INVESTIGATION OF MUSCLE FATIGUE FOR PROBLEMATIC FEET USING EMG

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INVESTIGATION OF MUSCLE FATIGUE FOR PROBLEMATIC FEET USING EMG

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

by

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I hereby, declared this report entitled “Investigation of Muscle Fatigue for Problematic Feet using EMG” is the results of my own research except as cited in reference.

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Date : 10th JANUARY 2020

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The members of the supervisory committee are as follow:

……..

(Dr. Zulkeflee Bin Abdullah)

ABSTRAK

Kaki rata yang juga dikenali sebagai Pes Planus adalah salah satu jenis kaki yang bermasalah. Salah satu cara untuk merawat masalah kaki rata adalah dengan menggunakan pelapik kasut ortotik untuk memberi sokongan, memperbaiki kecacatan dan memperbaiki pergerakan sendi dan anggota badan. Pelapik kasut ortotik yang diubahsuai boleh memuatkan kaki pesakit dengan sempurna dan berfungsi dengan lebih baik daripada pelapik kaki ortotik yang sedia ada di pasaran. Pengeluaran besar-besaran tidak sesuai untuk penghasilan pelapik kasut ortotik kerana pelbagai ciri dimensi berlainan untuk setiap individu. Oleh itu, pendekatan lain perlu dipertimbangkan dengan melaksanakan teknologi pembuatan tambahan bagi menghasilkan pelapik kasut ortotik yang diubahsuai. Tujuan kajian ini adalah untuk menentukan keberkesanan pelapik kasut ortotik TPU yang diubahsuai dengan ujian EMG, untuk mengenal pasti keletihan otot semasa kerja berulang dan untuk menafsirkan pengaruh pada keletihan otot dan mencadangkan pengoptimuman. Keberkesanan pelapik kasut ortotik TPU yang diubahsuai ditentukan dengan menjalankan ujian EMG ke atas subjek yang menderita dari masalah kaki rata. Eksperimen diulang sebanyak tiga kali dan data dicatatkan dalam graf bar. Keletihan otot dengan pelapik kasut dan tanpa pelapik kasut dibandingkan di bawah tiga tugasan yang berbeza iaitu berjalan, berlari dan menaiki tangga. Dengan menganalisis graf bar, pengaruh luaran untuk keletihan otot dinilai. Ujian EMG membuktikan bahawa keletihan otot dapat dikurangkan dengan menggunakan pelapik kasut ortotik TPU yang diubahsuai. Tugasan yang berlainan memberi kesan kepada keletihan otot yang berbeza bergantung atas beberapa faktor. Pelapik kasut ortotik TPU yang disesuaikan menawarkan sokongan, pembetulan kecacatan pada kaki dan pengurangan keletihan otot.

ABSTRACT

Flat foot which is also known as Pes Planus is one of the types of problematic foot. One of the way to treat flat foot problem is by using an orthotic insole as to provide support, correct the deformities and improve the movement of joints and limbs. The customised orthotic insole can fit the patient's feet perfectly and perform better than off – the – shelf insoles that already available in the market. A mass production is not suitable for the orthotic insole production due to the large range of dimension characteristic for each individual. Thus, another approach is necessary to be considered by implementing additive manufacturing technology to produce the customised orthotic insole. The purpose of this study is to determine the efficacy of customised TPU orthotic insole using EMG testing, to identify the muscle fatigue during repetitive work and to interpret the potential influence on muscle fatigue and suggest optimisation. The efficacy of customised TPU orthotic insole is determined by conducting EMG testing on subject who suffers from flat feet. The experiment is repeated three times and the data is recorded in bar graph. The muscles fatigue with insole and without insole is compared under three different tasks which are walking, running and stair climbing. By analysing the bar graph, the potential external influences for the muscles fatigue is evaluated. The EMG testing proved that the muscles fatigue can be reduce by using customised TPU orthotic insole. The varying assigned tasks affected the muscles fatigue differently depending on some factors. The customised TPU orthotic insole offers a support, correction for deformities on the foot and reduction of muscles fatigue.

DEDICATION

This thesis is dedicated first and foremost to Almighty God and myself. I never expected that I pushed myself until this far through the hardship and struggling over something seeming impossible to be done.

Lovingly to my parents, Mohd Husni Bin Ismail & Hasniza Binti Mustapha, the strong and gentle soul who always be there for me when I was down, taught me to never stop believing in Allah's plans and showering me unconditional love, guidance and support.

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In the name of Allah S.W.T, the Most Gracious and the Most Merciful. All high praise gives towards Allah S.W.T, because of Him I am able to complete Undergraduate Project 2 as the first step moving towards my career planning. In order to complete this thesis, I was always praying to Allah while hoping my journey was in His bless.

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LIST OF ABBREVIATIONS

ABS	-	Acrylonitrile Butadiene Styrene
AFO	-	Ankle and Foot Orthosis
AM	-	Additive Manufacturing
CAD	-	Computer Aided Dseign
CAM	-	Computer Aided Manufacturing
CNC	-	Computer Numerical Control
GLH	-	Gastrocnemius Lateral Head
EMG	-	Electromyography
EVA	-	Ethylene Vinyl Acetate
FDM	-	Fused Deposition Modelling
FO	-	Foot Orthosis
ID	-	Identification Data
KAFO	-	Knee, Ankle and Foot Orthosis
PA	-	Polyamide
PE	-	Polyethylene
PP	-	Polypropylene
PU	-	Polyurethane
PL	-	Peroneus Longus
PLA	-	Polylactic Acid
RF	-	Rectus Femoris
RMS	-	Root Mean Square
TA	-	Tibialis Anterior
TPE	-	Thermoplastic Elastomer
TPU	-	Thermoplastic Polyurethane

CHAPTER 1
INTRODUCTION

1.1 Background

Flat foot or also known as Pes Planus is a medial longitudinal foot arch in which the entire foot in contact with ground that the foot is in total collapse that might seems different with normal foot as shown in the Figure 1.1. It is might causing altered foot kinetics or poor postural stability due to abnormal foot structure. According to Kodithuwakku *et al*. (2019), flat foot occurrence can be multifactorial in which it could be present since birth which is known as congenital pes planus or it could be develop later in life which is known as acquired pes planus. The use of foot orthotic insoles is the corrective action on the flat feet patients that can reduce and sufficiently helps to achieve ideal support of foot while standing and walking (Nataraja & Sulaiman, 2015).

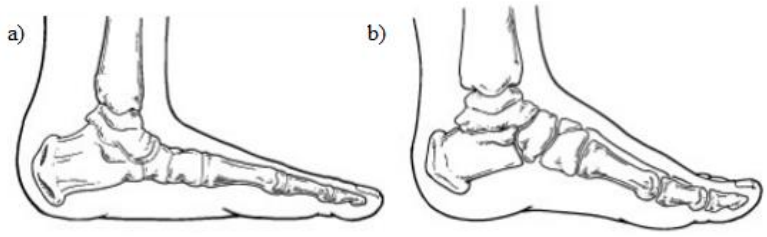

Figure 1.1: (a) Flat foot (b) Normal foot.

According to Davia *et al*. (2018), the traditional manufacturing process of customised orthotic insoles are either handcrafted or subtractive. Additive manufacturing (AM) techniques also known as 3D printing through fused deposition modelling (FDM) is the latest advance which is the new way to produce the orthotic insole. The foot muscles becoming weaker or tired after repetition of movements. Muscle fatigue is a sign where the decrease muscle ability performs over the time (Wan, 2015).

1.2 Problem Statement

Flat feet can cause pain all over the joints and muscles of the lower body which is including the ankles, knees along with the hips and lower back. People who suffer from flat feet may make even the simple daily motions painful and might discourage them performing their work duties or basic household tasks. The effective way to treat the pain of flat feet is to use the orthotic insoles support that are commonly worn inside the shoe which available at drugstores or pharmacies. However, the current orthotic insoles are not fit correctly for patient foot or give the support for the right areas of the body. The design of the orthotic insoles should be customisable that can put up for unique foot shapes and sizes due to the severity of foot arches.

Vacuum forming and subtractive manufacturing are the conventional manufacturing process to produce orthotic insoles (Davia *et al.*, 2018). Moreover, the traditional material of orthotic insoles that commonly used are cock, leather, metal, polypropylene, polyethylene and acrylic (Sivarajah, 2018). Thus, the common materials that have been used to produce orthotic insole are most likely compatible with the conventional manufacturing process which probably caused long time consuming and slow production rate. The flat foot patient could not afford to purchase the current customised insole that available in the market due the higher of production cost that caused the price is prohibitively expensive (Kim & Joo, 2019).

Muscle fatigue of the lower limb muscles follow most frequently due to repetitive movements in our daily activities. The overwork use of muscles might cause a muscles fatigue in a certain part or the body. Electromyography (EMG) is a well-known and acceptable measuring technique to analyse the muscle fatigue during repetitive work (Khanam *et al.*, 2015). This project expected to determine the muscle fatigue on the flat feet patients when using the customised TPU orthotic insole.

1.3 Objective

The objectives of this study is:

1. To determine the efficacy of customize TPU orthotic insole using EMG testing.
2. To identify the muscle fatigue during repetitive work.
3. To interpret the potential external influence on muscle fatigue and suggest optimisation.

1.4 Scope

This research focus on patient who suffers from flat foot in which the potential problems of the different shape and size of insoles due to the different severity foot arches. Other than that, this project involves appropriate muscles to attach EMG sensors during repetitive movement under several different tasks.

1.5 Significant of Study

The application of additive manufacturing (AM) technology in medical sector can be a treasured method apart of the application of AM in the industrial sector of manufacturing and prototyping. The use of the advanced FDM technique is expectedly would reduce the time consuming to produce or print a product. The effective methods and tools in testing the reliability of customised TPU orthotic insole as the best flexible material is highlighted as the result of the study. Thus, this research should come out with the comparison of muscle fatigue during repetitive works between using the customised TPU orthotic insole and barefoot.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter purposes are to discuss and extract all the information achieved from the previous research of the existing product all around the world and not only focusing in Malaysia. Moreover, there are a lot of people around the world have done the research on development of orthotic insoles as the solution to help patients who suffer from flat feet by producing it through additive manufacturing process which is the advance technique using the various material.

2.1.1 Human Foot Anatomy

In order to design any types of footware, it is important to have a depth knowledge of external, internal and anatomy of the foot. It assured to a well knowledge of the bone structure and musculature. The use of footwear is not only to provide protective covering but also povide a mechanical harmony as to improve the performance of design and engineering solutions for human biomechanics (Vass & Mohar, 1999).

The lowest point of human leg is foot. The structure of the foot along with the balance systems of natural body make humans not only capable of walking but also running, jumping and climbing. Human can do such things with the flexible structures of bones, joints, muscles and soft tissues of foot. The foot bones are usually divided into three segments as shown in Figure 2.1.

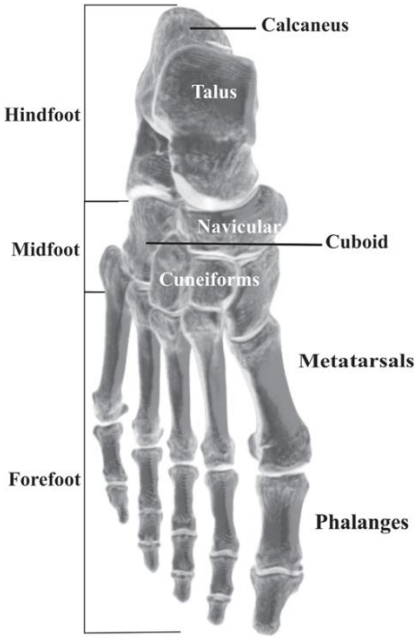

Figure 2.1: Segments of foot bones (Levangie, P. K., & Norkin, C. C., 2001).

The posterior segment known as rear foot or hindfoot composed of the talus and calcaneus. The middle segment known as midfoot composed of the navicular, cuboid, and three cuneiform bones. The anterior segment known as forefooot composed of the metatarsals and the phalanges (Roberts, D. *et al*., 2019; Ombregt, 2013; Özkan, 2005; Levangie, P. K., & Norkin, C. C.,2001).

There are three arches of foot; two longitudinal (medial and lateral) arches and one tranverse arch. The medial longitudinal arch is the most noticeable foot arch which absorb most of the shock of impact while walking, running and jumping. The lateral longitudinal arch is most visible in people who have very high arches. Both of these logitudinal arches are formed between tarsal bones and proximal end of the metatarsal. The transverse arch provides support and flexibility to the foot that situated in the coronal plane of the foot. It is

formed by the metatarsal bases, the cuboid and three cuneiform (Yamauchi & Koyama, 2019; Zipfel, 2011). Figure 2.2 shows the longitudinal and tranverse arches of the foot.

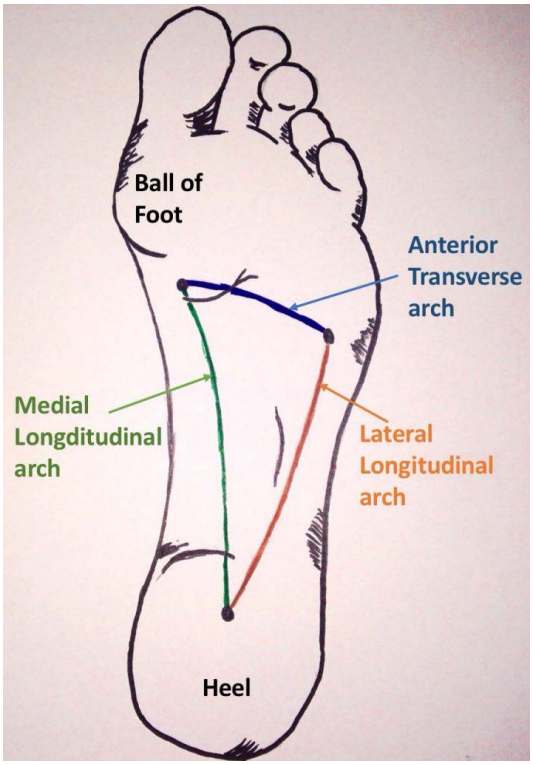

Figure 2.2: The longitudinal and transverse arches of the foot (Zipfel, 2011).

2.1.2 Types of foot

There are three category of foot types that classified depending on arch height. The foot arches that are formed by bones, tendons and ligaments have an important role in bearing body weight and movement functions through various of surfaces and daily activities over years. The arches are differentiating by height which are, high (cavus), neutral and low (planus). The height of the arches can be evaluate when a person is standing with full weight on their feet. Surmen *et al.* (2016) stated that there are three basic types of foot as shown in Figure 2.3 which are: -

i) Flat foot (Pes Planus) also known as overpronation has low arches. The foot is turned out away from the middle of the body. The heel is tilted toward the

outside of the body during the weight bearing phase of walking. Most of heavier people often have this kind of feet.

ii) Neutral foot is the normal arch between flat foot and high arched foot. This kind of foot is standard with weight that distributed evenly.

iii) High arched foot (Pes Cavus) also known as supinator or cavovarus has a very high arch. The heel is tilted towards the middle of the body caused more weight bearing on the outside of the foot and heel. Ankle sprains will occur frequently to a person who suffer for having this kind of foot.

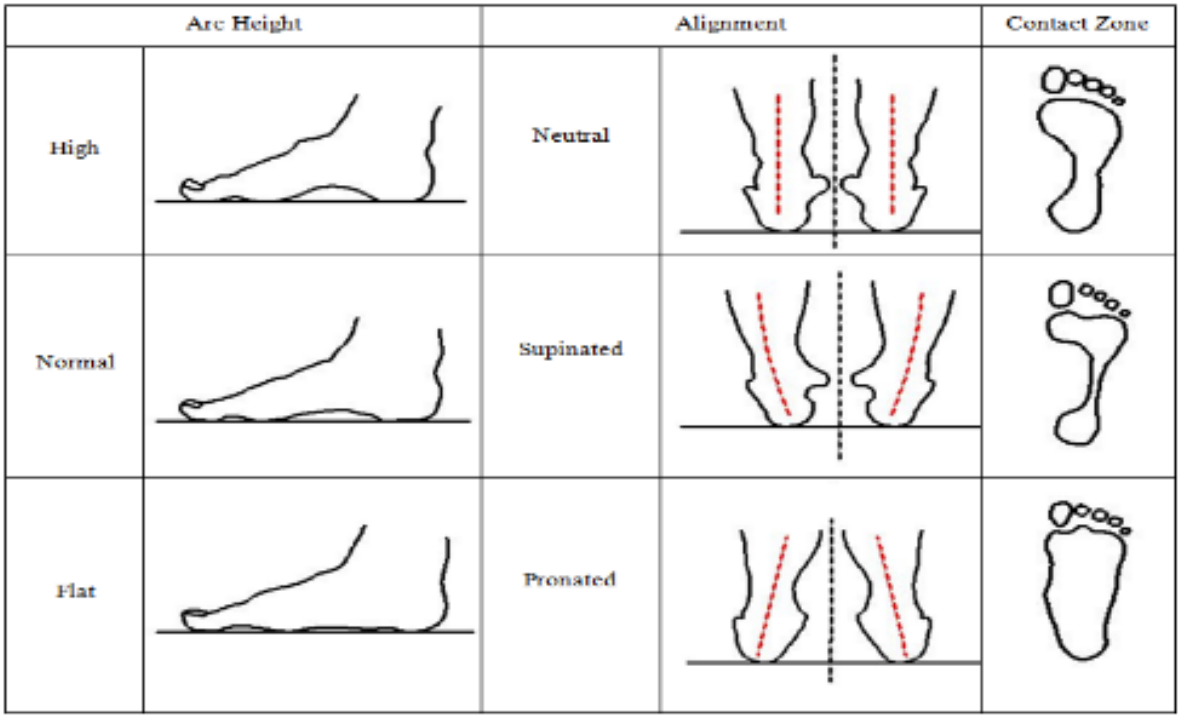

Figure 2.3: Basic types of foot (Surmen *et al.*, 2016).

2.1.3 Flat Foot

Flat foot which is also known as Pes Planus is the deformed structure of the foot bones. It occurs when plantar curve is partly or completely fallen or in the other word, the arch of the foot is contacted to the ground. Flat foot is estimated to affect about 3% to 25% of the adult population worldwide (Davia *et al.*, 2018). Meanwhile, there are approximately 90% children under of 2 that commonly found having a flat foot (H. J. Lee *et al.*, 2015).