Effects of Netbook and Tablet Usage Postures on the Development of Fatigue, Discomfort and Pain

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Abstract. The number of people using online tablets in public places has increased dramatically. Their postures are dominantly characterized by non-neutral and awkward positions that in the long term may lead to a higher risk of musculoskeletal disorders. The purpose of this study was to investigate the effects of tablet compared to laptop (i.e. netbook) usage postures on the development of fatigue, discomfort and pain. A total of 12 participants accomplished email typing tasks for 2 hours with four different usage configurations: 1) Netbook-on-table, 2) Netbook-on-lap, 3) Tablet-on-table, and 4) Tablet-on-lap. Changes in fatigue, discomfort, and pain were monitored based on pinch grip strength (tip pinch, key pinch, and palmar pinch), rating of perceived discomfort, and Phalen's & Reverse Phalen's tests, respectively. The results indicated that the effect of portable device placement was significant ($p < 0.05$), with varied effects across measurements. No effect of portable computer type was found. The interactive effect of portable computer type and placement was only significant for right tip pinch ($p < 0.05$). The findings of this study can hopefully be used to increase the awareness of tablet users about associated fatigue, discomfort and pain while using a tablet in public places that may lead to a higher risk of musculoskeletal disorders.

Keywords: *fatigue; musculoskeletal disorders; pain; posture; tablet.*

1 Introduction

The use of tablets has increased significantly worldwide. During the last decade, the amount of time people use online tablets away from their homes and offices has raised dramatically. It is expected that tablets will eventually slow other portable computer uses (such as laptop/notebook, netbook), although tablets may not substitute the need for desktop PCs for intensive computer work at the workplace. As a result, there is a quick and emerging shift regarding device use and work location that is associated with additional risks to the neck, thumbs and hands [1].

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Tablets are often used at home (in a non-desk setting), while travelling and in public places (e.g. cafes, hotel lobbies, airports, train stations) with a variety of postures during usage. The usage positions may include non-neutral and awkward postures, which may increase muscle activity, static loading and tendon strain, leading to a higher risk of musculoskeletal disorders.

Experts have documented guidelines on using desktop computers to promote good occupational health practices. These guidelines may not adequately address tablet ergonomics. Further study on the effects of tablet usage based on an ergonomic point of view is essential to prevent more people suffering from musculoskeletal complaints, such as low back pain and carpal tunnel syndrome (CTS). Recent studies reported that the prevalence of CTS in the general population due to entrapment of the median nerve at the wrist is estimated to be around 5-18% [2,3], where office workers seem to be mostly affected.

A number of studies have quantitatively measured postural variations during tablet usage and compared the results with desktop and/or laptop usage [4,5]. Compared with desktop computer usage, tablet usage is associated with more flexed and asymmetrical spinal postures, more flexed and elevated shoulders, and greater muscle activity around the neck [6-8]. Tablet usage will also increase wrist extension and wrist radial deviation angles if the tablet is located on the lap [9]. If there is no task variation, tablet usage is more associated with a greater risk of musculoskeletal problems than desktop usage [6].

Whilst most studies have concluded a postural degradation when using portable computer devices, its effect on fatigue is less known. The above studies (such as [6,8,9]) simulated computer tasks for only a short duration. In fact, discomfort, pain and risk of musculoskeletal disorders may increase after longer durations of usage [4,10]. The use of computers for two to four hours per day can increase the risk of neck and back pain 12 to 40 percent [11]. In addition, fatigue due to prolonged muscle effort has been considered as a surrogate measure of risk of musculoskeletal disorders [12,13]. Given a substantially increased amount of time during which people use a tablet and a variety of postures during tablet usage, this study was aimed at investigating the development of fatigue, discomfort and pain during tablet usage compared with netbook use with different postural usages.

2 Methods

2.1 Participants

A total of 12 participants (6 male and 6 female) were recruited from the student population of Institut Teknologi Bandung. The participants' average age was 23 years (standard deviation, SD = 2). All participants have personally owned a portable computer device (netbook and tablet) for at least two years [9,14] and have regularly worked with the device for at least two hours per day [15]. All participants were right-hand dominant and had no previous history of head, neck, back or upper extremity muscle disorders. Each participant gave informed consent prior to participating to the study.

2.2 Experimental Design

A repeated measures design was used to test the main effects of portable computer types (2 levels: netbook and tablet) and their placement (2 levels: on table and in lap) on discomfort and fatigue. Participants performed typing emails for two hours. All experimental sessions were conducted on different days with a break of at least 24 hours between two sessions. To minimize any order effects, exposure to computer types and their placement was counterbalanced. The experiment was carried out in the Ergonomics Laboratory of the Institut Teknologi Bandung, Indonesia. Lighting (330 lux), room temperature (18-22°C) and layout of furniture in the room were kept constant across sessions [16].

2.3 Independent Variables

The independent variables for this study included portable computer type (netbook and tablet) and their placement (on table and in lap). A recent study [7] reported that the "lap" position is the most preferred posture while using a tablet and the 2^{nd} most frequent posture while using a laptop. The netbook was a Toshiba NB510 Netbook with dimensions of 338 × 234 × 19.5 mm, screen dimension of 10.1 inches, mass of 1.25 kg, resolution of 1024 × 600 pixels, and running on the Windows 7 operation system. The tablet was an iPad 4 tablet with dimensions of 241.2 × 185.7 × 9.4 mm, screen dimension of 9.7 inches, mass of 0.62 kg, resolution of 1536 × 2018 pixels, and running on the iOS 7.1.2 operation system. The tablet was set to landscape orientation by utilizing its proprietary case, which can be adjusted to prop up or tilt the tablet.

A simple office-type chair (adjustable only for seat pan height) and a table were used, as shown in Figure 1. A single sofa-type chair (made of polyurethane, seat pan height of 35 cm, a slightly reclined backrest, with non-adjustable armrests) was used when the netbook or the tablet was located on the lap. In both conditions, participants were asked to sit in a comfortable position [7]. The tablet position on the lap referred to previous studies [8,9]. The participant configurations in the four experimental sessions can be seen in Figure 1.

Figure 1 The four experimental configurations: (a) Netbook-on-table, (b) Netbook-on-lap, (c) Tablet-on-table, (d) Tablet-on-lap.

2.4 Dependent Measures

The dependent measures were: decline in pinch grip strength (to measure fatigue), increase in rating of perceived discomfort (RPD), and increase in pain. Pinch grip strength was measured using a mechanical baseline pinch gauge with dimensions of (5×2.55×1 inch) and capacity of 60 lb. (28 kg) with the procedures following reference [17], including measurement of tip pinch, key pinch and palmar pinch. Participants were in seated positions with shoulders upright and the dominant elbow flexed at 90°.

Discomfort levels were assessed before and as soon as a participant had completed an experimental session using a modified version of Borg's CR-10 scale [18]. Participants were asked about their discomfort levels in the following body segments: neck, upper back, shoulder (left and right), elbow and forearm (left and right), and thumb (left and right). Pain levels were evaluated using a similar RPD scale, indicating 0 as "no pain at all" to 10 as "almost maximal pain". Participants were questioned about their pain level around the wrist area by conducting a Phalen's test and a Reverse Phalen's test. Both tests are generally used to determine an indication of carpal tunnel syndrome [19]. Both tests were conducted for 60 secs, with the postures shown in Figure 2.

Figure 2 Participant's postures while performing Phalen's test and Reverse Phalen's test.

2.5 Procedures

In their first session, all participants were briefed with a verbal and written description of the research. Participants completed a demographic questionnaire and then their baseline data (pre-experiment data) were taken in terms of pinch strength (based on tip pinch, key pinch and palmar pinch), discomfort levels using RPD, and pain assessment using Phalen's and Reverse Phalen's tests, respectively.

In each experimental session, participants were asked to accomplish 11 different email typing tasks for about two hours by re-writing articles written in emails and sending the emails to the author's email address. Each article consisted of several paragraphs with a total of 3000 words. Participants typed below each given paragraph. Participants were allowed to adjust seat height, backrest angle and gaze angle by tilting the device to the most comfortable angle for them. After completing all 11 tasks, post-experiment data were collected. Participants performed pinch strength tests (tip pinch, key pinch and palmar pinch). Then, their discomfort and pain levels were re-assessed using the same procedures taken for the baseline data.

2.6 Data Analysis

Fatigue development was defined as the decline in pinch strength and was computed as percentage loss (post-experiment vs. baseline). Discomfort and pain increments were simply expressed as the increase in discomfort and pain scales (pre- and post-experiment). A 2x2 repeated measure analysis of variance (ANOVA) was employed to determine the presence of main and interactive effects on each dependent measure. The analysis was performed on SPSS ver. 20.0. Significance for all statistical tests was concluded at $p < 0.05$.

3 Results

Based on our random visual observation (supported by a digital camera), wrist positions during the typing task using a netbook located on the lap was more deviated (deviation angle of 30.25° ± 8.5° across participants) compared with using the table (deviation angle of 28.43° ± 6.12° across participants). While using a tablet located on the lap and on the table, wrist position had deviation angles of 32.54° ± 8.35° and 31.01° ± 4.71° across participants, respectively.

3.1 Fatigue

Computer device placement significantly affected left tip pinch strength. Fatigue was not identified using key pinch or palmar pinch strength. Mean left tip pinch declines were 0.13 and 0.16 kg if placed on the table and in the lap, respectively (a difference of approximately 16%, as shown in Figure 3).

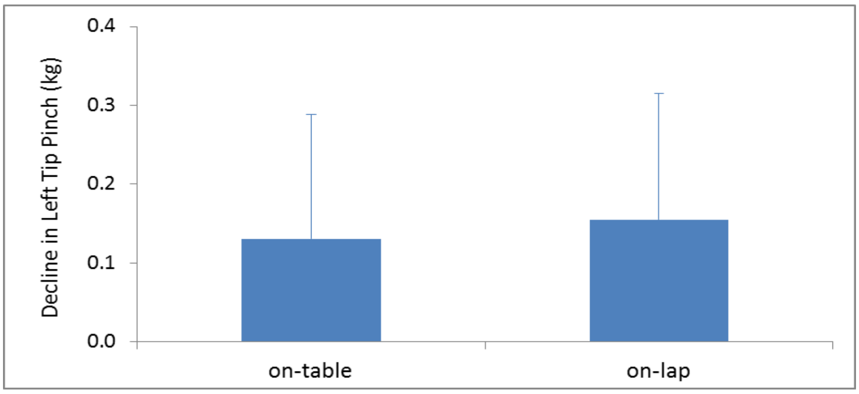


Figure 3 Significant effect of device placement on fatigue measured by left tip pinch decline. Error bars represent standard deviations.

The interactive effect of computer device type x placement had a significant effect on fatigue, with a greater placement-related difference among netbooks than tablets (Figure 4). The decline in right tip pinch after working with a netbook located on the lap was almost five times higher than if the netbook was located on the table. However, the difference in right tip pinch decline of a netbook located on the lap versus on the table was only 8%.

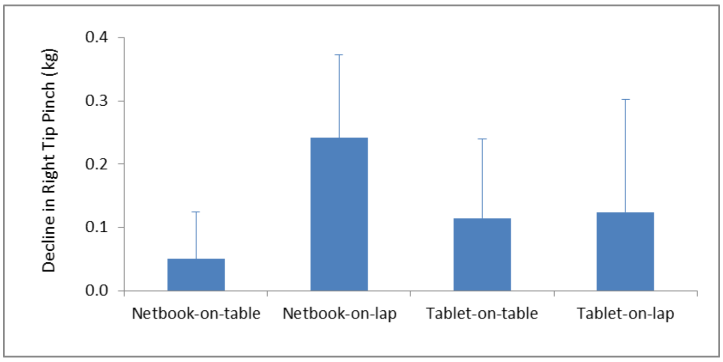
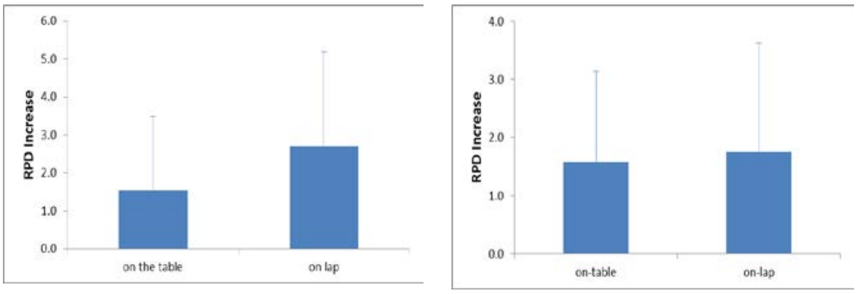


Figure 4 Significant interactive effect of device type x placement on fatigue measured by right tip pinch decline. Error bars represent standard deviations.

3.2 Discomfort

After performing a two-hour email typing task, computer device placement significantly affected discomfort increment in two body segment areas: neck and right elbow-forearm ($p < 0.05$). Mean RPD increases at the neck were 1.54 and 2.71 if located on the table and on the lap, respectively. The difference in RPD increase between both placements for the neck was higher than that for the right elbow-forearm (76% vs. 11%), as shown in Figure 5.

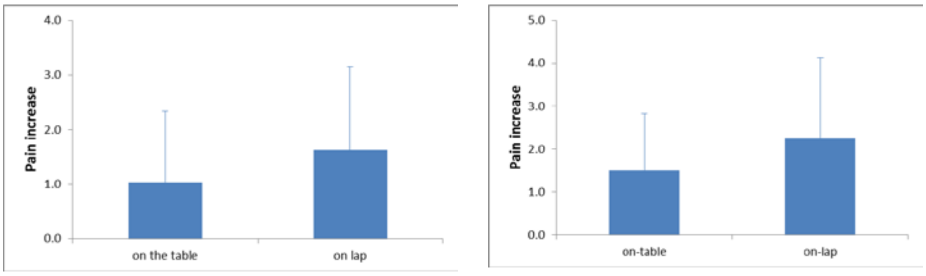


(a) (b)

Figure 5 Significant effects of device placement on discomfort at (a) neck and (b) right elbow-forearm. Error bars represent standard deviations.

3.3 Pain

Similar to fatigue and discomfort, the effect of portable computer type was not significant on pain development. However, computer device placement significantly affected pain measured by both Phalen's and Reverse Phalen's tests. The mean pain increases measured using Phalen's test were 1.04 and 1.63 kg if placed on the table and on the lap, respectively (a difference of approximately 56% as shown in Figure 6). The difference in pain increase between both placements measured using Reverse Phalen's test was slightly lower than that of Phalen's test (a difference of about 50%).



(a) (b)

Figure 6 Significant effects of device placement on pain based on (a) Phalen's test and (b) Reverse Phalen's test. Error bars represent standard deviations.

4 Discussion

The main goal of the present study was to investigate the development of fatigue, discomfort and pain during tablet usage compared with laptop (i.e. netbook) usage. There were several motivations for this work. First, there is an increasing number of people using tablets in public places. Second, people appear to have a lack of awareness of musculoskeletal disorder risks associated with tablet usage and guidelines for tablet ergonomics have not been established yet. Third, few studies have assessed fatigue, discomfort and pain during tablet usage for a long duration.

There were two main results of this study. First, device placement (on table vs. on lap) significantly affected the development of fatigue, discomfort at the neck and right elbow-forearm, and pain. Second, the main sensitive measure for monitoring fatigue development during tablet usage was left hand tip pinch strength.

Our data suggest that wrist and neck postures seem to be the main issues during tablet and netbook usage. These results are in line with the findings in [8] and [9], in which head and neck flexion angles of tablet users overall are far from neutral angles due to the tablet's screen position relative to the user's eyes, and mean or median wrist extension values were greater than 30° due to the influence of tablet location in relation to the elbow, especially for input devices below elbow level.

All our participants were dominant right-hand. Therefore, while typing, their left hands might tend to be static and leaning on the devices. After a long duration such a position may increase tension and fatigue. This result is in accordance with [9], mentioning that non-dominant body parts tend to be associated with awkward positions. In this study, we found a significant effect of the placement of the device on fatigue, measured by left tip pinch decline. A significant effect of the placement on discomfort at the right elbow-forearm seems due to two reasons: awkward posture of wrist extension and repetitive typing tasks.

Interestingly, pain development was observed during the 2-hour email typing task due to tablet/netbook placement (on lap vs. on table). Computer typing tasks are related to the risk of carpal tunnel syndrome (CTS), which may be diagnosed using Phalen's and Reverse Phalen's tests. Both measurements have relatively fair to good sensitivity [19]. It has been known that an awkward hand working posture without armrests when typing on a keyboard is a risk factor of CTS. Typing on a tablet may result in a higher risk of fatigue, discomfort, pain, and CTS. While using a netbook's keyboard, wrists and fingers tend to lean relatively relaxed on the netbook in a standby position. Using tablets with a touchscreen keyboard, there is additional strain on the wrist, even in a standby position since the users have to lift their fingers in order to not touch the screen.

In addition to CTS, our study suggests that typing with a device on the lap may increase the risk of neck pain. The position requires the neck to bend when viewing the screen. It seems that the effect of device type (tablet or netbook) cannot be differentiated. In fact, based on the observed postures (shown in Figure 1), neck flexion angles of tablet users appear to be higher than those of netbook users. We argue that the effect may exist but is not statistically significant. Further study with larger and more homogeneous samples is needed.

Several limitations of the present study are worth noting. Firstly, a laboratory study with simulated email typing task may have altered our real participants' behaviors in using a netbook or tablet. Secondly, we have asked participants to execute email typing while in fact various activities can be done using a portable computer, such as games, browsing, watching movies, etc. Users may have task variations. Besides, in a real life, people may dynamically change their postures while using tablets/netbooks. Though tablet usage is more associated with higher risks of fatigue, discomfort and pain, the effects may be less meaningful if, in a natural setting, users dynamically alter their postures. Thirdly, only 12 participants were recruited for this study. Based on our sample size calculation referring to [20,21], 12 participants is actually enough with the probability of type I error (α) = 0.05 and power (1-β) = 0.8. However, further study with a higher number of participants would reveal more interesting results.

5 Conclusions

Usage of a portable computer (netbook or tablet) located on the lap significantly resulted in higher fatigue, discomfort (at neck and elbow-forearm), and pain than when located on a table. We identified that the most appropriate indicator for monitoring fatigue in a typing task was tip pinch reduction. In addition, wrist pain (as a surrogate measure of CTS) can be assessed using Phalen's test and Reverse Phalen's test. Our study suggests that users should be aware of their awkward neck and wrist postures while using portable computers in public places. A dynamic posture, in addition to frequent break and task variations, may reduce risks of musculoskeletal problems.

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