Ergonomics Intervention in Inspection and Final Process Section at Medical Manufacturing Company

by

Siti Norsyahadah binti Azizan
(1832422798)

A dissertation submitted in partial fulfillment of the requirements for the degree of
Master of Science in Manufacturing Systems Engineering

School of
UNIVERSITI MALAYSIA PERLIS

2020

ACKNOWLEDGMENT

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

I wish to express my sincere appreciation to my supervisor, Dr. Nurul Ikhmar binti Ibrahim, who had guided and encouraged me to be professional and did the right thing even when the road got tough. Without her persistent helped, the goal of this project would not have been realized.

I also would like to thank Mr Mohd Asyraf b Che Doi who always gave me support, guidance and advice during the period of completion of this dissertation.

My thanks and appreciation also to all the staff of the Cardinal Health Sdn Bhd, Dr Mohd Zahiruddin b Md Zain, Dr Ahmad Humaizi b Hilmi, and all lecturers and friends.

Finally, I wish to acknowledge the support and great love of my family members, my mother, Nor Milah binti Abdul Latif; my father, Azizan b Dahaman, my siblings, my husband, and kids. They consistently support during all of this hard work and this work would not have been possible without their help and support.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ART	Assessment of Repetitive Tasks
BOSS	Body Symptom Survey
DOSH	Department of Safety and Health
ERA	Ergonomics Risk Assessment
ERF	Ergonomics Risk Factor
IEA	International Ergonomic Association
MAC	Manual Handling Assessment Chart
MFA	Muscle Fatigue Assessment
MHT	Maximum Holding Time
MNC	Multi-National Company
MSD	Musculoskeletal Disorder
NMQ	Nordic Musculoskeletal Questionnaire
OCRA	Occupational Repetitive Action
OWAS	Ovako Working Posture Analysis System
PSSI	Prolonged Standing Strain Index
REBA	Rapid Entire Body Assessment
ROSA	Rapid Office Strain Assessment
RPE	Rating Perceived Exertion
RULA	Rapid Upper Limb Assessment
sEMG	Surface electromyography

LIST OF SYMBOLS

AFH	Anti-fatigue mat thickness
AR	Arm Reach
EH	Elbow height
HT	Holding Time
IAQ	Indoor air quality
JH	Jig height
MA	Muscle activity
SD	Standing duration
ShH	Shoe height
WBV	Whole-body vibration
WP	Working posture

Intervensi Ergonomik dalam Proses Pemeriksaan dan Akhir di Syarikat Pembuatan Perubatan

ABSTRAK

Pendekatan intervensi ergonomik penting bagi mengatasi masalah yang berkaitan Musculoskeletal Disorder (MSD) di sektor pembuatan perubatan. Salah satu intervensi yang paling biasa adalah mengubah posisi kerja daripada duduk kepada berdiri supaya kecekapan pekerja dapat ditingkatkan. Walau bagaimanapun, kedudukan berdiri yang berpanjangan dapat menyebabkan ketidakselesaan dan keletihan di bahagian bawah badan dan boleh menyumbang kepada risiko kesihatan yang signifikan kepada operator. Oleh itu, dalam kajian ini intervensi ergonomik untuk mengawal risiko MSD kerana kedudukan yang berpanjangan disiasat dan dinilai untuk mencadangkan penyelesaian yang paling sesuai. Kajian ini dilakukan mengikut garis panduan yang dikeluarkan oleh Jabatan Keselamatan & Kesihatan (JKKP) Malaysia yang melibatkan empat tugas penting; (1) Pengenalpastian MSD, (2) Pengenalpastian faktor-faktor risiko ergonomik (3) penilaian masalah dan (4) mencadangkan intervensi ergonomik. Sebilangan besar aduan dikenalpasti adalah keletihan dan kesakitan pada kaki dan betis disebabkan oleh kedudukan berdiri statik yang berpanjangan dan aktiviti pengulangan di stesen 4-2 di bahagian Pemeriksaan dan Proses Akhir. Sebab utama ialah operator di stesen 4-2 perlu berdiri tanpa kasut sekurang-kurangnya lapan jam setiap hari dan satu jam secara berterusan dan pada masa yang sama perlu menginjak pedal kaki untuk menyelesaikan tugas. Skor Indeks Ketegangan Berdiri Berpanjangan (IKBB) menunjukkan keadaan yang tidak selamat. Empat penyelesaian dicadangkan iaitu menyediakan kasut kepada operator, menggantikan pedal kaki (suis kaki) dengan alat elektro-pneumatik, menyediakan kerusi duduk dan giliran pekerjaan. Penilaian semula IKBB menunjukkan perbezaan yang signifikan terhadap skor IKBB dengan intervensi ergonomik. Kajian ini menunjukkan kedudukan berdiri yang berpanjangan memberi kesan pada anggota badan bahagian bawah terutama ketidakselesaan pada paha dan kaki. Pada masa hadapan, kajian perlu dilaksanakan menggunakan penilaian objektif untuk menyokong keputusan dan keputusan intervensi ergonomik perlu disahkan setelah beberapa minggu dilaksanakan.

Ergonomics Intervention in Inspection and Final Process at Medical Manufacturing Company

ABSTRACT

Ergonomics intervention approach is important to overcome problems related to Musculoskeletal Disorder (MSD) in the medical manufacturing sector. One of the most common interventions is changing the working condition from sitting to standing position so that workers' efficiency can be increased. However, prolonged standing can contribute to discomfort and fatigue at lower body parts and may pose significant health risk to the operator. Therefore, in this study ergonomics intervention to control MSD risk due to prolonged standing was investigated and assessed to propose the most suitable solution. This study was conducted according to the Department of Safety & Health (DOSH) Malaysia guideline which involved four important tasks; (1) MSD identification, (2) Ergonomics Risk Factors identification (3) problem assessment and (4) propose the ergonomics intervention. High number of complaints were found regarding fatigue and pain at leg and foot caused by prolonged static standing and repetition at station 4-2 at Inspection and Final Process Section. The main reason was operators at the station 4-2 need to stand without shoes for at least eight hours daily and one hour continuously and at the same time need to step on a foot pedal to complete tasks. The Prolonged Standing Strain Index (PSSI) score showed an unsafe condition. Four solutions were proposed which are to provide the operator with shoes, substitute the Foot Pedal with an electro-pneumatic device, provide a sit-stand chair and job rotation. The PSSI reassessment showed a significant difference on PSSI scores with the ergonomics intervention. This study shows that prolonged standing will give major impact on the lower limbs especially foot and leg discomfort or pain. For future work, the study needs to conduct an objective assessment to support the results and the ergonomics intervention needs to be validated after a few weeks of implementation.

CHAPTER 1 : INTRODUCTION

1.1 Overview

Ergonomics is defined as laws or science of work. It is a scientific study on the interaction between human and other elements of systems that applies theory, principles, data, and methods in order to optimize human well-being and overall system performance (IEA, 2017). Ergonomic practices are often used in the workplace for designing and evaluation of tasks, jobs, products, environments and systems by considering body capacity and limitations. Advantages of applying ergonomics at workplace include eliminating physical hazards, reducing employee illness, reducing expenditure on workers' compensation and health treatment costs, and improve productivity (Middlesworth, 2016).

Ergonomics has been implemented in many industries such as agriculture, healthcare, construction and manufacturing. Ergonomics application in manufacturing industry is mostly focusing on ergonomics intervention. Examples of intervention are by (1) eliminating the unnecessary process, tools or machines, (2) substitution or replacing the suitable tools or equipment, (3) physical modification of jobs, workstations, tools, equipment or process, (4) administrative control from policy, standard operating procedure, awareness training and education or job rotation, and (5) the use of personal protective equipment (DOSH, 2017). Nevertheless, the implementation of ergonomics/ergonomics intervention in manufacturing industry might not be comprehensive due to challenges, for example, lack of knowledge, lack of support from top management, and human resources and time constraint (Mustafa et al., 2009).

In order to increase production capacity, some of the tasks, especially at production line, may not design based on the workers' capabilities. For example, workers may have to adopt awkward posture to reach or transferring a box, sitting for a total of six hours per day or pushing a full cart of boxes. Another example is the prolonged standing posture particularly at an assembly line. Standing position is preferred because the workers can move freely, productivity can be increased and it is a form of an active lifestyle (Halim & Omar, 2011; Tikkanen et al., 2013).

However, prolonged standing may pose a health risk to the worker. Muscle fatigue, mental stress, pain at lower legs and low back pain are the major consequences of prolonged standing (Gregory & Callaghan, 2008). Working for longer hours may exacerbate the problem because there is lack of recovery and rest on the lower legs. When prolonged standing is combined with other ergonomics risk factors such as repetition, the level of risk of getting Musculoskeletal Disorder (MSD) is higher, thus, compromising the workers' health and safety.

1.2 Research Study Background

Research study was conducted at a Multi-National Company (MNC) located in Northern region of Peninsular of Malaysia. The company is a medical device manufacturer that produces a few types of natural rubber urinary catheters as shown in Figure 1.1 and packs gloves for the international market. The main function of medical urinary catheters is used to drain the bladder. The company has been operating since 1983. There are more than 400 workers consist of professionals, technical, administrative and operators. Current research is focusing on the production of catheters.

Figure 1.1 Variety of urinary catheters produced in the company

All catheters are processed and handled manually from the beginning until the end. There are six main processes, but the company only performed five processes, which are divided into five main sections as shown in Figure 1.2. Each section has several workstations dedicated to certain tasks. Details of tasks performed in each workstation can be referred to Appendix A.

The making of catheters starts with Latex Compounding, which is a mixing material process. Tasks performed in this section are cleaning the mixing tank and, preparing and arranging the material composition. The process continues with producing a balloon, which is one of the components in catheters. Some of the tasks performed are dipping the balloon in the water, mixing it with calcium carbonate and cutting the balloon using a scissor. Then, at the Main Production section, the process is longer and more complex than the balloon process. This section is the most important to ensure the quality of the product. Some of the tasks include inserting the balloon into the catheter, making a hole and, arranging catheters for chlorination and curing processes. The process continues at the Inspection and Final Process Section. In this section, the catheters are inspected, assembled and packed into an internal bag and pouch. Tasks that are carried out during inspection process are measuring and trimming of the catheters, and inspection of the balloon using a foot pedal. Once finished, all catheters will be sterilized by a third-party (i.e. outsourcing). Finally, in the packaging process, the catheters are packed in a box and the carton. All shipping documents are compiled at this section.

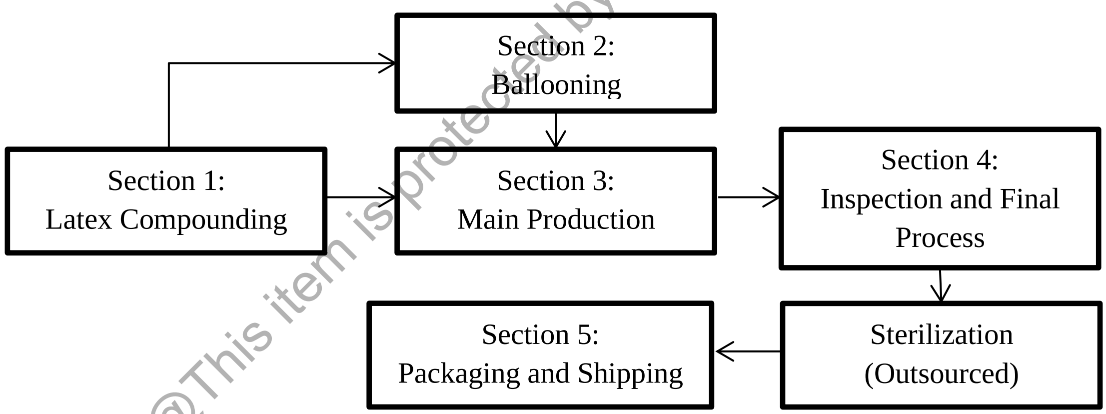

Figure 1.2 Catheters Manufacturing Processes/Sections at the company. Sterilization processed is carried out at another company

1.3 Problem Statement

As described before, catheters produced at this company are done manually. In the last three years, the company aims to increase production capacity with minimal expenditure. One of the strategies is to change the working condition from sitting to standing at almost all sections. The operators need to work in standing condition for 8 hours per day with an hour lunch break. In order to ensure this change is successful, the company has implemented modifications across all workstations by adjusting the height of the worktable using Asian women's elbow height as a reference (because only female workers are performing the work using a table).

This change of working condition may increase exposure to ergonomics risk and musculoskeletal disorder (MSD). The total time for a worker to stand is eight hours, which is over the recommended standing time – less than one hour continuously or less than four hours in total (Halim & Omar, 2012; Meijsen & Knibbe, 2007). Some of the main issues associated with prolonged standing are low back pain and body functional disability due to damage to the musculoskeletal system (Fewster et al., 2017). The situation becomes more challenging when workers are demanded to do overtime that requires them to stand up to twelve hours per day. Due to prolonged standing, there will be lack of muscle recovery and body rest. As a result, workers may experience stress and fatigue that could contribute to major health risks such as chronic venous disorders, circulatory problems, possibility of increase stroke risk, difficulty in pregnancy, and degenerative damage to the joints of the spine, hip, knees and feet (Halim & Omar, 2011; Mohamad et al., 2018).

Besides, most of the tasks, particularly in section 4, require workers to use a foot pedal to activate a pneumatic system as shown in Figure 1.3. The condition not only demands the workers to perform high repetitive movement but also with uncomfortable posture condition. This condition is defined as an awkward posture because the operator’s body weight is supported on one leg either right or left (Keyserling et al., 1992). The prolonged condition of awkward posture may lead to strain and can be harmful to the musculoskeletal system (Savino et al., 2016).

Prolonged standing may increase the risk of getting MSD. Problems associated with prolonged standing exposes workers to multiple health problems. These problems are exacerbated with an increase exposure to other ergonomics risk factor such as awkward posture. Therefore, the aim of current study is to investigate prolonged standing problems when producing catheters by using ergonomics tools in order to reduce the level of risk of developing MSD.

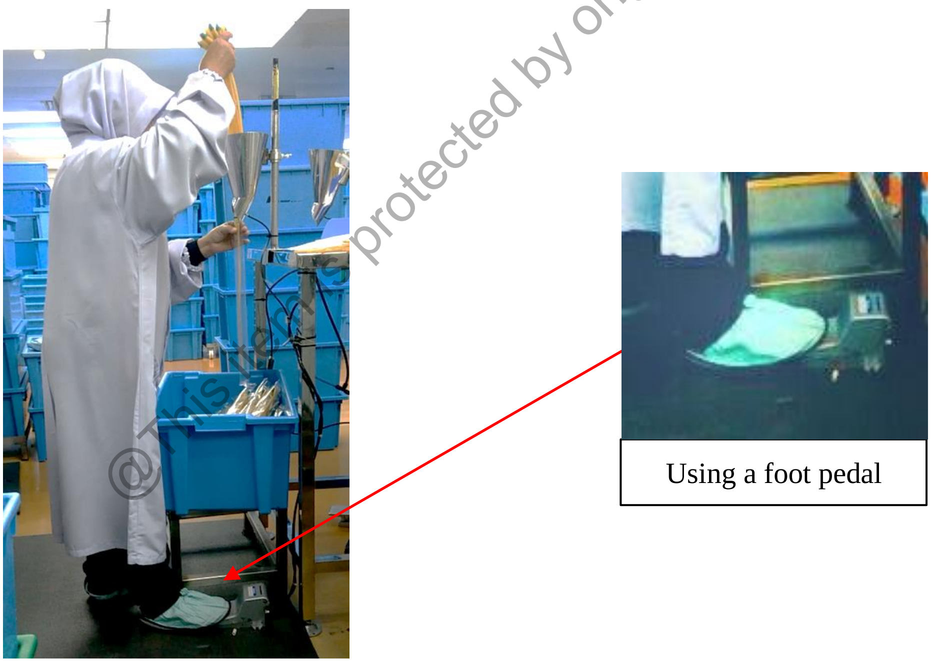

Figure 1.3 Normal activity at station 4-2 – using a foot pedal and prolonged standing

1.4 Objective

The present study has the following objectives:

i. To identify main ergonomics problem and the most critical section in the production of catheters.
ii. To determine the root cause of MSD symptoms and risk level in the critical section identified.
iii. To propose ergonomics intervention solution to control MSD symptom.
iv. To assess and validate the ergonomics intervention using an ergonomics tool.

1.5 Scope of Study

DOSH (2017) guidelines are used to assess the ergonomics risk factors at each section. At beginning of the study, all sections are analysed to identify area of study. Then, one section, which is the most critical area based on the highest number of MSD symptoms and ergonomics risk factors, is investigated. The investigation is focusing on prolonged standing tasks at workstations in the Inspection and Final Process Section (section 4). Tools used are Prolonged Standing Questionnaire and Prolonged Standing Strain Index (PSSI) developed by Halim and Omar (2010, 2012). Further, validation of the proposed solution is only using the PSSI tool, without implementation.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

This chapter focuses on reviewing keywords, ergonomics risk assessment methods, key issues faced by employees in company, and interventions used previously to overcome the prolonged standing problem.

2.2 Ergonomics

Ergonomics is derived from Greek word where 'ergon' means work and 'nomos' means law. In other words, ergonomics means the laws or science of work (IEA, 2017). Ergonomics considers the interaction between labour, machines, and the environment in order to facilitate an effective physical and mental of the worker. The interaction factors include such as the working conditions, muscles systems, body circulation and respiration of people inside the work (Sofuoglu et al., 2015). Ergonomics has an important role in identifying the risks, developing reliable assessment tools, and defining protective recommendations to reduce or avoid the risk of exposure, improve the work organization, and design suitable workplaces (Capodaglio, 2017).

Implementation of ergonomics is already taken seriously by developed countries and has a positive impact on the company. A review conducted by Kolus et al., (2018) showed that when ergonomics or human factors is applied and considered in product, process and workstation designs as well as the whole operating system, the human and system conditions had improved. These improvements were in terms of workload, fatigue, injuries, health quality, productivity, efficiency and effectiveness. For example, in a study to improve energy efficiency in manufacturing process and system, Mawson & Hughes, (2019) used ergonomics or human factor elements as key factors to ensure the development tools to improve energy efficiency is succeeded. The study showed that ergonomics could give big impact especially health and profit and become the most important element to consider in the manufacturing sector.

2.2.1 Ergonomics Risk Factors (ERFs)

Ergonomics Risk Factors (ERFs) occur when there is attribute, characteristic or exposure that could cause risk to musculoskeletal strain or stress and ultimately cause injury (DOSH, 2017). There are seven primary ERFs, which are awkward posture, repetition, static posture, forceful exertion, contact stress, vibration, and environmental factors (noise, illumination, temperature, and ventilation). Prolonged exposure to any of these risk factors increases the likelihood of a worker to get MSD. For the purpose of current study, three ERFs are reviewed as follows:

2.2.1.1 Awkward Posture

Posture consideration is very important, especially in product, task, and workstation designs. This is because a good neutral posture, which is defined as stress free position, helps to reduce risk of getting MSD or bodily pain and fatigue. According to DOSH (2017), an awkward posture is defined as body movement (i.e. head, shoulders, trunk, hand, elbow, wrist and knee) which deviate from a neutral position for a duration of more than two hours a day. Examples of awkward posture are over-reaching, working with the neck or back bent more than 30 degrees without support, and working with hand above the head, squatting and kneeling. For example, Keyserling et al., (1992) stated that using a foot pedal while standing is considered as an awkward posture.

2.2.1.2 Repetitive Motion

Repetitive motion is defined as doing the same activity or repeated movement of the same group of muscles at a rapid rate on a long duration with a little chance for recovery or rest. If the cycle of movement is more than two times in a minute, the task is considered as highly repetitive (DOSH, 2017).

Repetition is one of the most common risk factors in the manufacturing sector. It usually occurs at the assembly line, clothing and shoe industries, food industry, packaging, electronics industry and plastics industry (Da Costa & Vieira, 2010). In Europe, repetition was found as the second factor of developing MSD (Schneider et al., 2010). Repetition will result in muscle fatigue conditions after performing high intensity, high frequency and longer duration tasks (Corlett & Bishop, 1976; Kubo et al., 2001).

2.2.1.3 Static and sustained posture

Static or sustained posture defined by DOSH (2017) as very small, minimal or restricted movement of muscle for a long period of time. According to Miedema et al., (1997), maintaining a permanent posture over long periods of time can contribute to fatigue due to lack of blood flow and the delivery of oxygen to the less active muscle (Antle et al., 2015; Callaghan et al., 2010). A posture is considered as static posture if its longer than 30 minutes for sitting or longer than two hours for standing (DOSH, 2017). Prolonged sitting often occurred to employees working in the office (e.g. a secretary typing using a keyboard), while prolonged standing occurred in manufacturing industries (e.g. assembly line work). Prolonged standing will cause discomfort at lower limb and low back pain due to reduction in venous return, leading to blood pooling and increase in hydrostatic venous pressure (Antle et al., 2015; Fewster et al., 2017). Also, the combination of static posture with other ERF especially forceful exertion and awkward posture will increase the risk of having MSD (Jaffar et al., 2011).

2.2.2 Ergonomics Awareness and Challenges

In Malaysia, ergonomics has been introduced since 1992 by the National Institute of Occupational Safety and Health (NIOSH). After 15 years, ergonomics awareness is still not taken seriously. According to Mustafa et al., (2009), up to 2008, the level of awareness among industry differ with only 35.6% have high awareness, whereas 51.1% have moderate awareness and 13.3% have low awareness. This rate, however, was based on the feedback received from industry with a respond rate of only 22.5%. On the other hand, the Social Security Organisation (SOCSO) claimed that ergonomics awareness has increased among the employers and employee with rapid increase of MSD reports since 2010. The increasing of awareness may due to introduction of ergonomics at the workplace by foreign top management working in Malaysia especially in multinational companies, local Malaysian universities offering ergonomics programs and research as well as training and consultation service provide by an academician (Mustafa et al., 2009).

However, there are still some challenges in practising ergonomics in Malaysia. Shikdar et al., (2002) listed six key challenges to implement ergonomics, which are human operators, equipment, tasks, workplaces, environment, and management. This is supported by Mustafa et al., (2009) who found in their study that lack of information and training, start-up pressure, top management support, human resources and time, financial resources, and interest in implementation were the common challenges of practicing ergonomics especially in manufacturing industries. As a result of these challenges, most of the companies do not take this issue seriously and do not organize ergonomics teams to practice ergonomics at their workplace (Mustafa et al., 2009). Therefore, it increase the injury, higher cost of employee's compensation claims for medical, motivation and loss of the productivity (Abdul Rahman et al., 2018; Deros et al., 2015; Nawawi et al., 2018).

2.2.3 Musculoskeletal Disorder (MSD)

Musculoskeletal Disorders affects musculoskeletal of human system including connecting tissue as well as the locomotors apparatus, i.e. muscles, tendons, the skeleton, cartilage, the vascular system, ligaments, and nerves (DOSH, 2017; Schneider et al., 2010). MSD may develop over time when a person is exposed to the combination of ERFs while performing a task. The risk is higher when the worker is performing a highly intense task, more frequently, and in longer duration (Caroly et al., 2010). The MSD could be very chronic and can affect a person's quality of life.

In Malaysia, MSD problems are reported to SOCSO each year as shown in Figure 2.1. This graph shows that MSD problems at the workplace increases exponentially every year. MSD was the second highest reported of occupational disease in manufacturing industries (DOSH, 2019).

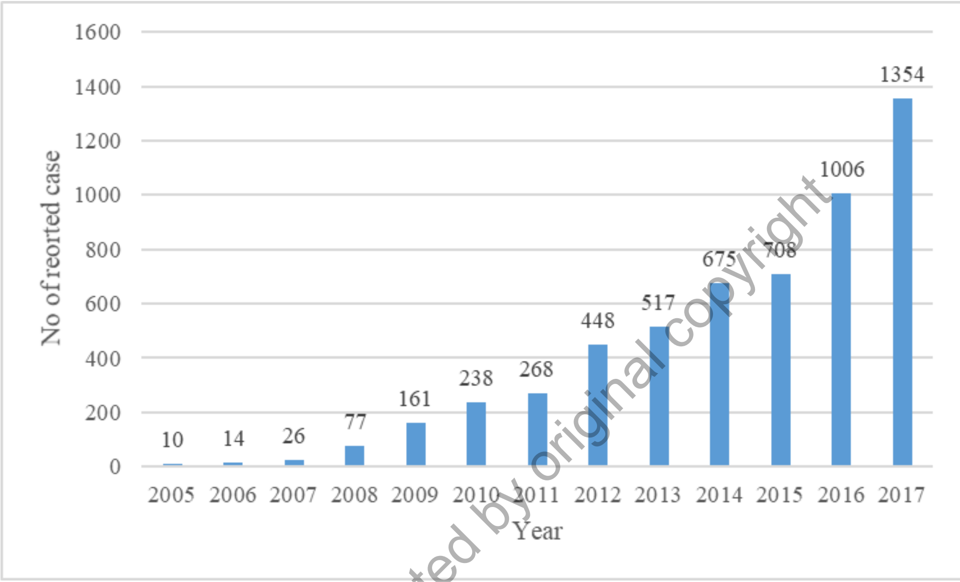

Figure 2.1 Trend of reported musculoskeletal disorders (MSDs) among Malaysian employer and employee from 2005 – 2017 (DOSH, 2017; Social Security Organisation, 2015, 2016, 2017)

MSD starts with symptoms. Halim & Omar, (2010) categorized these symptoms into seven types, starting with fatigue, numbness, tingling, swollen, strain, hot/cold, hamstring and worst-case is sprain. Whereas, Che Doi et al., (2018) categorized pain conditions into four stages, namely mild discomfort, discomfort, pain but able to do work and pain but unable to do the job anymore. When these symptoms persist, they can lead to work-related pain such as Carpal Tunnel Syndrome (CTS), Trigger finger and Thoracic outlet syndrome.

2.3 Prolonged standing

Standing position is categorized as a natural position but it will become hazardous if the standing time duration exceed more than four hours per day or one hours continuously without interrupted with other activities (Coenen et al., 2017; Halim & Omar, 2012; Meijsen & Knibbe, 2007).

Prolonged standing condition usually occurs in sectors namely in agriculture, construction, hospitality, food, education, retail and manufacturing sector (Coenen et al., 2017; Schneider et al., 2010). Working in standing position is preferable because it is comfortable and safe especially when either heavy weights have to be lifted, bulky objects have to be handled or the task requires frequent movement from one station to another (Pheasant & Haslegrave, 2006). Moreover, standing position could contribute to increase productivity (Halim & Omar, 2011) especially at the assembly line. Other possible reason for standing position could be due to health reason where it is believed that muscle activity during standing is 2.5 times more active than in sitting condition (Tikkanen et al., 2013).

The main problems for prolonged standing are low back pain and pain at lower legs such as ankle and foot. Waters & Dick, (2015) reviewed ten studies reporting evidence that workers have low-back problems after standing over 50% of the work shift. This is supported by Fewster et al., (2017), which found that people who initially do not have low back problems will get low back discomfort after two hours of standing upright. Mohamad et al., (2018) found that most operators will feel body discomfort at thigh and foot ankle when workers need to stand up to twelve hours/day. This is because, when the operators' body exceeds body tolerance, it can damage the musculoskeletal system such as muscle, tendons, joint and tissues and may contribute to body functional disability.

Using a foot pedal may increase the injury or pain at the lower legs. Using a foot pedal restrict the legs' movement as they are required to remain in the same position over a long period of time. This condition is defined as an awkward posture by Keyserling et al., (1992) because the operator's body weight is supported on one leg only, either right or left leg. The constant standing position with body weight supported on one leg will lead to strain and the musculoskeletal system will become harmful (Savino et al., 2016; Thun et al., 2011). The continuous harm conditions will contribute to job dissatisfaction and decrease in work efficiency (Arsalani et al., 2014).

The situation becomes worse when workers have to work for longer hours. Without muscle full recovery and body rest, it could contribute to major health risks such as chronic venous disorders, circulatory problems, the possibility of increase stroke risk, difficulty in pregnancy, and degenerative damage to the joints of the spine, hip, knees and feet (Halim & Omar, 2011; Mohamad et al., 2018). Furthermore, the constant condition with high repetitive and frequency will increase the MSD risk even if the posture is in normal condition because it will induce fatigue (Cui et al., 2020). The conditions occur due to muscular activity relative to their maximal contraction.

2.3.1 Factors to Reduce Risk from Prolonged Standing

In order to protect and reduce MSD risk or fatigue from standing position, a few things must be considered. First is the standing surface condition. Surface condition is very important because it can help to reduce the tibial shock to the lower limbs (Lavender et al., 2019). At the same time, standing surfaces are important in controlling leg oedema for industrial workers who needs to stand for at least eight hours (Zander et al., 2004). Besides, wearing proper and comfortable shoes are also important to reduce foot and lower leg swelling (Zander et al., 2004).

Second factor is workers' reaching condition. The reach position is depended on head height. If the workers reach things above their head it will categorize as awkward posture. Figure 2.2 illustrates the appropriate placement of object based on reach frequency where it categorize as usual, occasional and rare work with head rotation and normal visual at ± 45º (Clark, 2012). The first area, usual work is for high reach frequency work, for example, reaching a screw to assemble a product in an assembly line. An example of occasional work is reaching a main part to assemble at conveyor whereas for rare work is arranging the finished product to another place. Reaching below head and reaching based on frequency area are very important to design a suitable workstation in order to protect workers' health.

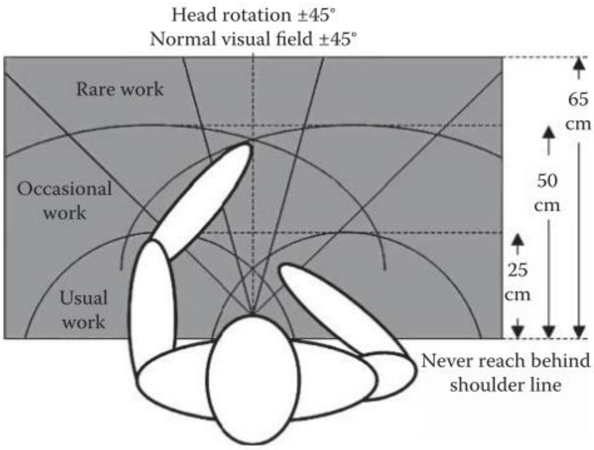

Figure 2.2 Reach Dimension for standing task (Clark, 2012)

The work surface height is also important in standing condition. According to Clark (2012), the best surface height will depending on the type of work - precise, normal or heavy with the main reference point is the elbow height. For precise work, the working height should be about 5 cm above elbow height, normal work is about 5-10 cm below elbow height and heavy work should be about 20-40 cm below elbow height (Clark, 2012; McCauley, 2011). Inappropriate working height will exposed the operators to shoulder, neck, back and hands discomfort or pain (Hernandez-Arellano et al., 2015). As an example, a low working surface height will affect tall operators where this condition would create high stress to the spine (Han et al., 2013). A common solution to accommodate operators' variability of height is using an adjustable workstation (Agarwal et al., 2018; Asadi et al., 2019; Barbieri et al., 2019; Hernandez-Arellano et al., 2015). However, it is not preferred to be used in the manufacturing sector (Clark, 2012). So, to reduce the ERFs due to height variability issue, using the Malaysian anthropometric data (Mohamad et al., 2010) is very important in current study .

Foot and knee position are also essential in order to provide sufficient room for the operators to move and change posture while working (Clark, 2012). Moreover, there are two types of task characteristics that need to be avoided to minimize the effect of fatigue from standing position; (1) use of foot pedals in standing workstation, and (2) placing a display above eye height (the primary visual task should be within 10° downward of the direct line of sight and within 15 ° right and left) (Clark, 2012).

2.4 Ergonomics Risk Assessment (ERA)

DOSH (2017) listed a comprehensive Ergonomics Risk Assessment (ERA) guideline to help the local industries to systematically assess ergonomics at workplace. There are three levels of assessment, (1) identification of workers' health condition (proactive technique), (2) identification of ERF (Initial ERA), and (3) investigate the causes through advanced assessment. Common ERF assessment tools are shown in Table 2.1.

2.4.1 Level 1 - Proactive technique

The first level is to assess the workers' health condition through either a proactive or reactive technique. The purpose is to decide whether ergonomics risk assessment should be conducted. There are two approaches in this level – proactive and reactive techniques. The proactive techniques include observation (walkthrough) method and answering an employee's self-assessment survey. In observation, several factors or information are observed such as body posture, workstation conditions, movement either static or dynamic, repetition condition, task duration per cycle and reaching condition. While the reactive techniques include reviewing medical records, accident records, complaints, quality and performance status. However, due to challenges of implementing ergonomics practice (as discussed in section 2.2.2), using a proactive technique is more relevant to Malaysian conditions. Proactive technique is an alternative usually taken by the top management in order to improve the working condition.

Table 2.1 Ergonomics Risk Factors Assessment Tools (DOSH, 2017)

Ergonomics Risk Factor	Assessment Tools
Posture	a- Rapid Upper Limb Assessment (RULA) b- Rapid Entire Body Assessment (REBA) c- Ovako Working Posture Analysis System (OWAS) d- Biomechanics Analysis
Forceful Exertion	a- Manual Handling Assessment Chart (MAC) b- Borg scale c- Snook table d- Revised NIOSH Lifting Equation
Repetitive Motion	a- Assessment of Repetitive Tasks (ART) b- Occupational Repetitive Action (OCRA) Checklist c- OCRA Index
Workstation Design	a-Rapid Office Strain Assessment (ROSA) b-Anthropometry Analysis
Environmental	a- Comply to Applicable Regulations, Industrial Code. Practice Standard and Guidelines b- Use designated specific measurement instruments

Common self-assessment survey tools used are Nordic Musculoskeletal Questionnaire (NMQ) and currently the Body Symptom Survey (BOSS). However, BOSS is more suitable to be used because the question structure is simpler and suitable for industrial applications (Che Doi et al., 2018). The survey is divided into two sections: (1) details information and (2) body symptoms (refer to Appendix B). Results from the survey helps in identifying body parts symptoms related to musculoskeletal disorders.

2.4.2 Level 2 - Initial ERA

The second level is to conduct an Initial ERA to identify ERF(s) that occurs at the workplace. A checklist is used to investigate 9 ERFs, which are awkward posture, static and sustained posture, forceful exertion, repetitive motion, vibration, lighting, temperature, ventilation and noise. An ERF requires an advanced assessment if there is at least a total of 6 activities for awkward posture, and at least one activity for other ERFs. At the end, a summary of Initial ERA will be presented as shown in Table 2.2. This step is very important to determine and confirmed the MSD symptom is due to work.

The application of Initial ERA is quite limited as it was only published in 2018. One study that has used Initial ERA was to identify the ERF occurred at an infrastructure construction site. A total of 352 bar bender workers participated in this study. It was found that, the bar bender were exposed to awkward posture, static posture, and forceful exertion (Daruis et al., 2019).

Table 2.2 Initial ERA Form (DOSH, 2017)

Risk Factor	Total Score	Minimum requirement for advance assessment	Result of Initial ERA	Any pain or discomfort due to risk factors as found in Musculoskeletal Assessment (Yes/No)	Need advance ERA Yes/No
Awkward posture	13	≥6		Neck Shoulder Upper Back Lower back Forearm Wrist Hand Hip/ buttocks Thigh Knee Lower leg Feet	
Static and sustained posture	3	≥1			
Forceful exertion	1	1			
Repetitive motion	5	≥1			
Vibration	4	≥1			
Lighting	1	1			
Temperature	1	1			
Ventilation	1	1			
Noise	2	≥1			

2.4.3 Level 3 – Advanced Assessment: Prolonged standing Assessment

There are various assessments that are often used by ergonomists in studying prolonged standing situations. According to Halim & Omar, (2010) there are three types of assessments that are commonly used, which are subjective, objective and combination methods. Subjective method is a measurement where participants are asked to mark their discomfort on a rating scale, which are carried out through a questionnaire survey (Bisht & Khan, 2013; Halim & Omar, 2010). A common example of subjective method is the Borg Scale (also called Rating Perceived Exertion (RPE)) (Bisht & Khan, 2013; Halim & Omar, 2010). A recent tool was developed by Halim & Omar, (2010) that is called prolonged standing questionnaire. It is a subjective method approach to obtain psychological feedbacks of respondents that can be used to investigate the risk of prolonged standing.

Moreover, the objective method is to help in verifying the authenticity of the subjective tests based on information on physiological and biomechanical responses of subjects through scientific responses of the human body (Bisht & Khan, 2013; Halim & Omar, 2010). Examples of technical instrument used for the objective method are optical leg volume meter, perometer, volumeter, and surface electromyography (sEMG) (Bisht & Khan, 2013; Halim & Omar, 2010).

For the combination of methods that use subjective and objective approaches is the Prolonged Standing Strain Index (PSSI). PSSI was developed by Halim & Omar (2012) to help employees and management teams using simple but comprehensive approach to assess problem due to prolonged standing in the workplace. PSSI tool has been used in industries such as automotive industry welder.

There are limited tools that can be used to assess prolonged standing especially on the lower limb. Using different types of assessment is important to get an accurate and reliable assessment of prolonged standing problem. Thus, for present study three tools will be used to determine the level of MSD risk and the causes of MSD, which are prolonged standing checklist by DOSH, Questionnaire for prolonged standing and PSSI.

2.4.3.1 Checklist for Standing Work by DOSH

Checklist method is a simple method to identify the cause of the problem at standing workstation. It is part of proactive technique to identify the ergonomics risk factor. DOSH Malaysia has introduced a checklist for assessing standing jobs. Until recently, however, there is no specific case studies using the checklist have been conducted. The checklist consists of 10 questions covering aspects such as assessment of operators' cloth and foot care, body posture and movability during working. This checklist usually used as part of walkthrough task during initial or problem identification. The identification of improper standing workstation design is really important for improvement in order to reduce fatigue, increase ability to perform task and reducing MSD risk injuries.

2.4.3.2 Questionnaire for Prolonged Standing

This tool has four objectives: (i) to capture worker feedback due to prolonged standing, (ii) to understand the correlation between prolonged standing exposure and fatigue in the general body and lower extremities, (iii) to identify the root causes of discomfort and pain, and (iv) to identify possible counter measures from worker's opinion (Halim & Omar, 2010). The questionnaire is structured into four sections: (i) demographic information and job activities, (ii) level of discomfort and pain they experienced while performing jobs, (iii) history of pain and treatment taken, and (iv) suggestion for improvement (Halim & Omar, 2010).

2.4.3.3 Prolonged Standing Strain Index (PSSI)

The PSSI is a scientific-based study to quantify the risk factor of standing condition where it mixed between objective and subjective methods (Halim & Omar, 2012). This method is suitable and comprehensive to use for present study as this tool assesses the whole body for standing position. It could identify the ERFs that are related to task that requires prolonged standing in every workstation. This tool considers six risk factors that quantify the risk level of prolonged standing, which are working posture (WP), muscle activity (MA), standing duration (SD), holding time (HT), whole-body vibration (WBV), and indoor air quality (IAQ) (Halim & Omar, 2012). The risk factors are structured from three important components, which are human, machine and workplace environment. The risk factors are analysed individually to determine the risk level. Each risk level is assigned a multiplier to represent the severity of discomfort and fatigue. An overall numerical score based on multiplier for each risk factor is calculated using equation 2.1. The score is used to assign risk for a specific job into a “Safe,” “Slightly unsafe,” or “Unsafe” category strain index (Halim & Omar, 2012).

$$PSSI = WP \times MA \times SD \times HT \times WBV \times IAQ \qquad (2.1)$$

where;

WP = working posture

MA = muscle activity

SD = standing duration

WBV = whole-body vibration

IAQ = indoor air quality