DESIGN AND DEVELOPMENT OF ERGONOMICS MOUSE TRAY FOR OFFICE WORKERS

TIONG JING YIN
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UNIVERSITI TEKNIKAL MALAYSIA MELAKA
2018

DESIGN AND DEVELOPMENT OF ERGONOMICS MOUSE TRAY FOR OFFICE WORKERS

This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering

by

TIONG JING YIN

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941101-08-5512

FACULTY OF MANUFACTURING ENGINEERING

2018

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **DESIGN AND DEVELOPMENT OF ERGONOMICS MOUSE TRAY FOR OFFICE WORKERS**

Sesi Pengajian: **2017/2018 Semester 2**

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2. Hal ini adalah kerana ianya merupakan projek yang ditaja sepenuhnya oleh syarikat luar (ErgoWorks Sdn. Bhd.) dan hasil kajiannya adalah sulit.

Sekian dimaklumkan. Terima kasih.

Yang benar,

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PER: STATUS MAKLUMAT TERHAD UNTUK MAKLUMAT DALAM PROJEK SARJANA MUDA OLEH TIONG JING YIN.

Adalah dimaklumkan bahawa Tiong Jing Yin (941101-08-5512) telah menganalisa laporan-laporan kami dalam menjayakan projek sarjana muda beliau. Sebahagian besar maklumat yang beliau gunakan adalah bersifat peribadi dan sulit, kerana melibatkan maklumat peribadi klien-klien kami. Oleh itu, diminta supaya laporan projek sarjana muda beliau diberi status "terhad".

Sekian, terima kasih.

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Date : 11 June 2017

DECLARATION

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Date : 11 June 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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(Dr. Radin Zaid Bin Radin Umar)

ABSTRAK

Beberapa penerbitan melaporkan kepada isu-isu muskuloskeletal dalam kalangan pekerja pejabat. Hanya sedikit usaha campur tangan memberi tumpuan kepada menyelesaikan masalah ini dari sudut kawalan kejuruteraan pandangan. Siasatan lanjut telah dijalankan antara pekerja pejabat dan didapati isu-isu yang berulang seperti miskin postur, pergerakan berulang-ulang, dan tempoh penggunaan tetikus boleh meningkatkan faktor risiko atas pekerja pejabat. Upper Limb Musculoskeletal Disorders(ULMDs) telah menjadi sangat biasa dalam kalangan pekerja pejabat. Projek ini bertujuan untuk merekabentuk dan membangunkan satu dulang tetikus prototaip yang kos efektif dan boleh memperbaiki postur pekerja pejabat bila menggunakan tetikus komputer. Metodologi ini dibahagikan kepada tiga fasa - fasa 1, Fasa 2 dan Fasa 3. Fasa 1 merangkumi kajian kesusasteraan, meneliti laporan-laporan penilaian profesional ergonomik yang dikumpul dari syarikat ergonomik. Fasa 2 adalah penilaian keperluan pekerja pejabat, spesifikasi Reka bentuk, produk conceptualization, mengumpul dimensi papan kekunci dan mengecil turun rekabentuk konsep dengan menggunakan ciri dan kaedah pemeriksaan dan mendapatkan maklum balas daripada profesional ergonomik. Di samping itu, Solidworks digunakan untuk melakukan simulasi dan analisis ke atas faktor tekanan dan keselamatan cadangan dulang tetikus. Analisis kos dibangunkan dengan menggunakan analisis Breakeven untuk mengira kuantiti dan kos breakeven prototaip polylactic asid (PLA) dan prototaip Aluminium. Selain itu, lima orang pakar-pakar profesional ergonomik akan dipilih untuk menguji dan menilai cadangan dulang tetikus. Kesimpulannya, ia adalah diperhatikan bahawa postur profesional ergonomik telah bertambah baik dan jarak antara menaip dan komputer tetikus telah dikurangkan. Hasil purata masa yang diambil oleh subjek untuk menyelesaikan tugasan yang diberi dengan menggunakan dulang tetikus yang dicadangkan adalah lebih pendek daripada masa yang diambil dengan menggunakan cara tradisional.

ABSTRACT

Several publications reported high prevalence of musculoskeletal issues among office workers. Only a few interventions efforts have focused on solving the problem from an engineering control point of view. Further investigations of office workers identified recurring issues such as poor posture, repetitive motion and duration of using mouse may increase the risk factors of Upper Limb Musculoskeletal Disorders(ULMDs). ULMDs are become very common in office working area. The aim of this project is to design and develop a prototype mouse tray that is cost effective and can improve the upper limb posture when using computer mouse. The methodology was segregated into three phases- Phase 1, Phase 2 and Phase 3. Phase 1 includes literature review, review reports of professional ergonomics assessments that collected from consulting ergonomic company. Phase 2 is need assessments of office workers, design specifications, product conceptualization, collecting dimensions of keyboard and narrowing down the conceptual design by using Pugh's screening method and getting feedback from professional ergonomics consultants. In addition, Solidworks software was used to do simulation and analysis on stress and safety factor of proposed mouse tray. Cost analysis was developed by using Breakeven Analysis to calculate the breakeven quantity and breakeven cost for PLA prototype and Aluminium prototype. Besides, five professional ergonomics consultants were selected to test and evaluate the proposed mouse tray. In conclusion, it was observed that the upper limb posture of the professional ergonomics consultants was improved and the distance between alphabet typing and computer mouse was reduced. The results of average time taken for subjects to complete the given task by using proposed mouse tray is shorter than the time taken by using traditional approach.

DEDICATION

Only

my beloved father, Tiong Bun Liang

my appreciated mother, Lim Tia See

my adored sisters, Lee Ling, Lee Kien and Shu Yin

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

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LIST OF ABBREVIATIONS

CCOHS	-	Canadian Centre for Occupational Health and Safety
EHRS	-	Environmental Health and Radiation Safety
EMG	-	Electromyography
MSD	-	Musculoskeletal System Disorder
NIOSH	-	National Institute of Occupational Safety and Health
PLA	-	Polyactic Acid
RMS	-	Root Mean Square
RULA	-	Rapid Upper Limb Assessment
ULDs	-	Upper Limb Disorders
USB	-	Universal Serial Bus
WRULDs	-	Work-related Upper Limb Disorder

CHAPTER 1

INTRODUCTION

1.1 Background

In the 21st century, computer has become an essential electronic device in daily life. Computer is defined as a gadget that takes instruction and perform the commanded instructions and operations accordingly. Computer able to store and process the data quickly, therefore increase the productivity of worker. Computer has been widely used in different places such as hospitals, banking sectors, business, marketing and etc. Chris (2014) found that computer is the device that commonly used in the workplace. According to Harvey & Peper (2010), the usage of mouse in a working day can equal or more than the time spent using a computer keyboard for working. As personal computer become more popular in working area, a dramatically increased in the number of office workers suffer from upper extremity musculoskeletal pain (Harvey & Peper,2010).

Reality Mine (2014) which is a technology data business that measure and collect consumers behavioural data. The statistics from Reality Mine shown that 64% of American used computer in the workplace during the week in year 2014 as shown in Figure 1.1. According to the statistics from the Organisation for Economic Co-operation and Development (2012), the average American spend approximately 1790 hours every year in work. Department of Statistics Malaysia (2010) stated that employees who use computer in workplace increased 91,660 persons in 2007, which has increased 10.2% as compared to 83,159 persons in 2006. Usage of computer in the workplace has risen dramatically, there are 6 in 10 workers using a computer for their work in 2000 as compared to 3 in 10 workers in a decade earlier (Marshall, 2001).

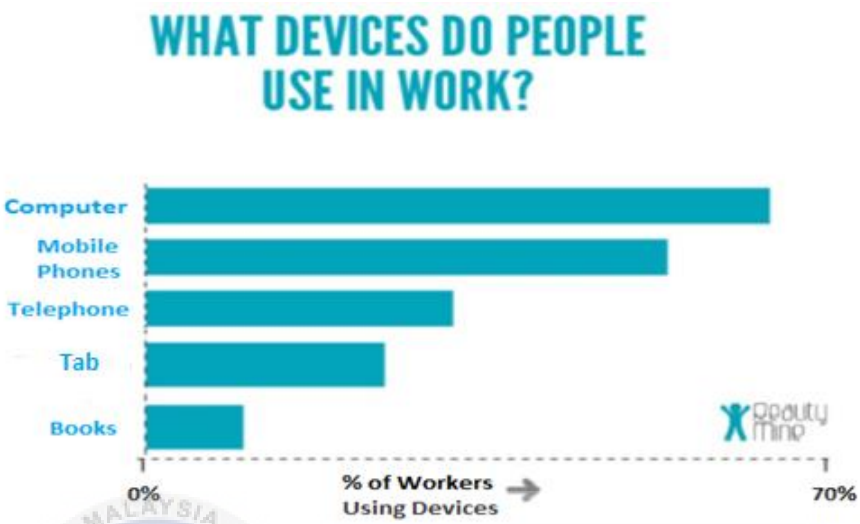


Figure 1.1: Type of device that American used in work in year 2014 (Reality Mine,2014)

Office workers are mostly key-in data, data processing, emailing and much more which mainly using computer mouse and keyboard typing. They conducting daily routines in front of computer for long hours. Majority office workers spend 5 to 8 hours on computer per day (British Psychological Society, 2012). Poor upper limb posture when using computer and mouse for a long period may increase the risk to injury. The more extreme posture or non-optimal posture when using mouse can cause discomfort in upper limbs (Harvey & Peper,2010). Upper limb disorders (ULDs) is become very common in office working area. ULDs are defined as the pain that involving from fingers to shoulder. From the European statistical data, it was found that 41.3% of office clerks is suffer from upper limb pain (Andriana et al., 2016). Therefore, an ergonomic design set-up in the workstation is important to ensure the comfort and safety for the workers. Ergonomic defined as a workstation designed that fits to human. According to Handbook of Industrial Engineering published by Salvendy (2001), ergonomic defined as the "the science of fitting workplace condition and job demands to the capabilities and inabilities of the worker", is an important element in a proper designed workstation.

The need to use computers during working in office workstation is increases as the ease of using computer to store data save the time and increase the productivity of workers. This resulting the occupational health and safety problems among office workers are continuously increasing which obviously can lead to reduce in performance and productivity of office workers. Harvey and Peper (2010) stated that the estimated cost to business ranges from 4 to 20 billion annually lost due to productivity, medical cost and lost time of office workers.

1.2 Problem Statement

Poor upper limb posture when using mouse for a prolonged period may increase the risk to injury. Thus, decrease the productivity and efficiency of office workers. Upper limb musculoskeletal symptoms may affect work performance and productivity. The occurrence of symptoms is highly correlated with reduced productivity (Mats, Ewa & Allan, 2002). In the research of Mats et al. (2002) stated that the incorrect position of mouse is also the factor that weakly related with reduced productivity among the office workers.

Coggon et al. (2000) reported that upper limbs disorders are commonly occur due to improper workplace set-up. The existing workstation set-up causes an awkward posture for long period of using computer due to the poor ergonomic workstation set-up. The common workstation set-up is the distance between the keyboard and mouse might not optimal. The extended keyboard with numerical pad on the right hand side might not often used by the office worker. Thus, there is a distance between alphabet typing and the mouse, the productivity and efficiency of workers decrease due to wasting of time to access the mouse for long working hours. Besides, the arm is in poor posture which is not in straight if there is a distance between the alphabet keyboard and mouse. For a long period of time, these may cause damage of hand muscle or nerves which can lead to upper limb disorders.

1.3 Objectives

The objectives that should be achieved for this project are listed below:

1. To capture upper limb posture of current office workers when using mouse at office workstation.
2. To design and develop a prototype mouse tray that is cost effective and can improve the upper limb posture when using mouse.
3. To validate how the proposed mouse tray may improve office workers' efficiency in terms of reducing the time to access the mouse and providing a better upper limb posture.

1.4 Scopes

The scopes of research are as follow:

a) Research on how the posture of office workers using mouse at office workstation. This research focuses more on the upper limb problems which may affect the health of office workers and working efficiency in terms of time to access the mouse. Mainly focus on office workers who mostly used alphabet typing.
b) Design and develop a prototype mouse tray that is cost effective and can be installed in the existing computer workstations to improve the upper limb posture of office workers. The 3D design of proposed mouse trays will be drawn by using Solidworks software.
c) To verify the performance of office workers through their productivity in term of time needed to access the mouse. Simulation and analysis of proposed mouse tray will be done by using Solidworks software. Participants selected must be at least used 3 – 5 hours of computer per day.

1.5 Significant of Study

This project could introduce a new product that helps to improve in upper limb posture of office workers. This is because office workers having a tendency towards poor upper limb posture due to the workstation set-up. The poor posture for long term may affect the health of office workers. A mouse tray is designed to potentially minimize poor upper limb posture issues among office workers.

This project aims in developing a prototype mouse tray that is cost effective and would be improved the upper limb posture during the long working hours. Therefore, in terms of cost effective mouse tray this could be economical to the company. The prototype mouse tray would design to be installed to the existing computer workstations instead of changing a new workstation. Besides, this project would focus on the design to reduce the office workers' cumulative exposure to risk factors which may affect their efficiency and health. According to Ong (1990), a poor workstation design causes unnecessary muscular strain and fatigue for uses thus resulting productivity decreased.

1.6 Organization Report

The studies in the awkward and static posture of office workers when using mouse, effect of health when using long period of mouse in poor upper limb posture, risk factors and several designs of mouse tray by other researcher will be discussed and reviewed in Chapter 2 – Literature Review. Besides, the studies that shown the prevalence rate of upper limb musculoskeletal disorder will also be discussed in Chapter 2 Section 1. In Chapter 2 Section 2 will discuss about the placement of mouse effect on the risk of experience in upper limb poor posture. Duration of mouse may effect on health of office workers will also discuss in Section 2. In Section 3, image of mouse tray and its limitations will be discussed while the office workstation set-up will be discussed in Section4. In Chapter 3 – Methodology will discuss in three phase. Phase 1 will be conducted by using literature review to identify issues in office setting and review reports of current office workstation set-up issues. Phase

2 will discuss the customer needs, described the design requirement and constraints of proposed mouse tray according to the issues that are collected. In Phase 3, Solidworks software is used to do simulation and analysis on upper limb posture of users when using proposed mouse tray and getting feedback from the participants about the proposed mouse tray. In Chapter 4 will focus on the results that obtained from Phase 1, Phase 2 and Phase 3. Results are analysed from actual reports of professional ergonomics assessments and from UTeM staffs in Phase 1. Phase 2 will discuss the conceptual design and mock-up prototype of the proposed mouse tray. Besides, stress and safety factor analysis of proposed mouse tray will be simulated by using Solidworks. Cost analysis will be discussed by using breakeven analysis to calculate the breakeven cost and breakeven quantity of the proposed mouse tray. Phase 3 will focus on the feedback from professional ergonomics consultants. Conclusion of this study will be made in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Upper Limb Musculoskeletal Disorders among Office Workers

According to Bongers et al. (2006) and Klussman et al. (2008), musculoskeletal disorders (MSDs) are the major category of injuries in workplace. Office workers has been linked with higher rates of MSDs prevalence through exposure to physical and psychosocial stressors in the workplace (van den Heuvel et al.,2006: Janwantanakul et al.,2008). Maakip et al. (2016) from La Trobe University in Melbourne conducted a study and found that the prevalence rate of MSDs is high which is 92.8% in the study of public sector office workers in Malaysia. In Australia, the prevalence rates of MSDs among 767 office workers is 71.2% (Maakip et al., 2016). The summarized is shown in Table 2.1. Similarly, Harcombe et al. (2009) also examined office worker in New Zealand and found that the percentage of prevalence rate of MSDs is 84% in 2008. The statistics of prevalence of MSDs among office workers in different countries is summarized as shown in Table 2.2.

Table 2.1: Comparison of prevalence of MSDs discomfort in Malaysia and Australia (Maakip et al.,2016)

	Malaysia (n= 417)		Australia (n= 767)	
	n	%	n	%
Prevalence of MSD discomfort (last 6 months)				
Yes	387	92.8	546	71.2
No	30	7.2	221	28.8

Table 2.2: Summarized of prevalence of MSDs among office workers in different countries.

Country	Percentage of prevalence of MSD among office workers
Malaysia	92.8%
New Zealand	84.0%
Australia	71.2%

Several studies about MSDs are conducted and make a comparison between two different countries which are Australia and Malaysia. According to survey that conducted by Maakip et al. (2016), it was found that the rates of pain in Malaysia is 93.4% of female and 90.5% of male office workers had experienced in musculoskeletal discomfort, while in Australia, 72.1% of female and 68.8% of male office workers are experienced in musculoskeletal problem. The rates of MSDs among office workers are higher in Malaysia compared to Australia.

Eltayeb et al. (2009) reported that prevalence rates of work-related neck and upper extremity pain among office worker consists of 31% and 54% respectively with 2-year follow-up. According to Eijckelhof et al. (2013) stated that wrist radial-ulnar velocities and accelerations were found to be higher among office worker which may cause by increased mouse movement speed especially for highly overcommitted office workers. From the statistics that shown by Health and Safety Executive (2017), the prevalence of work related upper limb disorders (WRULDs) in 2015/16 was 222,000 total cases (case rate of 690 per 100,000 people employed). The Figure 2.1 shows the statistics of prevalence rate of WRULDs in Great Britain. From the statistics, the prevalence rate of WRULDs for the last five years is broadly flat, there was no significantly difference compare to the previous year.

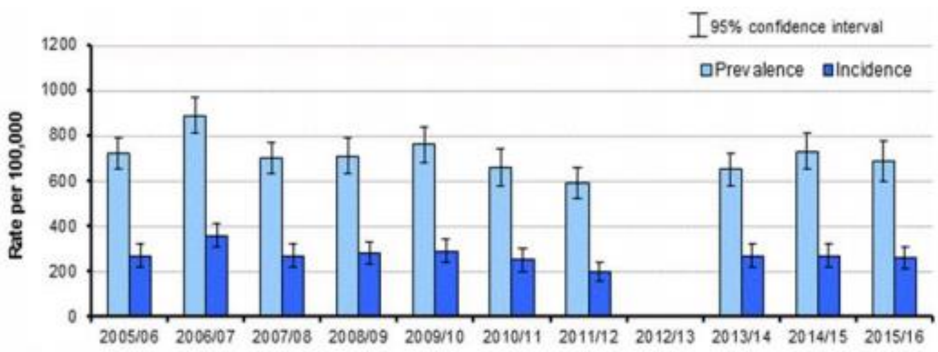


Figure 2.1: Prevalence (total case) rate of WRULDs per 100,000 people employed in the last 12 months in Great Britain (Health and Safety Executive,2017)

A survey was done by Tella et al. (2011) in Nigeria and reported that the prevalence rates of upper extremity musculoskeletal disorders in neck (66.8%), shoulder (60.1%), followed by hand (32.6%), upper arm (32.0%), lower arm (31.5%), wrist (28.1%) and elbow (22.5%) among computer users in bank. Besides, the study by Shikdar et al. (2007) reported that the major complaint of work-related musculoskeletal disorders among computer users including shoulder (45%), lower back (43%), neck (30%) and wrist (30%) complaints. From the two studies, it was found that most of the computer users experienced upper limb problems.

According to the study by Akodu et al. (2015) stated that office workers prevalence of neck, upper limb and low back pain was 59.3%, 76.0% and 71.3% respectively in Nigeria as shown in Figure 2.2.

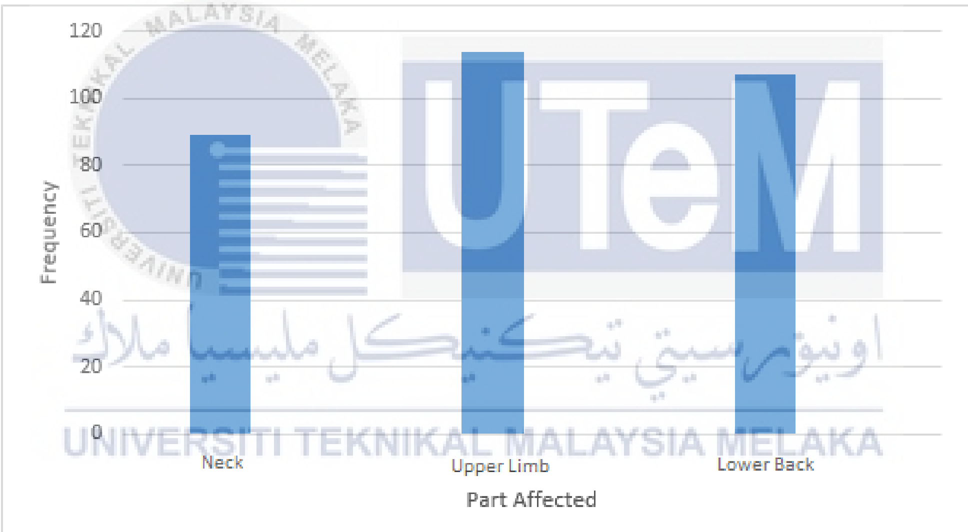


Figure 2.2: 12 month's prevalence and point prevalence of neck, upper limb and low back pain of the office workers adapted from (Akodu et al.,2015).

There are several studies report a wide range of issues that may be associated with the prevalence of upper limb musculoskeletal disorders. Poor postures, duration of using computers, duration of rest, repetitive motions, workstation set-up, job demands, job control and equipment design were among the potential factors identified. However, the physical factors that were discussed in most of the researchers reviewed are poor posture, static posture and duration of using mouse.

2.2 Poor Posture, Repetitive Motion and Duration of using mouse

Mouse is widely used as an input and pointing device of computer. The location of mouse in the workstation is important to avoid causing poor posture among office workers. The mouse placement may affect the upper limbs posture of office workers. Poor upper limbs posture for prolonged period may cause injury. Michael et al. (2012) researched the study by collecting results from different researchers to determines the level of discomfort according to the risk factors among the office workers' posture in workstation. ROSA method is used to examine in several risk factors depends on the position of: 1) chair, 2) monitor, 3) telephone and 4) mouse. From the results, it was found that the mean ROSA total scores are 5 and the final scores for chair (3.08), monitor (2.58), telephone (3.65), and mouse (4.13). The position of mouse causes a significant impact. Poor posture when using mouse may increase risks of experience ULMDs.

Cook & Kothiyal (1998) conducted the study of the muscle tension from office workers' upper arm while using computer mouse in 3 different positions. The surface electromyography (sEMG) was used to record muscular activity in 3 different positions as shown in Figure 2.3 are: 1) standard position of mouse with standard keyboard, 2) extreme position of mouse with standard keyboard and 3) modified position of mouse with compact keyboard. The study shows that the sEMG activity at standard position is 11µV, at extreme position is 19µV and at compact position is 5µV (Cook & Kothival,1998). The results in Figure 2.4 shows significant increase of muscle tension in different positions. The mouse placement in extreme having the highest muscle tension on upper limb and the compact position having the least muscle tension on upper limb.

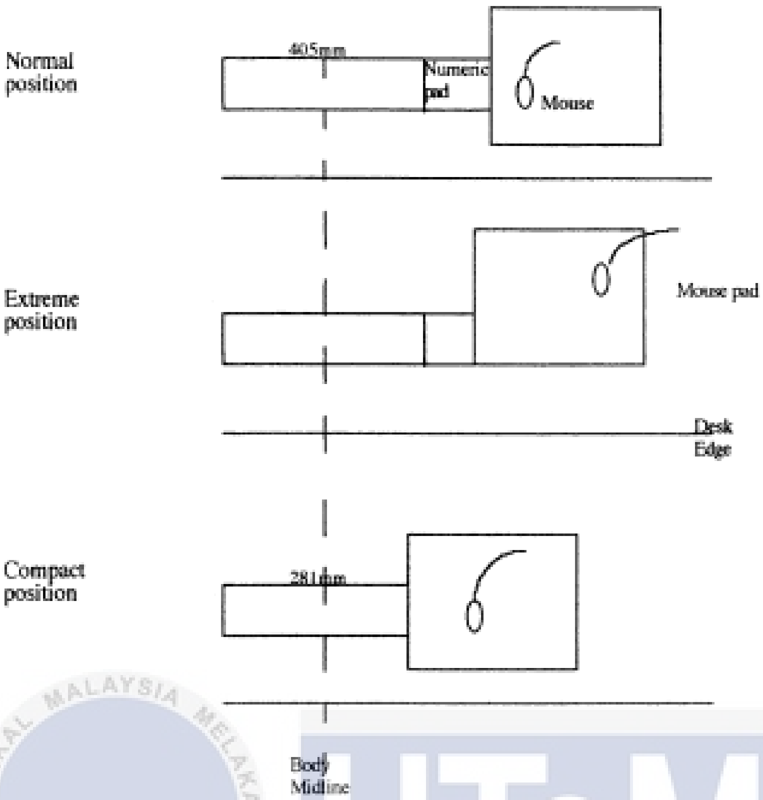


Figure 2.3: Experimental positions showing mouse placement with respect to keyboard. (Cook & Kothival,1998).

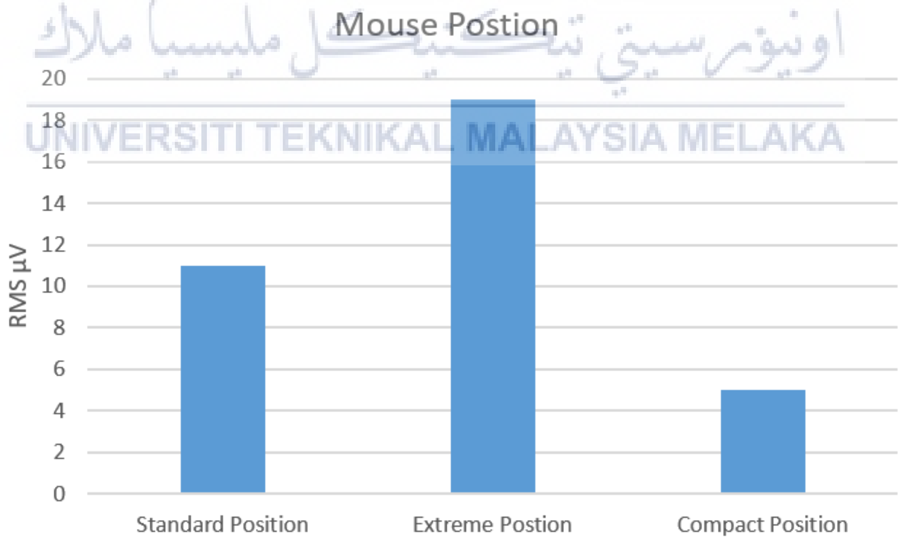


Figure 2.4: Median RMS for muscle tension for each mouse position adapted from (Cook & Kothival,1998).

Cook & Kothival (1998) also investigated the posture of upper arm by using RULA scores, score 1 for best upper arm posture while score 3 for the poor upper arm posture in three different position. Figure 2.5 illustrates the percentage of subjects with RULA score in three different positions of mouse. 80% of subjects given score 1 which is best upper arm posture for modified position which 90% of subjects given score 3 which is poor upper arm posture for extreme position.

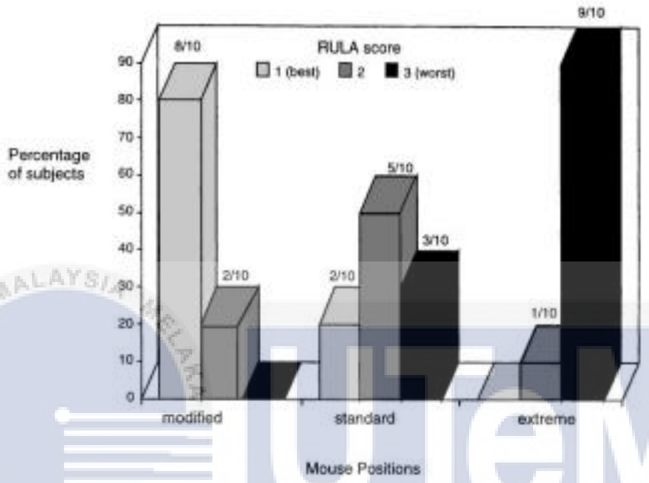


Figure 2.5: RULA scores for upper arm on each mouse position. (Cook & Kothival,1998).

Canadian Centre for Occupational Health and Safety (CCOHS) (2017) which is a primary national agency in Canada for the advancement of safe and healthy workplaces, stated that the reasons using a computer mouse regularly in bad position can be hazardous. The first reason is the repeating activities with poor posture such as clicking, scrolling, travelling when overuse the mouse leads to pain in top of hand, wrist, forearm and elbow, numbness and tingling in thumb and index finger and the range of motion become smaller as shown in Figure 2.6.

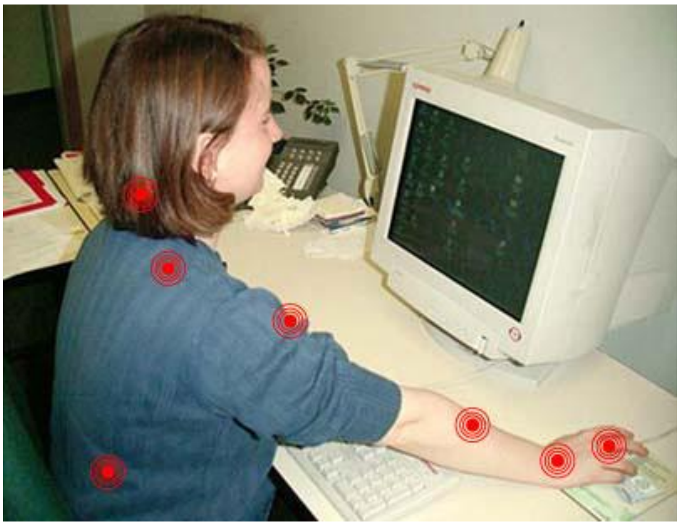


Figure 2.6: Several problems caused by repetitions activities when overuse the mouse. (CCOHS,2017)

The second reason is the location of mouse affect to poor upper limb posture when accessing the mouse due to the limited workplace design which caused that the mouse is placed on the right side of the keyboard. The users have to lean forward and remain unsupported arm caused awkward angle of hand which beyond the safe distance range for comfortable hand movements as shown in Figure 2.7. By maintaining this poor posture for a long period can cause pain and fatigue in shoulder (CCOHS,2017).

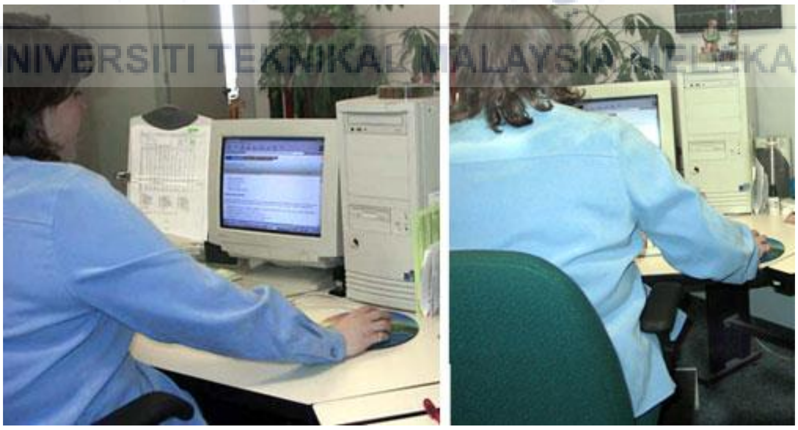


Figure 2.7: Mouse positioned at the right of keyboard resulting awkward angle (CCOHS,2017)
.

From the study that executed by Harvey & Peper (2010) shown that the muscle tension is significant increased when the experimental task is conducted which is drawn subjected name by using mouse in centre and right of keyboard for long duration. This result is supported by the research of Lee et al. (2008) which stated that the duration of exposure to the use of mouse with poor posture leads to a higher level of risk for musculoskeletal pain in forearm, wrist and hand.

According to Blatter & Bongers (2002), a questionnaire is distributed to office workers in different companies and reported that 1083 computer users used the mouse more than 6 to 8 hours per day which consisting of 60%. The results show significant increase in upper limb disorders when the duration of office workers using mouse is more than 6 to 8 hours per day. In addition, Ariens et al. (2001) found that workers who sat more than 95% of the time had more than twice the risk of developing discomfort or injuries compared to the workers who spent less time sitting down at the job.

2.3 Type of Mouse Trays

2.3.1 Patent search

Several publications focused on designing the mouse tray. The mouse tray may change the hand posture and comfortably when using the mouse. D'Souza & Poole (2003) designed a mouse tray which can be docking to laptop and can be mounted to any work surface such as table and shelf as shown in the Figure 2.8. Docking station is provided in every laptop which ease the consumer to connect. However, this design is not suitable for personal computer. There is no cable or wire extension for the mouse tray to connect to personal computer. In addition, laptop in the market mostly provided with 3 USB ports, this might be limited for office workers who want to transferring documents between portable storage devices and another USB ports for wireless mouse.

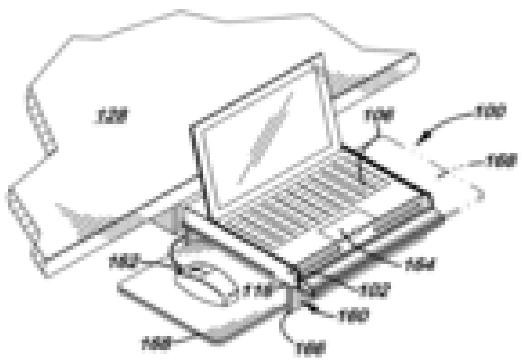


Figure 2.8: Patent of mouse tray (D'Souza & Poole, 2003)

The mouse tray which invented by Knoblauch (2000) is attached and fixed with the keyboard tray as shown in Figure 2.9. The mouse tray provides a space for locating the computer mouse. However, the extended keyboard tray for locating mouse increases the distance between the mouse and keyboard. Office workers may hard to access to the mouse due to the distance of mouse and keyboard. This may also cause the productivity of office workers decreased due to the longer time taken to access the mouse from keyboard.

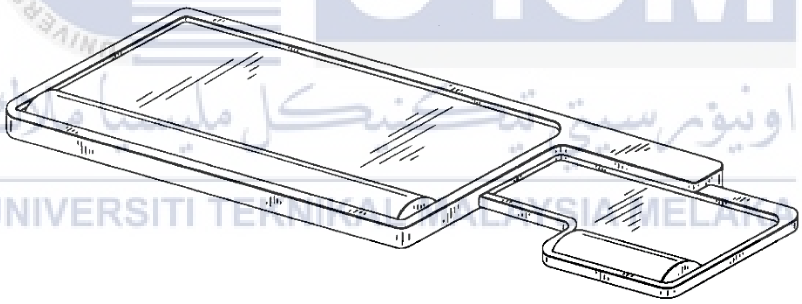


Figure 2.9: Patent of extended mouse tray (Knoblauch, 2000)

The design of mouse tray by Steenson (2006) is a multi-functional adjustable mouse tray that mounts on the arm of chair as shown in Figure 2.10. The mouse tray provides a comfortably accessible work surface to support arm when using computer mouse. On the other hand, the design is limited for the design of the arm of a chair. This is more difficult for office workers to access keyboard for long hours of working due to the block of mouse tray at the front which may cause an awkward posture of arm when typing.

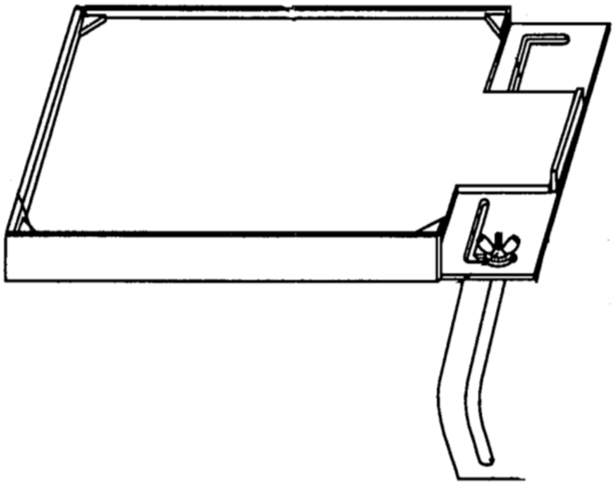


Figure 2.10: Multi-functional mouse tray (Steenson,2006)

Luginsland (2000) designed a mouse tray with padded forearm to support the arm which provides a comfortably position when using mouse as shown in Figure 2.11. The position of forearm is fixed by the padded forearm platform. This might cause increasing the rotation of wrist of office workers when moving the mouse to desired place.

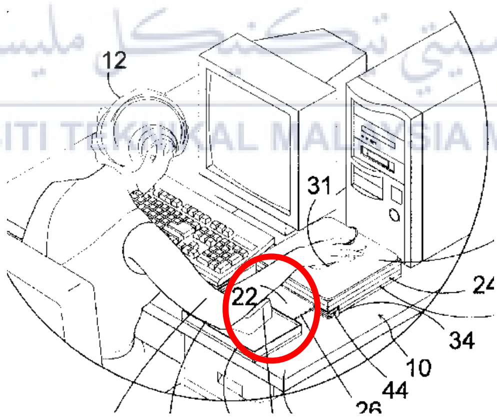


Figure 2.11: Mouse tray with padded forearm (Lunginsland, 2000)

The mouse tray that invented by McAllister et al. (2000) is an adjustable mouse tray which can be moved to left or right of keyboard tray shown in Figure 2.12. This is convenient for left handed person. This design does not minimize the problem of upper limbs problem that faced by office workers because the distance between the keyboard and mouse is not minimized compare with the existing workstation. Table 2.3 shows the summarise details of the type of mouse tray that had review in this section including strategies and limitations of each mouse tray.

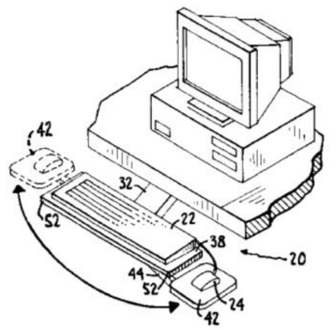


Figure 2.12: Adjustable mouse tray (McAllister et al., 2000)

Table 2.3: Mouse tray review summary

Author	Year	Strategy	Limitations
D’Souza & Poole	2003	Connected to docking station of portable computer.	Suitable for laptop only. Position of mouse tray is according to position of USB ports.
Knoblauch	2000	Extended mouse tray which attached with keyboard tray.	The position of mouse tray is fixed. Increase the distance between keyboard and mouse.
Steenson	2006	Multi-functional mouse tray that mounts on the arm of chair.	Distance between keyboard and mouse is far which takes time to access between keyboard and mouse. Limited for the design of arm of a chair.
Luginsland	2000	With padded forearm platform to support forearm.	Difficult to move arm from mouse to keyboard. Increase rotation of wrist.
McAllister et al.	2000	Adjustable mouse tray. Can be moved to left hand side or right hand side.	Time to access from mouse to keyboard is long.

2.3.2 Mouse trays on market

2.3.2.1 Swivel mouse tray

Figure 2.13 Swivel mouse tray (Amazon, 2017).

Swivel mouse tray with foam wrist can be mounted on right or left. The space for mouse movement is small. It slides from under the keyboard shelf. This mouse tray is made from black, durable wood fibre construction. The selling price of this mouse tray is $79.98 which is around RM326.41.

2.3.2.2 Mobo MECS-BLK-001 Chair mount ergo mouse tray system

Figure 2.14 Chair mount ergo mouse tray system (Amazon, 2017).

The MECS-BLK-001 is ergonomic and high-tech looks make it an attractive choice in all types of businesses. This revolutionary tray system attaches directly to the existing chair.

This will relieve or eliminate painful stress and strain across neck, back, shoulders and arms that result from everyday computer use. The selling price of this mouse tray system is $89.95 which is around RM367.09

2.3.2.3 Fully articulating mouse platform

Figure 2.15 Fully articulating mouse platform (Amazon, 2017).

Fully articulating mouse platform provide soft touch ergonomic knob which allows easy positive or negative tilt control adjustment. Lever-free arm, spring assist adjustable mouse platform mechanism raises and lowers for user personalized height adjustment. The mouse platform attaches to either side to accommodate left or right-handed mousing. The selling price of this product is $ 339.00 around RM1383.49.

There are many types of mouse tray in existing market. However, there are some limitations of mouse tray in the current market. There is very limited space for the movement of mouse. The users may experience contact stress on hand palm when using mouse. This may affect the health of users for long period of working hours. In addition, the mouse tray in existing market is costly which may be cost ineffective for a company to purchase mouse tray for every office worker.

2.4 Office Workstation Set-up

Office workstation set-up is essential to provide a comfortable working area for office workers who works long periods on a computer. The discomfort of workstation may cause by the poor ergonomic design of the office workstation. Rudakewyeh & Valent-Weitz (2015) conducted a field study to test the effects of the prevalence of upper limbs musculoskeletal symptoms among office workers. The training is conducted over a period of 4 months by changing the location of mouse platform close to the keyboard. The results shown that the prevalence of upper limbs musculoskeletal complaints reduced by an average of 40% among 365 office workers (Rudakewyeh & Valent-Weitz,2015). Environmental Health and Radiation Safety (EHRS) (2012) which is a section that focus on general safety issues encountered in office and laboratory setting for Research at the University of Pennsylvania in United States. The typical office workstation layout is shown in Figure 2.16 (EHRS,2012).

Figure 2.16: Typical office workstation layout (EHRS,2012).

Sillampaa et al. (2003) executed a study regarding the 2 different placements of mouse effects on the pain of upper extremity among office workers. The study is conducted in 2 placements of computer mouse which are: 1) mouse is next to keyboard and 2) mouse is placed on a separate table. The results show that the average percentage of office workers experienced pain in upper extremity is 50.77% when the mouse is placed beside keyboard as shown in Figure 2.17 while the average percentage for the mouse that placed on separate table is 39.23% as shown in Figure 2.18 (Sillampaa et al., 2003). The analysis shows that the mouse placed beside keyboard is 11.54% less complaints of pain in upper extremity than the mouse that placed on separate table.

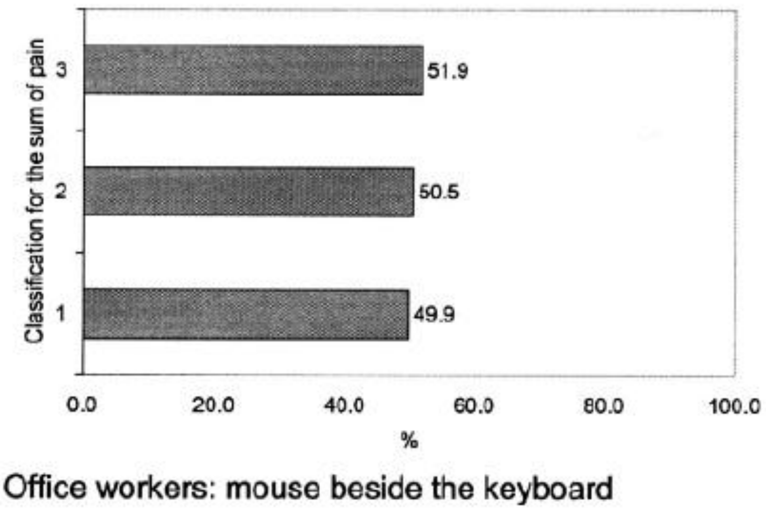


Figure 2.17: The percentage of pain when the mouse is placed beside the keyboard (Sillampaa et al., 2003).

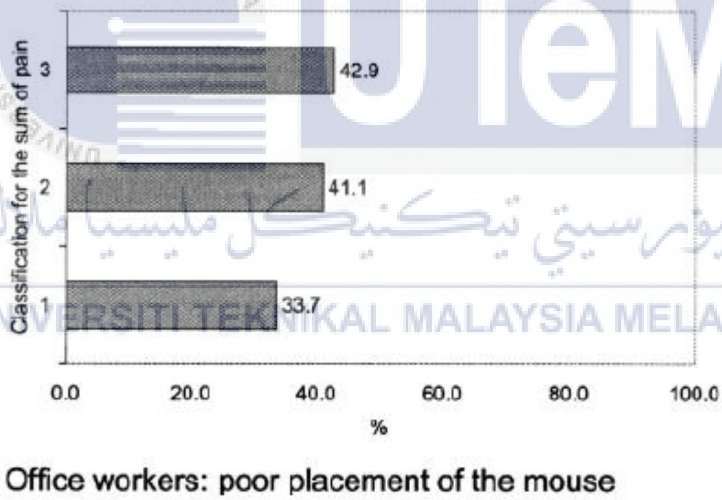


Figure 2.18: The percentage of pain when the mouse is placed on separate table (Sillampaa et al., 2003).

Onyebeke (2012) conducted an experiment to study the effect on upper extremity joint torques, forces, and muscle activity from office workers during computer mouse use in six support conditions as shown in Figure 2.19. The three single axis load cells (ATI) recorded activity in six support conditions are: 1) with no support, 2) support on forearm, 3) support on flat palm, 4) support on forearm and flat palm, 5) supported on raise arm and 6) supported on forearm and raised palm.

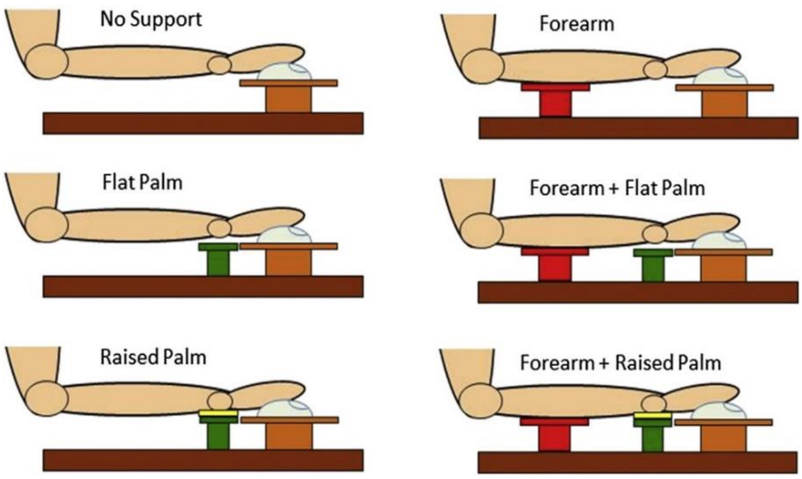


Figure 2.19: Six support conditions are recorded by ATI (Onyebeke,2012)

The ATI activity as shown in Figure 2.20 shows that largest force of 7.4N was applied by the subjected for the no support condition and smallest force of 0.5N with the raised palm support (Onyebeke,2012).

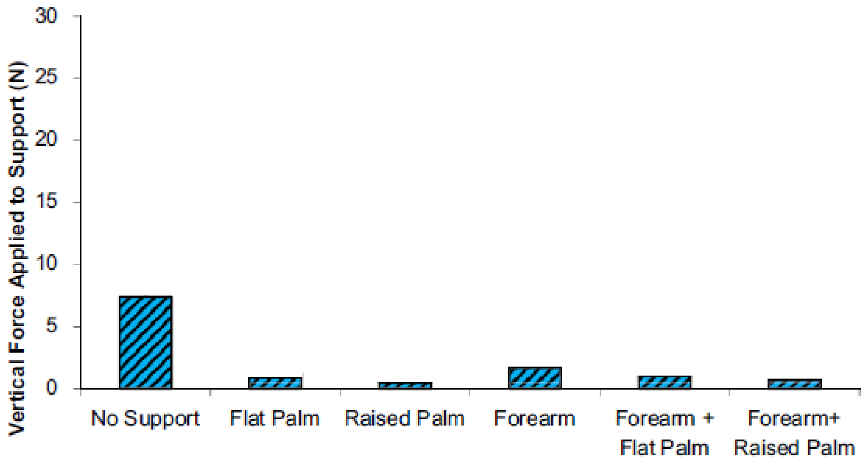


Figure 2.20: comparison of force applied to support in different conditions (adapted from Onyebeke,2012)

The results as shown in Figure 2.21 shows the discomfort score of without any support is 2.5, flat palm support is 1.5, raised palm support is 1.3, forearm support is 1.4, forearm and flat palm support is 1 and forearm and raised palm support is 0.8. The support conditions had less extreme posture in wrist, shoulder muscle and joint in shoulder and wrist compare to the condition without any support.

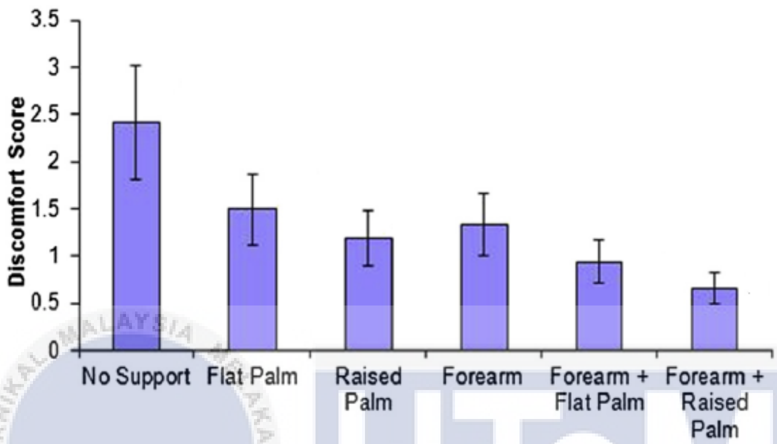


Figure 2.21: Discomfort score in different conditions (Onyebeke,2012).

CHAPTER 3

METHODOLOGY

3.1 Introduction

In Section 3.2, the methodology for Phase 1 is conducted by using literature review to identify issues in office setting and review reports of current office workstation set-up issues. The posture of office workers when using mouse are discussed in Section 3.2.1 and Section 3.2.2. Phase 2 are discussed in Section 3.3 which collect the customer needs, described the design requirements and constraints of proposed mouse tray according to the issues that are collected. Phase 3 is getting feedback of proposed mouse tray from professional ergonomics consultants which discussed in Section 3.4. Figure 3.1 shows the process flow of methodology.

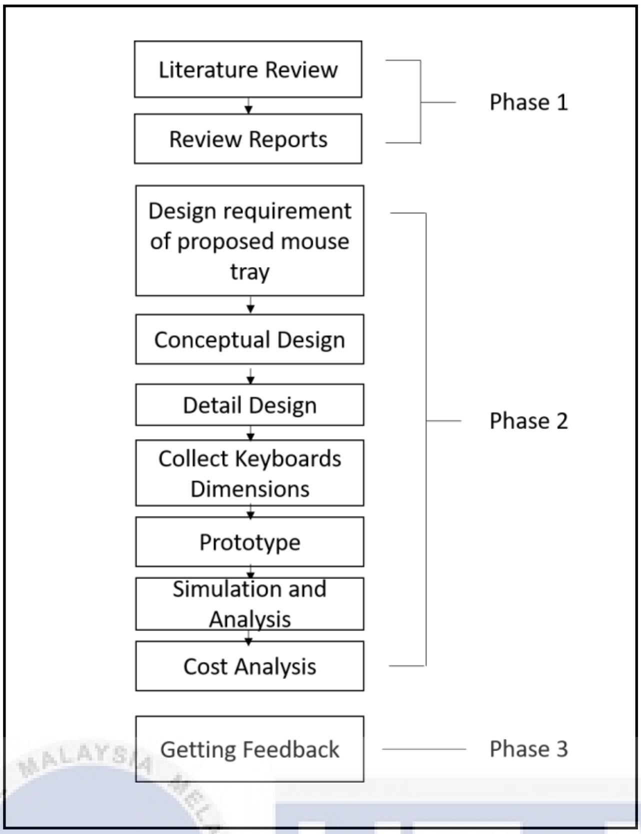


Figure 3.1: Process flow of methodology

3.2 Phase 1

3.2.1 Literature review

According to Onwuegbuzie et al. (2011), conducting a literature review is equivalent to conduct a research study, with the data that previous researchers gathers and analyse representing the information and data. Literature review is a first step that conducted to justify the need of this study and focus on the problems that are occurred. Internet database and journal database such as Google Scholar and Science Direct are used to search for relevant articles and studies. Search terms included "upper limb musculoskeletal among office workers", "risk factors among office workers" and "office workers' workstation layout" are used to narrow down and select the suitable and relevant studies. The abstract of the studies is reviewed to ensure the studies are related to the topic. The studies must include the specific criteria of this project which is upper limb symptoms among office workers. Relevant studies that done by previous researchers were analysed to get an overall background of the problem. The reference lists of each article were reviewed in detail to find additional articles. Moreover, reviewing published materials to know what have been done by previous researchers and potential opportunities that have not been tried by others. A review of mouse tray that have been done by previous researchers was summarized in chapter 2. The common recurring problems found throughout the literature review process were poor posture, repetitive motion and duration of using mouse.

3.2.2 Review reports of professional ergonomics assessments

Office workers' current workstation and the posture of office workers when using mouse are identifying in the report. The reports are collected from a consulting company that provided services related to ergonomic issues in workplace, customer complaint of work related discomfort or injuries of body part in order to maintain and increase productivity by using ergonomics scientific approach. A total of 1440 reports which written by ergonomic professionals are sorted into different field area such as manufacturing, communications, services, oil and gas and construction. Reports that are related to office setting are sorted to the different body parts – such as upper limbs, neck, eyes, legs, hips and back which are affected due to working tasks among the office workers. The statistics of office workers experienced discomforts in office setting among 728 office workers will analyse. Besides, the upper limb posture of office workers when using mouse and the placement of keyboard and mouse will be collected and analysed. Figure 3.2 illustrates the process flow of collect reports.

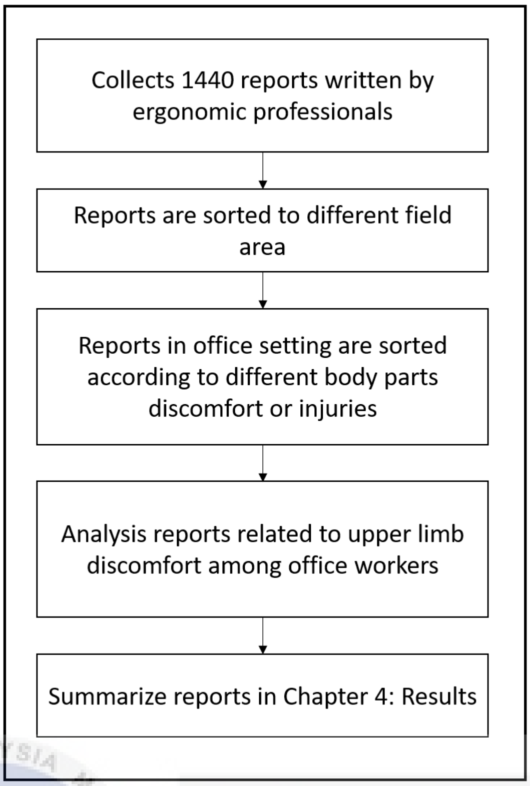


Figure 3.2: Process flow of collect reports written by ergonomic professionals

3.3 Phase 2

3.3.1 Needs assessment

This section discussed the user needs assessment extracted mainly from the first phase. The contents of the reports confirmed majority of the office workers exposed to upper limb poor posture due to the workstation set-up. Among the issues that were listed in the reports include poor posture due to location of mouse, body part affected and duration of computer usage with poor posture.

3.3.2 Design requirements of prototype

The design requirements provide a framework for the design development team to have a vision and ideas on the design and features of product. The issues obtained from literature review and raw data are concluded as below:

1. Awkward upper limb posture.
2. Location of mouse is too far.
3. Keyboard tray do not have extra space for mouse.

These two issues were recurring themes that have identified throughout the previous inquiry activities. A design is expected to reduce the risk exposure to develop upper limb problems among the office workers. Thus, it was concluded that the design specifications will be:

1. Improve upper limb posture.
2. Reduce the distance between mouse and keyboard.
3. Provide a platform for mouse to place on keyboard tray.
4. Cost effective.

3.3.3 Conceptual design on proposed mouse tray

In this section, the simple sketching of the proposed mouse tray in terms of rough dimensions and functionality will be discussed in detail manner. The concept ideas were come up by using external and internal search. External search is essential for searching solutions and gathering information. The aim of external search is finding the existing solutions to the problems. Conceptual ideas were searched externally by using patents, literature searches, internet search engines and competitive benchmarking by comparing with the similar existing products to solve a particular problem. Searching internally such as brainstorming, imagination and mind mapping by using personal knowledge and creativity to generate solution concepts.

The sketching at this point are very rough with representing the estimated dimension and the working mechanism of the proposed mouse tray. The conceptual designs are mainly focus on the office workers that often used on alphabet typing. The concepts were mainly focused on the issues and problems and based on the design requirements that have discussed earlier. Various designs are explored included simple mouse tray, adjustable mouse tray, moveable platform and transparent platform can be flipped.

3.3.4 Detailed design of proposed mouse tray

The detailed design of proposed mouse tray will focus on the dimensions and material used for the proposed mouse tray. The dimensions of the mouse tray depend on the final design proposed mouse tray and the dimensions of keyboard in order to fit most common models of keyboard that is used in office setting. The dimensions including length, width and thickness of proposed mouse tray. The material used for proposed mouse tray will be cost effective.

3.3.5 Collect keyboard dimension

The purpose of collecting keyboard dimension is to identify the details dimensions and constraints of the proposed mouse tray so that the proposed mouse tray may fit on majority of keyboard on existing market. The dimension of keyboard from different models and brands are collected from s selling computer equipment and parts shops. 27 of different models and brands of keyboard are measured. This study is to determine the followings: 1) length, 2) width, 3) dimension of numerical pad, 4) thickness and 5) height after extended. Figure 3.3, Figure 3.4 and Figure 3.5 illustrate the measurement area of keyboard.

Figure 3.3: Keyboard measurement

Figure 3.4: Keyboard measurement

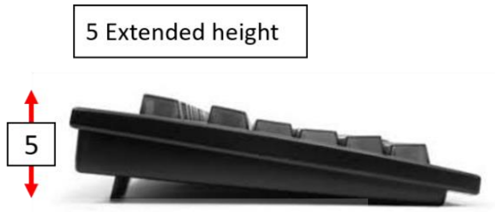


Figure 3.5: Keyboard measurement

3.3.6 Prototype

The prototype of mouse tray will be made according to the final design of the proposed mouse tray. The prototype will meet the design requirements of mouse tray which are:

1. Improve upper limb posture.
2. Reduce the distance between mouse and keyboard.
3. Provide a platform for mouse to place on keyboard tray.
4. Cost effective.

3.3.7 Simulation and analysis

Solidworks software will be used to do finite element analysis on proposed mouse tray to identify the amount of stress that it can withstand and safety factor of the proposed mouse tray according to PLA and Aluminium material.

3.3.8 Cost analysis

Cost analysis is developed by using Breakeven Analysis to calculate the breakeven quantity and breakeven cost for PLA prototype and Aluminium plate prototype. The fixed cost and variable cost will be determined. The breakeven point of each material will be calculated by using the following equation:

Breakeven point,

$$Q = \frac{F}{(P - v)}$$

Q = Breakeven quantity

F = Total fixed costs

v = Variable cost per unit

P = Selling price per unit

3.4 Phase 3

3.4.1 Getting feedback from five professional ergonomics consultants

The selection criteria were the potential participant must be at least 20 years old and average at least 35 hours of computer use per week. Five professional ergonomics consultants will be selected to test the proposed mouse tray. The upper limb posture of participants and the time required for participants to complete the given task will be captured and collected. A task will be given for participants that required repeat motions on accessing computer mouse and keyboard typing. The proposed mouse tray will be given to participants for one week in participants' office workstation to give feedback on the proposed mouse tray. The instructions and procedures were explained to each participant. The data collected before using the proposed mouse tray will be analysed during the one week when the participants test for the mouse tray. The upper limb posture of participants when using the proposed mouse tray and the required time to complete the given task will be captured and collected. The comparison between before and after used of proposed mouse tray on the participants' upper limb posture and time taken for participants to access the mouse will be made. The feedback form after one weeks of using proposed mouse tray are filled in by the participants. The question in the evaluation form were organized into three main sections: 1) Usability, 2) Usefulness and 3) Desirability. The usability section focuses on evaluating the overall easiness of using the proposed prototype. The questions in this section were designed not only to evaluate the usability of the current prototype, but also to direct the design to minimize specific usability issues in the next prototype iteration. The usefulness section consisted of questions to evaluate the potential benefits of the proposed prototype from the perspective of users. The desirability section consisted of several questions to estimate how excited and eager the users were use this proposed prototype in their daily work activities.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Chapter 4 will be segregated into three phase: Phase 1, Phase 2 and Phase 3 according to three objectives respectively. In Section 4.2, the results for Phase 1 are obtained from the reports collected from an ergonomic consulting company and among UTeM staffs. The comparison of the results that obtained from two sources will be made. The conceptual designs of proposed mouse tray will be discussed in Section 4.3 which is phase 2. Stress and safety factor analysis and cost analysis will be focused. In section 4.4, the result for Phase 3 which obtained the feedback from professional ergonomics consultants will be discussed.

4.2 Phase 1: To capture the current upper limb posture of office workers

4.2.1 Analysis of reports from ergonomic consultant company

Based on the reports that collected from an ergonomics consulting company as stated in Section 3.2. Reports collected were analysed and summarized in this section. There were total 728 of office workers reported they have discomfort on different body parts. Figure 4.1 shows 65% of the office workers were complained that they have discomfort on upper limb and other body parts while the other 35% were reported they do not have any discomfort that related to upper limb parts but they have discomfort on other body parts.

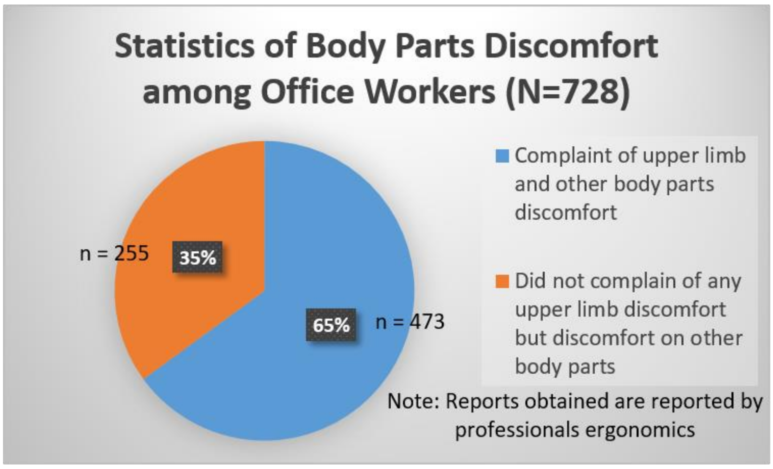


Figure 4.1: Statistics of body parts discomfort in office setting among 728 office workers.

Among 473 of office workers, 200 subjects from different companies are reported have upper limb discomfort only. Figure 4.2 illustrates the statistics of office workers have upper limb discomfort. 42% of office workers complained that they have discomfort in upper limb only while 58% of them complained they have discomfort not only upper limb part but other body parts as well.

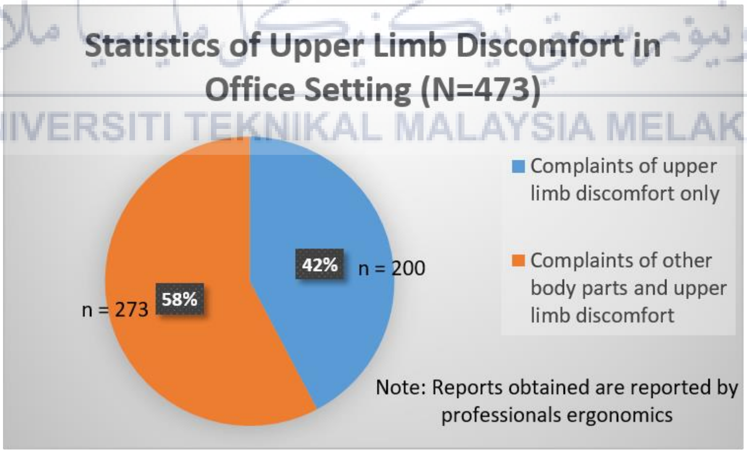


Figure 4.2: Statistics of upper limb discomfort in office setting among 473 office workers.

Table 4.1 shows the reports were collected among office workers from 14 different companies. 151 subjects from Oil & Gas 1 (75.5%), 12 from Oil & Gas 2 (6%), 9 from Oil & Gas 3 (4.5%), 2 from Oil & Gas 4 (1%), 4 from Manufacturing 1 (2%), 3 from Manufacturing 2 (1.5%), 2 from Manufacturing 3 (1%), 1 from Manufacturing 4 (0.5%), 10 from Communications (5%), 2 from Construction (1%), 1 from Services (0.5%) and the other 1 from Biotechnology (0.5%) as shown in Table 4.1.

Table 4.1: Number of subjects from different companies.

Company	Number of subjects (N=200)	Percentage of population
Oil & Gas 1	151	75.5%
Oil & Gas 2	12	6%
Oil & Gas 3	9	4.5%
Oil & Gas 4	2	1%
Manufacturing 1	4	2%
Manufacturing 2	3	1.5%
Manufacturing 3	2	1%
Manufacturing 4	1	0.5%
Communications	10	5%
Construction	2	1%
Services	1	0.5%
Biotechnology	1	0.5%

According to our findings among 200 subjects, which are illustrated in Figure 4.3, 67% which is 134 of the subjects are female while the other 33% which is 66 of the subjects are male.

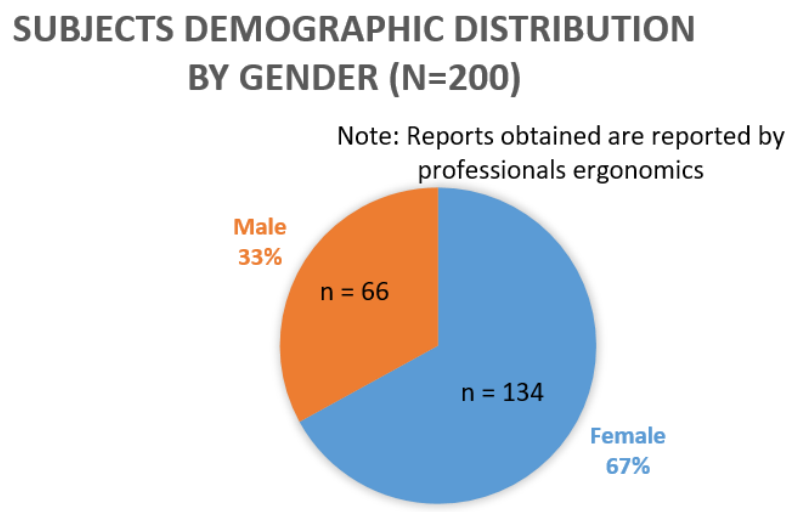


Figure 4.3: Subjects demographic distribution by gender among 200 office workers.

Figure 4.4 shows the office workers from different age range complaint have discomfort or injuries on upper limb part. As evident in Figure 4.4, 52 of office workers are at age range between 21-30, 53 persons at aged 31-40, 30 persons at aged 41-50, 28 persons at aged 51-60, 1 person above 60 years old, while the other 36 persons did not state their age in the report. From the analysis, the majority of office workers at aged 21-30 and 31-40 reported have discomfort or injuries on upper limb.

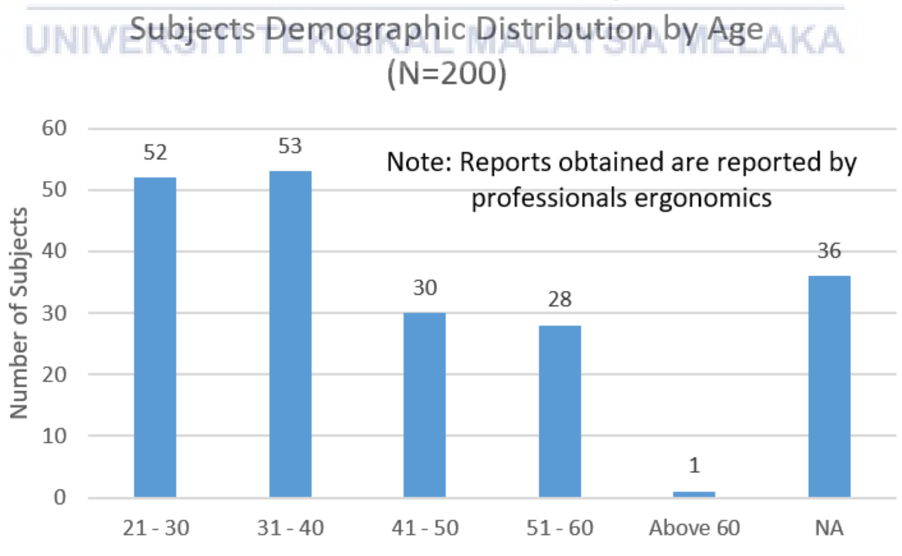


Figure 4.4: Subjects demographic distribution by age among 200 office workers.

The duration of computer use per day among 200 office workers is indicated in Figure 4.5. 1 subject reported that the average of computer use per day is less than 3 hours, 21 subjects are 3 to 5 hours, 125 subjects are 5 to 8 hours, 34 subjects are more than 8 hours and 19 subjects did not state the duration of computer use per day. Most of the office workers spend 5 to 8 hours on the computer a day for working.

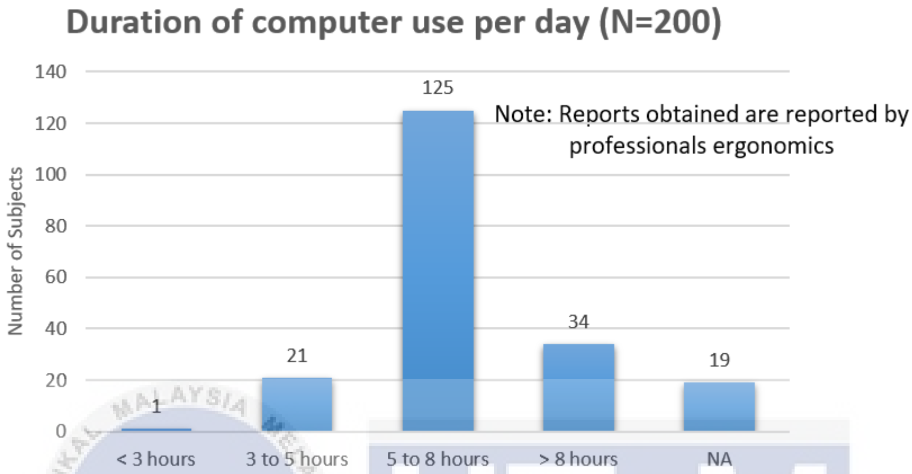


Figure 4.5: Duration of computer used per day among 200 office workers.

An analysis among 200 subjects as shown in Figure 4.6 is conducted through the observation of the office workers posture when using mouse. The analysis shows that 89% of office workers exposed to awkward upper limb posture when using mouse due to the position of the computer mouse while 11% of them have good posture and do not have any part of body deviate from neutral positions when using mouse. The statistics in Figure 4.6 shows that majority of the office workers exposed to awkward upper limb posture due to the location of mouse. Figure 4.7 illustrates the example of awkward posture of office worker when using computer mouse.

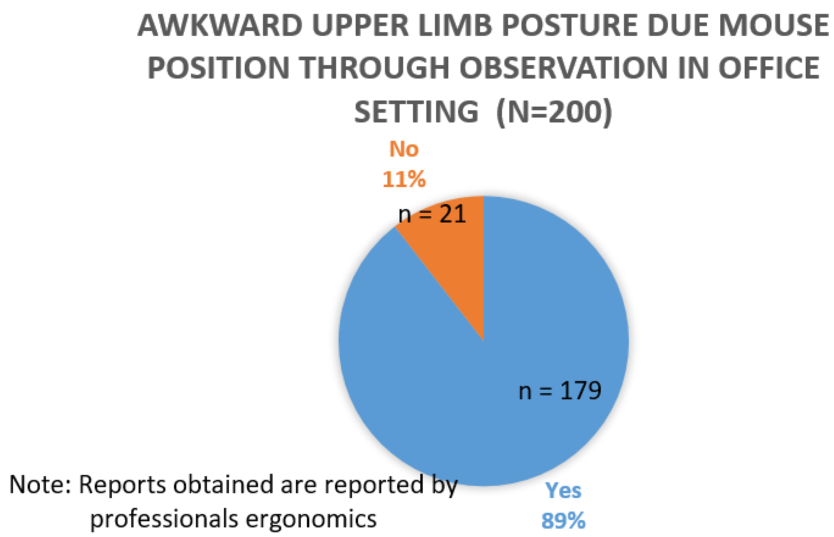


Figure 4.6: Statistics of awkward posture of office workers due to mouse position through observation from the reports.

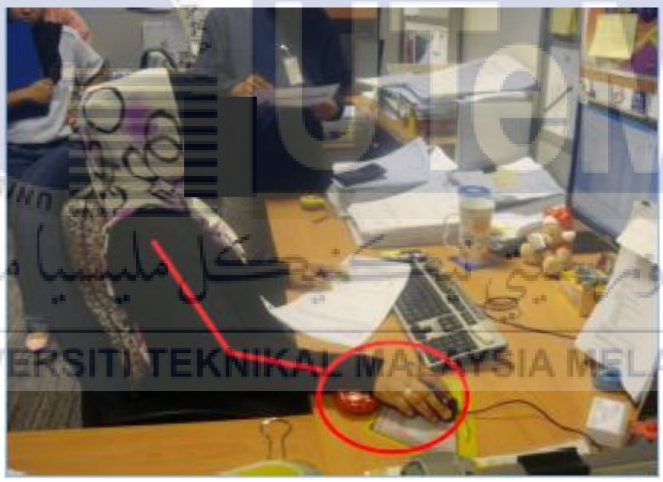


Figure 4.7: Awkward posture of office worker when using computer mouse.

According to the findings among 200 subjects which illustrated in Figure 4.8 there are 52% of office workers complain that they have experienced upper limb symptoms due to the location of mouse and 48% of them does not experience pain or discomfort that is due to the mouse location. However, 48% of them experience pain or discomfort on upper limb due to other problems such as position of keyboard, sitting posture, height of table, height of chair and angle of keyboard.

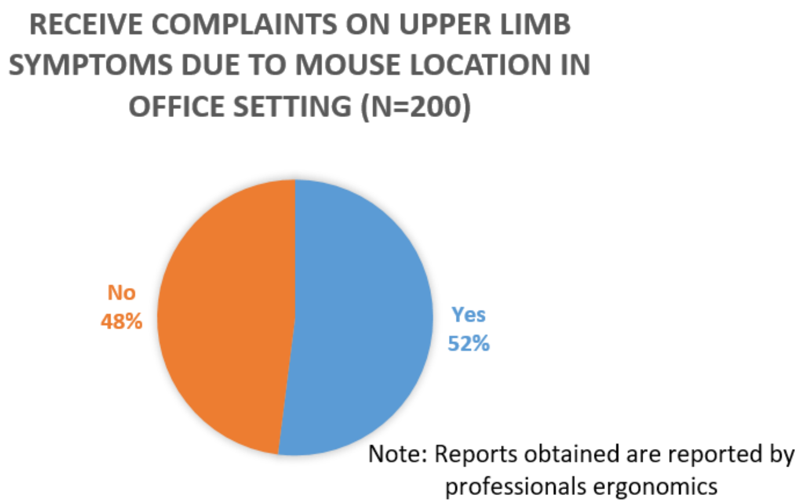


Figure 4.8: Complaints on upper limb symptoms among office workers due to mouse location.

The result in Figure 4.9 shows that 24% of office workers complain about they have discomfort or pain on hand, 54% on shoulder, 17% on forearm, 7.5% on elbow and arm, 25.5% on wrist, 15% on fingers and 4.5% on hand palm among 200 subjects. Majority of the office workers experienced shoulder, wrist and hand discomfort or pain.

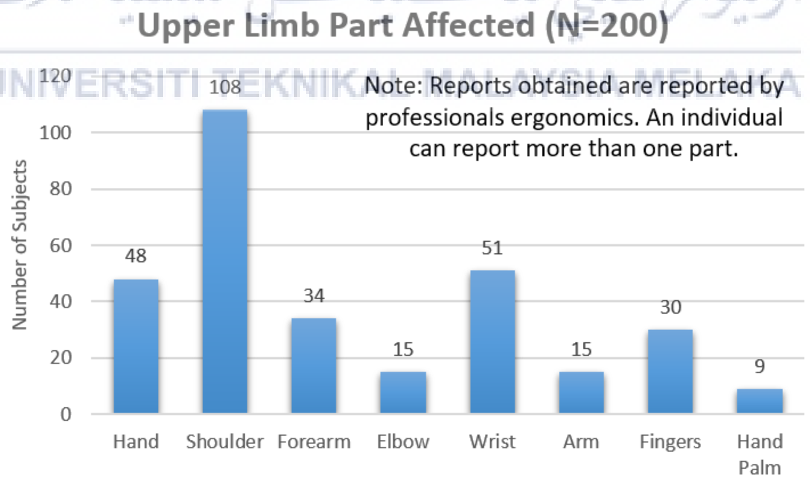


Figure 4.9: Frequency of upper limb part affected among office workers.

There was considerable variation in input device placement among 200 subjects as indicated in Figure 4.10 and Table 4.2, 87.5% of office workers used mouse and keyboard on the desk, 3% used a keyboard tray and placed the mouse on desk and 9.5% placed keyboard and mouse on tray. According to the findings, which are illustrated in Figure 4.10, majority of the office workers place their mouse and keyboard on the desk.

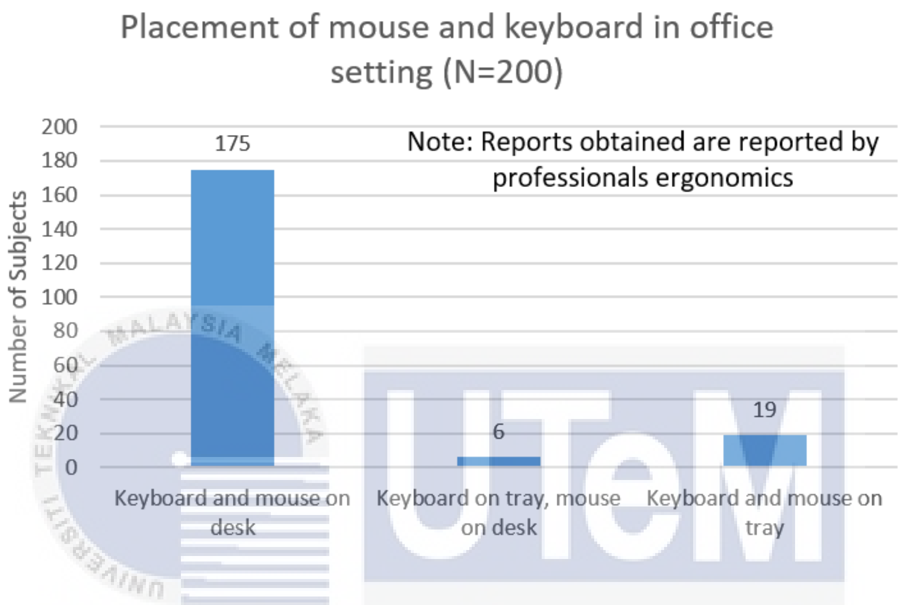


Figure 4.10: Statistics of mouse and keyboard placement among 200 subjects.

Table 4.2: Frequency and percentage of mouse and keyboard placement in different conditions.

Placement of mouse and keyboard	Frequency (N=200)	Percentage of population
Keyboard and mouse on desk	175	87.5%
Keyboard on tray, mouse on desk	6	3%
Keyboard and mouse on tray	19	9.5%
Total	200	100%

The figures below illustrated the majority of preferred office workstation layout which is keyboard and mouse on desk. The placement of mouse and keyboard in office workstation consists of three situations: 1) keyboard and mouse on desk, 2) keyboard on tray, mouse on desk and 3) keyboard and mouse on tray. Figures 4.11 show the subjects experienced awkward upper limb posture when using the computer mouse. The placement of mouse is placed on the right side which is far from the subject’s body due to the referred documents on the midline of the vision. The right shoulder of subject is abducted and elbow is extended in order to access the mouse. Prolonged shoulder abduction and elbow extended may associated with upper limb musculoskeletal disorders. In addition, the location of mouse as shown in the figures increased the reaching distance and time to access to the mouse comparing with the mouse is placed near to their body. The desk provided keyboard tray but the subject placed the keyboard and mouse on desk as shown in Figure 4.11(g).

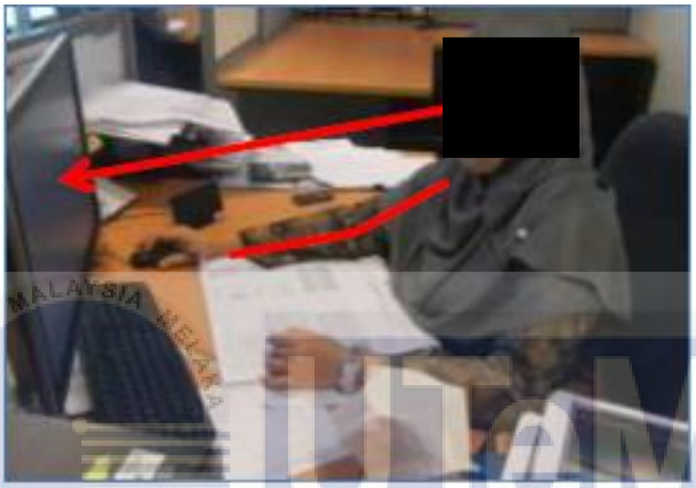


Figure 4.11 (a): Example of placement keyboard and mouse on desk.

Figure 4.11 (b): Example of placement keyboard and mouse on desk.

Figure 4.11 (c): Example of placement keyboard and mouse on desk.

Figure 4.11 (d): Example of placement keyboard and mouse on desk.

Figure 4.11 (e): Example of placement keyboard and mouse on desk.

Figure 4.11 (f): Example of placement keyboard and mouse on desk.

Figure 4.11 (g): Example of desk with keyboard tray but the placement of keyboard on desk.

The example of placement of keyboard on tray and the mouse on the desk as indicated in Figure 4.12. The reaching distance of mouse is far from the keyboard. Subject required a longer time to access the mouse and the work task required the same repetitive motion to move her hand from keyboard to mouse during the long working period. Thus, the productivity of subject may reduce in term of the time taken to access the mouse. Besides, the viewing monitor is placed at an angle to the subjects' body, subjects require to repeat the same awkward motion when looking at the documents place on the desk and viewing monitor.

Figure 4.12 (a): Example of placement of keyboard on tray and mouse on desk.

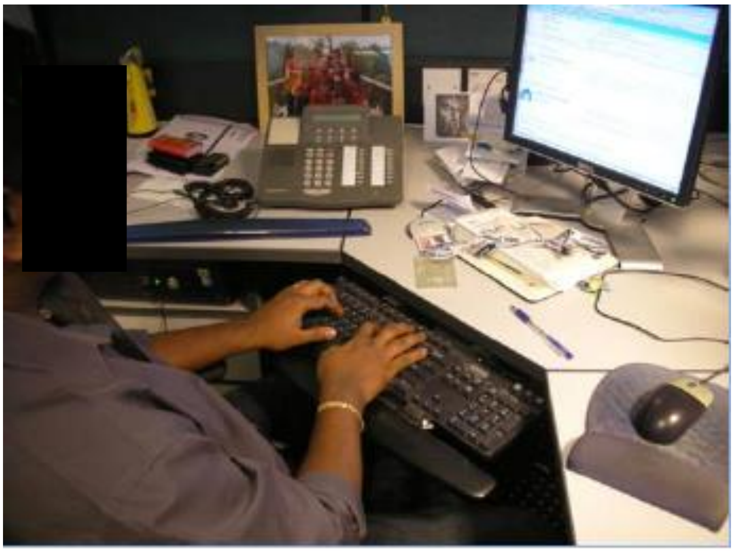


Figure 4.12 (b): Example of placement of keyboard on tray and mouse on desk.

Figure 4.12 (c): Example of placement of keyboard on tray and mouse on desk.

Figure 4.12 (d): Example of placement of keyboard on tray and mouse on desk.

Figure 4.12 (e): Example of placement of keyboard on tray and mouse on desk.

Figure 4.12 (f): Example of placement of keyboard on tray and mouse on desk.

The existing office tables on market provide a keyboard tray or drawer for the convenient of office workers. However, the keyboard tray or drawer does not have a mouse tray or sufficient space for the mouse. As evident in Figure 4.13(a), the table provided a tray but the space of tray is insufficient for both keyboard and mouse. There is only a limited space for the movement of mouse beside the keyboard. This causes the subject experienced contact stress and poor posture when using computer mouse as shown in Figure 4.13(b).

Figure 4.13 (a): Example of placement of mouse and keyboard on tray.

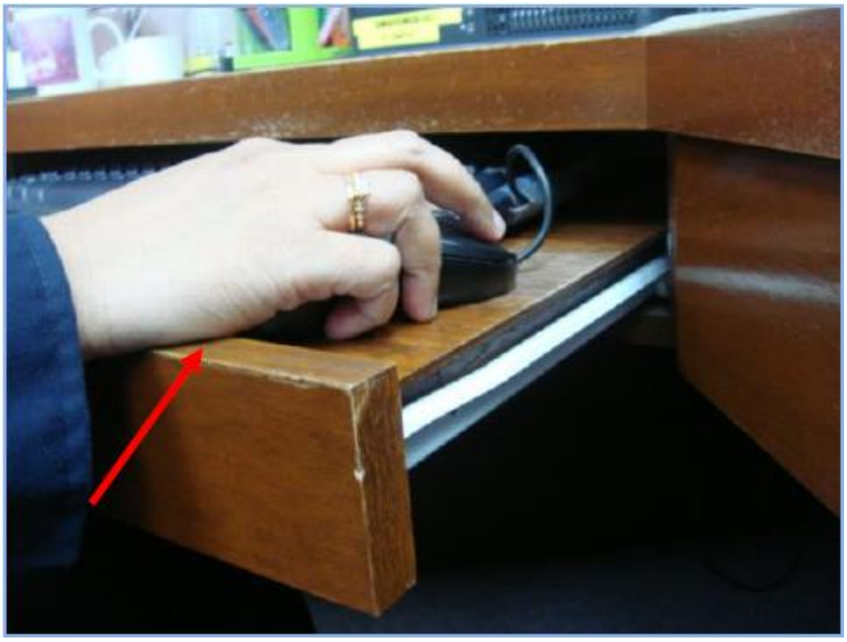


Figure 4.13 (b): Awkward forearm posture when using mouse.

In conclusion, the results from the reports showed that among 728 subjects, there are 65% of the office workers complaint on upper limb discomfort. Among 200 subjects, 52% of them are complaints on upper limb symptoms due to mouse location in office setting. However, through the observation on the posture of using mouse, 89% of the office workers have poor upper limb posture which is due to the placement of mouse. The most received complaints of discomfort on upper limb part is shoulder which is 108 complaints among 200 subjects.

There are 3 situations of mouse and keyboard placement in office workstation: 1) keyboard and mouse on desk, 2) keyboard on tray, mouse on desk and 3) keyboard and mouse on tray. The typical placement of keyboard and mouse is on desk. However, most of the office workers have problems on poor upper limb posture when using mouse. The mouse is placed far from the subject's body due to the referred documents or keyboard placement. The right shoulder of subject is abducted and elbow is extended in order to access the mouse. In addition, majority of the office workers spend almost 5 to 8 hours on computer per day. Prolonged shoulder abduction and elbow extended may associated with upper limb musculoskeletal disorders. The second situation is keyboard on tray and mouse on desk caused office workers required a longer time to access the mouse and the work task required the same repetitive motion to move her hand from keyboard to mouse during the long working period. Besides, office workers have to abduct their shoulder and extended their elbow due to the placement of mouse on desk. The problem of mouse location not only caused poor posture but also reduce in productivity of subject due to longer time taken to access the mouse. The existing office tables on market provide a keyboard tray or drawer for the convenient of office workers. However, the keyboard tray or drawer does not have a mouse tray or sufficient space for the mouse. Subjects exposed to extreme poor posture and increase the contact stress on hand palm and wrist.

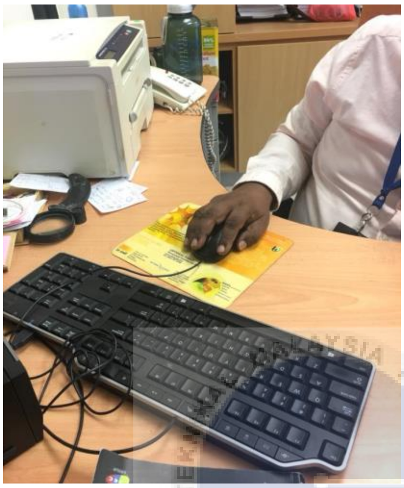
4.2.2 Collect data from UTeM staffs

4.2.2.1 Location of mouse and keyboard placement

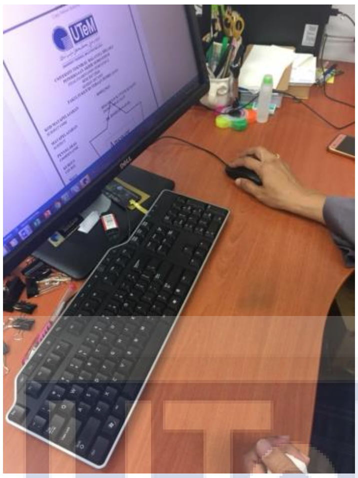
30 subjects from UTeM staffs are randomly selected to capture the location of mouse and keyboard at workstation among the UTeM staffs. There were two variation of input device placements among 30 subjects which are 1) Keyboard and mouse on desk and 2) Mouse on desk and keyboard on tray. 90% of UTeM staffs used mouse and keyboard on desk while 10% placed their mouse on desk and keyboard on tray. According to the findings which are illustrated in Table 4.3, majority of UTeM staffs placed their mouse and keyboard on the desk. Figure 4.14 and Figure 4.15 shown the examples of placement of mouse and keyboard among UTeM staffs in office setting. The results obtained from Section 4.2.1 and this session shown that majority of office workers placed their mouse and keyboard on desk. The keyboard tray on existing office desk may be too small to accommodate both the keyboard and mouse, the mouse is often placed whenever space tends to be available. Most of the office workers placed the mouse far aside of the keyboard which will cause poor upper limb posture during mousing activity and that can contribute to reduce the working productivity and health of office workers.

Table 4.3: Number of subjects and percentage of mouse and keyboard placement in different conditions.

Placement of mouse and keyboard	Number of Subjects (N=30)	Percentage of population
Keyboard and mouse on desk	27	90%
Keyboard on tray, mouse on desk	3	10%
Keyboard and mouse on tray	0	0
Total	30	100%



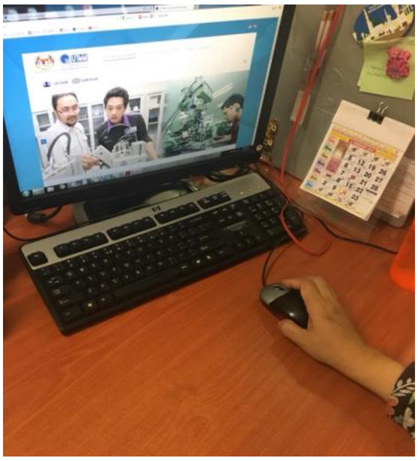
(a)



(b)

(c)

(d)



(e)

Figure 4.14: Examples of placement keyboard and mouse on desk among UTeM staffs.

Figure 4.15: Examples of placement mouse on desk and keyboard on tray.

4.2.2.2 Distance between mouse and keyboard

30 subjects from UTeM staffs are randomly selected to measure the distance between mouse and keyboard at workstation among the UTeM staffs. The distance between mouse and keyboard is measured from the centre of keyboard to the centre of mouse with respective to x-axis, y-axis and z-axis in unit of centimetre (cm). The method of measuring the distance between mouse and keyboard among 30 UTeM staffs is stated in Section 3.3.7. Table 4.4 illustrates the measurement of the distance between mouse and keyboard from 30 subjects. The positive values show that the placement of mouse or keyboard is higher than the centre

point while the negative values show that the placement of mouse or keyboard is lower than the centre point. The value of ‘0’ shows that the placement of mouse or keyboard is in line with centre point. From the result obtained, it can be concluded that most of the subjects placed their mouse and keyboard in an easy to reach distance.

Table 4.4: Measurement of distance between mouse and keyboard among 30 UTeM staffs.

Subjects	Distance between mouse and keyboard (cm)		
	X - axis	Y - axis	Z – axis
1.	42	0	0
2.	50	0	0
3.	30	21	13.5
4.	29.5	34	13.5
5.	42.5	8	0
6.	36	2	0
7.	42	5	0
8.	52	0	0
9.	23	18	0
10.	36	-2	0
11.	41	0	0
12.	30	-8	0
13.	39	2	0
14.	37	-18	0
15.	47	4	0
16.	38	7	0
17.	38	0	0
18.	25.5	26	16
19.	37	-5	0
20.	22	-9	0
21.	38	0	0
22.	37	0	0
23.	32	-3	0
24.	37	2	0
25.	33	-5	0
26.	53	6.5	0
27.	38	0	0
28.	45	-4	0
29.	29	-7	0
30.	39	0	0

4.2.2.3 Measurement of time with a given task

A task involves the use of keyboard typing and mouse interchangeably which representative their work task in real working scenario. 30 subjects from UTeM staffs are given a task by creating a new PowerPoint slides with instructions as stated in Section 3.3.8.

Subjects for this section as shown in Table 4.5 and Table 4.6 are arranged in the same order with the subjects in measurement for the distance between keyboard and mouse in Table 4.3. The time taken for subjects with placement of mouse and keyboard on desk are shorter than the subjects with placement of keyboard on desk while mouse on tray. The result on Table 4.5 shows that when the placement of mouse and keyboard on different surface, the distance between the mouse and keyboard is further, therefore the time taken for subjects to complete the given task is longer. However, there is an exception for subject 22, the time taken for subject 22 is longer than the subjects who also place their mouse and keyboard on desk. This is because the subject took longer time in adjusting the size of the image to the provided template. The average time taken for subjects to complete the given task by using mouse tray were shown in Table 4.6. The results show that the time taken for subjects to complete the given task by using proposed mouse tray is shorter than the time taken by using traditional approach. This is because the distance between alphabet typing and mouse is shorter when using proposed mouse tray and the upper limb posture of subjects were improved.

Table 4.5: Time taken for subjects to complete the given task using traditional approach.

Subjects	Time taken to complete given task using traditional approach (s)
1.	1.16
2.	1.33
3.	2.01
4.	2.15
5.	1.46
6.	1.21
7.	1.29
8.	1.23
9.	1.56
10.	1.34
11.	1.11
12.	1.44
13.	1.23
14.	1.54
15.	1.48
16.	1.36
17.	1.09
18.	1.59
19.	1.33
20.	1.20
21.	1.19
22.	2.10
23.	1.27
24.	1.19
25.	1.15

26.	2.03
27.	0.56
28.	1.49
29.	1.33
30.	1.03
Average	**1.38**

Table 4.6: Time taken for subjects to complete the given task using proposed mouse tray.

Subjects	Time taken to complete given task using proposed mouse tray (s)
1.	0.59
2.	1.21
3.	1.36
4.	1.29
5.	1.31
6.	1.16
7.	1.13
8.	1.05
9.	1.27
10.	1.27
11.	1.08
12.	0.59
13.	1.17
14.	1.14
15.	1.22
16.	1.15
17.	1.02
18.	1.33
19.	1.28
20.	1.15
21.	0.59
22.	1.11
23.	1.23
24.	1.12
25.	1.15
26.	1.43
27.	1.01
28.	1.26
29.	1.29
30.	1.02
Average	**1.13**

4.3 Phase 2: Design and Develop Proposed Mouse Tray

4.3.1 Conceptual designs on proposed mouse tray

In this section, the simple sketching of the proposed mouse tray in terms of rough dimensions and functionality will be discussed in detail manner. The concept ideas were come up by using external and internal search. External search is essential for searching solutions and gathering information. The aim of external search is finding the existing solutions to the problems. Conceptual ideas were searched externally by using patents, literature searches, internet search engines and competitive benchmarking by comparing with the similar existing products to solve a particular problem. Searching internally such as brainstorming, imagination and mind mapping by using personal knowledge and creativity to generate solution concepts.

The sketching at this point are very rough with representing the estimated dimension and the working mechanism of the proposed mouse tray. The conceptual designs are mainly focus on the office workers that often used on alphabet typing. The concepts were mainly focused on the issues and problems and based on the design requirements that have discussed earlier. Various designs are explored included simple mouse tray, adjustable mouse tray, moveable platform and transparent platform can be flipped. Figure 4.16 shows sketches of some concepts that were explored.

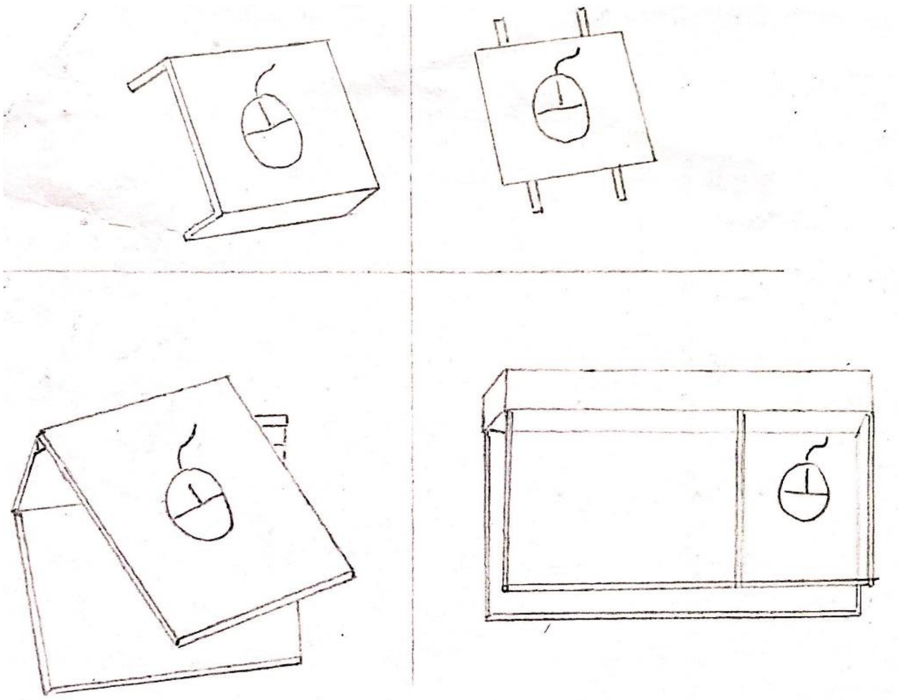


Figure 4.16: Example of concepts generated during the concept generation stage. From upper left clockwise: simple mouse tray, adjustable length mouse tray, moveable platform and transparent platform that can be flipped.

4.3.2 CAD drawings

Figure 4.17 shows sketching for conceptual design 1 of proposed mouse tray. The concept of the mouse tray is on the numerical pad. The distance between the keyboard and mouse is reducing instead of the location of mouse is on the right hand side of a full keyboard. Thus, a good upper limb posture and the time of accessing the mouse is reduced.

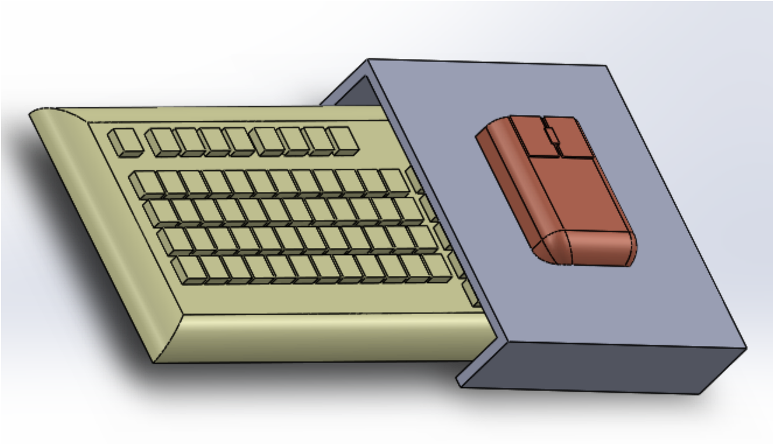


Figure 4.17: Conceptual design 1 of proposed mouse tray.

Figure 4.18 and Figure 4.19 show the mouse tray is designed to cover numeric portion of the keyboard for those who seldom use the numeric keypad. In addition, this design provides easy reaching distance and improve poor posture of users. The length can be adjusted up to 30cm and suitable for all kind of keyboard with different size and shape. The four screws provide adjustable height to fit user desired height to minimize the poor posture of upper limb.

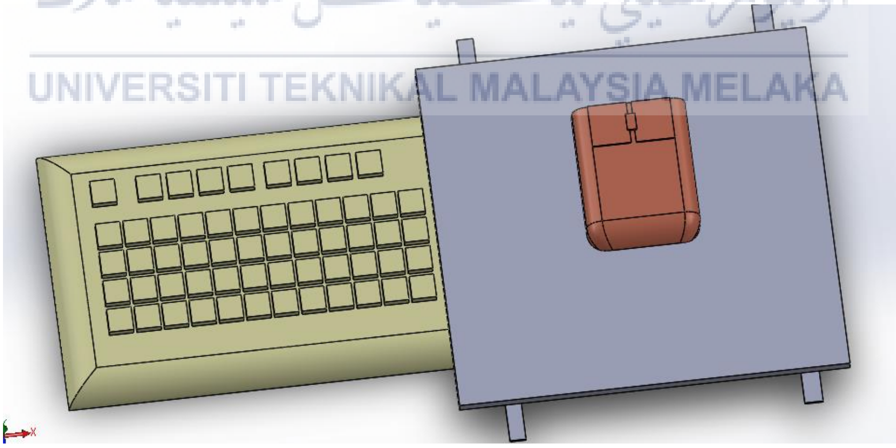


Figure 4.18: Conceptual design 2 of proposed mouse tray

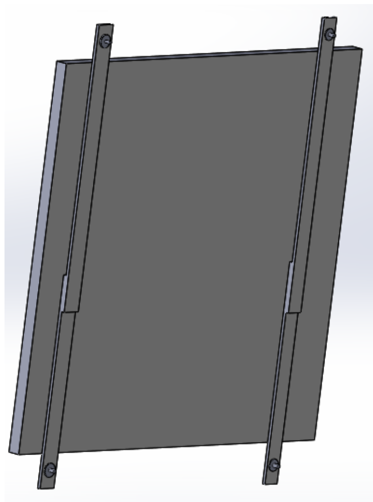


Figure 4.19: Conceptual design 2 of proposed mouse tray

Figure 4.20 shows the mouse tray with adjustable plate so that users can easily access to numerical pad when needed. The distance between the keyboard and mouse is reducing instead of the location of mouse is on the right hand side of a full keyboard. Thus, the productivity of office workers can be increased in term of the time needed to access the mouse.

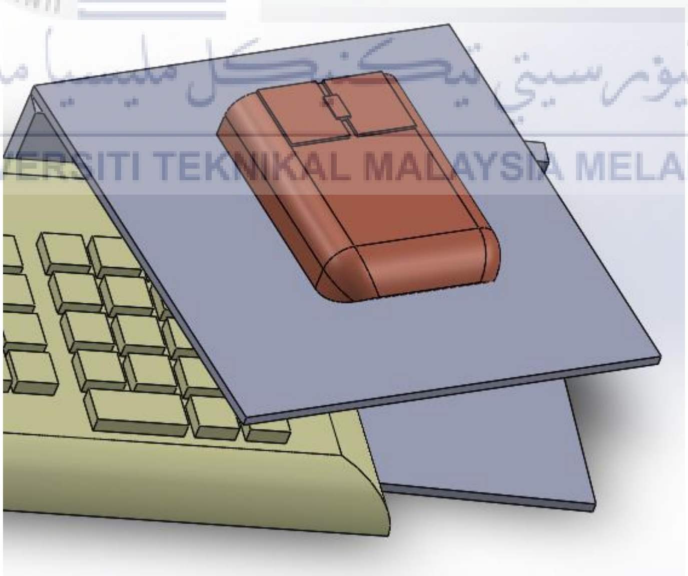


Figure 4.20: Conceptual design 3 of proposed mouse tray

Figure 4.21 illustrates a mouse tray offers several office workstation solutions in one compact package. The mouse is placed on the glass surface. The glass section can be folded down as a writing surface. It allows users to access to keyboard when the larger section is folded up. The small section can be folded up for user that frequently used in numeric keypad.

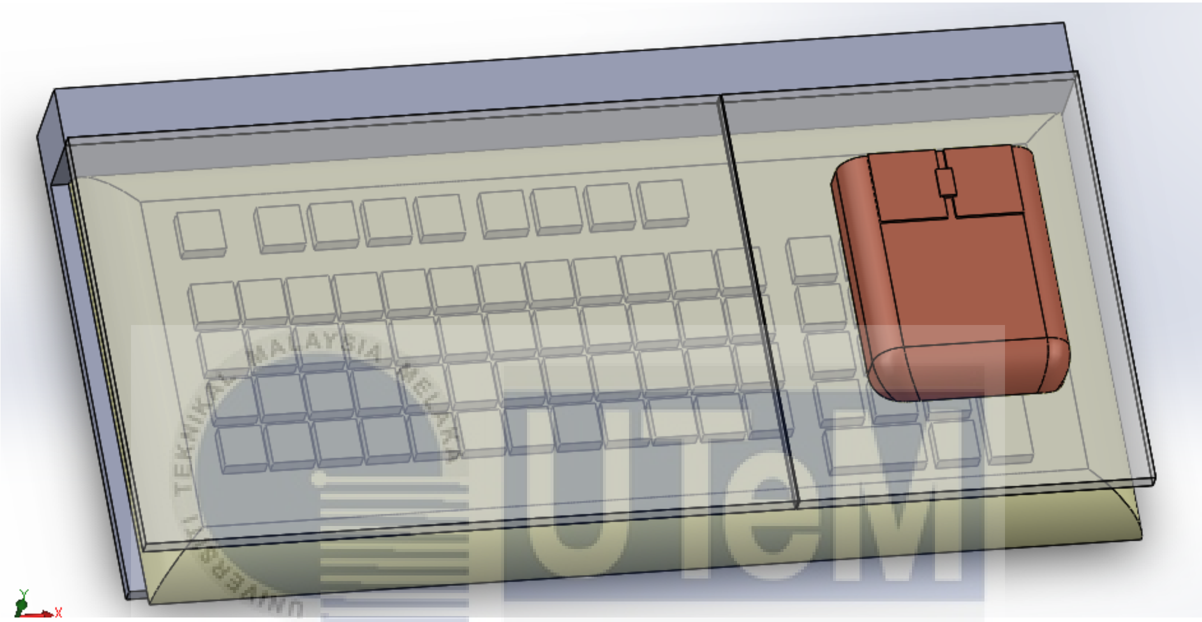


Figure 4.21: Conceptual design 4 of proposed mouse tray

4.3.3 Cardboard mock up prototype

In the early stage, methods of communicating conceptual ideas were sketches and verbal descriptions. Cardboard mock up prototypes are made according to the four conceptual designs. The sketches are very hard to imagine and the issues are not clearly defined. Cardboard mock up prototypes act as a method of communication evolved from sketches to a functional model and make ideas tangible. The four concepts of cardboard mock up prototypes are shown in the figures below. Figure 4.22 illustrates the cardboard mock up prototypes of conceptual design 1.

Figure 4.22: First concepts

Figure 4.23 and Figure 4.24 show the early stage cardboard prototypes of conceptual design 2. The design of the cover part as shown in Figure 4.25 is made up of cardboard. Conceptual design 2 has made improvement due to the design of cover part is too thick. Figure 4.26 and Figure 4.27 illustrates the second evolution of conceptual design 2. The second evolution of conceptual design 2 has made changes on cover part by using a thinner material to cover the adjustable stand.

Figure 4.23: Second concepts

Figure 4.24: Bottom part of second concepts

Figure 4.25: design of cover part

Figure 4.26: Second evolution of conceptual design 2

Figure 4.27: Side view of second evolution of conceptual design 2

Figure 4.28 shows the early stage cardboard prototypes of conceptual design 3. Conceptual design 3 has made improvement due to the design of red circle part is too weak to stand the force exert by hand palm when using computer mouse. At the early stage, pins were used to join the platform with the vertical stand. Figure 4.29 illustrates the second evolution of conceptual design 2. In second evolution, the joint has been redesigned. The joint was become stronger. However, it is still not strong enough to support the force. This conceptual design is not usable, thus this design was eliminated.

Figure 4.28: Cardboard mock up prototype of third concepts

Figure 4.29: Second evolution of conceptual design 3

The early stage of concepts 4 are illustrates in Figure 4.30. The concept of this design is to include the keyboard in the tray. However, this would produce a bulky design and no aesthetic. In addition, this design may be viewed as over-design and waste of material. The conceptual design has been improved to reduce the material used as shown in Figure 4.31.

Figure 4.30: Cardboard mock up prototype of fourth concepts

Figure 4.31: Second evolution of conceptual design 4

4.3.4 Wood mock up prototype

From the cardboard mock up prototype, it was found that some mechanisms are not strong enough and not easy to build up. In other words, the cardboard prototype could fail or break when doing testing by consumers. Wood mock up prototype is made to determine which concept design solution is feasible and further refinement on the product. The three concepts of cardboard mock up prototypes are shown in the figures below. Figure 4.32 illustrates the cardboard mock up prototypes of conceptual design 1. Conceptual design 2 is shown in Figure 4.33. Figure 4.34 shows the cardboard mock up prototypes of conceptual design 3.

Figure 4.32: Wood mock up prototype of conceptual design 1

Figure 4.33: Wood mock up prototype of conceptual design 2

Figure 4.34: Wood mock up prototype of conceptual design 3

4.3.5 Concept screening

4.3.5.1 Pugh's screening method

Three concepts were screened down using Pugh's screening method by professional ergonomics consultants The screening matrix consists of two main columns, the first one lists the selection criteria based on the customer needs, while the second one indexed the three concepts into independent columns. The concepts are scored using the reference based scoring method. Concepts are scored relative to the 5 level scoring system by using a "better than" (++ or +), "same as" (0), or worse than (-- or -) the traditional approach. The reason of using 5 level scoring system because it provides a more detailed and thorough evaluation. The overall score is determined by simply counting the plusses, minuses, and "same" for each alternative. According to the feedback from consultant company and results from Table 4.7, concepts 1 will be chose for the finalized design.

Table 4.7: Screening matrix used to evaluate the 3 concepts.

Selection Criteria	Concepts		
	1	2	3
Improve upper limb posture	+	+	+
Reduce the distance between mouse and keyboard	+	+	+
Provide a platform for mouse to place on keyboard tray	+	+	+
Cost effective	++	-	--
Total score	5	2	1

4.3.5.2 Feedback from ergonomic consultant company

The three concepts were discussed with ergonomic consultant company with the help of wood mock-up prototypes. Feedback from them would pave the way to gauge the acceptance of any of these concepts. Each of the concepts mechanism were presented to the ergonomic consultants. The session was well received with new ideas and modifications suggested by ergonomic consultants. Information gained from the session included:

- Avoid sharp corners and edges on the concepts.
- Concern about the height might be caused user’s shoulder lifted when using.
- The dimension of the concepts is acceptable.
- Spilt vote between Concept 1 and Concept 2, where Concept 1 had a slightly more votes.
- Suggested the material of the product could be plastic or sheet metal.

4.3.6 Stress and safety factor analysis

4.3.6.1 Polylactic Acid (PLA) prototype

A 30N force is applied on the top surface of the mouse tray in downward direction. The fixture is on the edges of both sides. From the analysis results in Figure 4.35, the maximum Von Mises stress value is 5.96MPa. This value is less than the yield point value of PLA which is 60MPa. This shows that the design is safe. The minimum safety factor of PLA prototype is 9.0 which is more than 1. This indicates that the design will not fail and is safe when 30N of force is applied.

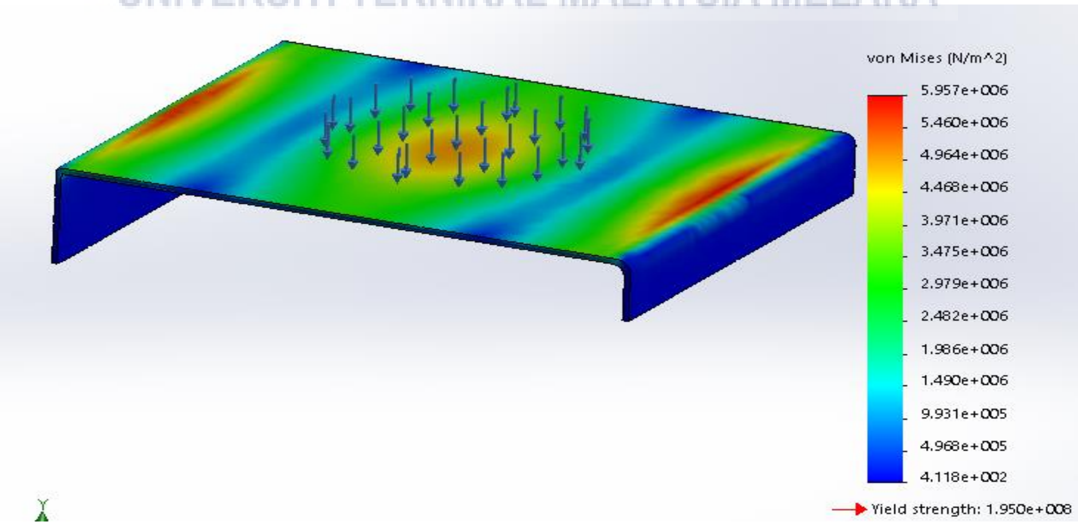


Figure 4.35: Stress and safety factor analysis for PLA prototype

4.3.6.2 Aluminium plate prototype

Similarly, the amount and direction of applied force and fixture is same as PLA prototype. From the analysis results in Figure 4.36, the Von Mises stress is at maximum towards close to the both end of the platform, and the value is 7.82MPa. This value is less than the yield point value of Aluminium which is 310MPa. This shows that the design is safe. Besides, the minimum safety factor of Aluminium plate prototype is 34 which is more than 1. This indicates that the design will not fail and is safe when 30N of force is applied.

Figure 4.36: Stress and safety factor analysis for aluminium plate prototype

4.3.7 3D printer prototype

Concept 1 is chosen from getting the feedback from consultant company and Pugh's screening method. The 3D printer prototype appeared to meet the product information that gained from consultant company to improve on the product, which are:

- Every edge and corner are designed with fillet to avoid sharp corners and edges.
- Optimum height to avoid user's shoulder lifted when using the proposed mouse tray.

The material used for this prototype is PLA. The estimate cost to produce this design is around RM11 and the estimate time is 9 hours. The weight of this prototype is 9.6grams. Both support legs are different length this is because the mouse tray is designed to be slanted to avoid the user's shoulder lifted when using. The dimension of the platform is 150mm x 180mm while the length of the supported leg is 330mm and 430mm. The thickness of the prototype is 120mm. The 3D printer prototype of concept 1 is shown in Figure 4.37. The material used for this prototype is not strong and will bend when using the mouse on it. In addition, the rough surface caused the mouse cannot move smoothly on it.

Figure 4.37 (a): 3D printer prototype

Figure 4.37 (b): 3D printer prototype

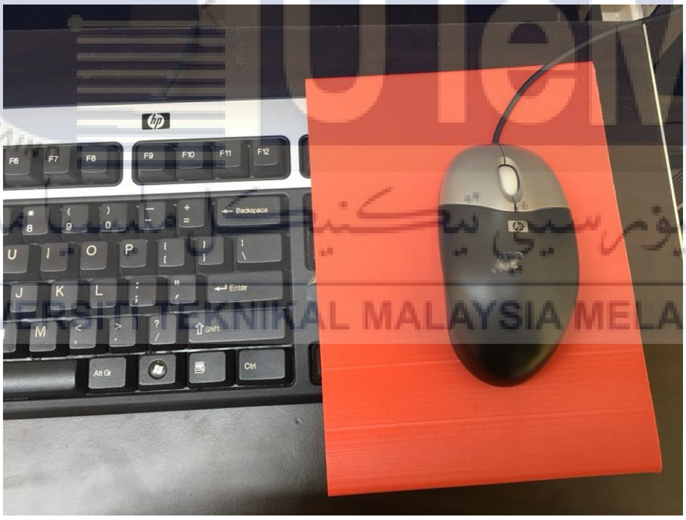


Figure 4.37 (c): 3D printer prototype

4.3.8 Final design of PLA prototype

The design of proposed mouse tray produced by 3D printer was improved to increase the strength and avoid bending when using computer mouse on it. The support of new proposed design was increased from two legs support to three legs support. Besides, ribs were added on the bottom of platform as shown in Figure 4.38 (c) to increase the stiffness of the proposed mouse tray. The dimension of the platform is 150mm x 180mm while the length of the supported leg is 330mm and 390mm.

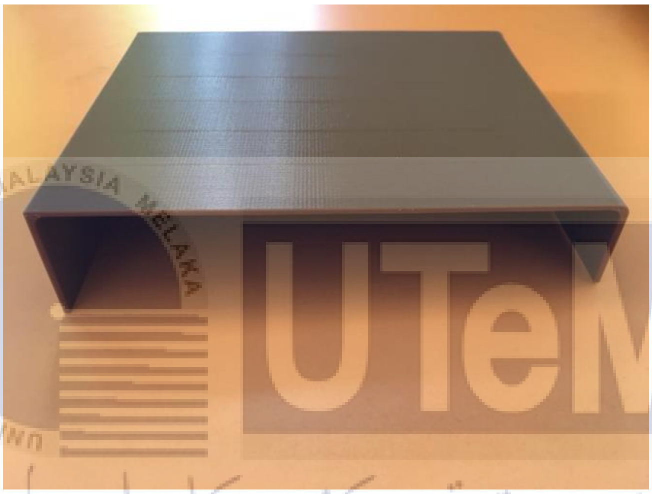


Figure 4.38 (a): Final design of PLA prototype

Figure 4.38 (b): Final design of PLA prototype

Figure 4.38 (c): Final design of PLA prototype

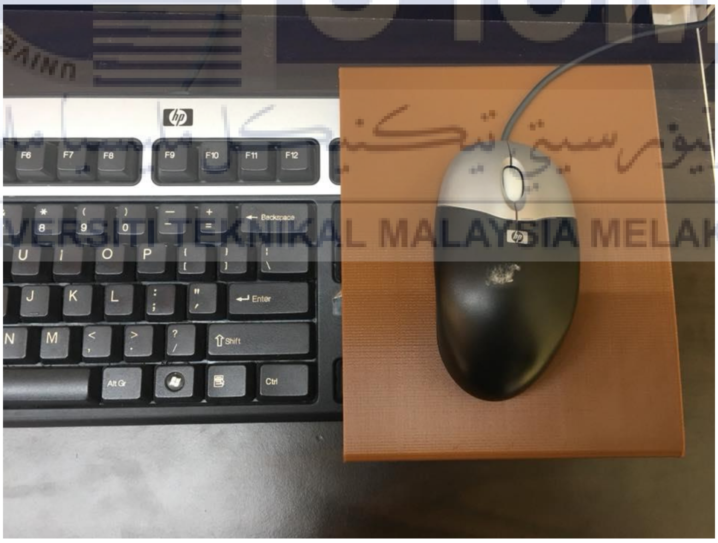


Figure 4.38 (d): Final design of PLA prototype

4.3.9 Final design of aluminium plate prototype

The material used for this prototype is aluminium plate. The estimate cost to produce this design is around RM16 and the estimate time is around 15 min per unit. Both support legs are different length this is because the mouse tray is designed to be slanted to avoid the user's shoulder lifted when using. The dimension of the platform is 150mm x 180mm while the length of the supported leg is 200mm and 330mm. The thickness of the prototype is 20mm. The aluminium plate prototype of final design is shown in Figure 4.39.

Figure 4.39 (a): Aluminium plate prototype

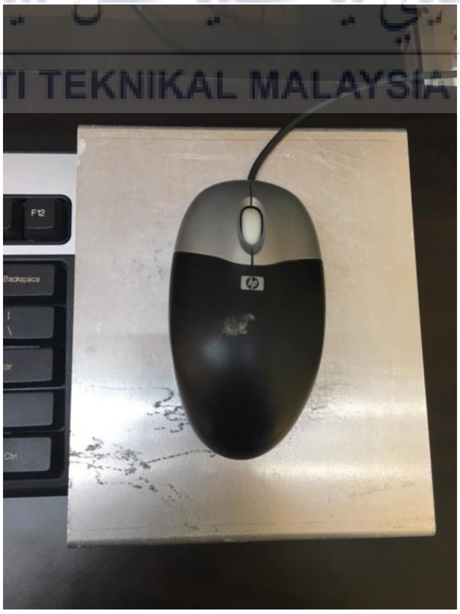


Figure 4.39 (b): Aluminium plate prototype

4.3.10 Cost Analysis

Cost analysis is developed by using Breakeven Analysis to calculate the breakeven quantity and breakeven cost for PLA prototype and Aluminium plate prototype. The variable cost for PLA mouse tray is lower than the Aluminium mouse tray as shown in Table 4.9. Figure 4.40 and Figure 4.41 show that breakeven quantity for PLA mouse tray is around 27 units and 61 units for Aluminium mouse tray. At this point, there is no profit or incurring loss. It is merely covering the total cost. For making a profit, the PLA mouse tray must sell above 27 units and above 61 units for Aluminium mouse tray. the breakeven quantity of PLA mouse tray is lower than the Aluminium mouse tray. However, the cycle time for PLA mouse tray is 12 hours per unit and for Aluminium mouse tray is 15 minutes per unit. The number of unit can be produced for PLA mouse tray is 2 units per day while for Aluminium mouse tray is 96 units per day as shown in Table 4.10. From the results can be concluded that the production for Aluminium mouse tray is faster.

Table 4.8: Fixed cost

Fixed Cost	Amount (RM/day)
Labour cost	45
Utilities	200
Total	**245**

Table 4.9: Variable cost

Variable Cost	Material	
	PLA	Aluminium
Material cost (per unit)	RM 11	RM 16

Estimated selling price per unit = RM 20

Breakeven point,

$$Q = \frac{F}{(P - v)}$$

Q = Breakeven quantity

F = Total fixed costs

v = Variable cost per unit

P = Selling price per unit

$$Breakeven\ quantity\ for\ PLA\ = \frac{245}{20-11} = 27.22\ units$$

$$Breakeven\ quantity\ for\ Aluminium\ = \frac{245}{20-16} = 61.25\ units$$

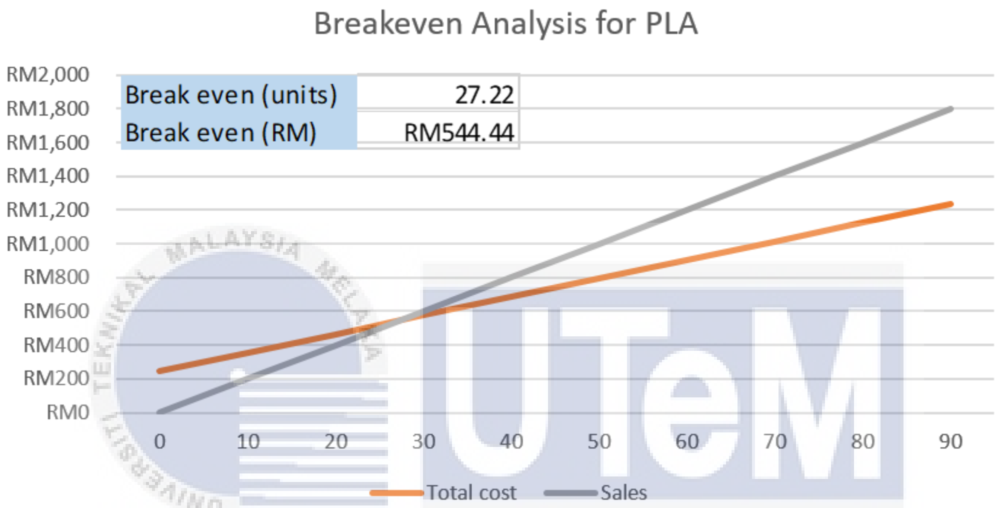


Figure 4.40: Breakeven analysis for PLA prototype

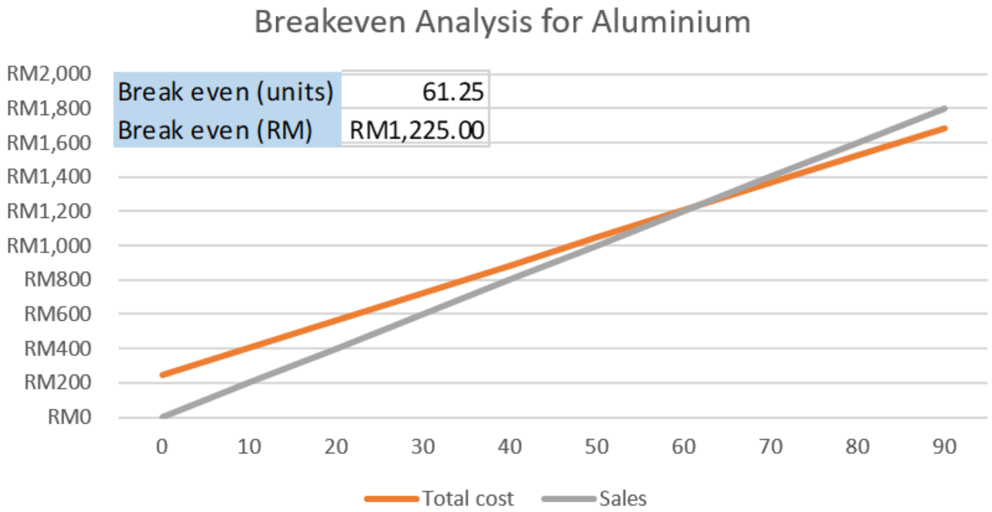


Figure 4.41: Breakeven analysis for Aluminium plate prototype

Table 4.10: Comparison between cycle time of PLA and Aluminium plate prototype.

Material	PLA	Aluminium
Cycle time	12 hours	15 minutes
Unit produced per day	2 units	96 units

4.4 Phase 3: Feedback from Professional Ergonomics Consultants

4.4.1 Results of evaluation form from professional ergonomics consultants

The question in the evaluation form were organized into three main sections: 1) Usability, 2) Usefulness and 3) Desirability. The usability section focuses on evaluating the overall easiness of using the proposed prototype. The questions in this section were designed not only to evaluate the usability of the current prototype, but also to direct the design to minimize specific usability issues in the next prototype iteration. The usefulness section consisted of questions to evaluate the potential benefits of the proposed prototype from the perspective of users. The desirability section consisted of several questions to estimate how excited and eager the users were use this proposed prototype in their daily work activities.

4.4.1.1 Usability

There are three questions under the usability section as shown in Table 4.11. All participants felt the proposed mouse tray is easy to use. Most of the people thought that the proposed mouse tray was neutral in term of the comfortable on upper limb when using it while one of the participants disagreed. She reported that she was used to the height of the traditional approach. All of them felt that they do not need a lot of changes on their way of doing things when using it.

Table 4.11: Distributions of the professional ergonomics consultants' responses on the usability of the proposed mouse tray.

I. USABILITY	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	1	2	3	4	5
It is **easy to use**.	0	0	0	1	4
Feel **comfortable on upper limb** when using it.	0	1	3	1	0
I do not need a lot of changes on my way of doing things to use this.	0	0	0	3	2

4.4.1.2 Usefulness

The usefulness section consisted of four questions focusing on evaluating the advantages of the proposed mouse tray. The results are shown in Table 4.12. Four of the five participants were neutral when asked if the proposed mouse tray improved their upper limb posture. One participant agreed that the proposed mouse tray improves his upper limb posture. All participants were in agreement that the distance of the placement of proposed mouse tray is easy to reach. When asked if they would rather use this proposed mouse tray than traditional approach, four of the participants were neutral opinion and one participant was agreed. Most of the participants agreed that the proposed mouse try will help to perform their work tasks efficiently and two were neutral on this.

Table 4.12: Distributions of the professional ergonomics consultants' responses on the usefulness of the proposed mouse tray.

II. USEFULNESS	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	1	2	3	4	5
The mouse tray **improves my upper limb posture.**	0	0	4	1	O
The distance of the placement of mouse is **easy to reach**.	0	0	0	4	1
I **would rather use this mouse tray** than traditional approach.	0	0	4	1	0
This mouse tray will help me to **perform my work tasks efficiently.**	0	0	2	3	0

4.4.1.3 Desirability

This section provides some assessment of the acceptance of the proposed mouse tray among the participants. A mix of views was seen when the participants were asked if they found the proposed mouse tray bring beneficial to them. Two of the participants were neutral on this, two of them were agreed and one of them was strongly agreed. When they were asked if they often use the proposed mouse tray during their works, one of them disagreed, two of them neutral on this and two of them agreed. Similarly, the results were same when they were asked whether their colleagues will want to use the proposed mouse tray. Four of the five participants were neutral opinion in terms of purchasing the mouse tray in future. Overall, three of the five participants were satisfied with the proposed mouse tray. Table 4.13 summarized the responses from the participants on their desirability for using the proposed mouse tray.

Table 4.13: Distributions of the professional ergonomics consultants' responses on the desirability of the proposed mouse tray.

III. DESIRABILITY	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	1	2	3	4	5
I **would really benefit** from the use of mouse tray.	0	0	2	2	1
I **often using this mouse tray** during my work.	0	1	2	2	0
I think some of **my colleagues will want to use** this.	0	1	2	2	0
I **would purchase** this mouse tray in the future.	0	0	4	1	0
Overall, I **satisfied** with the mouse tray.	0	0	2	3	0

4.4.2 Feedback from professional ergonomics consultants

The proposed mouse tray was tested by 5 professional ergonomics consultants in one week. Professional ergonomics consultants have been involved in thousands of assessment and mitigation projects. They have a lot of experiences and solve issues related to posture and ergonomics on daily basis. Their opinions are not theoretical but have lots of authority because of their professional experience in actual office work setting. Overall, they were satisfied with the proposed moue tray. Previously, the recurring issues were most of the office workers' shoulder were abducted and elbow extended when using the computer mouse due to the position of mouse is too far. In addition, the keyboard tray does not have enough space to put the computer mouse. It was observed that the upper limb posture of the professional ergonomics consultants was improved and the distance between alphabet typing and computer mouse was reduced as shown in Figure 4.42 and Figure 4.43.

Figure 4.42: The upper limb posture of subject in neutral posture.

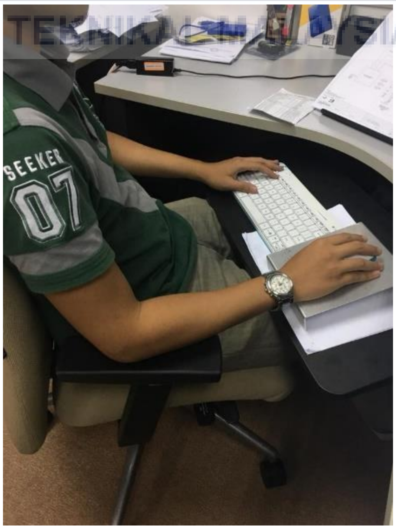


Figure 4.43: The upper limb posture of subject in neutral posture.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

A literature search revealed that several publications have identified connections between the office workers' activities and the prevalence of WMSDs. However, there have been a very limited number of research studies that have gone beyond the stages of problem identification and solutions. Reducing the distance between keyboard and mouse, provide a platform for mouse to place on keyboard tray, a cost effective product which is cheap to make and reducing the office workers' exposure to awkward upper limb posture may eventually to reducing the overall risk of them developing WMSDs. In this study, these issues were translated into the user's needs. The goal of the proposed mouse tray in this study was to address these issues and ultimately implement a functional prototype in the real office setting. The efforts focusing on usability, usefulness and desirability would need to be considered in order for the proposed mouse tray to be practical and applicable to office setting. A systematic design effort, integrating the knowledge or ergonomics and product design was then conducted. In this study, professional ergonomics consultants as the end users were involved throughout several design development stages, and through this process allowed the improvement in the design of the proposed mouse tray.

Design methodologies of collecting data and generating ideas were utilized to systematically guide the development of the product. The design iteration process included literature review, review reports from professional ergonomics and observation among UTeM staffs' office setting. Intervention concepts generated through these efforts were screened and narrowed down before being presented to professional ergonomics consultant in a second round of feedback. Mock-up models by using different types of material such as cardboard, wood, polylactic acid (PLA) and aluminium plate were made to facilitate the exchange of ideas. At last, a final design prototype was developed and another short interview with professional ergonomics consultants to evaluate it. The prototype will be given for end users to test for one week in their daily works. The feedback from the end users would determine if it was worthwhile to continue inverting effort in this particular concept. In general, it was observed that the professional ergonomics consultants were optimistic about the prototype. Overall evaluations on usability, usefulness and desirability indicated overall acceptance of the design.

The first objective of this research is to capture the upper limb posture of current office workers when using mouse at office workstation. The data collected are analysed. The results from the reports showed that among 728 subjects, there are 65% of the office workers complaint on upper limb discomfort. Among 200 subjects, 52% of them are complaints on upper limb symptoms due to mouse location in office setting. However, through the observation on the posture of using mouse, 89% of the office workers have poor upper limb posture which is due to the placement of mouse. The most received complaints of discomfort on upper limb part is shoulder which is 108 complaints among 200 subjects. The typical placement of keyboard and mouse is on desk. However, most of the office workers have problems on poor upper limb posture when using mouse. The mouse is placed far from the subject's body due to the referred documents or keyboard placement. The right shoulder of subject is abducted and elbow is extended in order to access the mouse. In addition, majority of the office workers spend almost 5 to 8 hours on computer per day. Prolonged shoulder abduction and elbow extended may associated with upper limb musculoskeletal disorders. The second situation is keyboard on tray and mouse on desk caused office workers required a longer time to access the mouse and the work task required the same repetitive motion to move her hand from keyboard to mouse during the long working period. Besides, office workers have to abduct their shoulder and extended their elbow due to the placement of mouse on desk.

The second objective is to design and develop a prototype mouse tray that is cost effective and can improve the upper limb posture when using mouse. The concept of the mouse tray is on the numerical pad. The distance between the keyboard and mouse is reducing instead of the location of mouse is on the right hand side of a full keyboard. Thus, a good upper limb posture and the time of accessing the mouse is reduced. The proposed mouse tray is cheap to make and can be installed into existing workstation.

The third objective is to validate how the proposed mouse tray may improve office workers' efficiency in terms of reducing the time to access the mouse and providing a better upper limb posture. The results of average time taken for subjects to complete the given task by using proposed mouse tray is shorter than the time taken by using traditional approach. The average time taken for subjects to complete the given task by using traditional approach is 1.38 minutes while the average time taken using proposed mouse tray was decreased to 1.13 minutes. This is because the distance between alphabet typing and mouse is shorter when using proposed mouse tray and the upper limb posture of subjects were improved. Previously, the recurring issues were most of the office workers' shoulder were abducted and elbow extended when using the computer mouse due to the position of mouse is too far. In addition, the keyboard tray does not have enough space to put the computer mouse. It was observed that the upper limb posture of the professional ergonomics consultants was improved and the distance between alphabet typing and computer mouse was reduced.

5.2 Recommendation

The prototype in this study was to provide a means to test a concept that was difficult for office workers to evaluate from verbal description and 2D sketches. An obvious future step is to improve on the design by further refining the prototype. The design flaws identified was the edge of the platform is not comfortable to use for a long period. The idea of an adding cushion on the edge to increase the comfortability should also be explored.

A higher level study employing a randomized control design of the experiment and a large subject sample from multiple company office setting should be performed in evaluating more refined iterations of the design. In addition, a more representative sample of office workers should be involved in those evaluations.

An additional for future work would include doing a time study of the postures involved during the use of the device. Work-sampling based approaches for postural behaviour analysis such as stress index analysis may be conducted to identify the posture of users with and without using proposed mouse tray. In addition, validate how the proposed mouse tray increase the work productivity and efficiency of office workers for a longer time study.

5.3 Sustainable Design and Development

Nowadays, the ideal of sustainability determined the value of the project highly for publics individuals to analyse the net value of the project. The principles of sustainability elaborated in terms of social, economic and environmental aspects.

This project involves social aspects, the proposed mouse tray is designed to fit on human arm with different hand size for comfortability purposes. With this device, the office workers can improve their upper limb posture when using mouse.

Besides, this project also involves in economic aspects, by comparing the mouse tray that available on the market shown in Section 2.3.2. Swivel mouse tray (RM326.41), MECS-BLK-001 (RM367.09) and Fully articulating mouse platform (RM1383.49). The cost of mouse tray for this project is implemented at a cost effective solution (RM20).

Moreover, in environmental aspects, the materials used in this project are polylactic acid (PLA) and Aluminium plate. PLA is a biodegradable material and bioactive thermoplastic aliphatic polyester derived from renewable resources which is environmentally friendly and sustainable. There is no waste of chemical component to the environment and this device does not affect the environmental related to pollution.

With these three aspects justification covers by the project's sustainable development. Hence, this project is highly sustainable.

5.4 Complexity

Conceptual design is a crucial stage in this project because it identifies key elements and sets the overall tone. Different stakeholders involved in this design process during finding design to ensure important details are included and realistic. Besides, different materials are used to create prototypes. In the early stage, methods of communicating conceptual ideas were sketches and verbal descriptions. The sketches are very hard to imagine and the issues are not clearly defined. Mock up prototypes act as a method of communication evolved from sketches to a functional model and make ideas tangible. The first design of prototype made by PLA is not strong enough to support the force applied when using computer mouse on it. The design is improved to increase the stiffness of the proposed mouse tray. This project also involved different machines in creating prototypes such as laser cutting machine, bending machine and 3D printer.

5.5 Long Life Learning (LLL) and Basic Entrepreneurship (BE)

Time management is important to complete this project within the limited time. I have room of improvement on managing time effectively. Gantt chart is used in this project for planning the timeline of the tasks ahead. Some tasks cannot be started until another tasks are finished. These factors need to be considered at the beginning and monitored throughout this project. In addition, communication skills are also important to allow office workers and professional ergonomic consultants to have better understanding on the purpose of this project and get input on their needs. Effective communications skills are also important to ensure accurate communication of information with technician in creating the prototypes for this project.

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Appendix A: Gantt Chart PSM 1

Task / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Identify Problem Statement														
Report Writing Introduction														
Sorting Reports Obtained from Ergonomics Consulting Company														
Study of Literature Review														
Appointing Methodology														
Conceptual Designs of Proposed Mouse Tray														
FYP 2 Presentation														
Draft Report Submission For FYP 1														

Planning Process   Actual Process

Appendix B: Gantt Chart PSM 2

Task / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Analyse Reports from Ergonomics Consulting Company															
Mock-Up Prototype															
Actual Prototype															
Report and Discussion of Project															
Conclusion and Recommendation															
FYP 2 Presentation															
Draft Report Submission For FYP 2															
Hardbound Report Submission															

Planning Process

Actual Process

Appendix C: Feedback Form

THIS FEEDBACK FORM IS FOR ACADEMIC PURPOSE ONLY. ALL INFORMATION WILL BE KEPT PRIVATELY AND CONFIDENTIALLY.

This participant feedback form consists of THREE (3) sections with TWO (2) pages. For the participant, please take a few minutes to fill out this form on the collection and recording of ethnicity data.

SECTION A: USABILITY

Please kindly tick (/) where applicable.

I. USABILITY	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	1	2	3	4	5
It is **easy to use**.					
Feel **comfortable on upper limb** when using it.					
I do not need a lot of changes on my way of doing things to use this.					

SECTION B: USEFULNESS

Please kindly tick (/) where applicable.

II. USEFULNESS	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	1	2	3	4	5
The mouse tray **improves my upper limb posture.**					
The distance of the placement of mouse is **easy to reach**.					
I **would rather use this mouse tray** than traditional approach.					

This mouse tray will help me to **perform my work tasks efficiently.**					

SECTION C: DESIRABILITY

Please kindly tick (/) where applicable.

III. DESIRABILITY	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	1	2	3	4	5
I **would really benefit** from the use of mouse tray.					
I **often using this mouse tray** during my work.					
I think some of **my colleagues will want to use** this.					
I **would purchase** this mouse tray in the future.					
Overall, I **satisfied** with the mouse tray.					

My suggestion on improving this design

____

____

____

THANK YOU FOR FILLING THIS FEEDBACK FORM.