มหาวิทยาลัยบูรพา
BURAPHA UNIVERSITY

รายงานวิจัยฉบับสมบูรณ์

การศึกษาประสิทธิภาพของอุปกรณ์นำเข้าเข้ามูลสำหรับการสอบข้อเขียน-การเปรียบเทียบระหว่างอุปกรณ์การเขียนและอุปกรณ์การพิมพ์

Performance study of input devices for generating writing with drawing tasks in written exams – a comparison between handwriting and typing devices

ดร.สุนันทา วงศ์จตุรภัทร

โครงการวิจัยประเภทงบประมาณเงินรายได้
(เงินอุดหนุนจากรัฐบาล)ประจำปีงบประมาณ พ.ศ. 2561

มหาวิทยาลัยบูรพา

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สัญญาเลขที่ 189/2561

รายงานวิจัยฉบับสมบูรณ์

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คณะวิทยาศาสตร์และสังคมศาสตร์
มหาวิทยาลัยบูรพา

ตุลาคม 2561

กิตติกรรมประกาศ

งานวิจัยนี้ได้รับทุนสนับสนุนการวิจัยจากงบประมาณเงินรายได้ (เงินอุดหนุนจากรัฐบาล) ประจำปีงบประมาณ พ.ศ. 2561 มหาวิทยาลัยบูรพา ผ่านสำนักงานคณะกรรมการวิจยแห่งชาติ เลขที่สัญญา 189/2561

ผู้วิจัยขอขอบพระคุณรองศาสตราจารย์ดร. นพพร โชติกกำธร ผู้ร่วมวิจัยที่ให้คำแนะนำและมีส่วนสนับสนุนอุปกรณ์การวิจัยที่มีความพร้อมและความทันสมัย และขอขอบพระคุณ คณะวิทยาศาสตร์และสังคมศาสตร์ที่ให้การสนับสนุนด้านเวลาและโอกาสในการพัฒนาทักษะด้านการวิจัย

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บทคัดย่อ

การสอบวัดผลทางการเรียนการสอน เป็นกระบวนการประเมินผลที่มหาวิทยาลัยใช้เป็นเครื่องมือสำหรับการประเมินผลสมฤทธิ์ทางการเรียน ซึ่งหากพิจารณาวิธีการสอบในลักษณะต่างๆ จะพบว่าการสอบวัดผลจะสามารถใช้อุปกรณ์อินพุตประเภทต่าง ๆ ได้ ซึ่งการวิจัยฉบับนี้เป็นการศึกษาการใช้อุปกรณ์อินพุตแบบดิจิทัลที่อาจมีผลกระทบต่อการใช้กล้ามเนื้อและนำไปสู่การบาดเจ็บของกล้ามเนื้อ

ในการวิจัยนี้ได้ตรวจสอบการเคลื่อนไหวของกล้ามเนื้อในขณะทำการสอบข้อเขียน ได้แก่ กล้ามเนื้อ trapezius (TRAP), biceps brachii (BB), flexor digitorum superficialis (FDS), extensor Carpi radialis brevis (ECRB) และกล้ามเนื้อ extensor digitorum Communis (EDC) โดยผู้วิจัยได้เก็บข้อมูลสัญญาณไฟฟ้ากล้ามเนื้อElectromyography ในขณะใช้อุปกรณ์ Boogie Board, Chromebook, iPad pro, Notebook Keyboard, ปากกากระดาษ และ Yoga Book กลุ่มตัวอย่างคือ โดยกลุ่มตัวอย่างคือนักศึกษามหาวิทยาลัยจำนวนยี่สิบคน

ผลการวิจัยพบว่า Boogie Board และปากกาลูกลื่นทำให้เกิดการใช้งานกล้ามเนื้อมากที่สุด กล่าวคือในขณะใช้ Boogie Board และปากกาลูกลื่นกลุ่มตัวอย่างมีแนวโน้มที่จะกล้ามเนื้อ FDS และ ECRB มากที่สุด นอกจากนี้ Boogie Board ยังทำให้เกิดการใช้งานกล้ามเนื้อ BB เพิ่มสูงขึ้นอย่างต่อเนื่อง ในขณะที่เมื่อเป็นการใช้อุปกรณ์ Yoga Book พบว่ากลุ่มตัวอย่างใช้กล้ามเนื้อ TRAP, FDS และ EDC เพิ่มขึ้นอย่างต่อเนื่อง แต่ในทางตรงกันข้าม Chromebook และ iPad pro ได้แสดงให้เห็นว่าการใช้กล้ามเนื้อ FDS และ EDC มีแนวโน้มลดลงอย่างต่อเนื่อง อย่างไรก็ตามเมื่อกลุ่มตัวอย่างใช้พิมพ์บนคีย์บอร์ดคีย์บอร์ด จะพบว่าการใช้งานกล้ามเนื้อ BB, FDS และ ECRB น้อยลง ดังนั้นจึงสรุปได้ว่าเมื่อการสอบวัดผลทางการเรียนการสอนที่อยู่ในรูปแบบของการเขียนคำบรรยายและแผนภาพ การใช้คีย์บอร์ดโน๊ตบุ๊คจึงอาจเป็นอินเตอร์เฟสที่เหมาะสมกว่าการเขียนด้วยลายมือ การค้นพบยังชี้ให้เห็นว่าอุปกรณ์การเขียนด้วยลายมือ ทำให้เกิดการเคลื่อนไหวของกล้ามเนื้อมากขึ้นและอาจนำไปสู่การบาดเจ็บของกล้ามเนื้อในอนาคตเมื่อต้องเขียนด้วยลายมือเป็นเวลานานๆ

คำสำคัญ การออกแบบตามหลักสรีรศาสตร์ การปฏิสัมพันธ์ระหว่างมนุษย์และคอมพิวเตอร์ การประเมินผลคลื่นไฟฟ้ากล้ามเนื้อ

Abstract

Examinations are an assessment and evaluation tool at University. These can be performed using different types of input devices to complete them. This present study investigated whether using digital input devices affects muscle activation than a traditional input instrument. We monitored the Electromyography (EMG) activity of trapezius (TRAP), biceps brachii (BB), flexor digitorum superficialis (FDS), extensor carpi radialis brevis (ECRB) and extensor digitorum communis (EDC) muscle activity during generative writing with drawing tasks in written exams using Boogie Board, Chromebook, iPad pro, Notebook Keyboard, Ballpoint Pen, and Yoga Book. Twenty university students were included in this study. The results showed Boogie Board, and Ballpoint Pen used the most muscle activity. When using Boogie Board and Ballpoint Pen, participants had a trend of using FDS and ECRB muscle activity the most. Additionally, Boogie Board had consistently the greatest BB muscle activity. Moreover, when using the indirect input device, Yoga Book, participants had an indicating a trend of increasing in TRAP, FDS and EDC muscle activities. In contrast, Chromebook and iPad pro had showed consistently lower FDS and EDC muscle activities. However, when typing on the Notebook Keyboard, subjects had the least BB, FDS, and ECRB muscle activity. Therefore, when a long writing scenario is required, a Notebook Keyboard may be a more suitable interface, especially in education. The findings also suggest that handwriting devices have a greater potential energy expenditure in performing handwriting tasks and muscular damage with the maintenance of motor patterns in handwriting tasks

Key words: Ergonomic design, Human computer interaction, Assessments, Electromyography

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Chapter 1

Introduction

1.1 Related Literatures

Prior research comparing pen and paper or handwriting vs. a digital writing tool (keyboard or tablet) have primarily focused on primary school students in early writing acquisition. These results have found inconsistencies within each theoretical perspective: cognitive-psychological theoretical perspective, neuroscience and learning theoretical perspective, and socio-cultural theoretical perspective (Wollscheid S. et al. 2016). For example, Kiefer et.al. (2015) examined the influence of pen- or keyboard-based writing training on reading and writing performance in preschool children. Results did not indicate a superiority of typing training over handwriting training in any of these tasks. In contrast, handwriting training was superior to typing training in word writing, and, as a tendency, in word reading.

Meanwhile, research on university students by Fortunati and Vincert (2014) and by Taipale (2014, 2015) compared the impact of writing and reading on paper with writing by digital writing tools and digital reading among university students in Italy and Finland. They found that students in Finland were more effective when using digital writing tools, while students preferred reading on paper.

Moreover, the EMG technique has been applied in various disciplines and areas of study: dental work, neurobiology, and sport physiology (Kim, et al., 2014; Milerad, Ericson, Nisell, Kilbom, 1991; Linderman 2009). Some other researchers have examined the difference in typing forces, muscle activity, comfort, and typing performance among virtual, notebook, and desktop keyboards and concluded that for long typing sessions or when typing productivity is at a premium, conventional keyboards with tactile feedback may be a suitable interface (Kim et al. 2014). Lin (2004) concluded that female typists typing continuously for 2 hours show maximum voluntary electrical activation (MVE) decreased after 2 hours typing, and they did not recover to the initial value even after a 10 minutes break. A study by Shin and Zhu (2011) examined the physical risk factors associated with touchscreen keyboard use in a desktop computing setting. They show that using a touchscreen increased muscle activity in the shoulder and neck muscles. Several authors have proposed the use of EMG techniques to provide new empirical evidence in the study of muscle fatigue, i.e. Armstrong, et al. 1994; Fernstro, Ericson, Malker 1994; Gerard et al. 1999; Marklin, Simoneau 2001. They use the EMG as a tool to find the appropriate typing force on a keyboard to reduce the physical load during typing. Lundervo,

(1958) recorded increasing muscular activities not only in the shoulder and upper arm muscles, but also in the forearm muscles.

This study differs from prior work by applying interdisciplinary research; it addresses the substitution of digital input devices for traditional input instruments in written exams. First, by applying EMG data, we seek to find out whether using a digital input device (keyboard with Boogie board interface and tablet with stylus) affects muscle activation, shoulder and neck comfort, differently than a traditional input instrument. Second, we analyze hand, palm and wrist accommodations, body posture and sight distance to develop tools and techniques to enable creating suitable systems and to achieve efficient, effective, and safe interaction (Dix, 2004). Third, we include variables that are explained in the TAM model to expand our understanding of IT adoption. Finally, we analyze the relationship between the various dimensions considered in this study, especially the EMG data, self-reporting and preferences. This study has been tested multiple times using digital input devices and traditional pen and paper in written exams.

1.2 Background & Rationale

Examinations are a very common assessment and evaluation tool at University. Universities are spending more money each year on test administration, such as preparing exam scripts and answer sheets, as well as storing such scripts and sheets. If we analyze all characteristics of examination administration, we see that digital input devices such as keyboards and digital handwriting instruments make possible a more efficient examination process for test administration and review [1&2].

Previous research results have indicated that both computer keyboard characteristics and handwriting instruments can affect users' risks for developing injury and health risks from working conditions, especially during long sessions [3&4]. Moreover, in examination conditions, existing research indicates that assessment can be impacted by the type of device that was used to complete it [5 & 6]. However, digital input devices are increasingly being used especially for test administration, e.g. pen-based testing in drawing, sketching, graphing, and writing text containing a mathematical equation [7-10]. Although digital input devices are increasingly widely used, it is still unclear exactly what type of digital input devices could be more suitable for generating writing with drawing tasks in written exams [11&12].

An important question in this new generation writing scenario is whether using digital input devices affects muscle activation differently than a traditional input instrument differently than a traditional input instruments. Thus, it is important to understand the use of input devices that may affect physical risk factors and student performance. In this work we intend to empirically answer this research question. In this work we compare generating writing input using six types of device: Notebook Keyboard, Pen and Paper, Yoga Book, Chromebook, iPad pro, and Boogie Board.

1.3 Objectives

1. To analyze and compare the impact of various input devices for writing with drawing tasks in written exams in terms of the differences in muscle activation, hand, palm and wrist accommodation, and body posture.
2. To evaluate the effects of input devices on writing accuracy, writing speed, and writing efficiency in written exams.
3. To compare several input devices' comfort levels while performing writing with drawing tasks in written exams.

1.4 Conceptual Framework

We briefly review the foundations and main framework that address the issue of completing examinations using the different types of input devices.

HCI focuses on the ways in which humans make, or don't make use of computational artifacts, systems and infrastructures. The research in this field seeks to improve human-computer interaction by measuring the usability of computer interfaces (Grudin, 1992). HCI helps us to precisely understand why desirable properties of computer interfaces are good and other software is bad (Barkhuus, Polichar, 2011). Developers must attempt to 1) understand the factors that determine how people use technology as well as how it relates to psychology, ergonomic and other social and cultural values; 2) to develop tools and techniques to enable creating suitable systems; and 3) to achieve efficient, effective, and safe interaction (Dix, 2004).

Due to the fact that both computer keyboard characteristics and handwriting instruments can affect users' risks for developing injury and the health risk of working conditions, (Ravindra, 2009; Kim, 2014), it is important to understand how different usage of digital input devices may increase muscle activity. Typically, muscle activity is recorded from the right extensor digitorum communis (EDC), right flexor digitorum superficilalis (FDS), and right trapezius (TRAP) muscles (Basmajian and De luca, 1985; Perotto and Delagi, 1994; Jensen et al., 1993). The collection of data by applying Electromyography (EMG) electrodes to the skin is a set of techniques which monitor and record the muscle activity (Kumar, 1996). EMG can provide insight into patterns of muscle activation, intensity of activation, and information about muscle fatigue (Joines et al. 2006).

When introducing a new interaction device in the education context it is necessary to evaluate its use in order to facilitate the decision to move to the use of digital input technology when we are confident that this will not result in a degradation of the examination process. Among information system researchers studying the system acceptance behavior of users, the Technology Acceptance Model (TAM) proposed by Davis is one of the most widely accepted theories. TAM was the first model to mention psychological factors affecting computer acceptance, and the model assumes that both perceived usefulness (PU) and perceived ease of use (PEU) of a new technology are central to influencing the individual’s attitude towards using that technology. An individual’s attitude is hypothesized to influence the behavioral intention to use a certain technology, finally relating to actual use (Davis, 1993).

1.5 Expected benefit

The contribution of this research is a design guideline for input device functionality that is consistent with examination conditions, as well as an outline of how these augment the examination process to facilitate learning. Moreover, this design guideline is aimed at maximizing productivity by reducing students' fatigue and discomfort, reducing errors and increasing input speed, particularly during periods of extended use. Finally, to answer: ‘what exact type of input device makes students feel comfortable while composing their response under examination conditions’. The technology of the text entry interface and its components is reviewed and critically evaluated as to its potential advantages, disadvantages, and implications for student performance. Universities can have more confidence that this will not result in reduced student performance and scores. Thus University boards can take the decision to determine a policy for test administration. This study would help demonstrate the best practices for a University wanting to implement innovation for their examinations. This research result allows an efficient examination process for all parties involved, reflected in decreased correction times and lower copying and printing costs.

Chapter 2

Methods

2.1 Subjects

Twenty university students at Burapha University and King Mongkut's Institute of Technology Ladkrabang, Thailand, (17 males and 3 females), aged between 20-22 years, participated in this study. Participates were recruited to take part in the study through institutional e-mail, by telephone or by personal contract. Eighteen subjects were right hand dominant and all subjects met the criteria, based on their experience of touch typing with no history of upper extremity musculoskeletal disorders or pain, discomfort, trauma or sequelae related to the upper limbs. The typing speed for all subjects was 46.15 words per minute (WPM) with an accuracy of 94.21 percentage. The typing speed was collected using an online typing test program (https://10fastfingers.com/typing-test/thai) with the subject’s own conventional keyboard during subject recruitment. This experimental protocol was approved by the University’s Human Subjects Committee and each subject signed an informed consent prior to their participation in the study.

Table 1 Basic data of participants

N=20	**Classification**
Gender	17 males, 3 females
Right hand dominant	18
Age (years) [mean (range)]	21.27 (20-22)
Typing speed (word per minute) [mean (range)]	46.15 (33- 61.6)
Accuracy (%) [mean (range)]	94.21 (91.226-97.176)
Experienced touch typing (years) [mean (range)]	7.72 (7-10)

2.2 Experimental design

Because the nature of high-stakes assessment limits the amount of experimentation that can be undertaken, it would be suitable to ask students to sit a mock examination. Each of the participants is cited at a different time to participate in the experiment. Before evaluating the various input devices, the subjects could familiarize themselves with different writing devices including Boogie Board, Chromebook, iPad pro, Notebook Keyboard, Ballpoint Pen, and Yoga

Book. Moreover, the seat and work surface were adjusted to match each subject's anthropometry along ANSI/HFES standards [13]. Participants were given different versions of the input devices and one writing exercise that required the participants to complete a paragraph of text containing an alphanumeric and geometrical content. Then students completed a task within 15 minutes (900s) for each different input device. They were also allowed 10 minutes break before starting the next version of the input device, to minimize any residual fatigue effects of the previous condition. Each exercise was followed by completing a questionnaire. Finally, during an interview we asked participants to describe their experience with the writing tool and asked them to compare their experience with all writing devices and their preferences. During the writing sessions, writing accuracy and speed were recorded by screen recorder software. The order of the input devices was randomized and counterbalanced to minimize any potential confusion due to the input device testing order [14-16].

2.3 Equipment and Material

2.3.1 Electromyographer

The Surface Telemetry EMG version BTS Free EMG300 wireless (BTS Bioengineering Corp.), which is a 16-channel system, with a mode rejection of 126 dB was used to collect the surface EMG (sEMG) signals, conditioned with a digital band-pass filter between 10Hz-350Hz. EMG signals were recorded using digital data at a sample rate of 1000 Hz. Disposable Ag/AgCl surface electrodes with an 8 mm diameter pick up area (Ambu Blue Sensor P, REF: P-00-S/50) were placed with a 20-mm inter-electrode spacing over the five muscles.

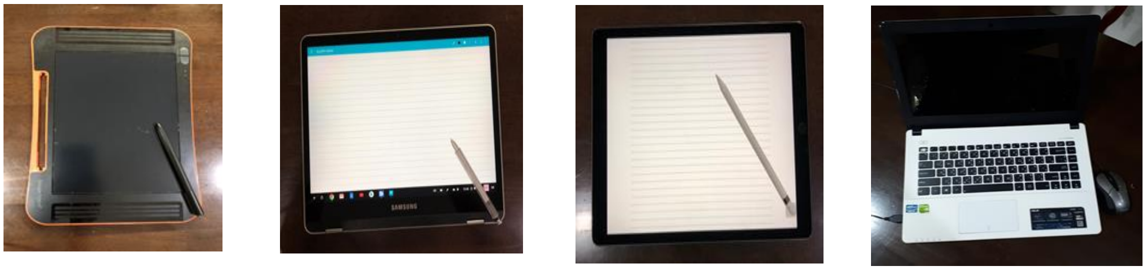
2.3.2 Writing material

In the repeated–measures laboratory experiment, participants performed writing for fifteen minutes sessions on each of six input device conditions including Boogie Board, Chromebook, iPad pro, Keyboard, Ballpoint Pen and paper and Yoga Book (see Figure 1).

The subject wrote on foolscap folio, with line spacing of 8 mm and paper gramature of 56g/m 2(g), using a pen with blue ink ballpoint, with medium point of 0.7 mm and line width of 0.4 mm, with hexagonal barrel. This object was conceived and developed as to be clean and reliable, and it is now the world's most-used writing instrument [17] and more precision with handwriting task [18 &19].

The digital pen technology characteristics included Boogie Board, Chromebook, iPad pro and Yoga Book. Each of the digital pen technologies used in the study were chosen to cover a regular characteristic of digital pen technologies that are on offer. We considered the characteristics based on the accuracy, weight, grips, length, shape, tip size, and other functionality such as touch sensitivity, and electronic erasers.

The Notebook Keyboard had palm rests and tactile feedback. The key spacing (center-to-center distance) was approximately 19 mm on all the keyboard and all conformed to ANSI [13, 20].



Boogie Board Chromebook Ipad Pro Notebook Keyboard

Ballpoint Pen and Paper Yoga Book

Figure 1 Input devices used in study

2.3.3 Muscle activity

Muscle activity was recorded from the trapezius (TRAP), biceps brachii (BB), flexor digitorum superficialis (FDS), extensor carpi radialis brevis (ECRB) [4, 21-23], were selected for their main functions to stabilize and move the upper arm during fine dexterity activities such as handwriting [21], as well as the extensor digitorum communis (EDC) were selected for their major role in extending the phalanges, then the wrist, and the elbow. The EDC tends to separate the fingers as it extends them [4].

2.3.4 Electrode placement

The location of muscles was identified through palpation during voluntary contraction [24&25]. The active electrodes for the TRAP muscle were placed 2 cm lateral to the halfway point between C7 and the right acromium process [26]. The BB was identified by asking the subject to flex their forearm in the supinated position and then the palpate muscle mass in the dorsal aspect of the upper arm emerges [27]. The EDC was identified by palpating the muscle on the dorsal side of the forearm one third of the way up the forearm and having the subject wiggle their fingers. The electrodes were located where the muscle contractions could be felt [24&25]. Similarly, the FDS was located by touching the muscle on the palmar side one third of the way up the forearm and locating the electrodes where the muscle contractions could be felt [24&25]. The ECRB was identified by asking the subject to flex the wrist and palpate the muscle mass approximately 5 cm distal from the lateral epicondyle of the elbow, on the dorsal side of the arm just lateral to the brachioradialis [27] (Figure 2).

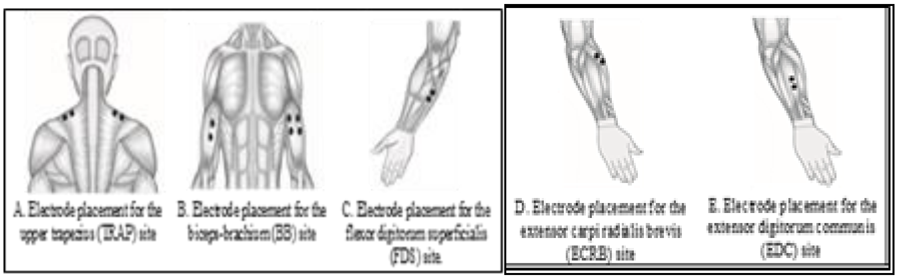

A. Electrode placement for the upper trapezius (TRAP) site
B. Electrode placement for the biceps-brachium (BB) site
C. Electrode placement for the flexor digitorum superficialis (FDS) site
D. Electrode placement for the extensor carpi radialis brevis (ECRB) site
E. Electrode placement for the extensor digitorum communis (EDC) site

Figure 2 Electrode placement

Prior to applying the EMG electrodes to the skin, the electrode contact area was prepared by shaving where necessary and then the skin surface was cleaned with Alcohol 70o GL prior to electrode fixation in order to reduce contact impedance [28]. Then, both proximal and distal upper limb muscles were selected for EMG evaluation. The electrodes were connected to wireless surface sensors and the system communicates with a PC through a WiFi router, which manages 5 probes simultaneously.

2.4 EMG data acquisition and analysis system

The electrodes were connected wirelessly to the BTS Free EMG300 (BTS Bioengineering Corp.) with a common mode rejection of 126 dB and then they were converted from analog-to-digital (A/D). The raw EMG data was fed into a specific analysis system programed with EMG-Analyzer software for further analysis. The analysis system used Root Mean Square (RMS) to eliminate the interference of ambient electromagnetic fields [29], and Butterworth high pass filter at 20 Hz was used to apply additional digital filters to minimize the phase shift phenomenon in the RMS algorithms [29]. Moreover, the analysis system was equipped with a band pass in the range of 10-350 Hz filter that were needed to avoid anti-aliasing effects within sampling [29].

The filtered EMG data from the TRAP, BB, FDS, ECRB and EDC muscles was normalized relative to Maximum Voluntary Contractions (MVC) (see Figure 3), the 10th (static), 50th (median) and 90th (peak) muscle activities were calculated [30]. To obtain the two MVCs, the subjects were instructed to extend their wrists and fingers up against isometric resistance (EDC) and to flex their fingers down against isometric resistance (FDS) with verbal encouragement. To obtain TRAP MVCs, the isometric resistance was applied as subjects performed a continuous single shoulder shrug with their arms at their sides and without bending or twisting at the hips/waist [31&32]. To obtain BB MVCs, the subjects were instructed to exert a force with the elbow flexor muscles and to minimize the involvement of other muscles [33]. Each contraction time lasted for three to five seconds [34]. Five MVCs were collected from which the maximum RMS signal over a 1s period was identified and used to normalize the EMG data.

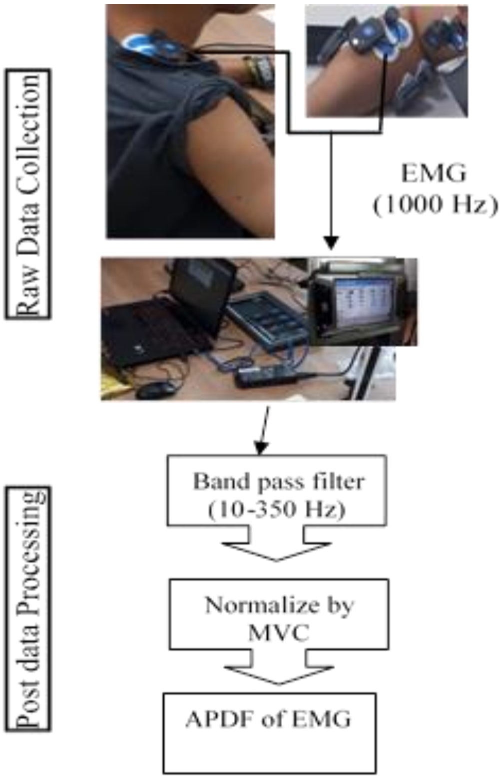


Figure 3 Experimental setup

2.5 Data analysis

In order to reduce variation and condense the colossal data, the section corresponding to the task execution was divided into 6 times periods of electrical activity (EA). The first collection started at the second of 30-s epoch (time window) and the next collection was done every 150 second. An analysis system was calculated EMGs values for every 30-s epoch [35]. Filtered EMGs was normalized by the maximum voluntary contractions (MVC). The data was analyzed with statistical software SPSS for Windows (version 21.0) (SPSS Inc., Chicago, IL, USA).

We employed the method of means contrast based on analysis of variance (ANOVA) for the following reasons: (I) the sample followed a normal distribution, (II) the number of groups to be analyzed was greater than two, (Yoga Book, Chromebook, iPad pro, Boogie Board, note book key board and Ballpoint Pen) (III) all the samples were the same size (this is a small number: 20 subjects). ANOVA is an inferential statistic for analyzing the mean difference between muscle activity. This statistic can control Type I errors. In those cases, having a difference between the means, an additional exploration of the difference among means multiple comparisons test, is needed. Any statistical significance was followed-up with a post-hoc Tukey HSD to determine whether there were significant differences between handwriting and typing devices.

2.6 Result

The results of the EMG analysis indicated variations in muscular behavior during the execution of the writing with drawing tasks in written exams as follows.

1. Trapezius

The results indicated that there were differences in trapezius (TRA) muscle activity between input devices (Figure 4). The Yoga Book had a significantly higher static (10^{th} percentile) muscle activity compared to the Chromebook and Notebook Keyboard ($p<0.05$) and a higher median (50^{th} percentile) muscle activity compared to the Chromebook and iPad respectively ($p<0.05$) whereas the Ballpoint Pen had a significantly higher peak (90^{th} percentile) muscle activity compared to *Notebook Keyboard* ($p<0.05$).

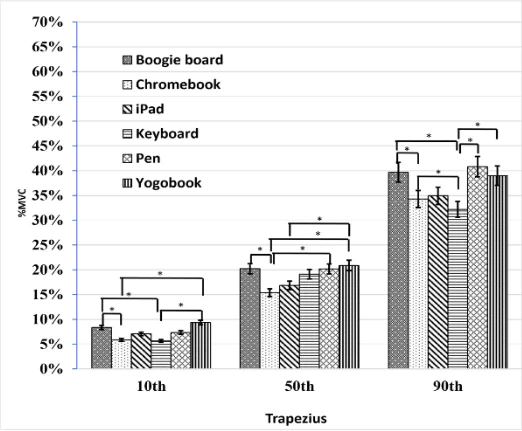


Figure 4 Comparison of 10th 50th and 90th %tile muscle activity of trapezius. *statistical significance at $\alpha = 0.05$.

2. Biceps brachii

There were significant differences in the static median and peak biceps brachii (BB) muscle activities across the input devices (Figure 5). The Boogie Board showed a consistently higher BB activity for the 10th 50th and 90th percentile muscle activity whereas the Notebook Keyboard had a lower static, median and peak ($p<0.05$) muscle activity.

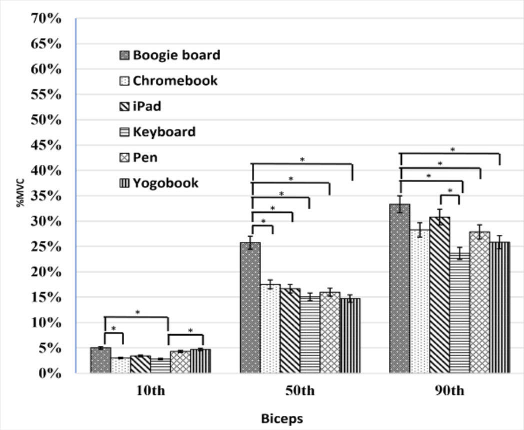


Figure 5 Comparison of 10th 50th and 90th %tile muscle activity of biceps brachii. *statistical significance at $\alpha = 0.05$.

3. Flexor digitorum superficialis

There were significant differences in static median and peak Flexor digitorum superficialis (FDS) muscle activities across input devices (Figure 6). The Ballpoint Pen showed a higher FDS activity for the 50th and 90th percentile muscle activity with the Notebook Keyboard having a consistently lower static ($p<0.05$), median ($p<0.05$) peak ($p<0.05$) muscle activity.

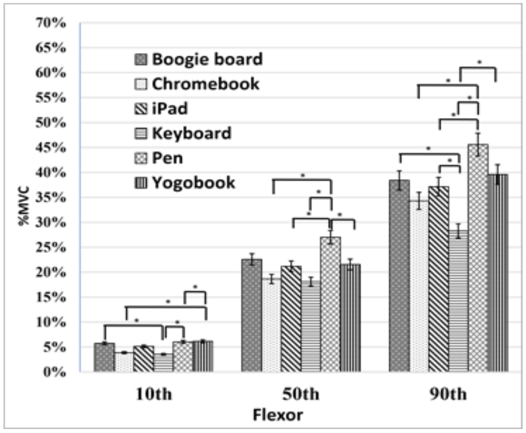


Figure 6 Comparison of 10th 50th and 90th %tile muscle activity of Flexor digitorum superficialis. *statistical significance at $\alpha = 0.05$.

4. Extensor carpi radialis brevis

There were significant differences in static median and peak extensor carpi radialis brevis (ECRB) muscle activities across input devices (Figure 7). The Ballpoint Pen showed higher ECRB activities for the 50th and 90th percentile muscle activity with the Notebook Keyboard having a consistently lower static ($p<0.05$), median ($p<0.05$) peak ($p<0.05$) muscle activity.

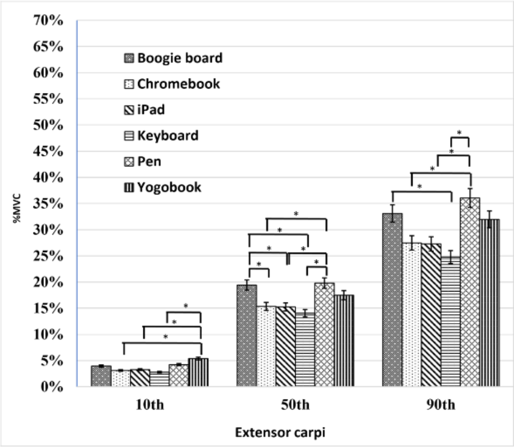


Figure 7 Comparison of 10th 50th and 90th %tile muscle activity of extensor carpi radialis brevis. *statistical significance at $\alpha = 0.05$.

5. Extensor digitorum communis

There were significant differences in the static median and peak extensor digitorum communis (EDC) muscle activities across the input devices (Figure 8). The Yoga Book had the highest peak ($p<0.05$) muscle activity (90th percentile) when compared to Chromebook and Notebook Keyboard respectively, whereas Chromebook showed lower EDC activities for the 50th and 90th percentile muscle activity compared to the Boogie Board and Ballpoint Pen (50th percentile) ($p<0.05$), and Boogie Board, Ballpoint Pen and Yoga Book (90th percentile) ($p<0.05$) respectively. Moreover, the Boogie Board had a higher static muscle activity (10th percentile) when compared to the Chromebook and the Notebook Keyboard ($p<0.05$) respectively.

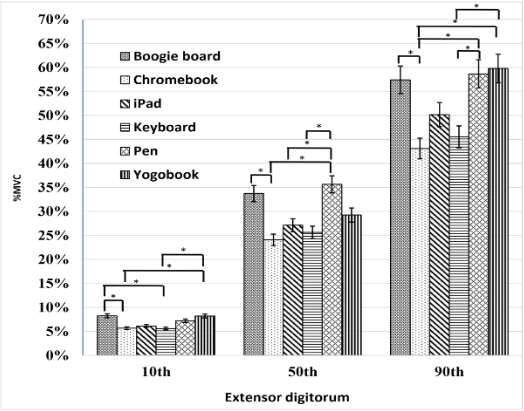


Figure 8 Comparison of 10th 50th and 90th %tile muscle activity of extensor digitorum communis. *statistical significance at α = 0.05.

Chapter 3

Discussion

The present study evaluated whether using digital input devices affects muscle activation, physical risk factors and student's performance, differently than a traditional input instrument. The EMG results indicated that when using a Boogie Board and Ballpoint Pen, participants had a trend of higher FDS and ECRB muscle activities. Although, this present study showed that writing with a Ballpoint Pen required the higher muscle activity for FDS and ECRB muscles compared to Boogie Board, there was no muscle activity difference between the Boogie Board and Ballpoint Pen. This is likely because the Boogie Board tip felt almost like a real pen and friction between the stylus and the slate was similar to Pen and paper [36]. Moreover, during interview, some participants expressed their opinion about enjoying writing with a Boogie Board. "Because the friction between the nib and surface is smooth and resembles regular pen and paper"

When expressing feelings about the Ballpoint Pen, the subjects often commented that "I had to press harder on the tip of the Ballpoint Pen nib to write with it, as the Ballpoint Pen nib is not fluid and smooth". "the feed's ink is not flowing smoothly, so I have to press hard on the Ballpoint Pen nib". This finding in the FDS and ECRB muscle activities corresponds with previous studies. Almeida, et al., [21] found that a pen's muscle activity showed a higher FDS muscle activity compared to ECRB muscle activity while perform handwriting tasks. Due to the difference of grasp patterns, there is an expenditure of different muscle activities (see Figure 9 and Figure 10) [21,37]. Thus, beyond the grasp pattern, the nib and ink feed are the most important component that may affect muscle activity.

Additionally, when using a Boogie Board, participants had consistently higher BB activities for the 10th 50th 90th percentile muscle activities, compared to other devices (Figure 5). However, to our knowledge, there were only a few previous studies using EMG to Boogies Board. This is likely because the adoption of proximal joint movements, such as shoulder elevation and elbow flexion, during the handwriting [21].

Figure 9 Participant' s handwriting samples from Boogie Board

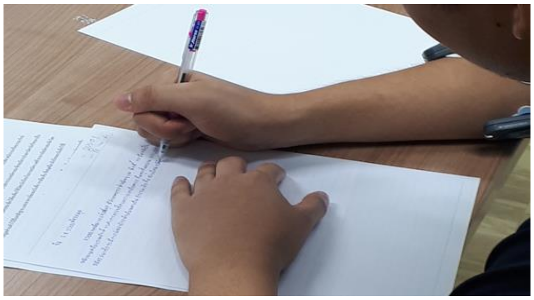


Figure 10 Participant’ s handwriting samples from Ballpoint pen

Moreover, if we analyzed the Boogie Board, the results showed the EDC muscle was higher for the 10th 50th 90th percentile muscle activities compared to other muscle activities (See Fig. 11). This is likely because of the major role of the EDC muscle in extending the phalanges, then the wrist, and the elbow. The EDC tends to separate the fingers as it extends them, and it extends the medial four digits of the hand (Kim et. al., 2014). When expressing feelings about the Boogies Board, the subjects commented that “because of the similarity between a black screen of slate and line color of stylus, it created the difficulty of seeing the appearance of stokes, so I had to alter my writing size”. “Sometimes, I had to press harder on the tip of stylus nib to write with it, because of the color of stokes and black screen is not contrast”. Thus, beyond stylus accuracy and precision of strokes, the contrast between background and text color invoke a stronger connection to one’s writing because it forced them to alter their writing size and variety of pressures, and these may ultimately affect muscle activity (Annett, 2014) (see Fig. 12 A).

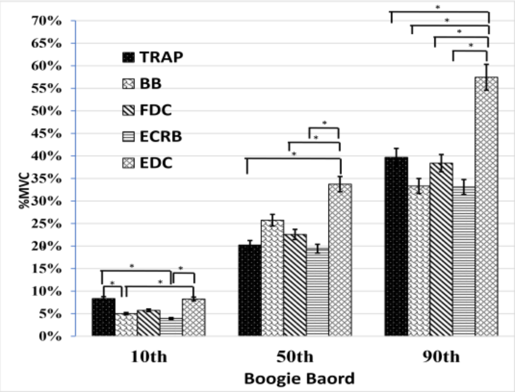
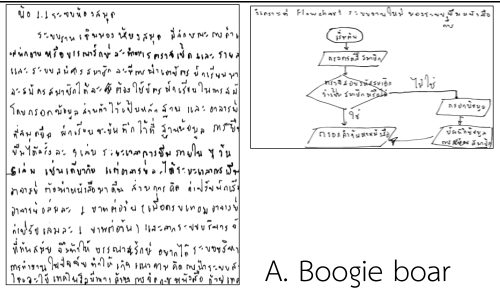
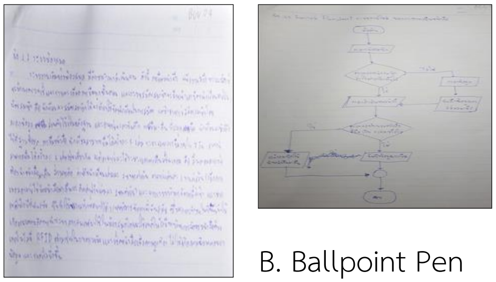


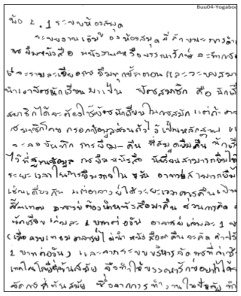
Figure 11 Comparison of the TRAP, BB, FDC, ECRB and EDC muscle activities of the Boogie Board



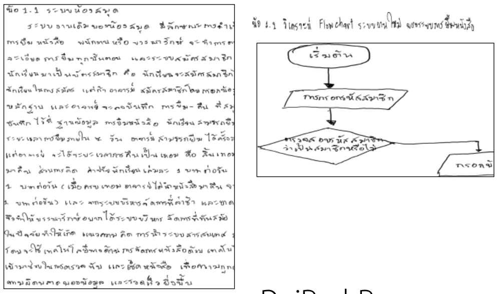
A. Boogie boar



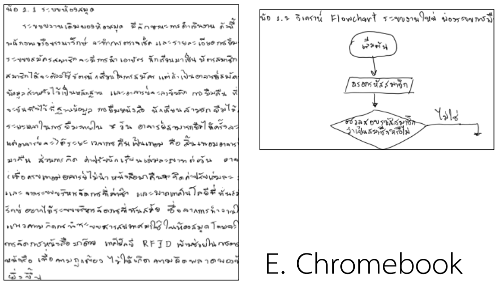
B. Ballpoint Pen



C. Yoga Book



D. iPad Pro



E. Chromebook

Figure 12 The images were cropped to show details of the character' size and the variety of stroke pressure created using Boogie Board compared to handwriting sample from other devices. (Participants No.4)

Interestingly, when using the indirect input device, Yoga Book, participants had consistently higher TRAP, FDS, and EDC activities especially for the 10th percentile muscle activities, compared to Chromebook ($p<0.05$). However, to our knowledge, there were few previous studies using EMGs on Yoga Book. Also, we analyzed the screen recorder and video data regarding the subject’s writing. We found that participants wrote with a variety of pressure in handwriting. Some participants had more difficultly forming and terminating writing with the Yoga book (see Figure 12 C). When participants begin to write, they had to look at the screen to monitor their stroke as well as seeing what they had already written on the screen whilst the subject wrote down on the touch slate (halo keyboard) (see Figure 13). These were thought to be a result of mismatch of the interaction between the nib on the touch slate and the appearance of digital ink on the screen. Many participants commented on the appearance of their stroke beautification and their aesthetics. Moreover, they expressed opinions about a mismatch of the movement between the nib and digital ink on screen, if it forced them to alter their writing size, needed them to write slower and required more attention. Participants most often expressed the opinion “difficult to control” “The writing on the line are not easier to master than other devices”. These may lead to a higher energy expenditure with the maintenance of a motor pattern in handwriting tasks [10, 21]. Therefore, inking on screen with alter their writing size would likely have higher muscle activities.

However, if we analyzed TRAP, FDS, and EDC activities for the 50th 90th percentile muscle activity, then we see that the Yoga Book indicated variations in muscle activities. The possible reason would be the difference in adapting movement patterns for individuals. When handwriting events were improperly handled, many more modified their behavior than participants were comfortable with, so they would have a different movement style [10] and eventually it may lead to the difference of muscle activities.

Figure 13 The usage of Yoga Book with stylus

When using Chromebook and iPad Pro, participants had consistently lower FDS (see Fig. 6) and EDC (Figure 8) activities for the 10th 50th 90th percentile muscle activities. Although, the iPad pro had a higher FDS and EDC muscle activity than Chromebook, there were no muscle activity differences between the Chromebook and iPad Pro. This is likely because the both of stylus had pressure sensitivity and low latency to enable smooth inking on the screen [38]. Moreover, when participants expressed opinions about Chromebook and iPad Pro, they were frequently described as “different and easy to control” by participants. Participants had positive writing experiences with them and felt that their display surface felt “smooth” which is a prominent feature identified as an ideal characteristic. In additions, with unintended touch, participants could write in a comfortable position and could rest their palm on the display (see Fig. 14 and Fig.15). Many participants felt that the stylus tip felt almost like a real pen and there was enough friction between the stylus and screen to feel natural. Interestingly, stroke beautification and productivity were similar between them (see Figure 12 D and E). Thus, our analysis of all the descriptive and letter formation shows that lower FDS and EDC muscle activities among Chromebook and iPad Pro may be caused by the mature grasp pattern which is the handwriting activity itself modifying the muscular performance when controlling the stylus on the surface [39]

Figure 14 The usage of Chromebook

Figure 15 The usage of iPad Pro

When typing on the Notebook Keyboard they had consistently the lowest BB (Figure 5), FDS (Figure 6) and ECRB (Figure 7) muscle activity for the 10th 50th and 90th %tile muscle activities. The possible reason might be due to subjects being able to rest either their fingers or hands during typing [4,21] as well as an adjustment the chair and work surface to match each user's anthropometry in accordance with ANSI/HFES standards [13]. Thereby the preferred working position for most Notebook Keyboard participants is the forearms being parallel to the floor and elbows at the sides; this allows the hands to move easily over the keyboard [40 &41] (see Figure 16). If not, then Notebook Keyboard for long period of time may affect muscle strain and risk of carpal tunnel syndrome or other kinds of repetitive strain injury [42-45]. Moreover, previous studies, Callegari, et al., [46] and Nag, et al., [47] found that when using the Notebook Keyboard, the hand and wrist rest would support the user's wrists as they type, and the BB and EDC muscle activity showed a reduced percentage of fatigue. This may lead to a muscle-selective reduction in the occurrence of fatigue and thus provide direct evidence that they may prevent work-related musculoskeletal disorders

Figure 16 The usage of Notebook Keyboard

In addition, if we analyze the Notebook Keyboard's muscle activity especially for the 50th percentile muscle activity: TRAP (19.118 %MVC), BB (15.0680 %MVC), FDS (18.0930 %MVC), ECRB (14.0560 %MVC) and EDC (25.6406 %MVC), then we see that the EDC muscle is the highest muscle activity. This may play a major role in extending the phalanges, then the wrist, and finally the elbow. It also tends to separate the fingers as it extends them, and it extends the medial for digits of the hand. Similarly, the TRAP muscle is a higher muscle activity. This may be a function of the TRAP muscle to support the arm [4,48]. This finding corresponds with previous studies, Kim et. al., [4] and found that the Notebook Keyboard's muscle activity showed a tendency to be an intermediate TRAP muscle activity. The reason is the difference in muscle activities by typing force [4,49], higher typing forces applied to a Notebook Keyboard are more likely to be affected by key activation force than the typing speed [4]. As this present study allowed subjects to type at their preferred speed, this may have affected the difference in muscle activity by typing force [4,49]. As a result, muscle activity may be problematic due to the typing forces reduce with lower key activation forces and that the lower typing forces resulted in reduced muscle activity [4], and the study condition where subjects may use different typing forces, further clarification should be made in future studies to draw conclusive information.

Chapter 4

Conclusion

Universities allocate more budget each year on test administration, and the use of digital input devices are increasingly being used, especially for test administration. However, computer keyboard characteristics and handwriting instruments can affect user's risks for developing injury and health risks from working conditions. Therefore, it is important to understand whether using digital input devices affects muscle activation, physical risk factors and student's performance. In conclusion, the study demonstrated that there were differences between handwriting and typing devices for generating writing with drawing task in written exams. This work provided insight evidence of the difference between input devices in muscle activity. According to the result obtained in the EMG activities, using a Boogie Board, and Ballpoint Pen may be detrimental to muscle damage after trying to generate writing tasks for long sessions, especially in written exams that require the student express their knowledge with alphanumeric and geometrical content. Moreover, when using indirect input device like the Yoga Book, participants had an indicating a trend of increasing in TRAP, FDS and EDC muscle activities. These were thought to be a result of the pressure on the nib of the Ballpoint Pen and the altered of the writing size when using the Boogie board and Yoga Book. These could be crucial when the accumulate over time. Besides, participants had positive experiences with Chromebook and iPad Pro and felt that these were ideal characteristics for generating writing. When typing on the *Notebook Keyboard*, subjects had the lowest BB, FDS, and ECRB muscle activity, this may imply that using a Notebook Keyboard may be an efficient tool for generating writing with drawing task, especially geometrical content in written exams. Thus, when a task involves alphanumeric and geometrical content, it is more likely that the technological advances could be most advantageous [50].

Limitations and Future direction.

Even though over a short experimental period, the results of this experiment indicated the tendency of user's risk for developing health problems from long-term use of IT instruments for writing. There are a number of limitation to this study. Fist, we eliminated specific factors: the thinking time, short and long answer for writing, and the revision level by participants that may impact or influence the real writing examination. Second, this study focused only on muscle activity and did not include typing forces. Since Notebook Keyboard had consistently the lowest muscle activities, it is uncertain if participants used substantially different typing forces that reduce with lower key activation forces and that the lower typing forces resulted in reduced muscle activity [4], future research should take into account the limitation of this study by including using a force platform and investigating the individual keystroke force profiles.

Chapter 5

Output

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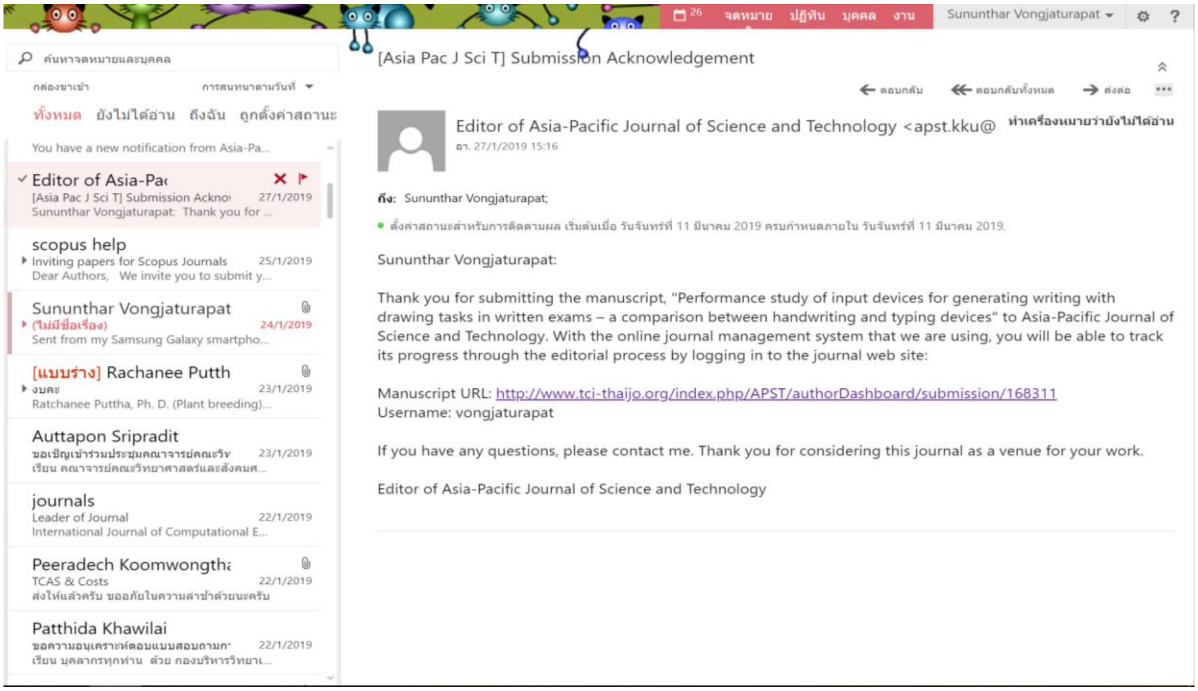

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Performance study of input devices for generating writing with drawing tasks in written exams – a comparison between handwriting and typing devices

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Abstract

Examinations are an assessment and evaluation tool at University. These can be performed using different types of input devices to complete them. This present study investigated whether using digital input devices affects muscle activation than a traditional input instrument. We monitored the Electromyography (EMG) activity of trapezius (TRAP), biceps brachii (BB), flexor digitorum superficialis (FDS), extensor carpi radialis brevis (ECRB) and extensor digitorum communis (EDC) muscle activity during generative writing with drawing tasks in written exams using Boogie Board, Chromebook, iPad pro, Notebook Keyboard, Ballpoint Pen, and Yoga Book. Twenty university students were included in this study. The results showed Boogie Board, and Ballpoint Pen used the most muscle activity. When using Boogie Board and Ballpoint Pen, participants had a trend of using FDS and ECRB muscle activity the most. Additionally, Boogie Board had consistently the greatest BB muscle activity. Moreover, when using the indirect input device, Yoga Book, participants had an indicating a trend of increasing in TRAP, FDS and EDC muscle activities. In contrast, Chromebook and iPad pro had showed consistently lower FDS and EDC muscle activities. However, when typing on the Notebook Keyboard, subjects had the least BB, FDS, and ECRB muscle activity. Therefore, when a long writing scenario is required, a Notebook Keyboard may be a more suitable interface, especially in education. The findings also suggest that handwriting devices have a greater potential energy expenditure in performing handwriting tasks and muscular damage with the keeping of motor patterns in handwriting tasks.

Keywords: *Assessments; Electromyography; Ergonomic Design; Human Computer Interaction*

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1. Introduction

Examinations are a very common assessment and evaluation tool at University. Universities are spending more money each year on test administration, such as preparing exam scripts and answer sheets, as well as storing such scripts and sheets. If we analyze all characteristics of examination administration, we see that digital input devices such as keyboards and digital handwriting instruments make possible a more efficient examination process for test administration and review [1&2].

Previous research results have indicated that both computer keyboard characteristics and handwriting instruments can affect users’ risks for developing injury and health risks from working conditions, especially during long sessions [3&4]. Moreover, in examination conditions, existing research indicates that assessment can be impacted by the type of device that was used to complete it [5 & 6]. However, digital input devices are increasingly being used especially for test administration, e.g. pen-based testing in drawing, sketching, graphing, and writing text containing a mathematical equation [7-10]. Although digital input devices are increasingly widely used, it is still unclear exactly what type of digital input devices could be more suitable for generating writing with drawing tasks in written exams [11&12].

The key question in new generation writing scenario is whether using digital input devices affects muscle activation differently than a traditional input instrument differently than a traditional input instruments. Thus, it is necessary to understand the use of input devices that may affect physical risk factors and student performance. In this work we intend to empirically answer our research question. We compare generating writing input using six types of device: Notebook Keyboard, Pen and Paper, Yoga Book, Chromebook, iPad pro, and Boogie Board.

2. Methods

2.1 Subjects

Twenty university students at Burapha University and King Mongkut's Institute of Technology Ladkrabang, Thailand, (17 males and 3 females), aged between 20-22 years, participated in this study. Participates were recruited to take part in the study through institutional e-mail, by telephone or by personal contract. Eighteen subjects were right-hand and all subjects met the criteria, based on their experience of touch typing with no history of upper limbs musculoskeletal disorders or pain, morbidity or sequelae related to the upper extremity. The typing accuracy for all subjects was 94.21 percentage with a speed of 46.15 words per minute (WPM). The typing speed and accuracy were collected using an online typing test program (https://10fastfingers.com/typing-test/thai) with the subject’s own conventional keyboard. This experimental protocol was approved by the University’s Human Subjects Committee and each subject signed an informed consent prior to their participation in this study.

Table 1 Basic data of the participants

N=20	**Classification**
Gender	17 males, 3 females
Right hand dominant	18
Age (years) [mean (range)]	21.27 (20-22)
Typing speed (word per minute) [mean (range)]	46.15 (33- 61.6)
Accuracy (%) [mean (range)]	94.21 (91.226-97.176)
Experienced touch typing (years) [mean (range)]	7.72 (7-10)

2.2 Experimental design

Because the nature of high-stakes assessment limits the amount of experimentation that can be undertaken, it would be suitable to ask students to sit a mock examination. Each of the subjects is cited at a different time to participate in this study. Before evaluating the various input devices, the subjects could familiarize themselves with different writing devices including Boogie Board, Chromebook, iPad pro, Notebook Keyboard, Ballpoint Pen, and Yoga Book. Moreover, the seat and work surface were adjusted to match each subject's anthropometry along ANSI/HFES standards [13]. Participants were given different versions of the input devices and one writing exercise that required the participants to complete a paragraph of text containing an alphanumeric and geometrical content. Then students completed a task within 15 minutes (900s) for each different input device. They were also allowed 10 minutes break before starting the next version of the input device, to minimize any residual fatigue effects of the previous condition. Each exercise was followed by completing a questionnaire. Finally, during an interview we asked participants to describe their experience with the writing tool and asked them to compare their experience with all writing devices and their preferences. During the writing sessions, writing speed and accuracy were recorded by screen recorder software. The order of the input devices was randomized and counterbalanced to minimize any confusion due to the input device testing order [14-16].

2.3 Equipment and Material

2.3.1 Electromyographer

The Surface Telemetry EMG version BTS Free EMG300 wireless (BTS Bioengineering Corp.), which is a 16-channel system, with a mode rejection of 126 dB was used to collect the surface EMG (sEMG) signals, conditioned with a digital band-pass filter between 10Hz-350Hz. EMG signals were recorded using digital data at a sample rate of 1000 Hz. Disposable Ag/AgCl surface electrodes with an 8 mm diameter pick up area (Ambu Blue Sensor P, REF: P-00-S/50) were placed with a 20-mm inter-electrode spacing over the five muscles.

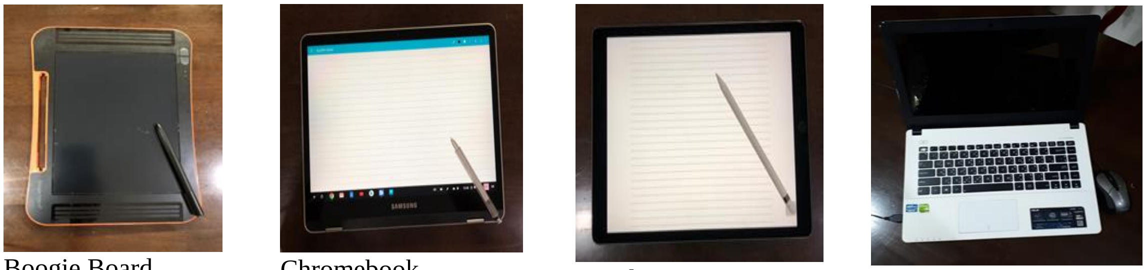
2.3.2 Writing material

In the repeated–measures laboratory experiment, participants performed writing for fifteen minutes sessions on each of six input device conditions including Boogie Board, Chromebook, iPad pro, Keyboard, Ballpoint Pen and paper and Yoga Book (see Figure 1).

The subject wrote on foolscap folio, with line spacing of 8 mm and paper gramature of 56g/m 2(g), using a pen with blue ink ballpoint, with medium point of 0.7 mm and line width of 0.4 mm, with hexagonal barrel. This object was conceived and developed as to be clean and reliable, and it is now the world's most-used writing instrument [17] and more precision with handwriting task [18 &19].

The digital pen technology characteristics included Boogie Board, Chromebook, iPad pro and Yoga Book. Each of the digital pen technologies used in the study were chosen to cover a regular characteristic of digital pen technologies that are on offer. We considered the characteristics based on the accuracy, weight, grips, length, shape, tip size, and other functionality such as touch sensitivity, and electronic erasers.

The Notebook Keyboard had palm rests and tactile feedback. The key spacing (center-to-center distance) was approximately 19 mm on all the keyboard and all conformed to ANSI [13, 20].



Boogie Board Chromebook Ipad Pro Notebook Keyboard

Ballpoint Pen and Paper Yoga Book

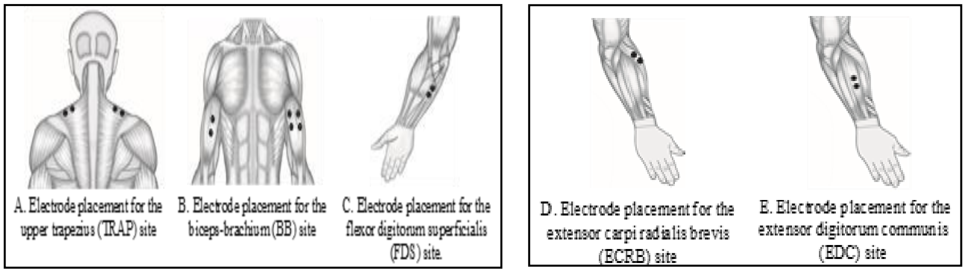
Figure 1 Input devices used in study

2.3.3 Muscle activity

Muscle activity was recorded from the trapezius (TRAP), biceps brachii (BB), flexor digitorum superficialis (FDS), extensor carpi radialis brevis (ECRB) [4, 21-23], were selected for their main functions to stabilize and move the upper arm during fine dexterity activities such as handwriting [21], as well as the extensor digitorum communis (EDC) were selected for their major role in extending the phalanges, then the wrist, and the elbow [4].

2.3.4 Placement of the electrodes

The location of muscles was identified through palpation during voluntary contraction [24&25]. Place active electrodes over TRAP muscle at the halfway point between C7 and the right acromion process [26]. The BB was identified by asking the subject to flex their forearm in the supinated position [27]. The EDC was identified by palpating the muscle on the dorsal side of the forearm one third of the way up the forearm and having the subject wiggle their fingers. The active electrodes were placed where the muscle contractions could be felt [24&25]. Similarly, the FDS was located by touching the muscle on the palmar side one third of the way up the forearm [24&25]. The ECRB was identified by asking the subject to flex the wrist and palpate the muscle mass approximately 5 cm distal from the lateral epicondyle of the elbow [27] (Figure 2).



A. Electrode placement for the upper trapezius (TRAP) site

B. Electrode placement for the biceps-brachium (BB) site

C. Electrode placement for the flexor digitorum superficialis (FDS) site.

D. Electrode placement for the extensor carpi radialis brevis (ECRB) site

E. Electrode placement for the extensor digitorum communis (EDC) site

Figure 2 Electrode placement.

To reduce contact impedance, the electrode contact area was prepared by shaving where necessary and then the skin surface was cleaned with Alcohol 70° GL [28]. Then, the electrodes were connected to wireless surface sensors and the system communicates with a PC through a WiFi router, which manages 5 probes simultaneously.

2.4 EMG data acquisition and analysis system

The electrodes were connected wirelessly to the BTS Free EMG300 (BTS Bioengineering Corp.) with a mode rejection of 126 dB and then they were converted from analog-to-digital (A/D). The raw EMG data was fed into a specific analysis system programed with EMG-Analyzer software for further analysis. The analysis system used Root Mean Square (RMS) to remove the interference of ambient electromagnetic fields [29], and Butterworth high pass filter at 20 Hz was used to apply additional digital filters to minimize the phase shift phenomenon in the RMS algorithms [29]. Moreover, the analysis system was equipped with a band pass in the range of 10-350 Hz filter that were needed to avoid anti-aliasing effects within sampling [29].

The filtered EMG data from the TRAP, BB, FDS, ECRB and EDC muscles was normalized relative to Maximum Voluntary Contractions (MVC) (see Figure 3), the 90th, 50th and 10th muscle activities were computed [30]. To obtain the two MVCs, the isometric resistance was applied as subjects performed a extend their wrists and fingers up (EDC) and flex their fingers down (FDS) with verbal encouragement. To obtain TRAP MVCs, the subjects were instructed to perform a shoulder shrug with their arms at their sides [31&32]. To obtain BB MVCs, the subjects were instructed to exert a force with the elbow flexor muscles [33]. Each contraction time lasted three seconds [34]. Five MVCs were collected from which the maximum RMS signal over a 1s period was identified and used to normalize the EMG data.

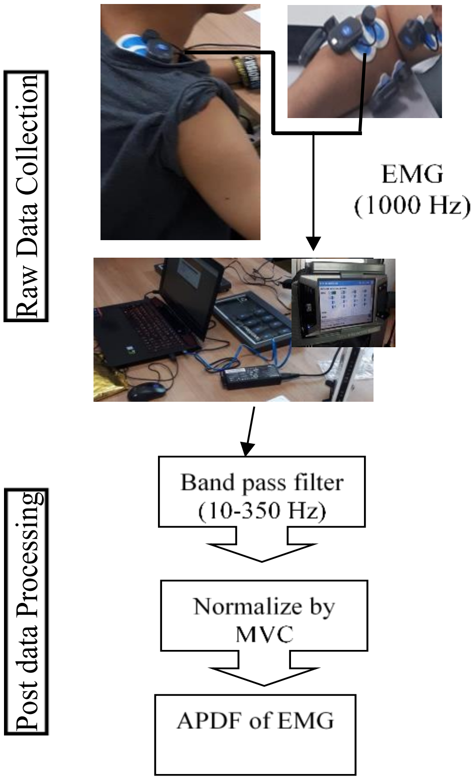


Figure 3 Experimental setup

2.5 Data analysis

To reduce variation and condense the colossal data, the section corresponding to the task execution was divided into 6 times periods of electrical activity (EA). The first collection started at the second of 30-s epoch (time window) and the next collection was done every 150 second. An analysis system was calculated EMGs values for every 30-s epoch [35]. Filtered EMGs was normalized by the maximum voluntary contractions (MVC). The data was analyzed with statistical software SPSS for Windows (version 21.0) (SPSS Inc., Chicago, IL, USA). We employed the method of means contrast based on analysis of variance (ANOVA) for the following reasons: (I) the sample followed a normal distribution, (II) the number of groups was greater than two, (Yoga Book, Chromebook, iPad pro, Boogie Board, note book key board and Ballpoint Pen) (III) all the samples were the same size (20 participants). ANOVA is an inferential statistic for analyzing the mean difference between muscle activity. This statistic can control Type I errors. Any statistical significance was followed-up with a post-hoc Tukey HSD to determine whether there were significant differences between handwriting and typing devices.

3 Result

The research results indicated variations in muscle activity during the performance of the writing with drawing tasks in written exams as follows.

3.1 Trapezius

The results of the EMG analysis indicated that there were differences in trapezius (TRA) muscle activity between input devices (Figure 4). The Yoga Book had a significantly higher static (10th percentile) muscle activity compared to the Chromebook and Notebook Keyboard ($p<0.05$) and a higher median (50th percentile) muscle activity compared to the Chromebook and iPad respectively ($p<0.05$) whereas the Ballpoint Pen had a significantly higher peak (90th percentile) muscle activity compared to *Notebook Keyboard* ($p<0.05$).

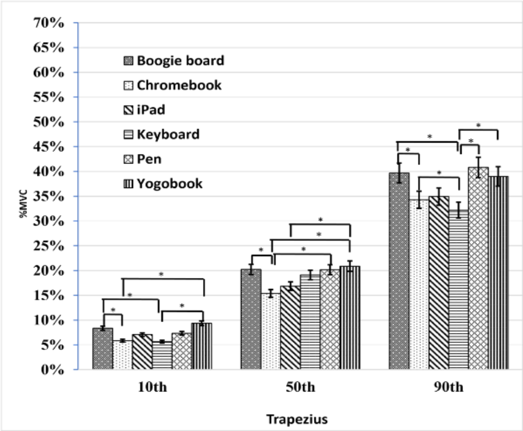


Figure 4 Comparison of 10th 50th and 90th %tile muscle activity of trapezius. * statistical significance at $\alpha = 0.05$.

3.2 Biceps brachii

There were significant differences in the 10th 50th and 90th %tile of biceps brachii (BB) muscle activities across the input devices (Figure 5). The Boogie Board showed a consistently higher BB activity for the 10th 50th and 90th percentile muscle activity whereas the Notebook Keyboard had a lower static, median and peak ($p<0.05$) muscle activity.

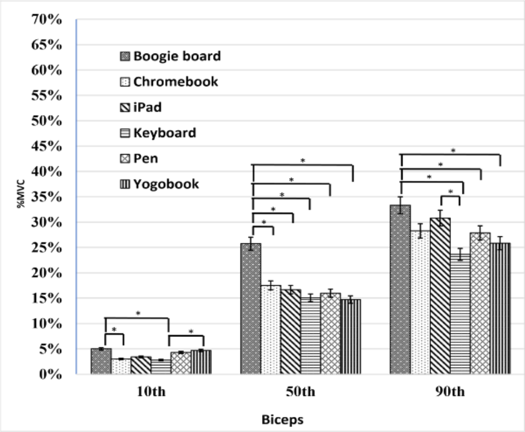


Figure 5 Comparison of 10th 50th and 90th %tile muscle activity of biceps brachii. *statistical significance at $\alpha = 0.05$.

3.3 Flexor digitorum superficialis

There were significant differences in the 10th 50th and 90th %tile of Flexor digitorum superficialis (FDS) muscle activities across input devices (Figure 6). The Ballpoint Pen showed a higher FDS activity for the 50th and 90th percentile muscle activity with the Notebook Keyboard having a consistently lower static ($p<0.05$), median ($p<0.05$) peak ($p<0.05$) muscle activity.

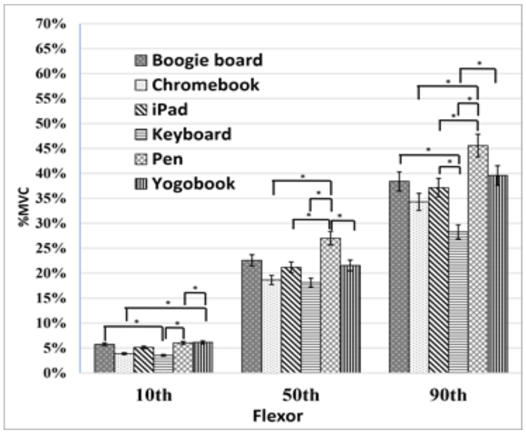


Figure 6 Comparison of 10th 50th and 90th %tile muscle activity of Flexor digitorum superficialis. *statistical significance at α = 0.05.

3.4 Extensor carpi radialis brevis

There were significant differences in the 10th 50th and 90th %tile of extensor carpi radialis brevis (ECRB) muscle activities across input devices (Figure 7). The Ballpoint Pen showed higher ECRB activities for the 50th and 90th percentile muscle activity with the Notebook Keyboard having a consistently lower static ($p<0.05$), median ($p<0.05$) peak ($p<0.05$) muscle activity.

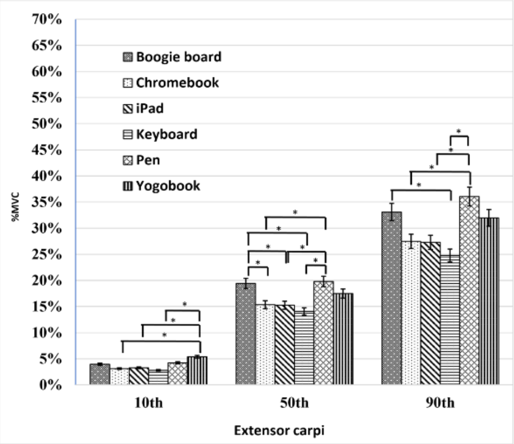


Figure 7 Comparison of 10th 50th and 90th %tile muscle activity of extensor carpi radialis brevis. *statistical significance at α = 0.05.

3.5 Extensor digitorum communis

There were significant differences in the 10th 50th and 90th %tile of extensor digitorum communis (EDC) muscle activities across the input devices (Figure 8). The Yoga Book had the highest peak ($p<0.05$) muscle activity (90^{th} percentile) when compared to Chromebook and Notebook Keyboard respectively, whereas Chromebook showed lower EDC activities for the 50^{th} and 90^{th} percentile muscle activity compared to the Boogie Board and Ballpoint Pen (50^{th} percentile) ($p<0.05$), and Boogie Board, Ballpoint Pen and Yoga Book (90^{th} percentile) ($p<0.05$) respectively. Moreover, the Boogie Board had a higher static muscle activity (10^{th} percentile) when compared to the Chromebook and the Notebook Keyboard ($p<0.05$) respectively.

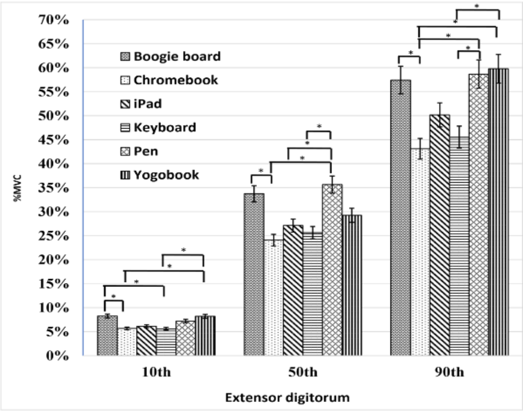


Figure 8 Comparison of 10th 50th and 90th %tile muscle activity of extensor digitorum communis. *statistical significance at α = 0.05.

4. Discussion

The present study evaluated whether using digital input devices affects muscle activation, physical risk factors and student's performance, differently than a traditional input instrument. The EMG results indicated that when using a *Boogie Board and Ballpoint Pen*, participants had a trend of higher FDS and ECRB muscle activities. Although, this present study showed that writing with a Ballpoint Pen required the higher muscle activity for FDS and ECRB muscles compared to Boogie Board, there was no muscle activity difference between the Boogie Board and Ballpoint Pen. This is likely because the Boogie Board tip felt almost like a real pen and friction between the stylus and the slate was similar to Pen and paper [36]. Moreover, during interview, some participants expressed their opinion about enjoying writing with a Boogie Board. "Because the friction between the nib and surface is smooth and resembles regular pen and paper"

When expressing feelings about the Ballpoint Pen, the subjects often commented that "I had to press harder on the tip of the Ballpoint Pen nib to write with it, as the Ballpoint Pen nib is not fluid and smooth". "the feed's ink is not flowing smoothly, so I have to press hard on the Ballpoint Pen nib". This finding in the FDS and ECRB muscle activities corresponds with previous studies. Almeida, et al., [21] found that a pen's muscle activity showed a higher FDS muscle activity compared to ECRB muscle activity while perform handwriting tasks. Due to the difference of grasp patterns, there is an expenditure of different muscle activities (see Figure 9 and Figure 10) [21,37]. Thus, beyond the grasp pattern, the nib and ink feed are the most important component that may affect muscle activity.

Additionally, when using a Boogie Board, participants had consistently higher BB activities for the 10^{th} 50^{th} 90^{th} percentile muscle activities, compared to other devices (Figure 5). However, to our knowledge, there were only a few previous studies using EMG to Boogies Board. This is likely because the adoption of proximal joint movements, such as shoulder elevation and elbow flexion, during the handwriting [21].

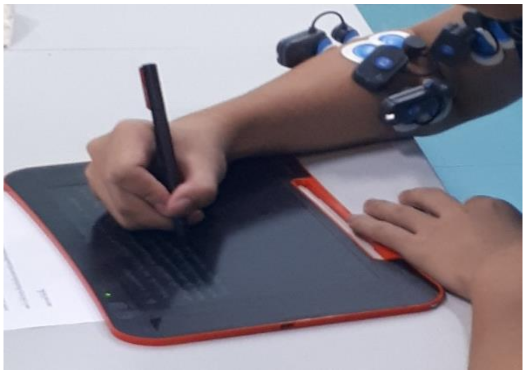


Figure 9 Participant' s handwriting samples from Boogie Board

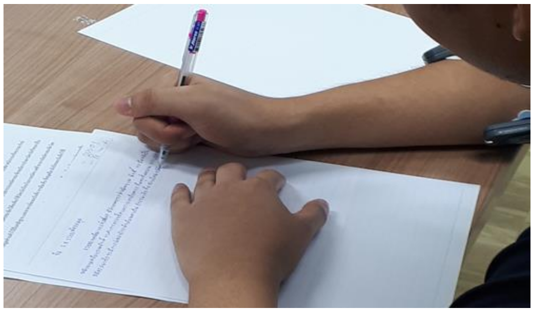


Figure 10 Participant' s handwriting samples from Ballpoint pen

Moreover, if we analyzed the Boogie Board, the results showed the EDC muscle was higher for the 10th 50th 90th percentile muscle activities compared to other muscle activities (See Figure 11). This is likely because of the major role of the EDC muscle in extending the phalanges, then the wrist, and the elbow. The EDC tends to separate the fingers as it extends them, and it extends the medial four digits of the hand [4].

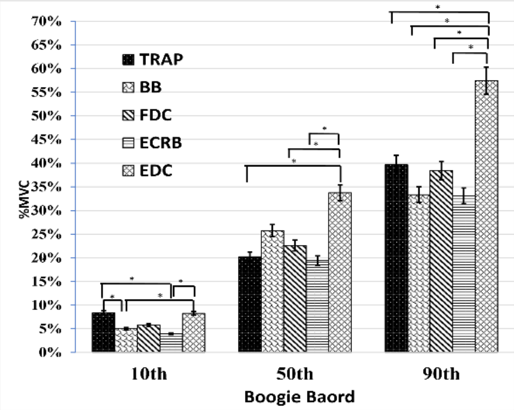
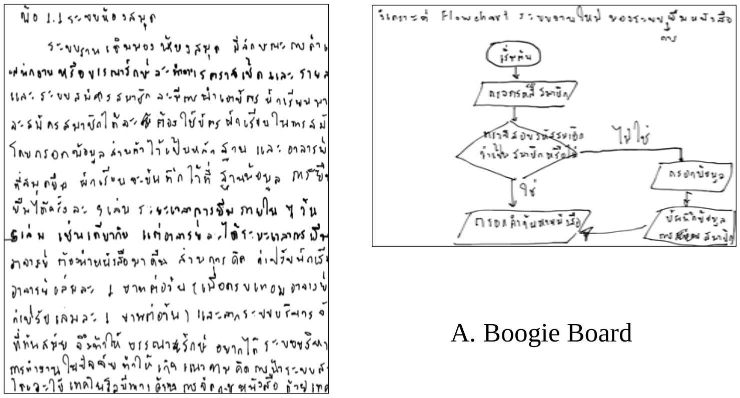


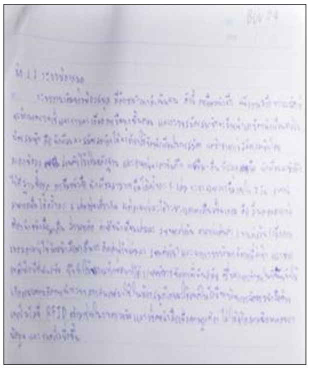
Figure 11 Comparison of the TRAP, BB, FDC, ECRB and EDC muscle activities of the Boogie Board

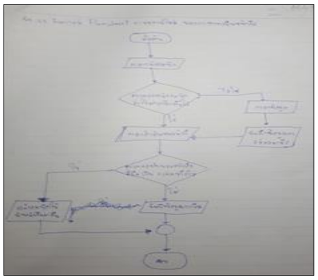
Besides, when expressing feelings about the Boogies Board, the subjects commented that "because of the similarity between a black screen of slate and line color of stylus, it created the difficulty of seeing the appearance of stokes, so I had to alter my writing size". "Sometimes, I had to press harder on the tip of stylus nib to write with it, because of the color of stokes and black screen is not contrast" (see Figure 12). Thus, our analysis of all the descriptive indicate that beyond stylus accuracy and precision of strokes, the contrast between background and text color invoke a stronger connection to one's writing because it forced them to alter their writing size and variety of pressures, and these may ultimately affect muscle activity [10].



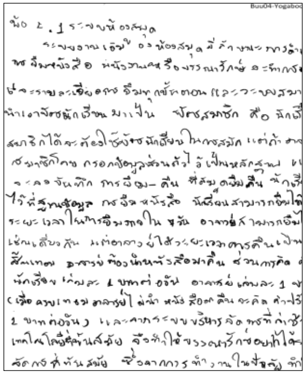
A. Boogie Board

Figure 12 The images were cropped to show details of the character' size and the variety of stroke pressure created using Boogie Board compared to handwriting sample from other devices. (Participants No.4)





B. Ballpoint Pen



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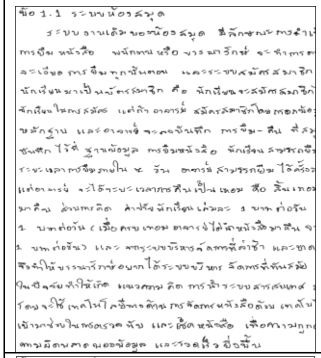
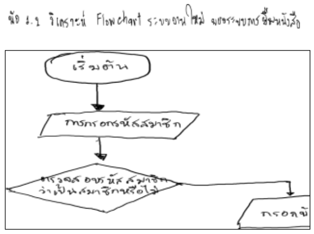
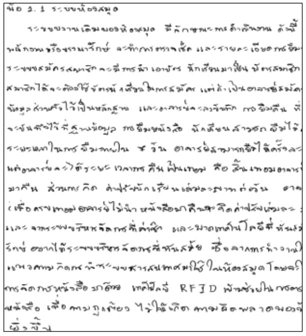
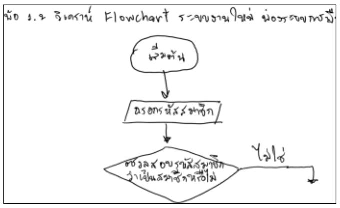
C.Yoga Book





D. iPad Pro





E. Chromebook

Figure 12 The images were cropped to show details of the character' size and the variety of stroke pressure created using Boogie Board compared to handwriting sample from other devices. (Participants No.4) (Cont.)

Interestingly, when using the indirect input device, Yoga Book, participants had consistently higher TRAP, FDS, and EDC activities especially for the 10th percentile muscle activities, compared to Chromebook ($p<0.05$). However, to our knowledge, there were few previous studies using EMGs on Yoga Book. Also, we analyzed the screen recorder and video data regarding the subject's writing. We found that participants wrote with a variety of pressure in handwriting. Some participants had more difficultly forming and terminating writing with the Yoga book (see Figure 12 C). When participants begin to write, they had to look at the screen to monitor their stroke as well as seeing what they had already written on the screen whilst the subject wrote down on the touch slate (halo keyboard) (see Figure 13). These were thought to be a result of mismatch of the interaction between the nib on the touch slate and the appearance of digital ink on the screen. Many participants commented on the appearance of their stroke beautification and their aesthetics. Moreover, they expressed opinions about a mismatch of the movement between the nib and digital ink on screen, if it forced them to alter their writing size, needed them to write slower and required more attention. Participants most often expressed the opinion "difficult to control" "The writing on the line are not easier to master than other devices". These may lead to a higher energy expenditure with the maintenance of a motor pattern in handwriting tasks [10, 21]. Therefore, inking on screen with alter their writing size would likely have higher muscle activities.

However, if we analyzed TRAP, FDS, and EDC activities for the 50th 90th percentile muscle activity, then we see that the Yoga Book indicated variations in muscle activities. The possible reason would be the difference in adapting movement patterns for individuals. When handwriting events were improperly handled, many more modified their behavior than participants were comfortable with, so they would have a different movement style [10] and eventually it may lead to the difference of muscle activities.

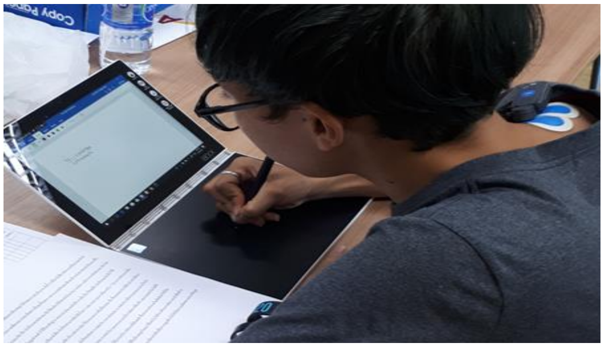


Figure 13 The usage of Yoga Book with stylus

When using *Chromebook* and *iPad Pro*, participants had consistently lower FDS (see Fig. 6) and EDC (Figure 8) activities for the 10th 50th 90th percentile muscle activities. Although, the *iPad pro* had a higher FDS and EDC muscle activity than *Chromebook*, there were no muscle activity differences between the *Chromebook* and *iPad Pro*. This is likely because the both of stylus had pressure sensitivity and low latency to enable smooth inking on the screen [38]. Moreover, when participants expressed opinions about *Chromebook* and *iPad Pro,* they were frequently described as "different and easy to control" by participants. Participants had positive writing experiences with them and felt that their display surface felt "smooth" which is a prominent feature identified as an ideal characteristic. In additions, with unintended touch, participants could write in a comfortable position and could rest their palm on the display (see Fig. 14 and Fig.15). Many participants felt that the stylus tip felt almost like a real pen and there was enough friction between the stylus and screen to feel natural. Interestingly, stroke beautification and productivity were similar between them (see Figure 12 D and E). Thus, our analysis of all the descriptive and letter formation shows that lower FDS and EDC muscle activities among Chromebook and iPad Pro may be caused by the mature grasp pattern which is the handwriting activity itself modifying the muscular performance when controlling the stylus on the surface [39].

Figure 14 The usage of Chromebook

Figure 15 The usage of iPad Pro

When typing on the Notebook Keyboard they had consistently the lowest BB (Figure 5), FDS (Figure 6) and ECRB (Figure 7) muscle activity for the 10th 50th and 90th %tile muscle activities. The possible reason might be due to subjects being able to rest either their fingers or hands during typing [4,21] as well as the seat and work surface was adjusted to match each user's anthropometry with ANSI/HFES standards [13]. Thereby the preferred working position for most Notebook Keyboard participants is the forearms being parallel to the floor and elbows at the sides; this provided the hands to move easily over the Notebook keyboard [40 &41] (see Figure 16). If not, then Notebook Keyboard for long period of time may affect muscle strain and risk of carpal tunnel syndrome or other kinds of repetitive strain injury [42-45]. Moreover, previous studies, Callegari, et al., [46] and Nag, et al., [47] found that when using the Notebook Keyboard, the hand and wrist rest would support the user's wrists as they type, and the BB and EDC muscle activity showed a reduced percentage of fatigue. This may lead to a muscle-selective reduction in the occurrence of fatigue [46]. Thus, preponderance of the evidence is that they may prevent work-related musculoskeletal disorders.

Figure 16 The usage of Notebook Keyboard

In addition, if we analyze the Notebook Keyboard's muscle activity especially for the 50th percentile muscle activity: TRAP (19.118 %MVC), BB (15.0680 %MVC), FDS (18.0930 %MVC), ECRB (14.0560 %MVC) and EDC (25.6406 %MVC), then we see that the EDC muscle is the highest muscle activity. This may play a major role in extending the phalanges, then the wrist, and finally the elbow. It also tends to separate the fingers as it extends them, and it extends the medial for digits of the hand. Similarly, the TRAP muscle is a higher muscle activity. This may be a function of the TRAP muscle to support the arm [4,48]. This finding corresponds with previous studies, Kim et. al., [4] and found that the Notebook Keyboard's muscle activity showed a tendency to be an intermediate TRAP muscle activity. The reason is the difference in muscle activities by typing force [4,49], higher typing forces applied to a Notebook Keyboard are more likely to be affected by key activation force than the typing speed [4]. As this study provided participants to type at their preferred speed, this may have affected the difference in muscle activity by typing force [4,49]. As a result, muscle activity may be problematic due to the typing forces reduce with lower key activation forces and that the lower typing forces resulted in reduced muscle activity [4], and the study condition where subjects may use different typing forces, further clarification should be made in future studies to draw conclusive information.

5. Conclusion

Universities allocate more budget each year on test administration, and the use of digital input devices are increasingly being used, especially for test administration. However, computer keyboard characteristics and handwriting instruments can affect user's risks for developing injury and health risks from working conditions. Therefore, it is important to understand whether using digital input devices affects muscle activation, physical risk factors and student's performance. In conclusion, the study demonstrated that there were differences between handwriting and typing devices for generating writing with drawing task in written exams. This work provided insight evidence of the difference between input devices in muscle activity. According to the result obtained in the EMG activities, using a Boogie Board, and Ballpoint Pen may be detrimental to muscle damage after trying to generate writing tasks for long sessions, especially in written exams that require the student express their knowledge with alphanumeric and geometrical content. Moreover, when using indirect input device like the Yoga Book, participants had an indicating a trend of increasing in TRAP, FDS and EDC muscle activities. These were thought to be a result of the pressure on the nib of the Ballpoint Pen and the altered of the writing size when using the Boogie board and Yoga Book. These could be crucial when the accumulate over time. Besides, participants had positive experiences with Chromebook and iPad Pro and felt that these were ideal characteristics for generating writing. When typing on the *Notebook Keyboard*, subjects had the lowest BB, FDS, and ECRB muscle activity, this may imply that using a Notebook Keyboard may be an efficient tool for generating writing with drawing task, especially geometrical content in written exams. Thus, when a task involves alphanumeric and geometrical content, it is more likely that the technological advances could be most advantageous [50].

6. Limitations and Future direction.

Even though over a short experimental period, the results of this experiment indicated the tendency of user's risk for developing health problems from long-term use of IT instruments for writing. There are a number of limitation to this study. Fist, we eliminated specific factors: the thinking time, short and long answer for writing, and the revision level by participants that may impact or influence the real writing examination. Second, this study focused only on muscle activity and did not include typing forces. Since Notebook Keyboard had consistently the lowest muscle activities, it is uncertain if participants used substantially different typing forces that reduce with lower key activation forces and that the lower typing forces resulted in reduced muscle activity [4], future research should take into account the limitation of this study by including using a force platform and investigating the individual keystroke force profiles.

7. Acknowledgements

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8. References

[1] Kurtz BL, Esmaili A, Tate SR. Active Learning During Lecture Using Tablets. SIGCSE '14 Proceedings of the 45th ACM technical symposium Computer science education, 2014. p. 121-126.

[2] Maiorana C, Sgarbossa L, Salomoni V. New methodologies in teaching e-structural mechanics using WWW, Comput Appl Eng Educ. 2008;16:189-210.

[3] Ravindra S, Hoffmann ER, Luximon A. Effects of pen design on drawing and writing performance. Applied Ergonomics 2009;40(2): 292-301.

[4] Kim JH, Aulck L, Bartha MC, Harper CA, Johnson PW. Differences in typing forces, muscle activity, comfort, and typing performances among virtual, notebook, and desktop keyboards. Applied Ergonomics 2014;45:1406-1413.

[5] Zabramski S, Neelakannan S. Paper equal screen; A comparison of a pen-based figural creativity test in computerized and paper form. Proceeding DESIRE '11 Proceedings of the Second Conference on Creativity and Innovation in Design; 2011. p. 47-50.

[6] Huff KC. The comparison of mobile devices to computers for web-based assessments. Computers in Human Behavior 2015;49: 208-212.

[7] Dualde BJ, Buendia V, Lemus, F. Cano LJ, Gutierrez.C, Cuba J, Lopez MA. Redesigning engineering courses by introducing digital ink technology. Paper presented at the IEEE Frontiers in Education Conference (FIE), October 23-26, Oklahoma, USA,2013.

[8] Kowalski SE, Kowlski FV, Gardner TQ. Lessons Learned When Gathering Real-Time Formative Assessment in the University Classroom Using Tablet PCs. Frontiers in Education Conference; FIE '09. 39TH IEEE, 2009 Oct 18-21 p.1-5.

[9] Isabwe GMN. Using Assessment for Learning Mathematics with Mobile Tablet Based Solutions. International Journal of Emerging Technologies in Learning 2014; 9(2): 29-36.

[10] Annett M, Anderson F, Bischof WF, Gupta A. The Pen is Mightier: Understanding Stylus Behaviour While inking on tablets. Proceeding of Graphics Interface Conference 2014, May 7-9; Canadian Information Processing Society Toronto, Ont., Canada, 2014. p. 193-200.

[11] Mogey N. Typing compared with handwriting for essay examination at university: letting the students choose. ALT-J. Research in Learning Technology 2010;18(1):29-47.

[12] Moge N. Students' choices between typing and handwriting in examination. Active learning in higher education 2012;13(2):117-128.

[13] ANSI/HFES100-2007. Human Factors Engineering of Computer Workstations. Human Factors and Ergonomics Society. Santa Monica, CA, USA; 2007.

[14] Gerard MJ, Armstrong TJ, Franzblau A, Martin BJ, Rempel DM. The effects of key switch stiffness on typing force, finger electromyography, and subjective discomfort. American Industrial Hygiene Association Journal 1999;60 (6):762–769.

[15] Gerard MJ, Armstrong TJ, Martin BJ, Rempel DM. The effects of work pace on intra-subject and inter-subject keying force, electromyography, and fatigue. Hum. Factors, in press. 2001.

[16] Pereira A, Hsieh CM, Laroche C, Rempel D. The effect of keyboard key spacing on typing speed, error, usability, and biomechanics, part 2: vertical spacing. Hum. Fact. J. Hum. Fact. Ergonomic. Soc 2013;56(4):752-759.

[17] Perry R. How products are made. Ballpoint pen. High Beam Research, Inc. 1998.

[18] Sassoon R. The art and science of handwriting. Oxford: Intellect; 2004.

[19] Goonetilleke RS, Hoffmann ER, Luximon A. Effects of pen design on drawing and writing performance. Appl Ergon 2009;40(2):292–301.

[20] International Organization for Standardization. Ergonomics of human—system interaction: Part 410. Design criteria for physical input devices (Reference No. ISO9241-410:2008). Geneva, Switzerland: Author 2008.

[21] Almeida PH, Cruz DM, Magna LA, Ferrigno IS. An electromyographic analysis of two handwriting grasp patterns. J. lectromyogr Kinesiol 2013; 23(4):838-43.

[22] Leonard JH, Kok KS, Ayiesha R. Prolonged writing task: comparison of electromyographic analysis of upper trapezius muscle in subjects with or without neck pain. Clin Ther 2010;161(1):29–33.

[23] Steinhart NS, Leurer KM. Analysis of proximal and distal muscle activity during handwriting tasks. Am J Occup Ther 2007; 61(4):392–8.

[24] Basmajian JV, De Luca CJ. Muscles Alive: Their Functions Revealed by Electromyography. Williams & Wilkins: Baltimore;1985.

[25] Perotto A, Delagi EF. Anatomical Guide for the Electromyographer: the Limbs and Trunk. Charles C. Thomas, Springfield, Ill., USA; 1994.

[26] Jensen C. Vasseljen O, Westgaard RH. The influence of electrode position on bipolar surface electromyogram recordings of the upper trapezius muscle. Eur. J. Appl. Physiol. Occup. Physiol 1993; 67 (3): 266-273.

[27] Criswell E. Cram's introduction to Surface Electromyography. 2nd ed.: United States of America; 2011.

[28] Hermens H, Freriks B, Merletti R, Stegeman D, Blok J, Rau G. European recommendations for surface electromyography – SENIAM 8. Enschede: Roessing Research and Development B.V. 1999.

[29] Peter K. The ABC of EMG-A Practical Introduction to Kinesiological Electromyography. Noraxon INC. USA;2005.

[30] Jonsson B. Measurement and evaluation of local muscular strain in the shoulder during contained work. J. Hum. Ergol 1982;11 (1):73-88.

[31] HarmsRingdahl K, Ekholm J, Schuldt K, Linder J, Ericson MO. Assessment of jet pilots' upper trapezius load calibrated to maximal voluntary contraction and a standardized load. J. Electromyogr. Kinesiol 1996; 6 (1): 67-72.

[32] Schuldt K, Harmsringdahl K. Activity levels during isometric test contractions of neck and shoulder muscles. Scand. J. Rehabil. Med 1988;20 (3):117-127.

[33] Riley ZA, Baudry S, Enoka RM. Reflex inhibition in human biceps brachii decreases with practice of a fatiguing contraction. Journal of neurophysiology 2008:100(5); 2843-51.

[34] Soderberg GL, Knutson LM. A guide for use and interpretation of kinesiologic electromyographic data. Phys Ther. 2000;80(5):485-98.

[35] Keenan KG, Cuevas FJV. Epoch length to accurately estimate the amplitude of interference EMG is likely the result of unavoidable amplitude cancellation. Biomed Signal Process Control. 2008; 3(2): 154–162.

[36] Boogie Board. [Internet]. 2018 [cited 2018 Jul 5]. Available from: https://www.myboogieboard.com/**.**

[37] Benbow M. Principles and practice of teaching handwriting. In: Henderson A, Pehoski C, editors. Hand function in the child: foundations for remediation. 2nd ed. St. Louis: Elsevier; 2006. p. 321–44.

[38] Statt N. Here's why Apple made the stylus that Steve Jobs hated: Styluses and screens have come a long way. The Verge. Vox Media. Archived from the original on September 10, 2015.

[39] Mann A M, Hinrichs U, Quigley A. Digital pen technology’s suitable to support handwriting leaning. The impact of pen and touch technology on education Hammond, Chapter 2., p.7-17. 2015.

[40] Arunesh C, Pankaj C, Surinder D, Rajender K. Ergonomics in the Office Environment: A Review. Proceedings of international conference on energy and environment; 2009: March, 19-21.

[41] Michael YCL, Justin GY, Jack TD. Evaluating the effect of four different pointing device designs on upper extremity posture and muscle activity during mousing tasks. Applied Ergonomics 2015; 47: 259-264.

[42] Hobday S. Keyboards designed to fit hand & reduce postural stress. Paper presented by S.W. Hobday at the ninth congress of the international ergonomic association, 2–6 September 1985, Bournemouth, England. PCD Maltron Ltd. 1985.

[43] Hobday S. A Keyboard to Increase Productivity and Reduce Postural Stress". Paper presented at The Annual International Industrial Ergonomics and Safety Conference, June 8–10, 1988 New 0rleans. PCD Maltron Ltd. 1988.

[44] Hobday, S. A Keyboard to Eliminate the Stress and the Pain". Computer Related Upper Limb Disorder. Paper presented to the 19th Annual Congress of IMART 4th May 1994. PCD Maltron Ltd. 1994.

[45] David R. The Split Keyboard: An Ergonomics Success Story. Human Factors: The Journal of the Human Factors and Ergonomics Society 2008;50 (3): 385–392.

[46] Callegari B, Maniglia M. Hand rest and wrist support are effective in preventing fatigue during prolonged typing. Journal of Hand Therapy 2018;31: 42-51.

[47] Nag PK, Pal S, Nag A, Vyas H. Influence of arm and wrist support on forearm and back muscle activity in computer keyboard operation. Appl Erg 2009; 40(2):86-291.

[48] Jensen C, Finsen L, Sogaard K, Christensen H. Musculoskeletal symptoms and duration of computer and mouse use. Int. J. Indus. Ergonom 2002;30 (45): 265-275.

[49] Armstrong TJ, Foulke JA, Martin BJ, Gerson J, Rempel DM. Investigation of applied forces in alphanumeric keyboard work. American Industrial Hygiene Association Journal 1994; 55 (1):30–35.

[50] Estibaliz AM, Candida DC, Jose IN, Inmaculada MJ, Manuel FRO. A comparative Study of Handwriting and Computer Typing in Note-taking by University Students. Media Education Research Journal 2016; 48(14): 99-107.

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Reference

[1] Kurtz BL, Esmaili A, Tate SR. Active Learning During Lecture Using Tablets. SIGCSE '14 Proceedings of the 45th ACM technical symposium Computer science education, 2014. p. 121-126.

[2] Maiorana C, Sgarbossa L, Salomoni V. New methodologies in teaching e-structural mechanics using WWW, Comput Appl Eng Educ. 2008;16:189-210.

[3] Ravindra S, Hoffmann ER, Luximon A. Effects of pen design on drawing and writing performance. Applied Ergonomics 2009;40(2): 292-301.

[4] Kim JH, Aulck L, Bartha MC, Harper CA, Johnson PW. Differences in typing forces, muscle activity, comfort, and typing performances among virtual, notebook, and desktop keyboards. Applied Ergonomics 2014;45:1406-1413.

[5] Zabramski S, Neelakannan S. Paper equal screen; A comparison of a pen-based figural creativity test in computerized and paper form. Proceeding DESIRE '11 Proceedings of the Second Conference on Creativity and Innovation in Design; 2011. p. 47-50.

[6] Huff KC. The comparison of mobile devices to computers for web-based assessments. Computers in Human Behavior 2015;49: 208-212.

[7] Dualde BJ, Buendia V, Lemus, F. Cano LJ, Gutierrez.C, Cuba J, Lopez MA. Redesigning engineering courses by introducing digital ink technology. Paper presented at the IEEE Frontiers in Education Conference (FIE), October 23-26, Oklahoma, USA,2013.

[8] Kowalski SE, Kowlski FV, Gardner TQ. Lessons Learned When Gathering Real-Time Formative Assessment in the University Classroom Using Tablet PCs. Frontiers in Education Conference; FIE '09. 39TH IEEE, 2009 Oct 18-21 p.1-5.

[9] Isabwe GMN. Using Assessment for Learning Mathematics with Mobile Tablet Based Solutions. International Journal of Emerging Technologies in Learning 2014; 9(2): 29-36.

[10] Annett M, Anderson F, Bischof WF, Gupta A. The Pen is Mightier: Understanding Stylus Behaviour While inking on tablets. Proceeding of Graphics Interface Conference 2014, May 7-9; Canadian Information Processing Society Toronto, Ont., Canada, 2014. p. 193-200.

[11] Mogey N. Typing compared with handwriting for essay examination at university: letting the students choose. ALT-J. Research in Learning Technology 2010;18(1):29-47.

[12] Moge N. Students' choices between typing and handwriting in examination. Active learning in higher education 2012;13(2):117-128.

[13] ANSI/HFES100-2007. Human Factors Engineering of Computer Workstations. Human Factors and Ergonomics Society. Santa Monica, CA, USA; 2007.

[14] Gerard MJ, Armstrong TJ, Franzblau A, Martin BJ, Rempel DM. The effects of key switch stiffness on typing force, finger electromyography, and subjective discomfort. American Industrial Hygiene Association Journal 1999;60 (6):762–769.

[15] Gerard MJ, Armstrong TJ, Martin BJ, Rempel DM. The effects of work pace on intra-subject and inter-subject keying force, electromyography, and fatigue. Hum. Factors, in press. 2001.

[16] Pereira A, Hsieh CM, Laroche C, Rempel D. The effect of keyboard key spacing on typing speed, error, usability, and biomechanics, part 2: vertical spacing. Hum. Fact. J. Hum. Fact. Ergonomic. Soc 2013;56(4):752-759.

[17] Perry R. How products are made. Ballpoint pen. High Beam Research, Inc. 1998.

[18] Sassoon R. The art and science of handwriting. Oxford: Intellect; 2004.

[19] Goonetilleke RS, Hoffmann ER, Luximon A. Effects of pen design on drawing and writing performance. Appl Ergon 2009;40(2):292–301.

[20] International Organization for Standardization. Ergonomics of human—system interaction: Part 410. Design criteria for physical input devices (Reference No. ISO9241-410:2008). Geneva, Switzerland: Author 2008.

[21] Almeida PH, Cruz DM, Magna LA, Ferrigno IS. An electromyographic analysis of two handwriting grasp patterns. J. lectromyogr Kinesiol 2013; 23(4):838-43.

[22] Leonard JH, Kok KS, Ayiesha R. Prolonged writing task: comparison of electromyographic analysis of upper trapezius muscle in subjects with or without neck pain. Clin Ther 2010;161(1):29–33.

[23] Steinhart NS, Leurer KM. Analysis of proximal and distal muscle activity during handwriting tasks. Am J Occup Ther 2007; 61(4):392–8.

[24] Basmajian JV, De Luca CJ. Muscles Alive: Their Functions Revealed by Electromyography. Williams & Wilkins: Baltimore;1985.

[25] Perotto A, Delagi EF. Anatomical Guide for the Electromyographer: the Limbs and Trunk. Charles C. Thomas, Springfield, Ill., USA; 1994.

[26] Jensen C.Vasseljen O, Westgaard RH. The influence of electrode position on bipolar surface electromyogram recordings of the upper trapezius muscle. Eur. J. Appl. Physiol. Occup. Physiol 1993; 67 (3): 266-273.

[27] Criswell E. Cram's introduction to Surface Electromyography. 2nd ed.: United States of America; 2011.

[28] Hermens H, Freriks B, Merletti R, Stegeman D, Blok J, Rau G. European recommendations for surface electromyography – SENIAM 8. Enschede: Roessing Research and Development B.V. 1999.

[29] Peter K. The ABC of EMG-A Practical Introduction to Kinesiological Electromyography. Noraxon INC. USA;2005.

[30] Jonsson B. Measurement and evaluation of local muscular strain in the shoulder during contained work. J. Hum. Ergol 1982;11 (1):73-88.

[31] HarmsRingdahl K, Ekholm J, Schuldt K, Linder J, Ericson MO. Assessment of jet pilots' upper trapezius load calibrated to maximal voluntary contraction and a standardized load. J. Electromyogr. Kinesiol 1996; 6 (1): 67-72.

[32] Schuldt K, Harmsringdahl K. Activity levels during isometric test contractions of neck and shoulder muscles. Scand. J. Rehabil. Med 1988;20 (3):117-127.

[33] Riley ZA, Baudry S, Enoka RM. Reflex inhibition in human biceps brachii decreases with practice of a fatiguing contraction. Journal of neurophysiology 2008:100(5); 2843-51.

[34] Soderberg GL, Knutson LM. A guide for use and interpretation of kinesiologic electromyographic data. Phys Ther. 2000;80(5):485-98.

[35] Keenan KG, Cuevas FJV. Epoch length to accurately estimate the amplitude of interference EMG is likely the result of unavoidable amplitude cancellation. Biomed Signal Process Control. 2008; 3(2): 154–162.

[36] Boogie Board. [Internet]. 2018 [cited 2018 Jul 5]. Available from: https://www.myboogieboard.com/.

[37] Benbow M. Principles and practice of teaching handwriting. In: Henderson A, Pehoski C, editors. Hand function in the child: foundations for remediation. 2nd ed. St. Louis: Elsevier; 2006. p. 321–44.

[38] Statt N. Here's why Apple made the stylus that Steve Jobs hated: Styluses and screens have come a long way. The Verge. Vox Media. Archived from the original on September 10, 2015.

[39] Mann A M, Hinrichs U, Quigley A. Digital pen technology's suitable to support handwriting leaning. The impact of pen and touch technology on education Hammond, Chapter 2., p.7-17. 2015.

[40] Arunesh C, Pankaj C, Surinder D, Rajender K. Ergonomics in the Office Environment: A Review. Proceedings of international conference on energy and environment; 2009: March, 19-21.

[41] Michael YCL, Justin GY, Jack TD. Evaluating the effect of four different pointing device designs on upper extremity posture and muscle activity during mousing tasks. Applied Ergonomics 2015; 47: 259-264.

[42] Hobday S. Keyboards designed to fit hand & reduce postural stress. Paper presented by S.W. Hobday at the ninth congress of the international ergonomic association, 2–6 September 1985, Bournemouth, England. PCD Maltron Ltd. 1985.

[43] Hobday S. A Keyboard to Increase Productivity and Reduce Postural Stress". Paper presented at The Annual International Industrial Ergonomics and Safety Conference, June 8–10, 1988 New 0rleans. PCD Maltron Ltd. 1988.

[44] Hobday, S. A Keyboard to Eliminate the Stress and the Pain". Computer Related Upper Limb Disorder. Paper presented to the 19th Annual Congress of IMART 4th May 1994. PCD Maltron Ltd. 1994.

[45] David R. The Split Keyboard: An Ergonomics Success Story. Human Factors: The Journal of the Human Factors and Ergonomics Society 2008;50 (3): 385–392.

[46] Callegari B, Maniglia M. Hand rest and wrist support are effective in preventing fatigue during prolonged typing. Journal of Hand Therapy 2018;31: 42-51.

[47] Nag PK, Pal S, Nag A, Vyas H. Influence of arm and wrist support on forearm and back muscle activity in computer keyboard operation. Appl Erg 2009; 40(2):86-291.

[48] Jensen C, Finsen L, Sogaard K, Christensen H. Musculoskeletal symptoms and duration of computer and mouse use. Int. J. Indus. Ergonom 2002;30 (45): 265-275.

[49] Armstrong TJ, Foulke JA, Martin BJ, Gerson J, Rempel DM. Investigation of applied forces in alphanumeric keyboard work. American Industrial Hygiene Association Journal 1994; 55 (1):30–35.

[50] Estibaliz AM, Candida DC, Jose IN, Inmaculada MJ, Manuel FRO. A comparative Study of Handwriting and Computer Typing in Note-taking by University Students. Media Education Research Journal 2016; 48(14): 99-107.