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The impact of using smartphones in two different sitting postures on muscle tension and fatigue in Thai young adults: a pilot study

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Abstract

This study aimed to assess the impact of smartphone uses in different sitting postures on the muscle activity of the back, neck, and upper extremities of Thai young adults. Seventeen male and female university students were randomly asked to perform text messaging communication via their smartphones using a social media program in two different sitting postures; 15 minutes in straight back posture (sb) followed by 15 minutes in not straight back posture (nb). The speed of data input was 40 words per minute. The EMG intensity and the change of spectral frequency were analyzed. The muscle of the back, neck, and upper extremities of eight muscles in both left and right sides were M.neck extensor, LNEX, RNEX; M.trapezius, LTRP, RTRP; M.wrist flexor, LWFL, RWFL; and M.wrist extensor, LWEX, RWEX. The results showed that the not straight back sitting posture with the text messaging via the smartphone reflected a fatigue level in M. left neck extensor ($p<0.05$). There was a decrease in the EMG intensity while performing a Maximum Voluntary Contraction of the M. right neck extensors and M. left trapezius after the 30-minute use of the smartphone device ($p<0.05$). These results indicate that the 30-minute use of smartphones with the data input of 40 words per minute without paying attention to the sitting posture increases muscle tension and muscle fatigue in Thai young adults.

Keywords: *ΔMPF, different sitting postures, EMG, muscle tension and fatigue, smartphones, sitting posture*

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1. Introduction

Social Media is, at present, a part of social life. It is especially true for young adults in Europe (Gustafsson, Thomée, Grimby-Ekman, & Hagberg, 2017). However, the social communication has increasingly grown, to become now a worldwide trend, in Thailand as well. The statistics from 2016 through May of 2017 show that 47 million Thais use Facebook, 11 million are active on Instagram, 9 million are on Twitter, and over 41 million Thais use mobile or smartphones with Line Application (iT24Hrs, 2017). Recently in 2018, not only the young adults but the Thai companies also have used social media, not only to promote and publish their services but also as part of their thoughtful business strategies targeting an international audience (Doan, 2019).

Statistics show that 83% of Thai mobile phone owners using Line as a smartphone connecting point to the internet, with the young adults showing a propensity to become smartphone addicts. Excessive texting with a fixed neck and fast repetitive movements raises high risks for local muscle fatigue which may lead to musculoskeletal disorders (Nordicom, 2013). Musculoskeletal Disorders or MSDs are injuries and disorders that affect the human body's movement or musculoskeletal system, which are muscles, tendons, ligaments, nerves, discs, blood vessels, and other organs (Malchaire, Cock, & Robert, 1996; Grieco, Molteni, De Vito, & Sias, 1998; Ariens, Bongers, Hoogendoorn, van der Wal & van Mechelen, 2002; Andersen et al., 2003; Thomsen et al., 2007). The body-parts affected by MSDs during the use of handheld smartphones over an extended period involve neck and shoulders (Berolo, Wells, & Amick, 2011). Recently, Gustafsson et al. (2017) also reported the association between text messaging and a growing MSD prevalence in the neck and upper extremities.

Recognizing these casual risks as harmful is essential for the prevention of MSDs. Specific aspects of MSD risk assessment include the perception of local muscle fatigue, which is the inability of the contractile and metabolic process of muscle fibers to continue supplying the same work output as an alert during repetitive work (Guyton & Hall, 2006). Handheld communication was studied previously. Specific points of the failures of "maintaining a required force," or inappropriate "exposure times" or both were already emphasized by Edwards (Edwards, 1981). Furthermore, a state of reduced capacity to perform work at a certain intensity (Heimer, 1987) and a work-induced reduction in the maximal muscle potentials to generate force or power output (Vollestad, 1997) were also considered as possible risk indicators. Regarding social issues, the assessment had to consider the impact on psychological factors such as the tasks associated motivation (Enoka,1995; Enoka & Duchateau, 2008). In fact, all conclusions were related to complaints due to fatigue from physical performance. The measurement of muscle fatigue by analyzing the lactate concentration in muscles via blood sampling during effort is almost impractical.

The studies regarding the use of smartphones with awkward postures emphasized that sitting with head bent forward without supporting the arms causes a static load in the neck and shoulder. Eitivipart, Viriyarojanakul, & Redhead (2018) reported that an increased rate of smartphone usage and the awkward postures are the main contributing factors to the incidence of musculoskeletal symptoms. The other factors related to the MSDs in this context are such as the neck flexion and visual demand during a long text message.

Considering the use of the smartphone and the awkward posture related to MSDs mentioned above, adopting a policy to tackle musculoskeletal dysfunction, especially in the young adults, is useful in the prevention of problems; however, it requires evidence about causes and consequences. Two specific research questions related to the topics had been raised:

"Does a fifteen-minute message texting in different postures create muscle overload in Neck, Upper Back, and Forearm muscles in Thai young adults?" and "Does a thirty-minute usage of smartphone-communication session induce a loss of muscle tension and fatigue?"

2. Objectives

The aims of this study were 1) to assess the impact of two different sitting postures during texting message with a smartphone on the muscle tension and fatigue of eight muscle groups of the neck, upper back, and upper extremities, and 2) to compare the muscle activity before and after texting message by the social media over thirty minutes.

3. Materials and methods

3.1 Study design

This cross-sectional study implemented a 'completed block design'. The subjects were asked to sign in an acknowledgement consent form after being informed about the scope and the advantages and disadvantages of the study. The Ethics Review Board of the Research Institute, at Rangsit University, approved the project code RSEC60/2559.

3.2 Study population and procedures

Seventeen subjects, male and female university students, participated voluntarily in the study (Table 1).

- *Inclusion criteria*

Healthy male and female university students aged 23±2 years and free of any reported musculoskeletal problem or accidental injury at upper extremities.

- *Exclusion criteria*

Unhealthy, injured students or those having MSDs problems in the upper extremities or those who have taken any medicine in the preceding seven days before the measurement date.

The subjects completed a questionnaire regarding their daily routine usage of network communication and identified the specifications of their mobile devices (size and weight). The subjects dressed in regular summer clothing.

Table 1 The biometric data of subjects participated in the study

	Age (years)	Weight (kg.)	Height (cm.)	BMI (kg/m^2)	Left hand grip/kg.bw	Right hand grip/kg.bw	Right hand breadth (cm.)	Right hand length (cm.)
Mean	22.59	57.35	163.29	21.34	0.49	0.54	9.15	17.38
S.D.	2.15	13.90	10.20	4.10	0.11	0.12	1.36	1.45

- *Complete block design:*

In each set of experiments, the two subjects (one pair) used their smartphones to communicate (mutually) for thirty minutes. Each pair of participants were assigned with odd and even numbers randomly. The odd pairs started with 15-minute texting in (sb) posture followed by another 15 minutes in (nb) posture. The even pair started with an (nb) posture followed by an (sb) posture for the same duration. The flow chart of the study protocol and the measurement parameters are shown in Figure 1.

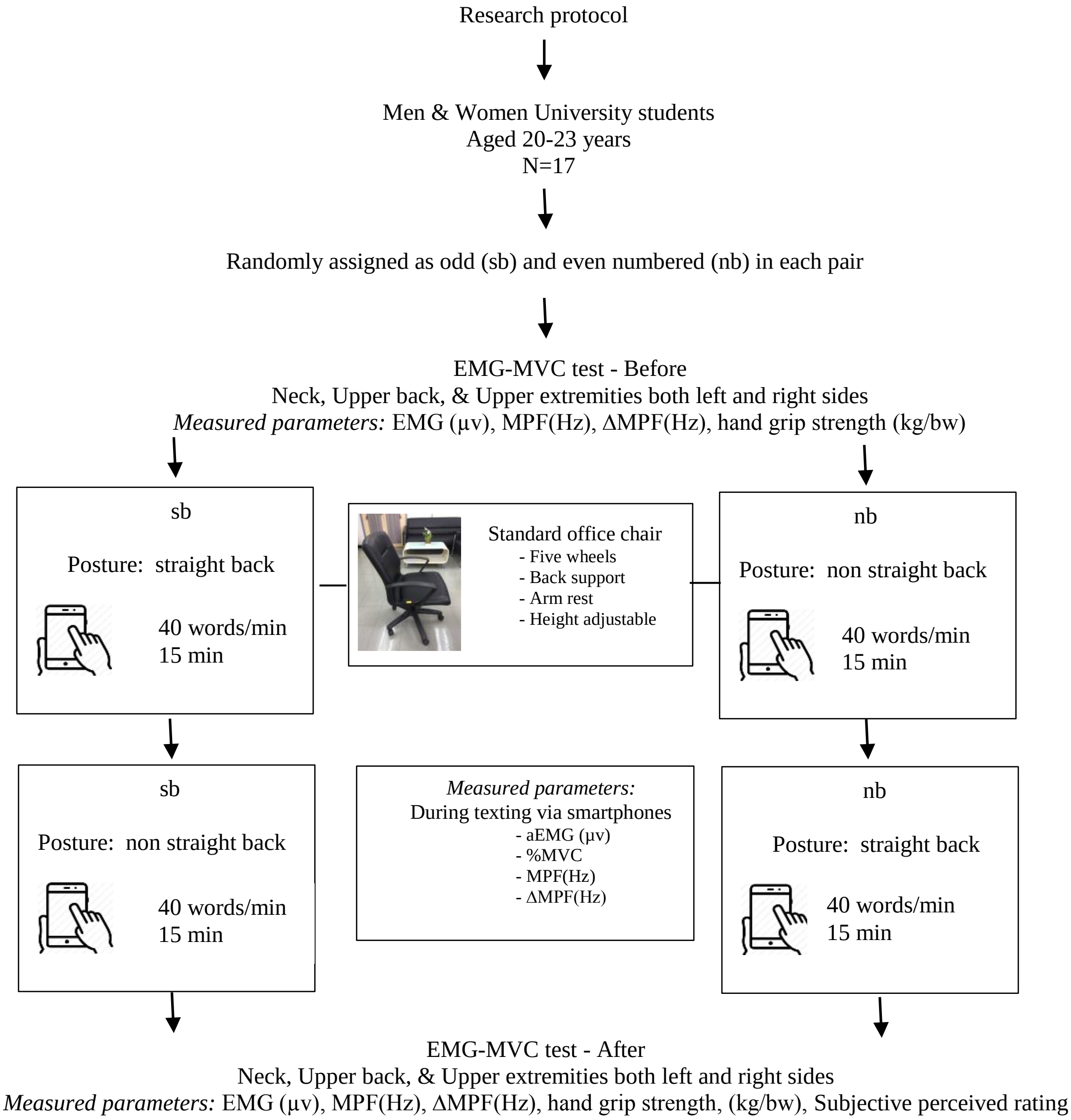

Figure 1 Flow chart of the study protocol and measurement parameters

3.2.1 Muscle, equipment and surface electrode placement:

- *The selected muscles*

The selected muscles were four groups of muscles, including each at the left (L) and right (R) sides. The muscles engaged during texting were the M. Neck Extensors: LNEX, RNEX; M. Trapezius: LTRP, RTRP; the M. Wrist Flexors: LWFL, RWFL; and M. Wrist Extensors: LWEX, RWEX.

- *Equipment and surface electrode placement*:

A Portable EMG registering device (ME3000P - Mega Electronics, Ltd., Finland) measured the eight muscles simultaneously. Three disposable electrodes were placed on each muscle belly. The set up for the Megawin registration was in the "raw mode" with a sampling rate of 250 Hz. The electrode used in this experiment was the Ambu Blue sensor P., Denmark.

3.2.2 Experimental setting

- *Posture*

For the straight back posture (sb), the subjects sat on a standard office chair (Figure 1), which has five wheels, armrest, backrest, and an adjustable height, throughout 30 minutes in a classic upright sitting position with an approximately 90° angle between the trunk and thigh joints without using the backrest and armrest. They held their smartphones with two hands (Figure 2A). The angle of the elbow joints was adapted to individual visual acuity or without any directive direction.

For the not straight back posture (nb), the subjects used a self-chosen comfortable sitting position on the same chair. They chose their sitting position independently, without any directive, and they may use the armrest and backrest support of the chair (Figure 2B).

Figure 2 Electrode placement and Operational sitting postures: A- straight back posture (sb), B- not straight back posture (nb)

3.2.3 Task

- *Text input speed*

The subjects used a social media program, Line, for communication. They were asked to promptly communicate with their partner. For the communication, the researcher prepared a Thai text conversation in font Angsana size 18 on the A4 paper. All tests and experiments were performed at the Ergonomics Laboratory, Rangsit University, with a room temperature of 25°C.

3.3 Workload assessment: Measurement variables and assessment criteria

There were three phases of a measurement including; 1) before communication 2) during communication, and 3) after 30 minutes of communication.

3.3.1 Before and after 30 minutes of communication: MVC test

The measurement variables and assessment criteria 'at,' 'before,' and 'after' 30 minutes of communication included muscle capacity (EMG amplitude) and muscle fatigue (ΔMPF) while performing the MVC-test.

- *EMG amplitude*:

MVC-neck extensor. For the MVC test of the upper neck (neck extensor), the subjects sat on the chair with the trunk and the head straight. They were asked to extend their neck backward as far as possible against a resistance given by the researcher.

MVC-trapezius. The subjects stood straight up and lifted their shoulders vertically against manual resistance provided by an experienced researcher.

MVC-wrist flexor and MVC-wrist extensor. Digital handgrip dynamometer was used to measure the EMG amplitude of the wrist flexor and wrist extensor.

The EMG amplitude (AEMG) was taken as the MVC of the muscles (in microvolts). The initial MVC was considered as a baseline for the maximal power/capacity in order to attenuate the inter- and intra-individual differences (Menz, 2005; Yoopat, Yuangnoon, Krukimsom, & Vanwonterghem, 2018; Yoopat, Pitakwong, & Vanwonterghem, 2019).

- *EMG frequency*

ΔMPF: The change in median power frequency (ΔMPF) during the MVC test obtained from the EMG signal spectral analysis was employed for assessing the endurance fatigue test using Meagwin software. ΔMPF shifting to a lower frequency or a change to a negative value indicated fatigues. (Kroemer & Grandjean, 1991; Ming, Pietikainen, & Hannine, 2006); Storr, de Vere Beavism, & Stringer, 2007; Williams & Kennedy, 2011).

3.3.2 During 30 minutes communication via smartphone

The measurement variables and their assessment criteria used while the subjects using their smartphone to communicate with their partner via Line included:

- *EMG registration (microvolts)*

The EMG registration (microvolts) and the calculation of the muscle workload (percentage of MVC) (Yoopat et al., 2019) were used. The standard threshold for work was set between 10-20% MVC for the efforts over the study period. (Kroemer & Grandjean, 1991).

- ΔMPF
- *The subjective perceived rating*:

The 'Perceived Exertion' scale (Borg & Kaijser, 2005) was used to rate the subjective evaluation. The subjects scored their perceived feelings on a 10-point linear scale from "0" as no fatigue to "10" as very fatigued with exhaustion, and they differentiated their experiences in an RPE sb, and nb posture.

3.4 Statistical analysis

Descriptive statistics were used to explain the biometric data of the subjects participating in the study. The Pair *t*-test compared the muscle capacity between Pre and Post results of the thirty minutes of using mobile communication. These also serve as comparison levels for the EMG variables between the different sitting postures that are (sb) posture and (nb) posture while communicating via a smartphone. The SPSS version 21 was used to analyze the data with the confidential Interval of 95% and the level of significance set at 0.05.

4. Results

The results of the biometric data (Table 1) showed that the subjects have a normal physiognomic structure, aged 23±2 years, and their BMI was less than 23 kg/m^2. The participants were dominantly right-handed, confirmed by the handgrip values between the left and right-hand sides (p<0.01).

The participants used their own devices with two sizes; Medium (M) and Small (S) devices, which are 8x15 cm and 5x12 cm, respectively. The weights varied from 172 g for the M size to 125 g for the S size. 36.7 percent of the students use the M-models while 63.3 percent use the S-models. They reached a texting speed of 40 words per minute during the communication.

According to the daily use of a smartphone for their communication, it was found that 43.30% spend less than 2 hours per day, 36.67% spend 2-5 hours per day, 16.70% spend 6-9 hours per day, and 3.30% spend more than 10 hours per day.

4.1 The impact of using smartphone communication on muscle activity before and after the experimental setting

The maximal activity (MVCs) in the pre- and post-tests reflected the total impact of the 30-minute communication workload on the muscle activities of the subjects (Figure 3). The muscle activity of the right neck (RNEX) and left trapezius (LTRP) decreased significantly after 30 minutes of using a smartphone for their communication (p< 0.05).

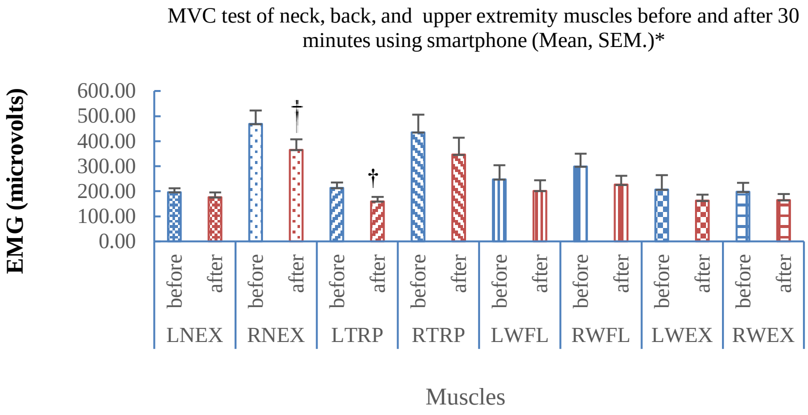

Figure 3 MVC test of neck, back, and upper extremity muscles before and after 30 minutes using a smartphone *(Mean, SEM). The pair- t-test compare mean between before and after 30-minute communication via a mobile application. † means the significant difference between before and after at p<0.05.

The change in the median power frequency while performing the MVC test showed an increase in the frequency after 30 minutes of mobile texting (Figure 4).

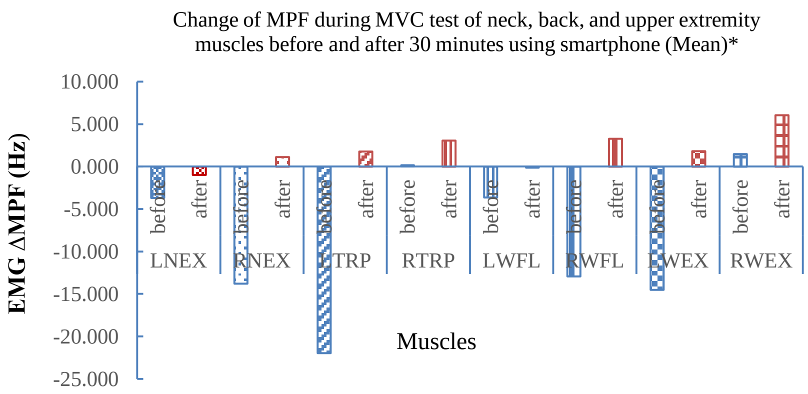

Figure 4 Change of MPF during MVC test of upper extremity muscles before and after 30 minutes using a smartphone for communication *(Mean).

4.2 The impact of using smartphones in two different sitting postures

The %MVC represents the work strain in the solicited muscles during the performance (Figure 4). The spectral analysis of the use of smartphone communication in the sb and nb of the same subjects presented in Figure 5.

The muscle workload was slightly high in the nb posture (mostly postural stress in the neck and shoulders). The %MVC of both postures were not significantly different. However, seven of the eight muscles had more than 10% MVC in both sitting postures, especially M. Wrist extensor, indicating some MSDs risk (Figure 5).

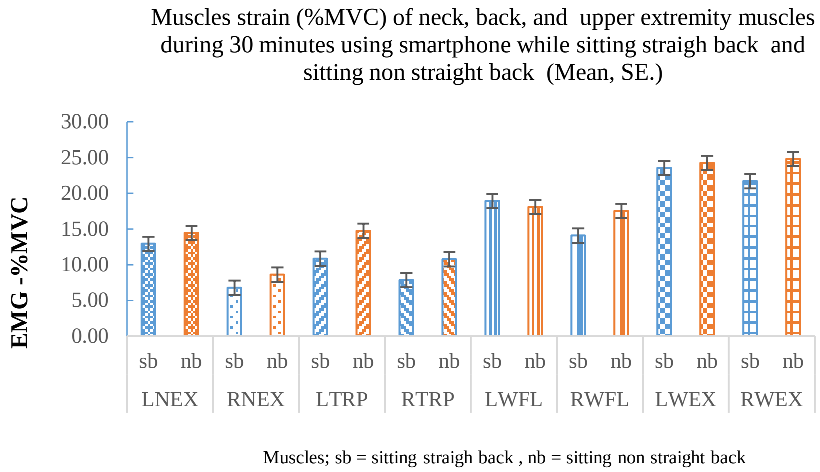

Figure 5 Muscles strain (%MVC) of upper extremity muscles for 30 minutes using a smartphone while sitting straight back (sb) and sitting not straight back (nb) (Mean, SE.)

The spectral analysis showed that sitting in both a straight back posture and a not straight back resulted in a negative change of the median power frequency in the M.LNEX. (p<0.05), RNEX, RTRP, LWFL, RWFL, RWEX, except the M.LTRP in the nb and M. LWFL in the sb posture (Figure 6).

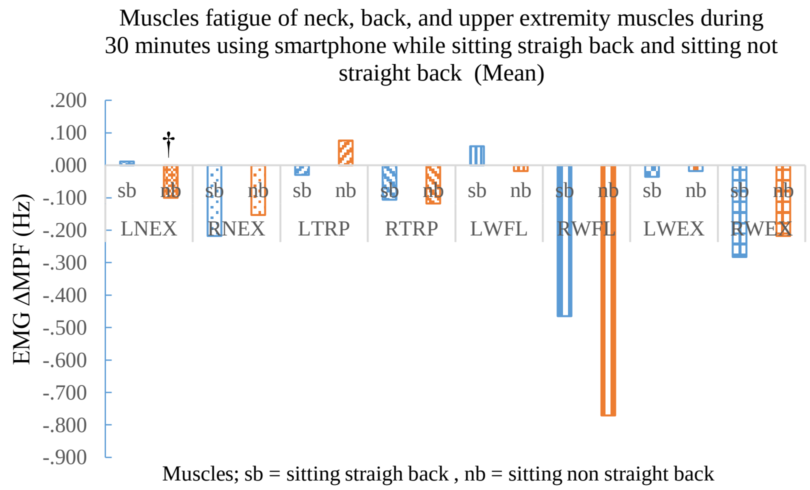

Figure 6 Muscles fatigue of upper extremity muscles during 30 minutes using a smartphone while sitting straight
*Back (sb) and sitting not straight back (nb) (Mean)
†The pair- t-test compares mean between sb posture,15 minutes and nb posture 15-minute communication via a smartphone showed a significant difference between sb posture and nb posture at p <0.05.

4.3 The subjective perceived rating

The median and standard error scores of the perceived feelings in the sb posture and the nb posture are 7 (0.268) and 4 (0.448), respectively, with the T-score of 6.925 and *p*-value = 0.000. The result, however, opposed the objective data.

5. Discussion

The daily use of smartphones of the subjects reported in this study was as high as the daily time spent on social networking by internet users worldwide from 2012 to 2018 reported by Clement, (2019), with the average of 136 minutes. It might be that the young adults in this era might have a higher risk for MSDs in their neck, upper back, and upper extremities.

The joint analysis of EMG amplitude (Figure 2) and EMG spectrum (Figure 3) from the muscle capacity test (MVC) implied that the 30-minute use of a smartphone with a speed of 40 words per minute allows the muscles to recover from previous muscle fatigue (Hägg, Luttmann, & Jager, 2000; Luttmann, Jager, & Laurig, 2000; Wang, Wang, & Ge, 2003; Jonkers, Nuyens, Seghers, Nuttin, & Spaepen, 2004; Cifrek, Medved, Tonkovic, & Ostojić, 2009).

The repetitive task of the forearm muscles and static stress at the neck and shoulder from the sitting posture resulted in a lower capacity, which may be due to fatigue from a lactate accumulation that changes the intracellular pH. The consequence was a decrease in muscle fiber conduction velocity that affects the motor unit action potential (MUAP). The change in MUAP resulted in the lowering of the median frequencies (Cifrek et al., 2009; De Luca, 1984; Brody, Pollock, Roy, De Luca, & Celli, 1991) which may have evolved from a temporary MSD into more chronic CTD (cumulative trauma disorders). The CTD could put hypothecation - not only on the professional career for the individuals - but also on state welfare systems. However, the speed of texting communication of 40 words per minute may allow an interval interchange between fatigue and recovery (Hägg et al., 2000; Wang et al., 2003; Jonkers et al., 2004; Cifrek et al., 2009).

The muscle tensions (% of MVC) between the two types of sitting postures were not statistically different (Figure 3). However, the values passed over the accepted standard of 10-20%MVC, and the M.wrist extensor muscle exceeded the 20%MVC threshold level. The increase in the muscle activities was in agreement with the report of Eitivipart et al. (2018) that, during smartphones use, the muscle activity of the upper trapezius, erector spinae, and neck extensor muscle increased. In the long term, this factor could lead to MSDs (Kroemer & Grandjean, 1991), as confirmed by later studies (Gordon, 2008; Menz, 2005; Ming et al., 2006; Storr et al., 2007).

The fifteen-minute use of smartphones on the movement system of Thai adults in the free (not straight back) sitting postures resulted in fatigue of the LNEX ($p<0.05$), compared to those of the straight back posture, due to the eccentric contraction of the neck from a forwarding head shift and an increased neck flexion. From Figure 2, the subjects in (nb) who chose to sit with a forwarding head, flexed neck, round back posture may experience the increased muscle activity of the antagonist neck muscle. The typical posture when using smartphones involves holding of the device with one or two hands below the eyes level, looking down at the devices, and using the thumb to type the text. This pattern forces the user to adopt an awkward posture such as a forward neck flexion which is often maintained for an extended period (Berolo et al., 2011).

The value of both postures showed negative fatigue sign in most of the muscles. The results agree with the study of Gustafsson et al. (2017), which reported that sitting without supporting the arms causes a static load in the neck and shoulder muscles. Furthermore, for the subjects who sit with their head bent forward, their neck and shoulder muscles may be influenced by their visual acuity while using a smartphone (Richter, Bänziger, Abdi, & Forsman, 2010; Richter, Banziger, & Forsman, 2011; Richter, Zetterberg, & Forsman, 2015). In the real working sitting situation, an appropriate chair with backrest and armrest is needed to reduce the muscle tension and fatigue.

The results of the perceived rating score during the use of smartphones for communication in the ‘sb’ posture were higher than that of the ‘nb’ posture (Figure 3). The reason is that the office chair is an important extrinsic factor in developing muscle tension and muscle fatigue. The subjects who sit in the straight back posture (sb) did not place the back upon the backrest and did not place the elbow upon armrest but when sitting with the not straight back posture (nb), the subjects placed the back and elbow upon the backrest and armrest of the chair, explaining why the nb posture was rated with a lower perceive score.

The formal proposed 'healthy' posture (the general advised biomechanical rules) is sitting with a straight trunk, with a natural curvature of the spine in balance with the pelvis (sb). This advised posture is, however, often neglected as people prefer a more comfortable and more relaxed posture (nb). Because of the experience in the 'nb' posture, this 'relaxation' might be a misleading psychosomatic impression that skips the fact the unused muscle may become at risk: either by reacting inappropriately to a sudden wrong movement (too slow of a reaction of stabilizing muscles may lead to for example a hernia) or missing the power-level necessary for a reasonable effort whenever a standard load becomes an overload (missing necessary capacity). The combination of fast intensive muscle contractions in small body parts (fingers) for data input with postural aspects (Sjogaard, Lundberg, & Kadefors, 2000; Mathiassen, 2006) over long periods form a hidden risk combination for young adults who often do not recognize, or neglect, the warning symptoms from discomfort. Young people should be warned of the risks of the wrong posture in order to maintain the necessary intrinsic muscle activities. The results may call for attention from younger adults.

The higher frequency of using social media (Clement, 2019) from 6 to 10 hours to more than 10 hours per day through smartphone devices shows a socio-cultural evolution which, in the long term, may create risks to coming generations, not only for MSD risks but also social and physical health risks due to isolation (active in limited circles) and degeneration of their physical condition due to a lack of body movement.

- *Methodological considerations*

The benefits of this study confirm the importance of objectifying workload and work-strain, especially in the context of risks for cumulative traumata as a result of low intensive muscle work in non-appropriate postures. In MSD-risk prevention, it is essential to raise awareness about Cumulative Trauma Disorders for those involved in contemporary professional activities, that is, the individual worker, management, prevention experts, other authorities and scientific experts. Awareness must be confirmed by concrete job-related arguments, and measured work strain (load versus capacity) confirming the subjectively formulated complaints with concrete facts. These conclusions are valid not only for younger people but also for all other mobile phone users irrespective of age.

- *Limitation of the study*

This quasi-experimental study aims to study the impact of using smartphones in two different sitting postures on muscle tension and fatigue in Thai young adults. The experiment was conducted in the laboratory condition at a temperature of 25 degrees Celcius. The ideal is to try to set the experimental condition as close to the real condition of young adults using smartphones as possible. The application of the surface EMG applied on eight muscles is high cost, and the analysis is time-consuming. For the setting posture of the not straight back posture or self-chosen posture (nb) of all subjects, the posture of all subjects cannot be the same. Some may use or not use backrest or armrest or adjust their sitting height. Unintentional bias can enter the study.

- *Implications*

The results of this study showed that a thirty-minute use of a mobile communication device in any posture (sb posture or nb) might lead to MSDs - even though estimated as a low physically demanding job. Forearms, neck, and shoulder muscles are susceptible to MSDs. Other than professional working conditions may present similar risks, such as chatting students, but the communication risk is seldom mentioned because eventual annoyances or pains are missing hard evident arguments.

Individual actions may include some movements such as stretching, often alternating frequently sitting-standing and regular movements like walking after periods of sitting during smartphone use. Finally, an anatomically correct posture is advisable to anticipate the occurrence of biomechanical disorders.

With the actual processing possibilities in hardware and software technology, it is advisable to solicit the manufacturers or developers input for these products to enhance their risk awareness, eventually by introducing technical or software-related warnings. Whenever an individual ‘threshold’ is reached, behavioral advises could be sent electronically, for instant; advise to slow down typing speed, an adapted time-management, such as a warning every 30 minutes (according to the results of this pilot study of the thirty-minute using of smartphones, the decrease of muscle activity in some muscles and fatigue or slower frequency of EMG activity (negative value of ΔMPF) in most of the muscle were found) or decreasing quality (such as typing errors) and others which may serve as overload symptoms.

The actual incidence and prevalence rates of musculoskeletal disorders, absenteeism, economic consequences, etcetera are well recognized in ad hoc scientific circles and policymakers. Manufacturers and all other decision-making management - levels - that, at present, are missing evident convincing arguments, should bring their alerting message to the daily practitioners level. Maybe, this study might be a preliminary attempt to objectify the evident risks that could contribute to the fight against this hidden individual and collective problem.

6. Conclusion

Thirty minutes of a smartphone communication with the texting speed of 40 words per minute in any posture (sb or nb posture) may lead to a muscle fatigue and an increase of muscle tension in the neck, back, and upper extremities in Thai young adults -even mobile use is estimated as low physically demanding- but being behavioral-technical ‘risk’ that merits some attention by serving as a warning to avoid overload in the biomechanical system, even in daily estimated easy and popular occupations.

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