in smartphone users with and without neck pain. We hypothesized that there would be a difference in the neck muscle activity in different neck flexion angles during smartphone use and a difference in neck muscle activity between smartphone users with and without neck pain. The findings of the current study may provide evidence which can be used to develop health guidelines for appropriate postures during smartphone use.

## 2. Methods

### *2.1 Study Design*

The study design was quasi-experimental; it was conducted in the Physical Therapy Laboratory, Faculty of Associated Medical Sciences, Khon Kaen University where the room temperature and light were controlled. Evaluation of neck muscle activity at each neck flexion angle was tested among smartphone usage in users with and without neck pain. The research proposal for this study was submitted to and approved by the Khon Kaen University Ethics Committee in Human Research before beginning the study (HE591321) based on the ethical principles of the Declaration of Helsinki. In addition, this study was approved for registration with the Thai Clinical Trial Registry (TCTR20180114001).

### *2.2 Sample Size*

A sample size estimation for repeated measure ANOVA was performed using the mean and standard deviation values of each outcome measure (muscle activity and pain) in our pilot study (Namwongsa et al. 2018). A power calculation was conducted based on a critical α-value of 0.05 and a power level of 90%, 22 participants were required in each group.

### *2.3 Participants*

Participants were recruited for this study by printed media advertisement posted on notice boards (in the area around the Khon Kaen University in Thailand) and also announcement posted via the social network Facebook. Participants were selected using a purposive sampling method. The 44 participants (22 participants in each group) were young adult aged smartphone users (between 18-25 years old), who had their own iPhone 5s (Apple Inc., USA) smartphone, at least 6 months' experience in using their smartphone and who spend at least 2 hours daily on their smartphone. Participants had to be right hand dominant and prefer to use dual handed text entry. Participants were excluded from the study if they had any of the following conditions: (1) any history of traumatic injuries , such as whiplash, or surgical interventions of relevant regions within the past year (Kim et al. 2012, Kim 2015, Xie et al. 2016), (2) other medical conditions which may have a negative effect on the spine and upper extremities such as a deformity (Kim et al. 2012, Xie et al. 2016), (3) chronic diseases affecting the musculoskeletal system such as rheumatoid arthritis, osteoarthritis and other connective tissue disorders (such as fibromyalgia) (Kim 2015, Xie et al. 2016), (4) neurological (Kim et al. 2012) and orthopedic disorders (Lee and Seo 2014) as well as sensory deficit (Xie et al. 2016), (5) visual problems (which cannot be corrected by glasses), dizziness and vertigo (Kim et al. 2012), (6) had taken any sedative drug or alcohol within the past 48 hours (Kim et al. 2012) and (7) had soft tissue around their neck region which limited a full degree of neck flexion. The exclusion criteria were screened for mainly from medical history and also clinical examination by an experienced physical therapist, prior to commencing of the study.

Participants were allocated into two groups differentiated only by the presence of pain: the control group without neck pain, and the case group with neck pain. For inclusion into the neck pain group participants had to have experienced pain during smartphone usage for more than 3 months in the past year (Xie et al. 2016). There were three additional inclusion criteria: area of pain, mechanical nature of pain and intensity of cervical symptoms. Relevant symptom area included pain on posterior neck or shoulder, which is the area from the superior nuchal line to the spinous process of the 1st thoracic vertebra. Mechanical characteristics consisted of symptoms provoked by sustained neck posture, neck movement or palpation of cervical musculature (Martinez-Segura et al. 2006). Intensity of pain level required at rest was at least a mild level (3 score or greater) measured using a Visual Analog Scale (Jensen et al. 2003).



### *2.4 Experimental Protocol*

The participants were asked to place a line perpendicular to the VAS line at the point that best represented their pain intensity before they began texting in each neck flexion angle. After that, the participants were instructed to continuously text A-Z alphabets on their smartphone by Line application (NHN., Japan) and send every set to the researcher while gripping their smartphone with both hands and texting using both thumbs on a smartphone in a 1 minute and 30 seconds session with 2 minutes of rest (Ning et al. 2015) in $0^o$, $15^o$, $30^o$ and $45^o$ of neck flexion angles. These angles were chosen following our pilot study (Namwongsa et al. 2018). The angles for each participant were sequentially tested in the same order but the starting angle was randomly allocated to individual participants (e.g. 30°, 45°, 0°, 15°). Both left and right sides of neck muscle activity was assessed (i.e. the Cervical Erector Spinae (CES) and the Upper Trapezius (UT)). During texting, the participants were asked to hold and adjust the smartphone height level and distance from their body, so that they could see the smartphone screen clearly, but the participant had to keep their neck bent in each neck flexion angle.

A Cervical Range of Motion (CROM) device (Performance Attainment Associates, USA) was used to measure and maintain the cervical range of motion in each of the neck flexion angles during assessment of cervical muscle activity. Intra-tester reliability of the assessor measuring cervical range of motion using this tool was performed in each of the neck flexion angles (ICC values ranged from 0.95-0.97).

In order to control the participants' trunk posture, the participants were also instructed to sit in a height-adjustable swivel chair with back support. All of them were told to lean back against the backrest of the chair to control their trunk angle in the same posture. During the resting time between each angle, the participants were allowed to rest in the natural resting posture of the neck which they felt comfortable and did not aggravate their neck pain.

The chair height was adjusted to a position that was comfortable for the participants, with their hips and their knees at approximately 90° flexion and the feet positioned shoulder width apart on the ground (Shin and Kim 2014, Xie et al. 2016). The participants were required to maintain a stable posture but were still allowed to have slight spontaneous movements (Xie et al. 2016). Participants used their own iPhone 5s (dimensions 123.8 x 58.6 x 7.6 millimeters, weight 112 grams) without a smartphone protector case as the standard smartphone in this study.

The participants were instructed to text at their customary speed and as accurately as possible, without amending any error while texting and without using the automatic "word complete" function during texting. Prior to the actual data collection, the participants were given 3 minutes to familiarize themselves with texting (Xie et al. 2016) in each of the neck flexion angles. The neck muscle activity at each neck flexion angle during smartphone use was assessed after the familiarization period. Finally, the participants were required to complete the VAS line again after texting at each of the neck flexion angles.

**Insert Figure 1 about here**

### *2.5 Outcome Measures*

Two outcome measures were used to test muscle activity and pain in the texting task**.** The outcome measures used were surface Electromyography **(**sEMG**)** and self**-**reported neck pain intensity**.**

#### *2.5.1. Neck Muscle Activity by Surface Electromyography* **(***sEMG***)**

The activation of neck muscles consisting of the Cervical Erector Spinae (CES) and the Upper Trapezius (UT) muscles were measured by sEMG. The skin over boundaries, both left and right sides of CES and UT were prepared to reduce skin impedance to below 10 kΩ by shaving hair at electrode sites, cleaning with alcohol, gently abrading the skin with light sandpaper and cleaning again with alcohol (Xie et al. 2016). The raw sEMG activations of these muscles were recorded from both left and right sides via a four channel MP-36 (BioPac systems, California., USA) by using a pair of 10 mm diameter Ag-AgCl disposable surface electrodes (EL 503) which were placed 25 mm apart (center to center).

The sampling rate of sEMG signal was set at 1,000 Hz with signal amplification of gain 1,000 and common mode rejection ratio as 110 dB. The frequency band-pass filter was set between 20 Hz and 500 Hz and notch filter was set at 50 Hz. A personal computer with an

A/D converter was used to record and analyze the EMG data. Location of surface electrode and amplitude normalization to Maximal Voluntary Contraction (MVC) was performed (Straker et al. 2008).

sEMG normalization procedures were carried out by having each participant perform three trials of resisted maximum voluntary isometric contractions (MVC). Each MVC was performed for 5 seconds, with 2 seconds of rest in between and 5 minutes of rest between both muscles (Greig et al. 2005). Muscle activity was tested in the sitting position for both left and right cervical and shoulder muscles. The CES muscles were tested with resisted neck extension while the UT muscles were tested with resisted shoulder elevation as described by Straker et al. (2008). All resistance was constant and was provided via velcro straps.

*2.5.2. Neck Pain Intensity by the Visual Analogue Scale*

The Visual Analogue Scale (VAS) is a continuous scale, it is a horizontal line of 100 mm in length, anchored by 2 adjectives: zero representing no pain in the left anchor and 100 representing worst imaginable pain at the right anchor (Williamson and Hoggart 2005, Mannion et al. 2007, Hawker et al. 2011). The participants were asked to place a line perpendicular to the VAS line at the point that best represented their neck pain intensity before and after the texting task was performed at each of the neck flexion angles.

***2.6 Data Analysis***

Descriptive statistics were used to analyze characteristics of the participant's variables. Continuous variables including age, weight, height, Body Mass Index (BMI), protector case weight, total time since starting to use the first smartphone until to current smartphone (years); T1, total time on smartphone per day (hours); T2, duration of neck pain symptoms (months); T3, neck muscle activity and pain intensity were analyzed by Mean±SD and median (interquartile range). Categorical variables including sex, preferred neck flexion angle were considered in terms of frequency (n) and percentage (%). The Shapiro-Wilk test was used to determine normality distribution. Normal distribution data (BMI, protector case weight, total time since started to use the first smartphone until to current smartphone (years), duration of neck pain symptom and pain intensity) were analyzed for difference between the groups using the independent t-test. Non-normal distribution data (age, weight, height and total time on smartphone per day) were analyzed for difference between the groups using the Mann-Whitney U Test. The difference between muscle activity and pain intensity within the group, which was not normally distributed data, was analyzed using the Friedman test and the Wilcoxon signed-rank test, which is a post hoc test. The difference between muscle activity and pain intensity between groups, which are not normally distributed data, was analyzed using the Mann-Whitney test and ANCOVA tests, respectively. A significant level was set at $p < 0.05$. Data were analyzed using the STATA program version 10 (STATA, College Station, TX, USA).

## 3. Results

### *3.1 General Characteristics of Participants*

Table 1 shows the general characteristics of participants in the two groups. There was no significant difference between groups with respect to general characteristics and participants' pattern of smartphone use. The VAS in the case group ranged from 30.00 to 45.50 millimeters and they had a neck pain duration range of between 3 to 12 months. Half of the participants in both groups reported their preferred neck flexion angles at $15^{o}$ in the control group and $30^{o}$ in the case group respectively.

**Insert Table1 about here**

### *3.2 Neck Muscle Activity at Each of the Neck Flexion Angles*

*3.2.1 Within Groups*

The neck muscle activity at each of the neck flexion angles is shown in Table 2. The Friedman test revealed a significant difference in median of %MVC in both muscles and both sides at each of the neck flexion angles within each group. Post hoc Wilcoxon signed rank tests showed significant difference between angles within each group as follows: 1) For both sides of CES, muscle activity at $0^o$, $15^o$ neck flexion angles were significantly different from other angles. At $30^o$ neck flexion angle, muscle activity was significantly different from $0^o$ and $15^o$ angles. At $45^o$ neck flexion angle, muscle activity was significantly different from $0^o$ and $30^o$ angles. The lowest muscle activity was found at $0^o$ neck flexion angle whereas the highest muscle activity was found at $45^o$ neck flexion angle. 2) For both sides of UT, only the muscle activity of $0^o$ neck flexion angle was found to be significantly different from the other angles. The lowest muscle activity was found at $45^o$ neck flexion angle whereas the highest muscle activity was found at $0^o$ neck flexion angle.

*3.2.2 Between Groups*

Neck muscle activity at each neck flexion angle between groups is shown in Figure 2. The Mann-Whitney Test revealed no significant difference between the median of %MVC in both muscles and both sides at each of the neck flexion angles between groups. However, the case group showed slightly higher muscle activity than the control group.

**Insert Table2 about here**

**Insert Figure 2 about here**

### *3.3 Neck Pain Intensity at Each of the Neck Flexion Angles*

*3.3.1 Within Groups*

There was no significant difference in the change of neck pain intensity after the texting task was performed at any of the neck flexion angles within both control group (*p* value = 0.202) and case group (*p* value = 0.721). The pain intensity at each of the neck flexion angles is shown in Figure 3.

*3.3.2 Between Groups*

The change of neck pain intensity after the texting task was performed at each of the neck flexion angles was significantly higher in the case group, when compared with the control group at $0^o$, $15^o$ and $30^o$ neck flexion angles (*p* value = 0.013, 0.035, 0.040 respectively) but no significant difference was found between groups with $45^o$ neck flexion (*p* value = 0.084). The pain intensity at each of the neck flexion angles between groups is shown in Figure 3.

**<u>Insert Figures 3 about here</u>**

## 4. Discussion

In this study, we investigated neck muscle activity at each of the neck flexion angles i.e. $0^o$, $15^o$, $30^o$ and $45^o$ during smartphone usage among users with and without neck pain. There were significant differences in muscle activity (CES and UT) at each of the neck flexion angles within each group; CES muscle activity increased while UT muscle activity decreased with increased neck flexion angle. There are two possible reasons for these findings. First because the weight taken by the spine dramatically increases when flexing the head forward at varying degrees (Hansraj 2014). Second, due to the actual anatomical function of these muscles. To keep the neck balanced, the extensor muscles are activated, thereby increasing the load placed on the CES (Greig et al. 2005, Xie et al. 2016) and UT muscles (Greig et al. 2005). However, at the smaller neck flexion angle such as $0^{o}$, participants had to raise their upper arms to hold their smartphone close enough for improved vision, so the UT muscle was activated in order to support the weight of the upper extremities and stabilize the shoulder girdle. In contrast, at the greater neck flexion angles such as $45^{o}$, participants improved their vision by flexing their neck close to the smartphone screen with some of them resting their upper extremities (hands or forearms) on their laps or at lower level. Gustafsson et al. (2011) reported that there were differences in muscle activity and kinematics when a group who had forearm support used different texting techniques which caused less UT muscle activity (Gustafsson et al. 2011). Therefore, this might also confirm that UT is predominantly a shoulder elevator and not a neck extensor muscle.

Further, Borisut et al. (2013) reported that biomechanically, sustained forward flexion of the neck results in increased compressive loading on the cervical spine and a creep response in the surrounding soft tissues. In addition, the source of pain is excessive loading of the cervical and shoulder girdle muscles, especially in low-load repetitive work which promotes over-activity of low threshold motor units (Sjøgaard et al. 2000). Other mechanisms, such as nociceptor sensitization due to intra-muscular shear forces are also considered to play a role (Visser and Van Dieen 2006). These phenomena may concurrently increase electromyographic activity of the cervical musculature, such as neck extensor muscles.

Our study did not find a significant difference at any of the neck flexion angles between groups although the case group showed slightly higher muscle activity than the control group. This non-significant difference may be due to the participants in the case group having mild pain (average VAS of 37 mm.) which may not have been enough difference from the control group who had no pain. O'Leary et al. (2011) showed evidence that a significant positive association was observed between superficial neck muscle activity and pain intensity ($p< 0.003$) in patients with neck pain. Our result corresponds with the finding reported by Xie et al. (2015) that young people with neck-shoulder pain had a consistently higher level of muscle activity in CES and UT while performing smartphone bilateral texting, smartphone unilateral texting and computer typing tasks when compared with healthy subjects (Xie et al. 2016). This result is consistent with the findings from previous research on altered motor control associated with work-related musculoskeletal disorders (Johnston et al. 2008, Kallenberg and Hermens 2006, Szeto et al. 2005, 2009).

Differences in the neck muscle activities were apparent at each of the neck flexion angles: the CES muscle activity increased ($0^{o}<15^{o}<30^{o}<\underline{45^{o}}$) while the UT muscle activity decreased ($\underline{0^{o}}>15^{o}>30^{o}>45^{o}$) following incremental neck flexion angles. Interestingly, with a neck flexion angle between $0^{o}$-$15^{o}$, the activity of both CES and UT muscles was acceptably low and at these angles, there was no difference in neck pain intensity between each of the other angles. There was no significant difference in neck muscle activity in each of the neck flexion angles between groups although the case group showed slightly higher muscle activity than the control group at all angles.

Half of the participants in both groups reported their preferred angle while performing the texting task as $15^{o}$ and $30^{o}$ in the control group and the case group, respectively. This is despite the fact that, in our study, higher neck flexion angles had higher muscle activity. The participants indicated that they chose these angles because they regularly used their smartphone at these angles, so they felt more familiar with these positions than when working at other angles. Surprisingly, 2 participants (10 %) from each group preferred to adopt $45^{o}$ of neck flexion while texting, although our findings indicated the highest muscle activity requirement at this specific angle.

There are limitations of the current study, which are: 1) little difference in pain intensity between both groups which may have affected the muscle activity difference between the groups. It may have been beneficial to have a greater baseline difference in pain intensity of participants, 2) only one model of smartphone was examined in the present study, so future studies should examine a variety of models and brands, and 3**)** the short duration of the task might not have been long enough to necessitate a considerable amount of muscle activity**.** Future research should include longer texting task duration.

There are many interesting issues for future studies, such as investigating neck muscle activity during smartphone usage in different age ranges such as the older population who may have existing degenerative conditions which could show different pain patterns from young adults. Different positions are adopted when using smartphones. Examining smartphone use in the lying position for example is worthy of consideration, as smartphone users also use their smartphones for prolonged periods of time when reclined, neck flexor muscle activity comparisons with neck extensor muscle activity when lying would have practical implications for many users. Further, a study about the effect of upper extremity support for decreasing neck flexion angle when using the smartphone may also be of interest to clinicians.

## 5. Conclusion

When smartphone users performed the texting task, there was a difference in the neck muscle activity at each of the neck flexion angles. There was a different trend in the neck muscle activity among smartphone users with and without neck pain which was slightly higher in symptomatic users. The effect of altered motor control is associated with their neck disorders. Clinically, practitioners may suggest both smartphone users with and without neck pain should consider their neck flexion angle and keep their neck flexion angle low e.g.

between $0^{o}$-$15^{o}$ when performing texting tasks to prevent increased neck muscle activation. The current study provides findings that may be used to develop evidence based prevention and health promotion guidelines, which in turn may reduce the problems of neck disorders associated with future smartphone use.

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**Disclosure**

The authors report no conflicts of interest in this work



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## List of Figure


**Figure 1.**The four neck flexion angles: (A) 0$^o$; (B) 15$^o$; (C) 30$^o$; (D) 45$^o$

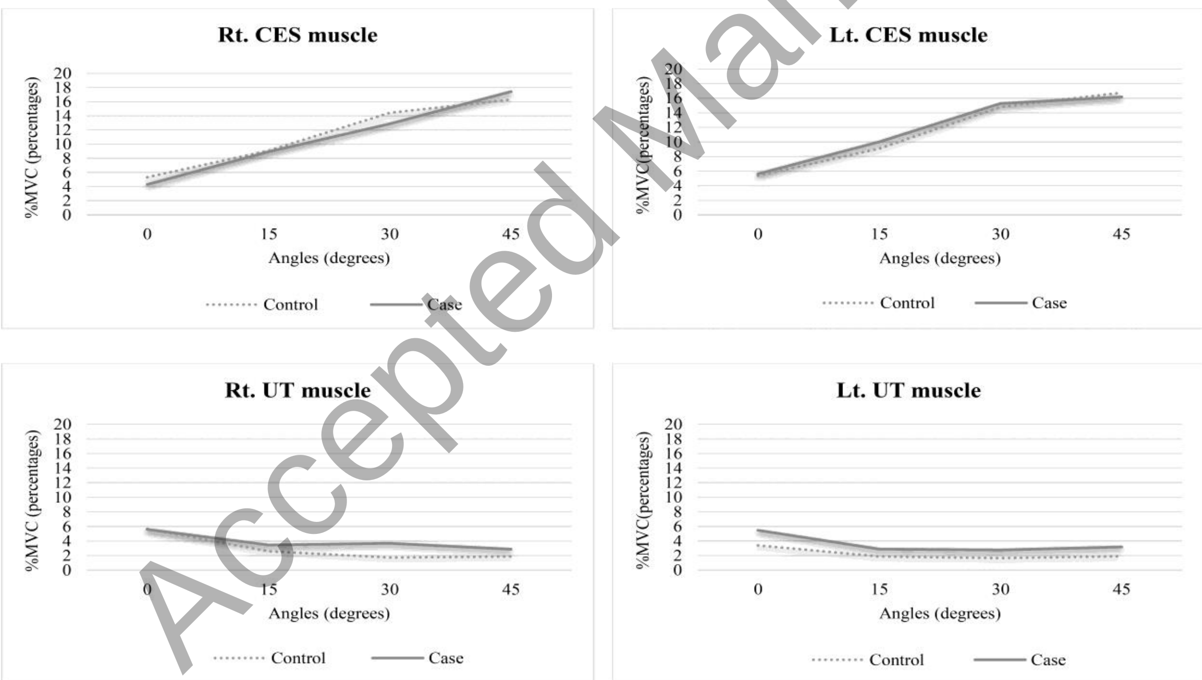


**Figure 2.** Neck muscle activity at each of the neck flexion angles between groups

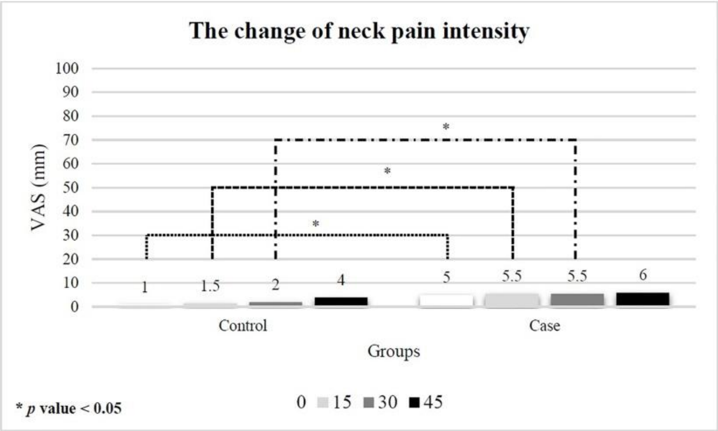


**Figure 3.** Neck pain intensity at each of the neck flexion angles

## List of Table

**Table 1**. General characteristics of participants in the control and the case groups.

| Variables (unit) | Control (n=22) | Case (n=22) | *p*-value |
|---|---|---|---|
| **Age (years)** | 21.50 ± 1.06 | 21.77 ± 1.60 | t = -666<br>*p* = 0.509 |
| **Weight (kilograms)** | 52.18 ± 5.04 | 56.50 ± 9.05 | t = -1.956<br>*p* = 0.057 |
| **Height (centimeters)** | 161.68 ± 5.92 | 163.09 ± 8.04 | t = -662<br>*p* = 0.511 |
| **Body Mass Index (kilogram/meter$^2$)** | 19.44 (18.76-20.91) | 21.72 (18.75-22.73) | Z = -1.597<br>*p* = 0.110 |
| **Protector case weight (grams)** | 15.65 (11.74-21.40) | 17.74 (12.68-26.15) | Z = -0.705<br>*p* = 0.481 |
| **T1 (years)** | 6.00(5.00-8.00) | 5.00(4.00-7.00) | Z = -1.092<br>*p* = 0.275 |
| **T2 (hours)** | 6.68 ± 2.78 | 8.18 ± 4.90 | t = -1.247<br>*p* = 0.219 |
| **T3 (months)** | - | 5.00 (3.00-12.00) | - |
| **Pain intensity(millimeters)** | 0.00 (0.00-10.75) | 37.00 (30.00-45.50) | - |
| **Sex** | | | |
| Male | 4 (18.20%) | 4 (18.20%) | - |
| Female | 18 (81.80%) | 18 (81.80%) | - |
| **Preferred neck flexion angle (degrees)** | | | |
| 0° | 4 (18.20%) | 4 (18.20%) | $\chi 2$ = 3.273 |
| 15° | **11 (50.00%)** | 5 (22.70%) | *p* = 0.070 |
| 30° | 5 (22.70%) | **11 (50.00%)** | |
| 45° | 2 (9.10%) | 2 (9.10%) | |

Data presented as Mean±SD, Median (interquartile range) and n (%)

T1 = Total time since starting to use the first smartphone until to current smartphone (years)

T2 = Total time on smartphone per day (hours)

T3 = Duration of neck pain symptoms (months)

**Table 2**. Neck muscle activity at each of the neck flexion angles within groups

| **Neck muscles** | **Groups** | **Muscle activity at each of the neck flexion angles (% Compared with MVC)** | | | | ***p*-value** |
|---|---|---|---|---|---|---|
| | | **0°** | **15°** | **30°** | **45°** | |
| **Rt. Cervical Erector Spinae** | **Control** | 5.33[b, c, d] (2.80-8.25) | 9.08[a, c, d] (7.82-12.02) | 14.42[a, b] (9.75-18.17) | 16.30[a, b, c] (12.57-23.69) | *p*< 0.001** |
| | **Case** | 4.29[b, c, d] (3.70-6.73) | 8.93[a, c, d] (6.61-12.44) | 12.87[a, b] (10.30-22.25) | 17.43[a, b, c] (12.58-24.27) | *p*< 0.001** |
| **Lt. Cervical Erector Spinae** | **Control** | 5.38[b, c, d] (3.91-8.25) | 9.12[a, c, d] (7.48-13.79) | 14.81[a, b] (11.41-17.31) | 16.76[a, b, c] (13.65-20.79) | *p*< 0.001** |
| | **Case** | 5.63[b, c, d] (3.61-7.31) | 10.03[a, c, d] (6.07-15.01) | 15.27[a, b] (10.75-21.02) | 16.18[a, b, c] (11.45-23.34) | *p*< 0.001** |
| **Rt. Upper Trapezius** | **Control** | 5.67[b, c, d] (2.11-12.23) | 2.61[a] (1.29-5.68) | 1.74[a] (1.09-5.75) | 1.89[a] (1.06-4.28) | *p*< 0.001** |
| | **Case** | 5.60[b, c, d] (4.03-10.94) | 3.47[a] (1.26-5.97) | 3.70[a] (0.93-6.23) | 2.88[a] (1.35-7.13) | *p*< 0.001** |
| **Lt. Upper Trapezius** | **Control** | 3.39[b, c, d] (2.70-10.91) | 1.87[a] (1.10-10.36) | 1.65[a] (1.00-6.35) | 1.91[a] (1.16-3.37) | *p*< 0.001** |
| | **Case** | 5.47[b, c, d] (2.73-22.05) | 2.89[a] (1.24-12.39) | 2.76[a] (0.75-9.80) | 3.17[a] (0.95-10.27) | *p*< 0.001** |

Data presented as Median (interquartile range), *p*-value from the Friedman test, ** significant difference at *p*-value <0.001 by the Wilcoxon signed-rank tests:

a = significant difference from 0° angle, b = significant difference from 15° angle, c = significant difference from 30° angle, and d = significant difference from 45° angle