UNIVERSITI PUTRA MALAYSIA

EFFECT OF FOOTWEAR INTERVENTIONS ON MUSCLE DISCOMFORT AND LOWER LEG MUSCLE FATIGUE AMONG INDUSTRIAL WORKERS

NOREEN ADILA BINTI OMAR

FPSK(p) 2022 23

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By

NOREEN ADILA BINTI OMAR

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in fulfilment of the Requirements for the Degree of Doctor of Philosophy

July 2021

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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July 2021

Chairman : Associate Professor Karmegam Karuppiah, PhD
Faculty : Medicines and Health Sciences

Introduction: Prolonged standing has been recognized as one of the factors which contributes about83% of MSDs among industrial workers (Zander, King and Ezenwa, 2004). Many ergonomics interventions have been recommended to reduce the effects of prolonged standing andvibration massage was found as an effective solution to delayed onset of muscle pain and discomfort. Objective: Thus, main objective of this study was to study the effect of prototype insole built-in massager on lower leg muscle discomfort among industrial workers during prolonged standing. Methodology: The study was conducted in a controlled room at a selected manufacturing company in Selangor which involved 110 male respondents. First phase of study involved the identification of characteristics in Product Design Specification (PDS) for an ideal prototype insole built-in massager. Then, second phase involved the experimental study design in which the prototype insole built-in massager being compared with other interventions (footrest and anti-fatigue mat) and control group (normalshoe). The respondents evaluated their discomfort rating using Borg's Scales Questionnaire for every 15 minutes. At the same time, sEMG electrodes were attachedDuring the 2-hours standing, all respondents would do a task which were sorting the mixed items at the workstation provided. Results and discussion: Results indicated that respondents do experience mild discomfort on all their body parts during the experimental study especially at the lower body parts. Interventions (prototype insole built-in massager, footrest and anti-fatigue mat) groups had showed reductions in discomfort rating for all body parts compared to control group.The sEMG results indicated that prototype insole built-in massager gave the lowest percentage of exertion (22.38 – 42.2%) for all muscles studied compared to other interventions (anti-fatigue mat and footrest). There was a positive effect of discomfort level on both left and right Tibialis anterior and Gastrocnemius with the usage of prototype insole built-in massager compared to control group.There was a significant difference of discomfort rating between control

and prototype insole built-in massager shoe group at ankle and feet, knee and calf part($p<0.05$).Besides, there were significant differences of means for sEMG level ($p<0.001$) of the prototype built-in massager with other interventions (anti-fatigue mat and footrest). Conclusion and recommendations: Overall, there were positive indicator that the prototype insole built-in massager reduced the muscle discomfort of lower leg muscles to the workers compared to other interventions.Vibration massager in the insoles increase the blood circulation by relaxing foot muscles and decrease the discomfort level of the feet. However, this study recommended a much bigger population and more variation in measurement was needed. This prototype insole built-in massager can also serve as the reference required for the future interventions of prolonged standing among industrial workers.

Keywords : insole built-in massager shoe, lower leg comfort, Gastrocnemius, Tibialis anterior, prolonged standing

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN INTERVENSI KASUT TERHADAP KESELESAAN OTOT DAN KELETIHAN OTOT BAWAH KAKI DALAM KALANGAN PEKERJA INDUSTRI

Oleh

NOREEN ADILA BINTI OMAR

Julai 2021

Pengerusi : Profesor Madya Karmegam Karuppiah, PhD
Fakulti : Perubatan dan Sains Kesihatan

Pengenalan: Berdiri lama telah diakui sebagai salah satu faktor yang menyumbang sekitar 83% MSDs di kalangan pekerja. Banyak intervensi ergonomi telah dianjurkan untuk mengurangkan kesan berdiri lama dan urutan getaran telah dijumpai sebagai penyelesaian yang berkesan untuk menunda permulaan sakit otot, rasa ketegangan otot dan intensiti kesakitan. **Objektif**: Oleh itu, objektif utama kajian ini adalah untuk menilai keberkesanan prototaip tapak kasut massager binaan dalam untuk ketidakselesaan otot kaki bawah di kalangan pekerja industri terpilih semasa berdiri lama. **Metodologi**: Penilaian dilakukan di satu bilik terkawal di syarikat pembuatan terpilih di Selangor dengan 110 responden lelaki terlibat. Tahap pertama kajian ini melibatkan pengenalpastian ciri-ciri dalam Spesifikasi Reka Bentuk Produk (PDS) untuk kasut prototaip insole terbina dalam yang sesuai. Kemudian, peringkat kedua melibatkan reka bentuk kajian eksperimental di mana prototaip tapak kasut massager binaan dalam ini dibandingkan dengan intervensi lain (alas kaki dan tikar anti-keletihan) dan kumpulan kawalan (kasut biasa). Responden menilai penilaian ketidakselesaan mereka menggunakan Borg's Scales Questionnaire untuk setiap 15 minit. Pada masa yang sama, elektrod sEMG dilampirkan dan digunakan untuk memantau aktiviti otot yang direkodkan untuk otot kaki bawah kanan dan kiri (Tibialis anterior dan Gastrocnemius posterior) responden. Selama 2 jam berdiri, semua responden akan melakukan tugas untuk menyusun item campuran di stesen kerja yang disediakan. **Hasil dan perbincangan**: Hasil menunjukkan bahawa responden mengalami ketidakselesaan pada hampir bahagian badan mereka semasa proses ujian, terutama bahagian badan yang lebih rendah. Kumpulan intervensi (prototaip insole built in in massager, footrest dan anti-fat mat) menunjukkan penurunan tahap ketidakselesaan bagi bahagian badan yang diuji berbanding kumpulan kawalan. Hasil sEMG menunjukkan bahawa prototaip tapak kasut massager binaan dalam memberikan peratusan tenaga yang paling rendah (22.38 -

42.2%) untuk semua otot yang dikaji berbanding dengan intervensi lain (tikar anti-keletihan dan tapak kaki). Terdapat kesan positif tahap ketidakselesaan pada kedua kiri dan kanan Tibialis anterior dan Gastrocnemius dengan penggunaan prototaip insole built-in massager berbanding kumpulan kawalan. Terdapat perbezaan yang signifikan dari tahap ketidakselesaan antara kawalan dan prototaip insole bawaan kumpulan kasut tukang pijat pada bahagian pergelangan kaki dan kaki, lutut dan betis ($p < 0.05$). Selain itu, terdapat perbezaan cara yang signifikan untuk tahap sEMG ($p < 0.001$) prototaip kasut pijat terbina dalam dengan campur tangan lain (tikar anti-keletihan dan sandaran kaki). **Kesimpulan dan cadangan**: Secara keseluruhan, terdapat petunjuk positif bahawa prototaip tapak kasut massager binaan dalam mengurangkan ketidakselesaan otot otot kaki bawah kepada pekerja berbanding dengan intervensi lain dan kasut biasa. Urutan getaran pada kasut meningkatkan peredaran darah dengan meregangkan otot kaki dan mengurangkan tahap ketidakselesaan kaki. Walau bagaimanapun, kajian ini mencadangkan populasi yang jauh lebih besar dan lebih banyak variasi pengukuran diperlukan. Prototaip tapak kasut massager binaan dalam ini juga dapat menjadi rujukan yang diperlukan untuk campur tangan masa depan yang berpanjangan di kalangan pekerja industri.

Kata kunci:tapak kasut massage binaandalaman, keselesaan kaki bawah, Gastrocnemius, Tibialis anterior, berdiri berpanjangan

ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious and the Most Merciful

Syukur Alhamdulillah. I would like to express the most thankful, grateful and deep appreciation to my supervisor and Chairman of the Supervisory Committee, Assoc Prof Dr Karmegam Karuppiah for his guidance, honesty and encouragement throughout my research.

I would like to extend my greatest attitude to the other members of my Supervisory Committee, Assoc Prof Dr Enoch Kumar A/L Perimal and Dr Vivien How for their guidance and help.

Thanksgiving isalso expressed to all staffs in Environmental Health Lab, Faculty of Medicines and Health Sciences for their help and guidance while my dataanalysis in the laboratories.Besides, I would like to thanks to all the male respondents involved directly in this study and the manufacturing company involved. Besides, I would like to extend my great thankful to the Deputy of Dean of Faculty of Medicine and Health Sciences, Prof Dr Muhammad Nazrul Hakim Abdullah.

An infinite thanks and gratitude I express to my lovely parents, Mr Omar Dawet and Mrs. Jamayah Laily,and my lovely husband and daughters, Mr Mohd Safwan Bin Mahmud, Aisy Humaira, Amna Khaleeda and Ameerah Aafrin,for all their support and encouragement throughout my research. Last but not least, I would like to express a special thanks to all my postgraduate friends at Faculty of Medicines and Health Sciences. Thank you.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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This is to confirm that:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

<	Less than
>	More than
BMI	Body Mass Index
G	Gastrocnemius
IEA	International Ergonomics Association
LIds	Lower Limb Disorders
LV	Local Vibration
ME	Myoelectric Signal
MSDs	Musculoskeletal Disorder
MVC	Maximum Voluntary Contraction
NIOSH	National Institute of Occupational Safety and Health
OR	Odds Ratio
OSHA	Occupational Safety and Health
PDS	Product Design Specification
RMS	Root Mean Square
sEMG	surface Electromyography
SOCSO	Social Security Organization
SPSS	Statistical Package for Social Science
TA	Tibialis Anterior
WMSDs	Work-Musculoskeletal Disorder

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

This introduction section introduces the subject matter and indicates its importance and validity throughout the study. Manufacturing industry is one of important contributor to Malaysia's economy. Based on Department of Statistics Malaysia, the sales growth of manufacturing industry is 10.8 %, rising to 67.8 billion as compared to 61.2 billion in 2017. Thus, a total number of employees engaged in the manufacturing industry in January 2018 also has been increasing about 2.5 % as compared to 1044346 persons in January 2017 (Department of Statistics Malaysia, 2018). Top of that, manufacturing industry workers are also exposed to variety working positions and standing position has remained common among many manufacturing industries around the world (Speed et al. 2018). Occupational standing has become widespread withint the industrialized countries and also across professions (Wall et al. 2019). Examples, prolonged standing has been reported previously among the automotive engine manufacturing plant workers in the Northern US (Gell et al., 2011) while among the process line workers at a metal stamping company in Malaysia (Halim et al., 2013). In this industry, workers are required to stand for long period (over 30 minutes to several hours) without being able to walk or sit during their work shift (Lee et al. 2018; Halim et al. 2014).

Prolong standing gave advantages and disadvantages to the workers itself. One of main advantage while standing work is it can provide a large degree of freedom to workers such as in manipulating materials and tools in their workstation, also when they are operating large machines and work pieces (Halim et al. 2014). However, working in a standing position for a long period also has been recognized to give disadvantages to the workers. In the industry, prolong standing can contribute to a decrease and loss to worker's health, worker's performance and loss to the company itself (Waters et al. 2015; Halim et al. 2014; Lin et al. 2012). In the aspects of health, workers may experience muscle discomfort and also muscle fatigue at the end of their working shift day (Lee et al. 2018; Halim et al. 2014). Musculoskeletal disorders (MSDs) are considered an important occupational health problem with bad consequences to the workers, employers, and society (Noorhashirin et al. 2018). Musculoskeletal pain and discomfort which affect the lower back and lower extremities, leg swelling and fatigue has been widely reported by those involved in prolonged standing tasks (Garcia et al., 2015; Waters et al. 2015). Werner et al., (2010) in a cross-sectional study of prolonged standing found that 24% met the case definition for foot or ankle disorder and that 52% had the symptoms of muscle discomfort. In the long term exposure, workers may experience occupational injuries such as work-related musculoskeletal disorders (WMSDs), chronic venous insufficiency, and carotid atherosclerosis

(Halim et al. 2014; Lin et al. 2012). In Malaysia, WMSDs are increasing as shown in the SOCSO report in 2014 as the number of cases increased sharply from 15 cases in 2006 to 517 cases in 2013 which considered about 34 times increments within 7 years (SOCSO, 2016). Based on the annual report of SOCSO, the number of cases rose to 1,607 in 2016 (SOCSO, 2016).

In terms of performance, the extended period of standing during the working hours has contribute a decrease in worker's working performance and contributions (Halim et al. 2014). This may due to the occupational injuries or any other health problems faced by the workers. The workers who suffer from the injuries must be referred to clinical experts for health treatment which this will involve amounts of consultancy and treatment costs. As a result, this will affect the company itself to pay for those payment and costs. Thus, in terms of the company profit, the decreased in worker's productivity, worker's compensation and health treatment costs will give disadvantageous and loss to the company (Halim et al. 2014).

Prolong standing required the back extensors to remain active over an extended period, which finally lead to muscle fatigue and discomfort (Rahim et al. 2010). Waters and Dick (2015) found a positive association between standing still and physical fatigue, discomfort, and pain among the workers in various occupations in Europe, Northern and Southern America, Asia and Australia. Fatigue can be defined as the decline in the ability of a muscle to generate force and the feeling of tiredness or exhaustion. Several physiological mechanisms have been proposed to explain the development of these adverse health effects. Zander et al. (2004) found that fatigue may merged from the increased production and accumulation of the metabolic waste that produced during the prolong static contraction. Standing induced static muscle contraction and can result in muscle discomfort (Lee et al. 2018; Speed et al. 2018) and may trigger the development of MSDs (Garcia et al., 2015). The accumulation of the metabolic waste may cause the muscles becoming more hypersensitive and prone to nociceptive activation, thus causing muscle discomfort (Lee et al. 2018). Muscle discomfort has been found to be the result of inflammation caused by pooling of blood in the lower extremities, reduced blood circulation and venous return and also gravity assisted blood backflow (Hughes et al., 2011; McCulloch, 2002).Discomfort have been defined as a feeling with slight pain and slight of unease (Cambridge advanced learner's dictionary, 2015). Thus, muscle discomfort was the feeling with slight pain and slight of unease of the muscles.

According to Halim et al. (2014), there are several risks factors that can contribute to muscle fatigue or discomfort due to prolong standing which were working posture, duration of standing, lighting, noise and indoor air quality. Thus, the risks factors can be categorized in three elements which are human, machines and environment. Therefore, when it comes to the interaction between human, machine and environment factors, it is called ergonomics.

According to Karmegam et al. (2008), the main aim in ergonomics was to eliminate and reduce the discomfort symptoms during interaction with machine.

Prevention of discomfort and fatigue on the body parts is the ultimate goal in ergonomics. Many ergonomics simulation systems have been introduced to improve the productivity, comfortness and safety of workers in manufacturing workplaces and many assessment tools have been suggested to analyze the risk factors associated with prolong standing (Halim et al. 2014). These interventions have included modifying the existing equipment, making changes in work practices and also purchasing new tools or other devices to assist in the production process. By making these changes, physical demands has been reduced, unnecessary movements has been eliminated, injury rates and their associated workers' compensation costs has been lowered and employee turnover has been reduced (OSHA, 2012). The hierarchy of hazard control as presented by NIOSH (2012), aimed to reduce the chance of injuries and design the work tasks that limit exposure for the workers to the ergonomic risk factors.

Administrative or work practice controls may be appropriate in some cases where engineering controls cannot be implemented or when different procedures are needed after the implementation of the new engineering controls. Personal protection equipment (PPE) have only limited effectiveness when dealing with ergonomic hazards. Thus, engineering control is the most preferable in reducing muscle discomfort due to prolong standing (OSHA, 2012). It is about the implementation of the physical change to the workplace, which reduces the hazard on the task. The effects of various types of interventions also have been widely investigated using respondents reporting of fatigue and discomfort and objective measures including changes in local muscle activity and changes in leg volume ((Halim & Omar, 2011; Mohd Noor et al., 2013; Redfern and Cham, 2000; Waters and Dick, 2015). The result of analytical study done by Lin et al. (2012) indicated that leg discomfort is significantly affected by prolonged standing especially in the first 2 hours. The workers should not allowed to stand more than 2 hours continuously or more than 30% of their work day with the absence of interventions such as anti-fatigue mats, sit-stand stools or chairs, especially designed footstools or supportive footwear (Waters and Dick, 2015).

Foot massage has been practiced for centuries as a part of foot care and can be very beneficial, particularly after a long day of standing (Ali, 2012). Currently, foot massage is considered as a tool to relieve pain, increase blood circulation, and treat diseases such as Plantar Fasciitis, Spurs, diabetes, and even detoxification of the body. There are many types of foot massage and vibration massage is one of the modern type of massage nowadays. Studies found that that a low frequency vibration applied has positive effect on reducing muscle activity, increase overall comfort level of users and provide good treatment of lower muscle fatigue (Tang et al. 2012). On the other hand, Khadijah et al. (2018) stated that shoe insole is an interior layer inside of shoes

that give additional comfort and has been used widely around the world in many types of shoes such as sneakers, formal shoes, sport shoes, and boots. Thus, the combination of vibration massage and insole of the users seems can give a comfort to the users especially workers who exposed to prolonged standing. The vibratory built-in massager insole that put in the shoe work by gently massaging the feet through a light vibration massage while wearing them (Oscar Hatzog, 2017). Oscar Hatzog (2017) explained that the vibration in the insoles of the shoe increase the blood circulation by relaxing foot muscles and decrease pain in the ball of the foot, the arch and the heel–all while providing the support of a typical insert.

There are many methods has been used to estimate and measure the muscle discomfort and fatigue while surface Electromyography (sEMG) has becoming the main preferred by the ergonomists (Chowdhury and Nimbarte, 2017). Electromyography (EMG) is an experimental technique, focusing with the development, recording and lastly the analysis of myoelectric signals (Konrad, 2005). Konrad (2005) explained that myoelectric signals (ME) are formed by physiological variations in the state of muscle fiber. The changes in the frequency spectrum of the SEMG signal which is a shift in the mean or median frequencies toward lower values or a change in the power of the low and high frequency components, were used as the common indicators of muscle fatigue and discomfort (Chowdhury et al., 2013).

Noorhashirin et al. (2018) has stated that about 40 million workers are affected by work-related MSDs (WMSDs). Since there was limited number of studies regarding the association of ergonomic interventions especially the availability of vibratory insole built-in massager shoe among industrial workers to reduce discomfort due to prolonged standing in Malaysia, this study was proposed and essential to be done. This study was focusing to study the effect of footwear interventions on muscle discomfort and lower leg muscle fatigue among industrial workers.

1.2 Problem Statement

This section 1.2 stated the problem being studied in this thesis. Currently, world population is estimated to reach about 6.9 billion, with 3.1 billion number of workers working in more than 55 major industrial sectors (Halim et al. 2012). A report done by Labor Force, Sydney found that, many workplaces in the industrial sectors contribute to occupational injuries while providing job opportunities if there was no awareness regarding occupational health and safety (Halim et al. 2012). In Malaysia, statistics of annual reports from the SOCSO (2014) stated that, a total number of 1169 employees had been reported under cases of invalidity with the total numbers of survivors' cases were 119 workers for the MSDS and connective tissue. Besides, based on Department of Occupational Safety and Health (DOSH) (2017), the annual report by SOCSO (2014) reported that the number of accidents which related

to WMSDs has increased from 14 cases in 2006 to 194 cases in 2012. In Malaysia, MSDs are on the increasing trend as shown in the SOCSO report in 2014 and the number of cases rose to 1,607 in 2016 (SOCSO, 2016).

On top of that, disease of the musculoskeletal system among industrial workers is increasing day by day in Malaysia (Zadry et al. 2013; Zein et al. 2015). The American Podiatric Association reported that in the United States there were 83% of industrial workers experienced lower back pain and feet pain and discomfort associated with prolonged standing (Zander et al. 2004). Researches have proved that standing for prolonged periods is related to various health problems, including lower back pain, lower extremity discomfort, and can cause varicose veins (Lin et al. 2012; Halim et al. 2012). A study done by Sholihah et. al. (2016) stated the people who keep standing in the wrong posture for quite a long time can cause musculoskeletal disorders (MSDs) because of the muscle tend to work in the static position. This will lead to the increase the tension of muscle and decrease the elasticity of tissue. The static contraction in leg and back also can occur because of prolonged standing (Halim et. al. 2012).

Various interventions also have been recommended in the literature to reduce the lower leg fatigue and discomfort caused by prolonged standing including anti-fatigue mats, shoe insole, footwear and footrest. The Department of Occupational Safety and Health (DOSH) in Malaysia also has suggested the employer to provide workstation accessories such as anti-fatigue floor mat, adjustable working surface to accommodate differences in employees' height, small foot bench such as footrest, and better soles for insoles for the workers (DOSH, 2002). A personalization of insole offers a solution that can provide a perfect fit and comfort to the shoes wearer based on the ergonomic considerations (Khadijah et al. 2018). Nowadays, insole is one of the parts of the shoe that give a perfect fit and comfort to the shoes wearer. In relation to industrial working situation, the sport shoe, safety shoes or boots are preferably prepared for each company especially among the production line and the insoles were different (Khadijah et al. 2018). Safety shoes focus more on the outside part of the shoe and this is where the problems arise among the workers when the foot of the workers developed acute aches and discomfort due to the usage of less effective insoles during prolonged standing. Research shows that oscillation of the ankle joints with a vibrator helps to induce release of a stiff ankle joint (Tupimai et al. 2016). Nevertheless, vibration while standing have showed benefits to some researches (Tupimai et al. 2016). Instead of giving pain to a person during the vibration process, standing in a neutral ankle position with body weight bearing also stimulates the stretching of calf muscles.

The gap of the study has been clearly addressed. Various interventions have been studied but giving conflicting results among researches. The Department of Occupational Safety and Health (DOSH) Malaysia guideline for prolonged

standing has recommend three interventions which are footrest, anti-fatigue mat and anti-fatigue mat with the absence of vibration massage. In fact, vibration massage was found as an effective solution to delay onset of muscle pain, enhance blood circulation and reduce feeling of muscular tension or pain intensity (Buttagat et al. 2016; Zainuddin et al. 2005; Farr et al. 2002). With this vibrating insole, workers may adapt well without disrupting their daily routine and activities. Previously, vibrating insoles only been applied as treatment/ rehabilitation for individuals with health and clinical issues. Thus, in order to filling the gaps in DOSH Guideline, this study was done to assess the effect of prototype insole built-in massager that use vibration massage.to reduce muscle discomfort and fatigue among the respondents.

1.3 Study Justification

This section 1.3 explained about the justification of the study matters. Musculoskeletal disorders (MSDs) have been a well known occupational health issue for workers over recent years and industrial workers were highly exposed to it. In developing countries such as Malaysia, numerous researches has found that heavy physical demand and improper posture while performing a task can cause MSDs especially tasks that need lifting activity and pulling or pushing tasks in various sectors. However, studies related MSDs among industrial workers in Malaysia and the ergonomic intervention which is a vibratory insole buil-in massager shoe to prevent lower leg muscle discomforts while standing were still limited. Most of the studies were focusing on the impact of other interventions (mat, footrest) and shoe insole without the vibratory shoe massager to leg discomfort. Thus, this study was essential to be done.

Numerous studies also found that prolonged standing leads to various health problems such as lower limb fatigue, pain, swelling and discomfort, venous blood pooling, low-back pain, and whole-body fatigue (Cham and Redfern, 1999; King, 2002; Lin et al., 2012; Madeleine et al., 1997; Reid et al., 2010; Thomas and Dick, 2014; Zander et al., 2004; Zhang et al., 1991). Muscle fatigue and blood pooling in the legs are two suspected mechanisms for the development of muscle discomfort in the lower leg during standing (Zander et al., 2004). Since the impact of standing related discomforts on health insurance, absenteeism, productivity and well-being is substantial problems, this study was aim to determine the muscle activity and dicomfort due to prolonged standing among industrial workers. Nevertheless, a large number of recent studies show that MSDs are still highly prevalent in certain occupational settings (Balogh et al. 2015).

According to Karimi et al. (2016), various ergonomic solutions have been done to reduce MSDs problems in the literature, including anti-fatigue mats, shoe inserts, footrest, sit/stand chairs, and footwear that was done by Chiu and Wang (2007), Hughes et al. (2011) and Thomas and Dick (2014). Besides, as

a new approach, therapeutic massage can be explored as another solution to this MSDs problems. Farr et al. (2002) found that therapeutic massages as an effective solution to delayed onset of muscle pain. Treatment of massage onto upper back region had shown an immediate decrease in EMG activity, feeling of muscular tension and pain intensity (Buttagat et al. 2016). According to Issurin (2005), low-intensity vibratory type massage (15-50 Hz frequency band) can help to improve the oxygen uptake, blood oxidation, muscle oxidation, local and general blood circulation. Previous study done by Tang et al., (2010) also found a low frequency of vibration has positive effect on reducing muscle activity and also increase the overall comfort level of respondents. On the other hand, an insole offers a solution that will provide a perfect fit and comfort to the shoes wearer. Hence, this research looks to explore a vibration massage technique which was inserted in an insole as the prototype insole built-in massager shoe to be another solution in reducing the discomfort caused by prolonged standing. Besides, the vibration massager uses the mechanical oscillations as a stimulus for human neuromuscular structures and then the energy is transferred from the vibration device to the human body or parts of it (Wu et al. 2020). In fact, there was limited study done regarding the effect of footwear interventions on muscle discomfort and lower leg muscle fatigue among industrial workers in Malaysia. Previous study done by Khadijah et al (2018) only focused on the personalization of insole that is expecting to help in improving the lumbar muscle fatigue that occurred to the workers in the production line with the absence of vibration massager.

1.4 Conceptual Framework

Section 1.4 was about the conceptual framework, which was a written or visual representation of an expected relationship between variables. Musculoskeletal disorders (MSDs) has been one of well-known occupational health issue for workers over recent years and industrial workers were highly exposed to it. Industrial workers were exposed to many working posture that can lead to MSDs such as heavy lifting, repetitive motion, prolonged standing, poor posture, vibration and overload. Prolonged standing has been identified to be the main risk factor among the industrial workers especially among the production line workers. Based on Zander et al. (2004), production line workers were exposed to prolonged standing and they required to stand in one area for long periods of time. According to the chairman of National Institute of Occupational Safety and Health (NIOSH), the MSDs cases had been increasing since 2008 in Malaysia (DOSH, 2012).

Numerous health problem have been associated with prolonged standing and lower leg discomfort was one of them. Lower leg muscle discomfort, Tibialis anterior and Gastrocnemius were studied in this study. Study done by Lee et al. (2018), Karimi et al. (2016) and Halim et al. (2012) point out that the muscle discomfort especially in the lower extremities of employees can be caused by prolonged standing in the workplace. Many intervention have been proposed based on evidence from the previous study to reduce the health effects to the

workers due to prolong standing. Various solutions have been recommended in the literature including anti-fatigue mats, shoe insole, unstable shoe, footwear and footrest. In this study, the muscle discomfort rating was assessed by using Borg's Scale Questionnaire and the muscle activity exertion was analysed by using sEMG. Figure 1.5 show the conceptual framework of the study.

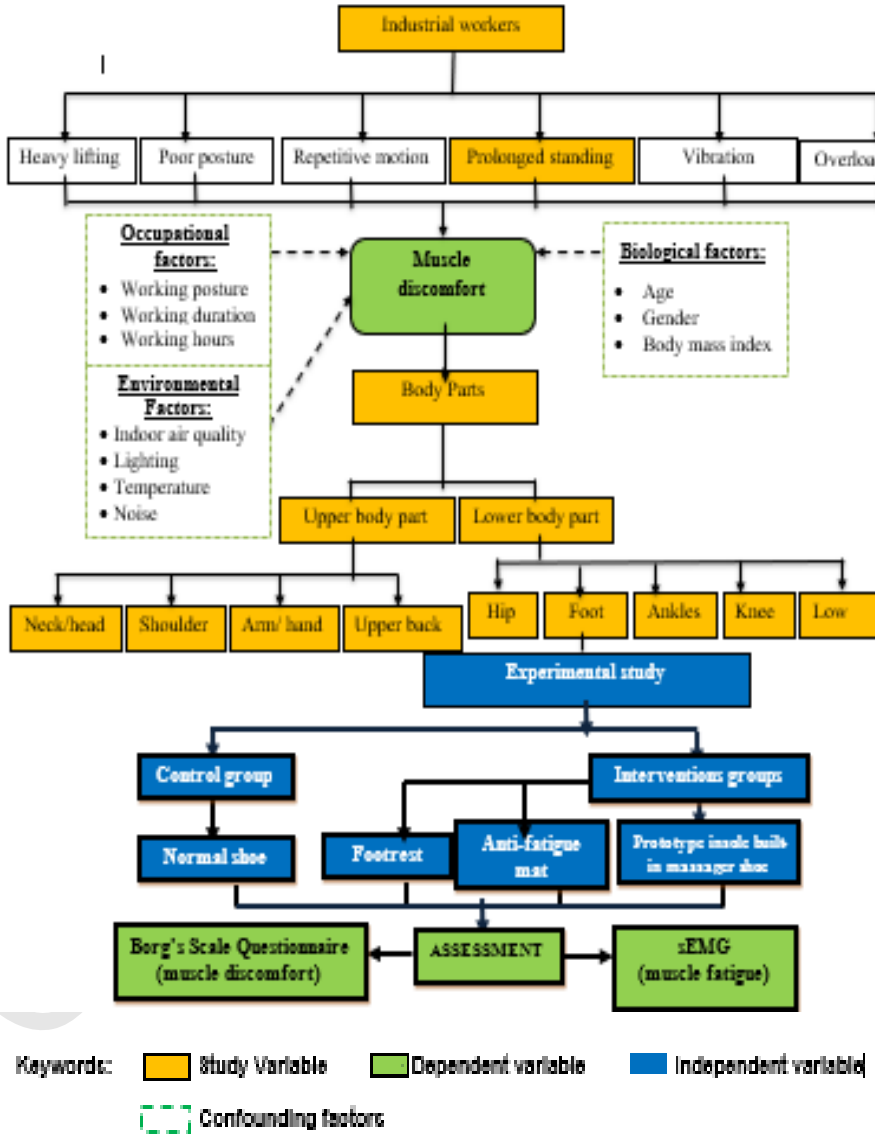

Figure 1.1: Conceptual Framework

1.5 Research Objectives

Section 1.5 sets out the research objectives (general and specific objectives) to be attained and hypotheses to be tested.

1.5.1 General Objective

To determine the effect of footwear interventions on muscle discomfort and lower leg muscle fatigue among industrial workers.

1.5.2 Specific Objectives

1. To identify important characteristics of Product Design Specification (PDS) to develop a conceptual design of prototype insole built-in massager for an industrial worker in order to reduce the lower leg muscle discomfort and muscle activity level due to prolong standing
2. To measure lower leg discomfort rating by using Borg's Scale questionnaire among control and interventions groups (prototype insole built-in massager, footrest and anti-fatigue mat).
3. To measure exertion of muscle activity (% of sEMG) among control and interventions groups (prototype insole built-in massager, footrest and anti-fatigue mat).
4. To compare lower leg parts discomfort rating by using Borg's Scale questionnaire between control and interventions groups.
5. To compare the exertion of muscle activity (% of sEMG) between control and intervention groups (anti-fatigue mat, footrest, prototype insole built-in massager shoe) using MANOVA analysis
6. To compare exertion of muscle activity (% of sEMG) of the prototype insole built-in massager shoe with footrest and anti-fatigue mat using One-way ANOVA

1.5.3 Hypothesis

1. There is a significant difference of the lower leg parts discomfort rating by using Borg's Scale questionnaire between control and interventions groups.
2. There is a significant difference of the exertion of muscle activity (% of sEMG) between control and intervention groups (anti-fatigue mat, footrest, prototype insole built-in massager shoe) using MANOVA analysis.

3. There is a significant difference of the exertion of muscle activity (% of sEMG) of the prototype insole built-in massager shoe with footrest and anti-fatigue mat using One-way ANOVA.

1.6 Conceptual Definition

Section 1.6 mentioned about the conceptual definition, which involve the underlying understanding of some keywords to attain before understanding how it is used or applied. In science, it is necessary to understand the subject of research prior to conducting effective research.

1.6.1 Musculoskeletal Disorder (MSDS)

MSDS is any injury, damage and disorder of the joints or other tissues in the upper or lower limbs or the back (Health, Safety Environment, 2015).

1.6.2 Muscle Discomfort

Lower limb disorders (LLDs) affect the legs and feet, from hips to toes. About 80% of damage to the hips, knees and legs at work is due to overuse. Workers may report lower limb pain, aching and numbness without a specific disease being identified or present (HSE, 2015).

1.6.3 Muscle Fatigue

Muscle fatigue is defined as a decrease in maximal force or power production in response to contractile activity (Gandevia, 2001). It is a symptom that decreases your muscles' ability to perform over time.

1.6.4 Surface Electromyography (sEMG)

Surface Electromyography (sEMG) is an experimental technique concerned with the development, recording and also the analysis of myoelectric signals (Konrad, 2005).

1.7 Operational Definition

Section 1.7 mentioned about the operational definition, which involve the statement of procedures the researcher is going to use in order to measure a

specific variable. It was important in order to make sure we use the correct procedures to measure the variables studied.

1.7.1 Musculoskeletal Disorder (MSDs)

Musculoskeletal Disorders (MSDs) are injuries and disorders that can affect human body movement or musculoskeletal system (such as muscles, tendons, ligaments, nerves, discs, blood vessels) (Konrad, 2005).

1.7.2 Muscle Discomfort

Muscle discomfort can be measured by using Borg's Scale questionnaire (Karmegam et al. 2012).

1.7.3 Muscle Fatigue

Muscle fatigue can be measured by the value of muscle activity exertion (%) using surface Electromyography (sEMG) (Balogh et al. 2015).

1.7.4 Surface Electromyography (sEMG)

Myoelectric signals can be formed by physiological variations in the state of the muscle fiber membranes (Konrad, 2005).

1.8 Scope of Study

This study may include the scope of study as follow:

1. Prolonged standing was identified as one of the highest risk factor of various health problems such as sore feet, swelling of the legs, varicose veins, general muscular fatigue, and low back pain, stiffness in the neck and shoulders, and body discomfort.
2. Prototype insole built-in massager was found as another solution in reducing the discomfort caused by prolonged standing among industrial workers.
3. Vibration massager uses the mechanical oscillations as a stimulus for human neuromuscular structures and can help to improve the oxygen uptake, blood oxidation, muscle oxidation, local and general blood circulation

4. Limited study done regarding the assessment of effectiveness on vibration insole massager shoe for lower leg muscle discomforts among industrial workers during prolonged standing in Malaysia

5. This study aimed to determine the effect of footwear interventions on lower leg muscle discomfort and muscle fatigue among industrial workers during prolonged standing.

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