



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**THE DEVELOPMENT ON FOREARM CRUTCHES TO
REDUCE UPPER LIMB PRESSURE DISTRIBUTION
EVALUATED BY EMG (ELECTROMYOGRAPHY)**

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering Technology (Product Design) with Honours.

by

TEO XUE CHEE

B071410209

940301-01-6998

FACULTY OF ENGINEERING TECHNOLOGY

2017

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: The Development On Forearm Crutches To Reduce Upper Limb Pressure Distribution Evaluated By EMG (Electromyography)

SESI PENGAJIAN: 2017/18 Semester 1

Saya **TEO XUE CHEE**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. ****Sila tandakan (✓)**

- SULIT** (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)
- TERHAD** (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
- TIDAK TERHAD**

Disahkan oleh:

Alamat Tetap:

NO. 30, Jalan Silat Gayong 4

Bandar Selesa Jaya, 81300, Skudai

Johor

Tarikh: _____

Cop Rasmi:

Tarikh: _____

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled “The Development On Forearm Crutches To Reduce Upper Limb Pressure Distribution Evaluated By EMG (Electromyography)” is the results of my own research except as cited in references.

Signature :

Author’s Name : Teo Xue Chee

Date : 15th December 2017

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Product Design) with Honours. The member of the supervisory is as follow:

.....

Umi Hayati Binti Ahmad

(Project Supervisor)

ABSTRAK

Tongkat merupakan sesuatu peralatan yang terutamanya berfungsi untuk membantu pergerakan pesakit yang menghadapi kecederaan ataupun yang menjalani pembedahan di anggota badan rendah. Walaubagaimanapun, penggunaan tongkat selalunya membawa kesan kepada pesakit seperti ketidakselesaan tangan. Objektif utama projek ini adalah untuk menganalisis pengagihan tekanan di struktur anatomi di tempat tangan semasa berjalan dengan tongkat lengan piawai dan tongkat lengan dengan tambahan pemegang baru. Pemegang ergonomi telah direka bentuk dan dihasilkan dengan getah silikon. Dua ujikaji, satu dengan tongkat lengan piawai dan satu dengan tongkat lengan dengan tambahan pemegang baru telah dijalankan oleh enam orang dewasa yang sihat, dengan dua orang yang pernah menggunakan tongkat lengan disebabkan kecederaan di anggota badan bawah. Pengagihan tekanan anggota badan atas telah diukur menggunakan penderia tanpa wayar Trigno EMG System dan mendapatkan isyarat EMG dengan komputer riba yang mempunyai Delsys EMGworks® Software semasa sukarela berjalan lima gaya berjalan 3 titik. Keputusan ujian EMG menunjukkan tambahan pemegang ergonomik dapat mengurangkan pengagihan tekanan atau aktiviti otot di anggota badan atas. Pemegang yang ergonomik seperti alur jari, alur ibu jari, bonjol tapak tangan dan kawalan hujung meningkatkan permukaan sentuh antara tapak tangan dengan pemegang dan mengurangkan tenaga diperlukan untuk pemegangan yang kuat. Satu lagi dapatan menunjukkan diameter pemegang ergonomik yang dihasilkan bersesuaian dengan sukarela yang tangan panjang 18.5 hingga 20.5 cm.

ABSTRACT

Crutch is a walking aid that mainly functions to maintain mobility of patients who injured or having surgery at lower extremities and it normally bring side effects such as hand uncomfortable to the patient. The main objective of this project is to analyse the pressure distribution on anatomical structure of the hand during ambulation with standard forearm crutch and additional handgrip forearm crutch. The additional ergonomic handgrip was designed and manufactured using vacuum casting, with silicone rubber as the raw material. Two experiments in ambulation on crutch, one with standard forearm crutches and one with additional handgrip forearm crutches were conducted with participation of six healthy adults, where two of them ever used forearm crutch because of injury at lower limb. The pressure distribution on upper limb when volunteer performing five 3-point gait were measured using wireless sensors of Trigno EMG System and EMG signal was acquired by laptop with Delsys EMGworks® Software. The results of the EMG test showed that the additional ergonomic handgrip reduce the pressure distribution or muscle activity on upper limb significantly. The ergonomic design at the handgrip such as finger groove, thumb groove, palm bulge and end guard increase the contact surface of inner hand with the handgrip, results in the lower energy needed to perform power grasp action. Another finding shows that the diameter of the ergonomic handgrip manufactured is suitable to volunteer within range from 18.5 to 20.5 cm of hand length.

DEDICATION

To my beloved parents,
Teo Soo Chea and Lim Siok Huang,
Who always support me in my life;
To my beloved project supervisor,
Umi Hayati Binti Ahmad,
Who always give me valuable suggestion and guidance;
To my beloved friends,
Who always encouraging me;
To my beloved laboratory assistants,
Who always explain questions that I asked patiently.

ACKNOWLEDGEMENT

I would like to express my greatest gratitude to everyone who have helped me, supported me and guided me throughout my project, especially my project supervisor, Umi Hayati Binti Ahmad. She is always guide me, lead me to the correct path and give valuable suggestion if anything is wrongly done. She helps me to arrange the time in conducting experiment as the equipment is shared by few students. I will not able to complete my project in time and successfully without the guidance of my supervisor.

Then, I would like to thank to my beloved parents and friends who always support me and inspire to achieve more. They encourage me all the time so that I do not have thought of giving up even though when met some difficulties at the rush and heavy hours.

Last but not least, I would like to thank to laboratory assistants in Project Lab and Rapid Manufacturing Lab who always explain the concept and assist me in produce my prototype sincerely. They help me a lot in understanding more about the equipment and material used in my project. I will not able to complete this project on time without their warm help.

TABLE OF CONTENT

Abstrak	i
Abstract	ii
Dedication	iii
Acknowledgement	iv
Table of Content	v
List of Tables	ix
List of Figures	x
List Abbreviations, Symbols and Nomenclatures	xv
CHAPTER 1: INTRODUCTION	1
1.0 Introduction	1
1.1 Background	1
1.2 Problem Statement	3
1.3 Objective	4
1.4 Scope	4
CHAPTER 2: LITERATURE REVIEW	6
2.0 Introduction	6
2.1 Crutches	6
2.1.1 Function of Crutch	7
2.1.2 Type of Crutches	7
2.1.2.1 Axillary Crutches	7
2.1.2.2 Non-Axillary Crutches	10

2.1.3	Crutch Fitting For a Patient	12
2.1.4	Crutch Gait	13
2.1.4.1	Swing-Through Gait	13
2.1.4.2	Two-Point Gait	14
2.1.4.3	Three-Point Gait	14
2.1.4.4	Four-Point Gait	15
2.1.5	Crutch Side Effect	15
2.1.6	Design of Ergonomics Crutch Handle	16
2.2	Upper Limb	17
2.2.1	Shoulder	18
2.2.2	Upper Arm	18
2.2.3	Lower Arm	19
2.2.4	Hand	19
2.2.5	Injury at Upper Limb	20
2.2.6	Optimum Diameter of Handle	21
2.3	Pressure Distribution When Walking On Crutches	21
2.3.1	Method of Pressure Distribution Measurement	23
2.3.1.1	Pressure Sensor	23
2.4	Electromyography (EMG)	24
2.4.1	Surface EMG	25
2.4.1.1	Procedure for Surface EMG	26
2.4.2	Intramuscular EMG	26
CHAPTER 3: METHODOLOGY		27

3.0	Introduction	27
3.1	Identify Project Title and Problem Statement	29
3.2	Project Planning	29
	3.2.1 Project Time Duration	29
	3.2.2 Gantt Chart	30
3.3	Study on Literature	32
3.4	Identify Project Objective, Scope and Methodology	32
3.5	Survey by Using Questionnaire	33
3.6	Conceptual Design	33
3.7	3D Modelling By Using Software	34
	3.7.1 Create 3D Modelling of the Additional Handgrip	35
	3.7.2 Create Mold Core and Cavity	37
3.8	Prototyping Using 3D Printers	39
3.9	Prototyping Using Vacuum Casting	40
	3.9.1 Production of Handgrip Mold	40
	3.9.2 Production of Silicone Handgrip	43
3.10	Run Experiment	47
	3.10.1 Volunteers Selection	47
	3.10.2 Muscles Identification	48
	3.10.3 Data Acquisition Procedure	48
3.11	Result Recording and Analysing	51
	3.11.1 Justify Improvement in New Handgrip	52
	3.11.2 Prototype Feedback Survey	52
3.12	Writing Result and Discussion	53

CHAPTER 4: RESULT AND DISCUSSION	54
4.0 Introduction	54
4.1 Experiment Result	54
4.1.1 EMG Result Analysis	54
4.1.2 Comparison of EMG Result	57
4.1.3 Identification of Suitable Hand Length for Handgrip Diameter	59
4.2 Questionnaire Result	63
4.3 Feedback Survey Result	64
4.4 Implication of The Finding	65
4.5 Limitation	65
CHAPTER 5: CONCLUSION AND FUTURE WORK	67
5.0 Introduction	67
5.1 Summary	67
5.2 Recommendation for Future Work	68
REFERENCES	69
APPENDICES	
A Survey Questionnaire Result	
B Handgrip Drawing	
C Handgrip Drawing (Upper Part)	
D Handgrip Drawing (Lower Part)	

- E Core and Cavity Assembly Drawing (Upper Part)
- F Core and Cavity Assembly Drawing (Lower Part)
- G Results of EMG Test
- H Amplitude Analysis of The EMG Signal

LIST OF TABLES

2.1	Maximum force and pressure in different hand areas	20
2.2	Recommended sizes for a set of four double-frustum handles	21
2.3	Mean (standard deviation) angular kinematics of the stance trials for the right lower extremity	22
2.4	Mean (standard deviation) pressure (kPa) of the sensor quadrants	23
2.5	Comparison between surface and intramuscular EMG	25
3.1	Location of wireless sensor	48
4.1	Optimum diameter for each volunteer	60
4.2	Feedback survey result	64

LIST OF FIGURES

1.1	Graph of injury, RC injury and pain percentage for walker/crutch, wheelchair and slipstream	3
2.1	Man holding stick (aba sceptre) as symbols of authority	7
2.2	Adjustable axillary crutch	8
2.3	Axillary crutch with platform	9
2.4	Ortho crutch	9
2.5	Telescoping underarm aluminium crutch	10
2.6	Triceps crutch	10
2.7	Forearm crutch with closed cuff	11
2.8	Adjustable forearm crutch	11
2.9	Platform crutch	12
2.10	Correct distance between crutch pad and axilla	12
2.11	Location of ulnar styloid	13
2.12	Swing-through gait	14
2.13	Two-point gait	14
2.14	Three-point gait	15
2.15	Four-point gait	15
2.16	Design of ergonomics handle	16
2.17	Posture of fingers for flat handle and with finger groove handle	17
2.18	Handle with finger grooves	17

2.19	Anterior view of right upper limb	18
2.20	Pressure distribution on hand	19
2.21	Position of lateral, ulnar, inter mediate and medial at forearm	22
2.22	Total pressure distribution of all volunteers	22
2.23	Averaged peak pressure values for each quadrant of the sensor	23
2.24	Novel Pliance ® Matrix sensors	24
2.25	Type of electrodes used in recording EMG result	25
3.1	Flowchart of the project	28
3.2	Gantt chart	31
3.3	Conceptual design 1	34
3.4	Conceptual design 2	34
3.5	Conceptual design 3	34
3.6	Isometric view of conceptual design 2	35
3.7	Side view of conceptual design 2	36
3.8	Standard forearm crutch handle	36
3.9	Inner surface that follows crutch handle shape	36
3.10	3D modelling of upper handgrip part	37
3.11	3D modelling of lower handgrip part	37
3.12	Ball and socket snap-fit	37
3.13	Parting line of upper part	38
3.14	Parting surface of upper part	38
3.15	Mold core and cavity before arrangement	38
3.16	Mold core and cavity after arrangement	39

3.17	Mold core and cavity of upper part (SolidWorks)	39
3.18	Mold core and cavity of lower part (SolidWorks)	39
3.19	Prototype print using UPS Print printer	40
3.20	Cutting wood blocks using disc cutter	41
3.21	Setting programming using SRP Player software	41
3.22	Measuring cutting tool height	42
3.23	Roughing process of cavity	42
3.24	Mold core and cavity of upper part	43
3.25	Mold core and cavity of lower part	43
3.26	Drying sprayed cores and cavities under the sun	44
3.27	Measuring mass of silicone	44
3.28	Mixture in vacuum machine	45
3.29	Clamping molds with G-clamps	45
3.30	Separate the mold using scraper	46
3.31	Removal of part from mold using air blow gun	46
3.32	Two sets of handgrip parts	46
3.33	Features of new design handgrip	47
3.34	Name and region of muscles involved	48
3.35	Activate the sensor by long-click the button	49
3.36	Location of sensors mounted on upper limb	50
3.37	Volunteer conducting Experiment 1	50
3.38	Volunteer conducting Experiment 2	50
3.39	Result of volunteer 2's brachioradialis muscle activity in Experiment 1	51

3.40	Amplitude of volunteer 2's brachioradialis muscle activity result in Experiment 1	52
4.1	EMG result of volunteer 3 in Experiment 1 (sensor 5)	55
4.2	EMG result of volunteer 3 in Experiment 2 (sensor 5)	55
4.3	Bar chart of comparing average peak voltage result of Experiment 1 and 2 for volunteer 1	57
4.4	Bar chart of comparing average peak voltage result of Experiment 1 and 2 for volunteer 2	57
4.5	Bar chart of comparing average peak voltage result of Experiment 1 and 2 for volunteer 3	58
4.6	Bar chart of comparing average peak voltage result of Experiment 1 and 2 for volunteer 4	58
4.7	Bar chart of comparing average peak voltage result of Experiment 1 and 2 for volunteer 5	58
4.8	Bar chart of comparing average peak voltage result of Experiment 1 and 2 for volunteer 6	59
4.9	Bar chart of comparing average peak voltage result among volunteers for sensor 1	61
4.10	Bar chart of comparing average peak voltage result among volunteers for sensor 2	61
4.11	Bar chart of comparing average peak voltage result among volunteers for sensor 3	61
4.12	Bar chart of comparing average peak voltage result among	62

	volunteers for sensor 4	
4.13	Bar chart of comparing average peak voltage result among volunteers for sensor 5	62
5.1	3D modelling of modified handgrip	68

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ABS	-	Acrylonitrile-Butadiene-Styrene
EMG	-	Electromyography
MU	-	Motor units
MSDs	-	Musculoskeletal disorders
QTM	-	Qualisys Track Manager
RC	-	Rotator cuff

CHAPTER 1

INTRODUCTION

1.0 Introduction

Backgrounds of the project, problems of the project, objectives of the project as well as scopes of the project are being discussed in this chapter.

1.1 Background

In this day and age, the probability to get an injury is high. Regardless performing a simple morning exercise or completing a heavy task, these activities might end up with a sprained ankle or a broken leg (Ghalekhani et al., 2016). Injuries at lower extremities not just bring the sense of pain, but also influence the routine work and activity. Thus, crutches have been created and used by humans for approximately 5000 years from the ancient time until now. It is a walking aid that mainly functions to maintain mobility of patients who injured or having surgery at lower extremities (Fischer et al., 2014). It minimizes the discomfort and pressure exerted on injured lower limbs by transferring the body weight from lower limbs to the upper limbs (Borrelli and Jr, 2013). By using a crutch, the injured body part can rest in a relaxing condition and avoids increasing seriousness of injury that can contribute to a longer healing time. Other than that, a crutch also plays a significant role on improving user's stability and balancing when ambulation by the enlargement of supporting base. There are several types of crutches that have different advantages and disadvantages to users, which are forearm crutches, underarm crutches, platform crutches, Strutters and leg support crutches as view in Livestrong website at <<http://www.livestrong.com/article/192684-how-to-keep-fit-with-crutches/>>. The crutch that used in this project is forearm crutch, also known as Lofstrand crutch or

elbow crutch. It can be classified into two categories, which are open and closed cuff crutch. The handgrips can be adjusted until it levels with wrist bone to minimize the wrist bone impact when gait. Some of the elbow cuff can even be adjusted until forearm cradles just below the elbow joint.

A good physical product brings value to its customers, no matter increasing their life standard or solving problems met in their daily life. A good product with ergonomic design can even improve the comfort and safety level of users. Ergonomics is the investigation and study of interaction between human and physical environment, including a product. Its main purpose is to enhance human health and the system performance. It is also to reduce stress and eliminate an injury that comes with the overuse of muscle, bad posture and repeated task while using a particular product. Thus, implementation of ergonomic principle in a product can greatly decrease the probability of suffering musculoskeletal disorders (MSDs) as its design is optimum for our body and muscle structure (Dennerlein, 2014).

Title of this project is the development on forearm crutches to reduce upper limb pressure distribution evaluated by EMG (electromyography), this is mainly focus on reducing the pressure exerted between user's upper limb and crutch. According to Daud et al. (2016), different country having different causes of injury, however, people that getting injured on lower limbs always choose to reduce force exerted on lower limb by lean on crutches. When using a crutch to balance body stability, it arises some side-effect including palm pain. Electromyography will be the equipment to measure electrical activity of muscles when they at rest and moved. In order to reduce the pressure distribution on upper limb when walking with crutches, additional ergonomics handgrip will be added on the crutches.

1.2 Problem Statement

Nowadays, fall or accident that leads to lower extremities injured is very common especially when human chasing for fitness and health. Forearm or elbow crutches enable lower extremities injured patient to perform ambulation and stance in an easier way by enlarging the supporting area and increasing the stability of the body (Sherif et al., 2016).

It is not to be denied that crutches play a very important role in assisting the daily life of injured patient, nevertheless, there are some problems occur while using the Lofstrand crutch. According to Sherif et al. (2016), walking on crutches usually can cause hand uncomfortable and injury because joints of the hands are too weak to bear entire body mass. For instance, during crutch gait with the legs completely unloaded with forces, the radiocarpal joint between the radius and carpus may be loaded more than 100% of body weight (Westerhoff et al., 2012). In addition, user can also suffer traumas and localised fatigue when performing power grip associated with repetitive hand action (Shiri et al., 2006). The contact between hand and elbow with the handgrip and cuff of the elbow crutches can normally trigger tenosynovitis in biceps tendon and contributes to ulnar neurapraxia at the wrist (Ginanneschi et al., 2009). Last but not least, ulnar bone fracture and complication such as skin hematoma can be caused when walking on crutch for a certain period (Molteni, 2016).

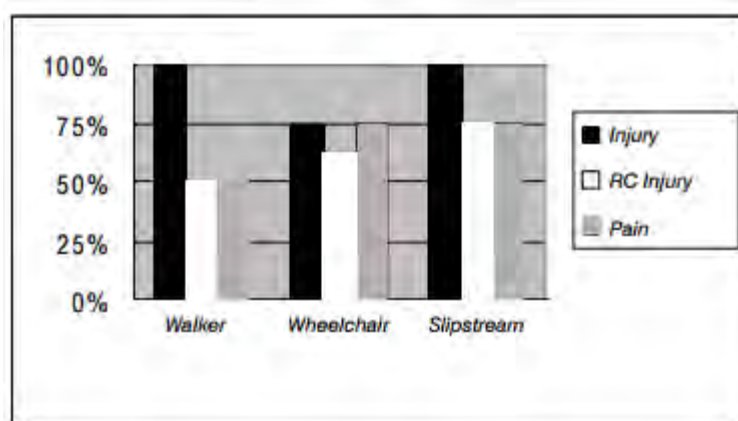


Figure 1.1: Graph of injury, RC injury and pain percentage for walker/crutch, wheelchair and slipstream (Source: <<http://www.scielo.br/aob>>

04/05/17)

1.3 Objective

Objective of a project is very essential as a guidance and direction throughout the project. Project will be suffered when conducting a plan without clarity and forethought. Defining of specific goals and objectives avoid the digression from the point. Thus, three objectives of this project have been listed below.

- 1) To develop an ergonomic handgrip that can assemble with the particular shape handle of forearm crutch
- 2) To analyse the pressure distribution on anatomical structure of the hand during ambulation with standard forearm crutches and additional handgrip forearm crutches
- 3) To determine the hand length that is suitable with the diameter of the handgrip

1.4 Scope

The scope of this project is only focus on walking on forearm or elbow crutches. Other types of crutches such as axillary or underarm crutches, platform crutches, Strutters and leg support crutches are not included in this project as the pressure distribution among these crutches are mostly different. Areas to be studied are focused on upper extremities, muscle involved are trapezius, deltoid, biceps brachii, brachioradialis and triceps brachii. The volunteer of this project study are adults that consist of male and female healthy volunteers with two of them ever used forearm crutches because of injury at lower limb. Three male and three female volunteers with about the same in heights and hand sizes will involve in this study. The equipment used in this project is electromyography (EMG), it is used to measure electrical activity of muscles when they at rest and moved. The data will be recorded when volunteers perform crutch gait. According to Timby (2009) and Heller (2016), crutch-walking gait can be categorized into four types, two-point gait, three-point gait (non-weight-bearing and partial weight-bearing), four-point gait and swing-through gait. Three-point gait with non-weight-bearing will be performed by volunteers and results of their