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The effect of psychosocial stress on muscle activity during computer work: Comparative study between desktop computer and mobile computing products

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Abstract.
BACKGROUND: The popularity of mobile computing products is well known. Thus, it is crucial to evaluate their contribution to musculoskeletal disorders during computer usage under both comfortable and stressful environments.
OBJECTIVE: This study explores the effect of different computer products' usages with different tasks used to induce psychosocial stress on muscle activity.
METHODS: Fourteen male subjects performed computer tasks: sixteen combinations of four different computer products with four different tasks used to induce stress. Electromyography for four muscles on the forearm, shoulder and neck regions and task performances were recorded.
RESULTS: The increment of trapezius muscle activity was dependent on the task used to induce the stress where a higher level of stress made a greater increment. However, this relationship was not found in the other three muscles. Besides that, compared to desktop and laptop use, the lowest activity for all muscles was obtained during the use of a tablet or smart phone. The best net performance was obtained in a comfortable environment. However, during stressful conditions, the best performance can be obtained using the device that a user is most comfortable with or has the most experience with.
CONCLUSIONS: Different computer products and different levels of stress play a big role in muscle activity during computer work. Both of these factors must be taken into account in order to reduce the occurrence of musculoskeletal disorders or problems.

Keywords: Electromyography, performance, typing activity, trapezius, visual display unit

1. Introduction

In the modern world, the use of computers and the Internet are common things. More and more people feel the need to access them anytime and anywhere.

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The needs and use of this kind of technology ubiquitously brought an explosion in the popularity of mobile computing products. The popularity of mobile computing products raises several concerns including well-known health problems such as musculoskeletal disorders (MSDs). MSDs not only affect workers' health conditions but also reduce performance and involve a very high cost [1, 2]. MSDs were responsible for 34% of all workplace injuries and illnesses in the year 2012 and reportedly cost between $45 to $54 billion to U.S economy [3, 4]. Upper body pains such as neck and shoulder pains are the most typical issues among MSD patients as a result of static posture, working technique and constant static muscle activity [1, 5–9, 18]. These problems might be worse for mobile computing product such as tablet and smart phone users because of the inseparable screen and keyboard. This condition is worse for the laptop users because it cannot be adjusted freely like general display terminals except for the angle [10]. Even though tablets can be used in various positions, a previous study shows that head and neck flexion angles for several typical positions during tablet usage are far from recommended neutral angles for visual display unit [11]. Consequently, there might be more concern for development of neck and shoulder discomfort.

The same thing might happen with smart phone usage because, like tablets, smart phones also have the capability and flexibility to be used in various positions. Although flexibility provides a huge benefit, it may also cause problems to users. For example, the size of smart phone allows users to use it in a small and crowded space / area such as in a subway train. In this space, sometimes, it is inconvenient for the user to place the phone higher (because of a privacy reason or have difficulty to use it in that position) which subsequently force users to bend or look down if they want to use the phone.

Many previous studies show that there is another factor that might play a role in the MSD symptom which is called psychosocial stress [12–15]. The definition of psychosocial stress was given as a stress that associated with a non-physical factor. It includes time pressure, low social support, high job demands, high mental workload, high memory demands, low reward, surveillance of workers, and high efforts [9, 12, 16–18]. In order to study the effect of psychosocial stress in a laboratory setting during computer usage, previous studies use different kinds of methods to induce stress including arithmetic tasks, time pressure and color-word tasks. The methods used by previous studies are summarized in Table 1.

Table 1
Summary of method used by previous studies to induce psychosocial stress

Methods	Authors
Arithmetic task	[14, 19–21]
Time pressure / speed task and precision task	[1, 8, 14, 18, 20, 22–25]
Stressful environment	[1, 9, 12, 26–30]
Color-word Task	[19, 28, 31]
Skill and intelligence task	[32–35]

The effect of psychosocial stress on muscle activity might depend on the type of task used to induce the stress. Different tasks may produce different levels of stress, hence lead to different effects on the muscle activity. Based on our literature review, stress induced by a stressful environment (including noise, verbal provocation, calling out any mistakes and evaluation by a supervisor) has the largest effect on trapezius muscle activity (but not on other muscle activity) followed by skill and intelligence tasks, time pressure tasks, arithmetic task and color-word tasks [1, 8, 12, 14, 18, 19, 28, 30]. Therefore, we believed that psychosocial stress would increase trapezius muscle activity (First Hypothesis). The difference from results obtained by previous researchers is because of different levels of stress produced by each category which consequently have a different level of effect on trapezius muscle activity (Second Hypothesis). The effect of these tasks on trapezius muscle activity is as follows:

$$\text{Stressfulenvironment} > \text{Skillandintelligencetask} >$$
$$\text{Timepressure} > \text{Arithmetictask} > \text{Color} - \text{wordtask}$$

Previous studies regarding mobile computing products show that they might cause worse MSDs problems on the user compared to desktop computer usage because of their physical factors. For example, detachable screens make the neck angles and head tilt of mobile computing product users become larger compared to desktop computer user [11, 36, 37]. A recent study by Kim et al. [38] between four virtual keyboards showed that muscle activity on the shoulder muscle was slightly higher for smaller virtual keyboards compared to other keyboards which might be caused by the visual demand. Meanwhile, a study by Villanueva et al. [39] on the effect of desktop and four portable computer usages showed that muscle activity in the neck extensor muscles for portable computers were significantly higher than desktop computers. The discomfort survey also showed that subjects have most musculoskeletal complaints and eye discomfort when they use the smallest portable computer. In addition, posture is also affected. When the size of visual display unit decreased, the degree of backward tilting was increased. Thus, it is expected that muscle activity during mobile computing product usage is higher compared to desktop computer usage on the same task (Third Hypothesis).

Aside from that, many people are not aware that these physical factors not only affect the physical body but induce psychosocial stress conditions as well. For instance, a small screen might induce visual demand that makes the user experience visual strain and tiredness [36, 37, 39] and a small keypad might require user concentration and precision [36, 39]. Furthermore, a smaller screen might produce larger error rates and decrease satisfaction [40]. In addition, a small screen might limit the information that can be obtained by the user, especially via video or text [41, 42]. Consequently, it might increase psychosocial stress. Yet, in spite of the popularity of mobile computing products, to our knowledge, there is no study that has used any mobile computing product in their psychosocial stress experiment. It is expected that the increment of muscle activity during a mobile computing product's usage under psychosocial stress conditions is larger compared to personal computer usage under the same conditions (Fourth Hypothesis).

Therefore, based on our first and second hypotheses, the objective of this study is to see the effect of different tasks (color-word, time pressure and stressful environment) used to induce the psychosocial stress on muscle activity. Meanwhile, based on our third hypothesis, another objective of this study is to see if there is any difference in effect for the usage of different computer products (desktop computer, laptop, tablet and smart phone) while working on the same task. Finally, based on our fourth hypothesis, the last objective of this study is to determine whether psychosocial stress conditions will have a different effect on muscle activity increment with different products.

2. Methods

2.1. Subjects

Fourteen healthy male students without musculoskeletal symptoms in the neck, shoulder and arm region were recruited from a university campus. Participants were experienced computer users. They also used at least one of these four devices at least for 4 hours per day and have experience in using other devices. Each participant provided informed consent before taking part in the experiment. Most of the participants have their own laptop and smart phone. Demographic data of the participants and their computer use profile were summarized in Table 2.

Table 2
Demographic data of the participants and their computer use profile

	Mean	SD
Age (years)	20.25	0.96
Weight (kg)	63	19.32
Height (m)	1.66	0.05
Body Mass Index (BMI)	22.99	7.01
Desktop computer usage (hours / week)	6.25	13.97
Laptop usage (hours / week)	25.58	14.58
Tablet usage (hours / week)	1.75	1.76
Smart phone usage (hours / week)	49	27.19

2.2. Workstation

Subjects sat at the same workstation (fixed table height) for all device usage. They can adjust their position and chair height to the most comfortable position before they start the experiment for each device and psychosocial stress task. There is no armrest provided. For the desktop computer, they can adjust the height of the monitor and for other devices; they can adjust the screen angle. The monitor used for desktop is Samsung CX1765 (445×340 mm), Lenovo Z480 (355.6×230 mm) for laptop, iPad Mini (200×134.7 mm) for tablet and Galaxy Note 2 (151.1×80.5 mm) for smart phone.

2.3. Procedure

In this experiment, if the participants are required to perform all conditions using all devices, even without any replication, they need to perform at least 16 trials. It will take a lot of time to do the experiment. Besides, the participants need to rest for the same amount of time in order to minimize the effect of fatigue. Thus, a large amount of trials and time needed for each participant to perform all conditions for all devices. In order to reduce the influences of other factors such as fatigue, or stress caused by a long experiment, the participants were instructed to perform the four conditions by using only two devices. In order to avoid any bias, the devices that they used were chosen randomly. However, in order to allow the participants to experience all the conditions used to induce stress, each of the participants used one of these combinations: desktop and tablet, laptop and tablet, desktop and smart phone, or laptop and smart phone. Besides that, each participant was needed to do two extra tasks using a third device. Subjects were allowed to rest for five minutes after each task. As the hypothesis of this study is that a stressful environment has the largest effect on muscle activity followed by color-word, time pressure and lastly plain copying; the experiment started with plain copying and ended with stressful environment in order to avoid any lasting effect from the last session.

2.3.1. Plain copying

Plain copying was chosen as a reference because it can be done using these entire products and there is no need for the subjects to use any extra equipment such as a mouse or stylus. Many previous studies used plain copying as a baseline for muscle activity [1, 14, 20, 27, 28]. The participants need to copy some text at their own comfortable pace and condition. They were instructed to make a correction if they see any error as they hit the key, but not to try to find the error by reading through all their works [1].

2.3.2. Color-word task

In this task, the name of a color was presented in another color on a power point slide with black background on a tablet screen while the researcher pronounced the name of the third color using voice [19, 28]. The words appear in a random position. Subjects were needed to type in which color the words were written on using four short keys: “D” = red, “F” = green, *J* = “blue”, “K” = yellow. Different sets of color-word tasks were used for each different device. They were reminded not to miss any words and they were told that if they make more than 10 mistakes, 10% out of their monetary compensation would be deducted.

2.3.3. Time pressure

This task is based on Hughes et al. [20] study. In this task, participants were asked to type at 20% faster than their comfortable pace. In order to help the participants to work in suitable pace, the new typing speeds were calculated and the target end word for each 1 minute interval were underlined. Subjects were told the time for every 1 minute interval to help them identify their performance during the task. Participants were advised that the main objective was to achieve the target, even if it meant committing more typing errors. It was not only that, the participants were also reminded if they could not achieve the target after five minutes, 10% of their compensation would be deducted.

2.3.4. Stressful environment

For this task, subjects needed to do the same plain copying task and they were asked to type as fast and as accurate as possible. Aside from working under supervision, participants were not allowed to do any correction and every time subjects made a mistake, the experimenter said it out loud. In addition, participants were encouraged to work faster every 30 seconds. Furthermore, an alarm clock with sound was placed in the same room [1]. The participants were told if they could not achieve the target after 5 minutes or made more than 10 mistakes, another 10% of their compensation would be deducted, respectively.

2.4. Questionnaire

Participants needed to fill out another questionnaire after they had finished the experiment. There were three parts of this questionnaire, namely:

1) Part 1–Perceived Task Stress

They need to compare the perceived stress between three tasks (color-word, time pressure and stressful environment) with the plain-copying task. The scale are from “much more relax”, “quite relax”, “slightly relax”, “no different”, “slightly stressful”, “quite stressful” and “much more stressful”.

All other tasks (color-word, time pressure and stressful environment) were compared to the plain-copying task in order to see the effect of different task on perceived stress clearly by letting the plain-copying task to act as a reference point. This is because plain-copying task was done under stress-free condition while all other tasks were done under some stressors which allow the comparison of perceived stress between stress and no stress tasks. Since all other tasks were anchored on one reference point, which is plain-copying task, this can increase the internal consistency (44).

2) Part 2–Perceived Device Stress

They need to compare the perceived stress between at least two devices for the same task. The same scales as in part 1 were used.

3) Part 3–Perceived Condition Stress

Some tasks have three or more stressors imposed on the participants simultaneously. For instance, the stressful environment task contains noise, time pressure, monetary reduction, verbal provocation and negative feedback. Thus, this part was used to find the effect of every stressor towards the participants. The participants were asked to rate from "0" for not stressful at all up to "5" for very stressful.

2.5. Electromyography (EMG) and Maximum Voluntary Contractions (MVC)

Muscle activity was recorded from the dominant upper trapezius, deltoid, extensor digitorum and extensor carpi ulnaris muscles using bipolar Ag-Cl surface electrodes. The distance used between recording areas was 20 millimeters [31, 32]. The skin was prepared by cleaning the located area. The EMG signals were sampled at 1024 Hz. The precise locations of EMG were based and adopted from previous studies [8, 43]. The EMG signals were measured using an EMG LAXTHA device and the signals were analyzed using TeleScan software version 3.09 (LAXTHA Inc., Korea). Isometric maximum voluntary contractions were performed for each muscle. At least three MVC were made for each muscle, and each MVC lasted at least three seconds.

2.6. Data analysis

The data were band filtered using 5 Hz and 500 Hz and then root mean square was calculated for three 5 s epochs at 60 s, 180 s and 300 s after the task was started. The value was then normalized with maximum EMG obtained from MVC. The average value was calculated from these three epochs.

Significant differences of perceived task stress, perceived device stress, perceived condition stress and EMG increment or decrement between different tasks and different devices were evaluated using repeated measures in Analysis of Variance (ANOVA). Statistical Package for the Social Sciences (SPSS) version 20.0 was used for data analysis with significance level set at $p < 0.05$ with 95% confidence interval.

3. Result

3.1. Perceived task stress

The difference of mean stress between plain-copying (0.000) and color-word (0.1667) was very low and not significant ($p = 0.638$). Thus, color-word can be considered as a "no stress" task. The time pressure task (mean = 1.4167) is significantly considered as in the middle of "slightly stressful" and "quite stressful" compared to the plain-copying task ($p < 0.000$) while the stressful environment task (mean = 2.1667) is considered as slightly more than "quite stressful" compared to plain-copying task ($p < 0.000$). The perceived stress between the time pressure and stressful environment task is also significant ($p = 0.002$).

3.2. Perceived device stress

Unexpectedly, there were no significant differences in stress between devices for any task.

3.3. Perceived stress for each of the stressor

In this section, the highest stress was induced by "the needs to change the screen between alphabets and symbols", followed by noise and typing accuracy. Other significant stressors were time pressure, verbal provocation, negative feedback, and small keypad. There are other stressors that can be considered as insignificant to the participants which are different color-word for both on screen and using voice, random positioning of appearance during color-word task, supervision by the researcher, small screen and compensation (monetary) reduction.

3.4. Muscle activity

EMG values for each muscle were analyzed into two categories which are by the effect of different tasks and by the effect of different devices. Figure 1 (a – d) shows a box and whisker plot with medians and 25–75 percentiles of electromyography activity (%EMGmax) for the upper trapezius, extensor digitorum, extensor carpi ulnaris and anterior deltoid respectively. There are 16 combinations of devices and tasks. The first two or three alphabets were devices (DC = desktop computer, LAP = laptop, TAB = tablet and SP = smart phone) and the last two alphabets were tasks (CW = color word, PC = plain copying, TP = time pressure and SE = stressful environment). For instance, DCCW means that a color-word task was done using desktop computer. Some data need to be excluded because of certain technical errors. Thus, on average, there were eight participants for each combination of device and task.

There is a clear effect of the level of stress on the upper trapezius muscle activity. Generally, trapezius muscle activity increased during time pressure task compared to plain-copying or color-word tasks and

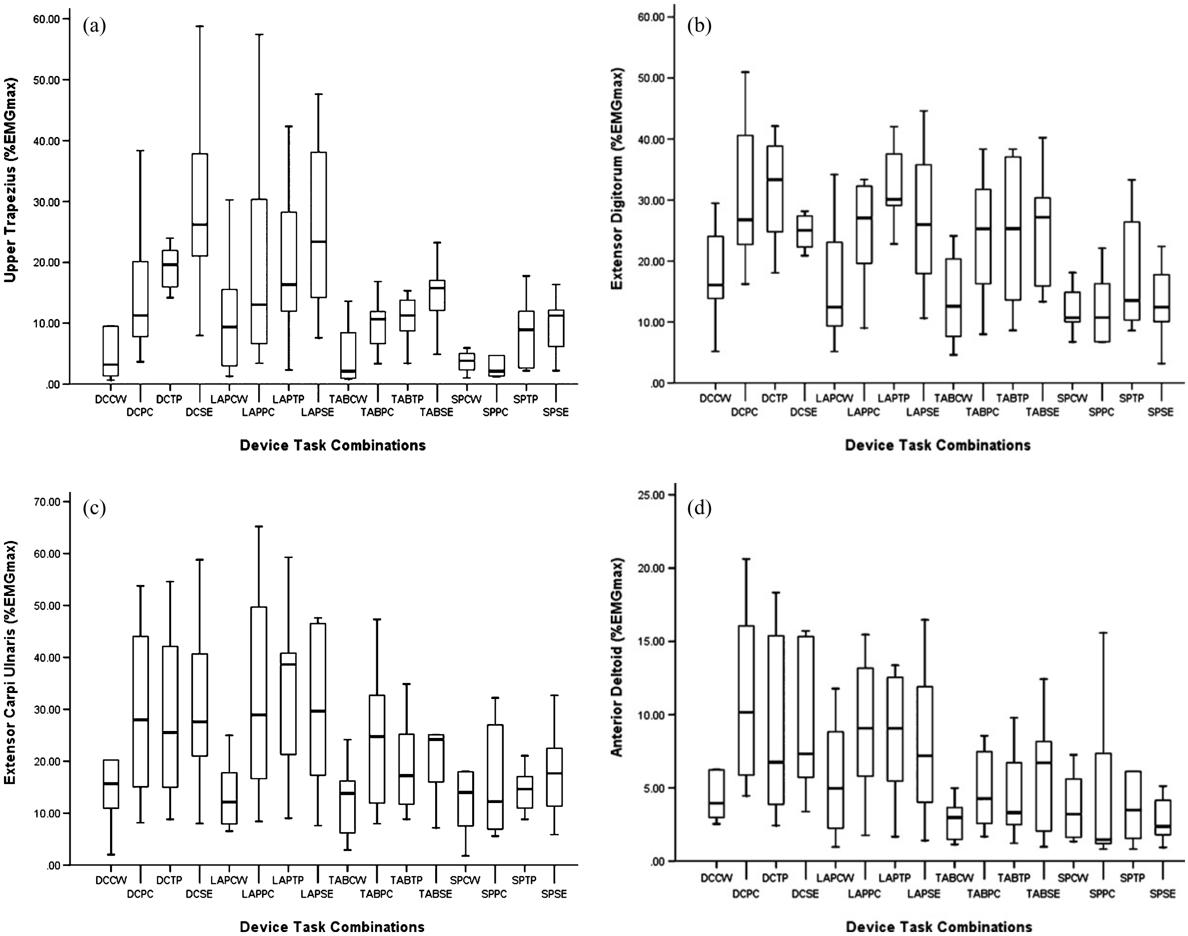

Fig. 1. Box and whisker plot with medians and 25–75 percentiles of electromyography activity (%EMG_{max}) under 16 combinations of devices and tasks for a) upper trapezius, b) extensor digitorum, c) extensor carpi ulnaris and d) anterior deltoid.

had a greater increment when they did stressful environment task. The statistically significant results for trapezius muscle activity were obtained for several task comparisons for each of the devices (Table 3). Aside from the trapezius muscle, other muscles also show significant increment. However, there is no clear relationship of the increment pattern.

Unexpectedly, the only increment that happened between a desktop computer and a mobile computing product was between a desktop computer and laptop. However, it is not statistically significant. At the same time, the comparison between a desktop computer and tablet / smart phone or between laptop and tablet / smart phone shows a significant decrement (Table 4). Muscle activity during the usage of a tablet and smart phone for all muscles and tasks is much lower compared to the muscle activity during the usage of a desktop computer and laptop.

3.4. Performances

The performance of participants was different depending on the task and the devices. The fastest typing speed was during the stressful environment task. Generally, the result shows that there are significant increments of typing speed from the plain-copying task to the time pressure and stressful environment tasks. However, there is no significant difference of typing speed between different devices for the same task which means most of the participants can type on smart phones or tablets as fast they type on desktops or laptops. Nevertheless, it should be noted that this might be true only for slow typists. Meanwhile, numbers of errors increased significantly for each task and the same thing happened for all devices. The lowest number of errors was obtained during the usage of a smart phone. The mean of typing speed in terms of

Table 3
The significant increment of muscle activity between two tasks

Muscle	Devices[1]	Tasks[2]		Mean (j) – Mean (i) (%EMG_{max})	p value[3]
		Task (i)	Task (j)		
Upper Trapezius	DC	CW	TP	15.4	**0.000**
			SE	24.5	**0.041**
	Lap	CW	TP	16.5	0.067
			SE	17.3	**0.009**
	Tab	PC	SE	7.5	**0.006**
		CW	PC	5.2	**0.069**
			TP	7.6	**0.046**
			SE	12.7	**0.009**
	SP	CW	SE	7.8	**0.018**
Extensor Digitorum	DC	CW	PC	11.7	**0.011**
			TP	16.3	**0.005**
			SE	10.5	**0.008**
	Lap	CW	PC	8.9	**0.031**
			TP	13.2	**0.012**
			SE	10.7	**0.007**
	Tab	CW	PC	10.4	**0.004**
			TP	13.0	**0.010**
			SE	9.3	**0.006**
Extensor Carpi Ulnaris	DC	PC	SE	10.2	0.057
		CW	SE	15.1	**0.022**
	Lap	CW	PC	19.6	**0.019**
			TP	18.5	**0.038**
			SE	16.9	**0.013**
	Tab	CW	PC	11.8	**0.029**
			TP	12.2	0.083
			SE	10.1	0.058
Anterior Deltoid	Lap	CW	PC	3.6	**0.013**
			TP	2.3	**0.046**
	Tab	CW	PC	2.1	0.050
			TP	3.5	0.096
			SE	2.5	0.086

[1]For devices: DC = desktop computer, Lap = laptop, Tab = Tablet computer, SP = smart phone.[2]For tasks: CW = color word, PC = plain copying, TP = time pressure, SE = stressful environment. [3]Repeated measures ANOVA (bold indicates significant effect $p < 0.05$).

words per minute (WPM) and number of error were summarized in Table 5.

Net values for performance were calculated to see the actual performance by the participants. Interestingly, the highest performance was obtained during the plain copying task using a desktop. In addition, the net performances of the participants were better during comfortable conditions compared to during stressful conditions. Besides that, during the time pressure and stressful environment tasks, the best performance was obtained during the usage of a laptop.

4. Discussion

Previous studies showed a different result in regards to the effect of psychosocial stress on muscle activity. Even for the most common muscle studied which is the trapezius muscle, the effect of stress on muscle activity can be divided into two main groups. One group found that when a certain psychosocial stress exists, the trapezius muscle will become affected and the muscle activity will be increased significantly [8, 12, 18, 21, 29–31, 35]. On the other hand, another group of researchers found that the existence of a certain psychosocial stress did not have any significant effect on trapezius muscle activity [9, 14, 18, 19, 23, 24, 27, 28]. Meanwhile, there are several studies that can be categorized in a third group where this group obtained a combination of the two aforementioned results [1, 25, 26, 29].

It is predicted that there is a relationship between the task used to induce the stress and the effect on trapezius muscle activity. We believe that this relationship is the main reason that leads to the result obtained by these previous researchers. This

Table 4
The significant decrement of muscle activity between two devices

Muscle	Task[1]	Devices[2]		Mean (i) – Mean (j) (%EMG_{max})	p value[3]
		Device (i)	Device (j)		
Upper Trapezius	PC	Lap	SP	16.6	0.090
	CW	Lap	Tab	7.9	0.086
			SP	8.6	0.091
	TP	Lap	SP	27.9	0.067
	SE	DC	SP	20.6	**0.028**
		Lap	SP	13.4	**0.022**
Extensor Digitorum	PC	DC	Tab	6.8	**0.017**
		Lap	Tab	4.4	**0.038**
	CW	Lap	Tab	3.9	0.075
	TP	Lap	Tab	6.3	**0.022**
	SE	DC	SP	4.4	**0.045**
Extensor Carpi Ulnaris	TP	DC	Tab	8.4	0.098
	SE	DC	Tab	13.1	0.085
			SP	13.4	0.060
Anterior Deltoid	PC	DC	Tab	6.8	0.017
		Lap	Tab	4.4	0.038
	CW	Lap	Tab	3.9	0.075
	TP	Lap	Tab	6.3	**0.022**
	SE	DC	Tab	4.9	0.054
			SP	6.1	**0.013**
		Lap	SP	4.4	**0.045**

[1]For tasks: CW = color word, PC = plain copying, TP = time pressure, SE = stressful environment. [2]For devices: DC = desktop computer, Lap = laptop, Tab = tablet computer, SP = smart phone. [3]Repeated measures ANOVA (bold indicates significant effect $p < 0.05$).

Table 5
Mean of the participants' performance in terms of WPM and number of error

Device	Words per minute (WPM)			Number of error		
	Plain copying	Time pressure	Stressful environment	Plain copying	Time pressure	Stressful environment
Desktop	24.1	27.4	30.9	0.6	12	16.6
Laptop	26.1	30.7	31.6	0.6	8.3	13.3
Tablet	21.1	25.3	26.6	0.4	8.3	9.9
Phone	20.9	24.7	27.5	0.4	7.3	9.6

is because each of the tasks used to induce stress produces a different level of stress and consequently has a different effect on muscle activity.

There is a wide range of stressors used in this study since normally, in the real work environment, multiple stressors or factors are present simultaneously. The effect of each one of them might be small but the combination of them might create a big effect. Previous researchers who obtained a significant activity increment in trapezius muscle activity used different kinds of stressors. In order to differentiate the effect of each stressor, part 3 of the questionnaire was used so that participants could rate the effect of each stressor separately. As a result, there were seven stressors that can be considered as significant in inducing the stress in this study.

This result was supported by part 1 of the questionnaire that shows the color-word task was considered as a 'no stress' task. This is because four insignificant stressors were used in color-word task. At the same time, time pressure task was in the position between 'slightly' and 'quite stressful' tasks. This is expected as the time pressure task contained several stressors that can cause significant stress to the participants. Finally, the stressful environment task was considered 'quite stressful' because not only did it have the same stressor as the time pressure task, but also some additional stressors that can cause significant stress.

As we were interested in finding the relation of muscle activity to the level of stress, the core part of this study is to prove that there is a different level of perceived stress between each of the tasks. Then, the result was validated by an EMG result in order to determine the effect of psychosocial stress on muscle activity, especially on the trapezius muscle.

4.1. The effect of different tasks used to induce psychosocial stress on muscle activity

The results obtained from the EMG measurements have proven the first and second hypotheses. The first hypothesis is accepted as true because the result showed a clear increment of trapezius muscle activity for the time pressure and stressful environment tasks compared to the plain-copying or color-word tasks.

Meanwhile, the second hypothesis stated that the increment is dependent on the level of stress. The higher the level of stress is, the higher the increment of trapezius muscle activity. This hypothesis stated that the plain-copying task has the lowest effect on trapezius muscle activity while the stressful environment has the highest effect. It was expected that the highest trapezius muscle activity in this study would result from the stressful environment task, followed by the time pressure task, and finally the color-word task. The result obtained has proven this hypothesis. The EMG result was matched with part 1 of the questionnaire's result. This is because in most conditions, there was a significant increment of trapezius muscle activity between the plain-copying or color-word task with the stressful environment task even though there was no significant increment between the plain-copying or color-word task with time pressure task. In addition, in the event there is a significant increment, the increment in trapezius muscle activity for the first comparisons is higher and more significant than the latter. Furthermore, there is no significant difference of trapezius muscle activity between the plain-copying and time pressure task even though at the same time there is significant difference in typing speed for both tasks. The significant increment that happened between the color-word task and time pressure task is most probably due to the increment of typing activity itself since the color-word task did not involve much typing. Besides that, the different increment of trapezius muscle activity can be seen clearly where the lowest activity was obtained during the plain copying task and the highest was obtained during the stressful environment task for all devices. This result matches Mclean and Urquhart [1] where they found that the increment in typing speed during a data entry task does not affect the muscle activation amplitude in the trapezius muscle.

This result is concurrent with previous research regarding the effect of psychosocial stress on trapezius muscle activity. These researches also showed that there were no significant differences for trapezius muscle activity during the color-word task [19, 28], greater effect during the time pressure task [8, 14] and the highest effect happened during the stressful environment task [1, 12, 30].

Aside from the trapezius muscle, other muscles did not show this kind of relationship. Besides that, as mentioned before, the significant increment that only happened between the color-word task and the other three tasks were most probably due to the increment of typing activity itself since the color-word task did not involve much typing.

4.2. The effect of different devices used under psychosocial stress on muscle activity

In third hypothesis, it is believed that mobile computing products can produce psychosocial stress because of its characteristics. However, this hypothesis cannot be accepted as true. This is because in comparison to the desktop computer, only a laptop showed a greater trapezius muscle activity. However, none of them were statistically significant. Not only that, all significant results show that muscle activity during the usage of tablet and smart phone is lower than during the usage of desktop computers and laptops. There is a contradiction between this study and Kim et al. [38] which showed that muscle activity in the shoulder muscle was slightly higher for a smaller virtual keyboard. However, this inconsistency might happen because of the differences in study design and equipment. Thus, direct comparison might not be meaningful.

There are several reasons why this result was obtained. First, in many conditions, laptops and desktops are quite similar. The main difference is that laptops do not have a detachable monitor which makes the angle of viewing quite limited compared to desktops. Thus, the result obtained was as expected. However, it is not significant enough. Secondly, most of the participants were not people who could do the typing process without needing to take a look at the keyboard. Thus, when they do the copying on a desktop computer or laptop, their heads move from monitor to keyboard and to monitor again in the process. This movement is minimized during the usage of tablets and smart phones, and consequently might lower their muscle activity. Meanwhile, the significantly lower activation in other muscles can be explained by the difference of keyboard size and touch screen capability. Since the keyboard / keypad size is very small for tablets and smart phones, the participants do not move or use their muscles as much as when they use desktop computers and laptops. In addition, the force they need to press a touch screen button is lower than the actual keyboard. Finally, in a study to determine the effect of precision demand and mental pressure on the load of the upper extremity, the authors found that unlike mental pressure, the precision had a small effect on trapezius muscle activity [29]. However, they also argued that in a case where the performance is essential, precision might has a hidden effect. This is because precision plays an important role in performance during computer work, and consequently on mental pressure. This relationship is also found in another study [22]. Thus, based on this argument, we also want to argue that since the participants can do the typing task with significantly less number of errors during the usage of tablet and smart phone, this might be another reason why trapezius muscle activity is significantly less compared during the usage of a laptop or desktop computer.

The fourth hypothesis cannot be taken as true as the third one has been rejected. Furthermore, there is no fixed patent of muscle activity increment found in any muscles for any devices.

4.3. Performance

In the earlier stage of this study, it was believed that, for word processing tasks, the performance during the usage of desktop computers would be significantly better in terms of typing speed and rate of error. However, the result of this study is quite the opposite since not only is the laptop better in terms of typing speed, but also the rate of error during the usage of tablet and smart phone is significantly lower than during the usage of desktop computer during stressful condition.

Nevertheless, it should be noted that this result might be true only for slow typists and this certain posture. This might lead to an argument that this result was obtained because most of the participants use smart phones much longer than desktop computers or laptops and are much more comfortable using smart phones than other devices. Yet, the same result was obtained for tablet even though most of the participants used tablet very seldom compared to other devices. In addition, the fact that the hour of usage for tablet is much lower compared to other devices did not affect their performance much both in terms of WPM and rate of error. They still can do the typing process using a tablet as fast as using other devices with a significant lower rate of error compared to desktop computer and laptop during stressful environment task.

Yet, it should be noted that for net performance, the best performance was obtained during the usage of desktop computer and plain copying task. This is interesting because the best result was obtained during the comfortable condition without any stress. Even though the participant can increase their typing speed, the stress made them make more mistakes. This result indicates that the best environment for the workers is the comfortable environment. Besides that, during the time pressure and stressful environment tasks, the best performance was obtained during the usage of laptop. This result might indicate that under stressful conditions, the best performance can be obtained using the device that they are most comfortable or has most experienced to.

4.4. Stressors

There are many stressors used in this study to induce psychosocial stress. Even though this study cannot clearly differentiate the effect of each stressor, the result from questionnaire (part 3) found that there were six stressors which considered as not stressful enough to increase the trapezius muscle activity. This result is matched with some previous studies which used some of these stressors and no significant differences in trapezius muscle activity were found. For instance, the effect of different color-word either on screen or using voice [19, 28], supervision by the experimenter [9] and adding to or deducting the compensation [26]. However, the comparison between this study and the previous ones for significant stressors are difficult to be made as these previous studies also combine more than one stressor in their experiments [1, 12, 30].

4.5. Limitations

There are several limitations in this study. First of all, there is no female participant involved. Many previous studies described that gender plays a big role in MSDs symptoms. However, none of the previous studies regarding the effect of psychosocial stress on trapezius muscle activity reported any difference in effect between men and women [20, 28, 29]. Thus, it is believed that it will not affect the result of this study that much. Another limitation is the limited choice of posture and small number of participants. As the design of the experiment for this particular study is quite big, only one posture was used for each device and task even though the range of posture is so wide, especially for mobile computing products. Different posture might have a different effect on muscle activity especially because this study involved four different kinds of devices. There could be another limitation caused by the questionnaire design. As the perceived task stress for a particular task was compared to another task, there might be some biases. Participants may generate the plain-copying task as an anchor (no stress), and then the perceived stress could be increased as they know the other tasks were done under some stressors [45]. Also, the order of task could have an impact on the perceived stress of tasks. For example, participants can remember better the difficulties and stresses of the more stressful ones than the less stressful ones as they conducted experiment in the order of perceived stress level. Consequently, the perceived stress for the last task (stressful environment) might be overestimated. The same thing might happen on perceived device stress. Finally, the participants in this study are young adults. Thus, the result might not be applicable to older adults.

5. Conclusion

This present study has examined the effect of psychosocial stress on muscle activity using different devices including desktop computers, laptops, tablets and smart phones. Combinations of several stressors were used for each task done in this study. The results from the questionnaire showed a clear distinction of stress perceived by the participants for each task. Based on the different of results found in previous studies regarding the effect of psychosocial stress on trapezius muscle activity (significantly increased, no significant effect or mixed result), we believe that it is caused by different level of stress. The result from this present study shows a clear indication that trapezius muscle activity will increase with the existing of psychosocial stress. Not only that, the increment of the activity was influenced by the level of stress used. The higher the level of stress is, the higher the increment. Meanwhile, it is found that the usage of tablets and smart phones are better than desktops and laptops in terms of muscle activity. Besides that, even though desktop computer is the best device to use during comfortable environment, it does not appear so in stressful environment. However, these results may only be applicable for slow typists and for particular postures. Psychosocial stress is common in a working world. Some precautions should be taken if the job involves a great level of stress. It will help the company in reducing the MSDs problem in the future.

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Conflict of interest

None to declare.

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