ERGONOMIC ASSESSMENT ON WORK-RELATED MUSCULOSKELETAL DISORDERS TO IMPROVE QUALITY AND PRODUCTIVITY OF WORKERS IN WOODWORKING INDUSTRY IN MALAYSIA

By

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

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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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Over the course of the twenty-first century, work-related musculoskeletal disorders (WMSDs) have persisted among blue collar workers. The primary aim of this study was to develop an anthropometric workstation design model that could reduce WMSDs and enhance comfort perception among industrial workers while performing their tasks. This study was conducted to investigate the needs and then design, develop, fabricate, and test a prototype of an industrial ergonomic trolley for industrial male workers.

In the first phase, a self-administrated questionnaire was distributed to 232 industrial workers from Peninsular Malaysia. This was to determine the prevalence of WMSDs among industrial workers in Malaysia. The result showed that the prevalence of WMSDs among industrial workers was 93.1%. Furthermore, it showed that the most affected part of the body was the lower back, with 62.1%, caused by industrial workers' job tasks. The most significant risk factors associated with body parts were gender, age, working hours, and most difficult tasks with MSDs, especially in the lower back. A survey on musculoskeletal pain and discomfort associated with work condition, sleep health, and social life in the second sequence was carried out via a self-administrated questionnaire. 54 industrial workers were chosen randomly from factories and rehabilitation centers to describe the MSDs pain and discomfort related to the work, life and sleep of industrial workers. The obtained results indicated that the lower back experienced the most prevalent pain caused by work conditions, sleep health, and lifestyle. Musculoskeletal discomfort of woodworkers was evaluated using Rapid Entire Body Assessment (REBA) and Quick Exposure Check (QEC) in the third phase. This was to investigate the exposure of risk factors for WMSDs in woodworkers across four main tasks of cutting, lifting, assembling, and finishing products. The study was conducted among 30 workers in three woodworking workshops in Selangor, Malaysia.

Throughout this phase, the demographic surveys, QEC, and REBA were examined. The results indicated that the most critical tasks were lifting and assembling. Hence, the recommendation for this study was to design a product to control the hazards. The design and development of the anthropometric workstation in the third phase and fourth sequence was carried out using anthropometric data obtained from woodworkers performing the lifting task. This study measured anthropometric dimensions of six industrial male workers. Four anthropometrics measurements including stature height, arm span, arm reach forward, and waist height were taken. The average height at 50^{th} percentile was chosen to design the industrial ergonomic trolley for the wood furniture industry.

Lastly, the validation of the design of the industrial ergonomic trolley was evaluated by REBA, QEC and interview session involved with ten male workers. The results showed that the industrial ergonomic trolley appeared to be a good design for industrial workers to reduce movement of the body posture in their daily lifting activity. In a nutshell, this study achieved the goal to design and develop an anthropometric workstation model that enhances the comfort perception and improves the quality and productivity of industrial workers.

Keywords: ergonomic assessment, work-related musculoskeletal disorders (WMSDs), anthropometric, woodworking industry, product design

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

PENILAIAN ERGONOMIK TERHADAP GANGGUAN OTOT BERKAITAN KERJA UNTUK MENINGKATKAN KUALITI DAN PRODUKTIVITI PEKERJA DALAM INDUSTRI KERJA KAYU DI MALAYSIA

Oleh

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Sepanjang abad kedua puluh satu, gangguan muskuloskeletal yang berkaitan dengan pekerjaan telah berterusan dalam kalangan pekerja kolar biru. Matlamat utama kajian ini adalah untuk membangunkan model reka bentuk stesen kerja antropometrik yang boleh mengurangkan gangguan muskuloskeletal yang berkaitan dengan pekerjaan dan meningkatkan persepsi keselesaan di kalangan pekerja perindustrian semasa melaksanakan tugas mereka. Kajian ini dijalankan untuk menyiasat keperluan dan kemudian mereka bentuk, membangun, memfabrikasi, dan menguji prototaip iaitu troli ergonomik perindustrian untuk pekerja perindustrian.

Pada fasa pertama, soal selidik tadbir sendiri telah diedarkan kepada 232 pekerja perindustrian dari Semenanjung Malaysia. Ini adalah untuk menentukan kelaziman gangguan muskuloskeletal yang berkaitan dengan pekerjaan dalam kalangan pekerja perindustrian di Malaysia. Keputusan menunjukkan bahawa kelaziman gangguan muskuloskeletal yang berkaitan dengan pekerjaan dalam kalangan pekerja perindustrian ialah 93.1%. Tambahan pula, ia menunjukkan bahawa bahagian badan yang paling terjejas adalah bahagian bawah pinggang, dengan 62.1%, disebabkan oleh tugas pekerjaan. Faktor risiko paling ketara yang dikaitkan dengan bahagian badan ialah jantina, umur, waktu bekerja dan tugas paling sukar dengan penyakit muskuloskeletal, terutamanya di bahagian bawah pinggang. Tinjauan tentang kesakitan dan ketidakselesaan muskuloskeletal yang berkaitan dengan keadaan pekerjaan, kesihatan tidur, dan kehidupan sosial dalam urutan kedua telah dijalankan melalui soal selidik yang dikendalikan sendiri. 54 pekerja perindustrian dipilih secara rawak daripada kilang dan pusat pemulihan untuk menerangkan kesakitan dan ketidakselesaan

penyakit muskuloskeletal yang berkaitan dengan pekerjaan, kehidupan dan tidur pekerja perindustrian. Keputusan yang diperoleh menunjukkan bahawa bahagian bawah belakang mengalami kesakitan yang paling lazim disebabkan oleh keadaan kerja, kesihatan tidur, dan gaya hidup. Ketidakselesaan muskuloskeletal pekerja di dalam bidang perkayuan dinilai menggunakan Rapid Entire Body Assessment (REBA) and Quick Exposure Check (QEC) dalam fasa ketiga. Ini adalah untuk menyiasat pendedahan faktor risiko gangguan muskuloskeletal yang berkaitan dengan pekerjaan dalam bidang perkayuan, merentasi empat tugas utama iaitu memotong, mengangkat, memasang dan kemasan produk perkayuan. Kajian ini dijalankan dalam kalangan 30 pekerja di tiga bengkel kerja kayu di Selangor, Malaysia. Sepanjang fasa ini, tinjauan demografi, QEC dan REBA telah dinilai. Keputusan menunjukkan bahawa tugas yang paling kritikal ialah mengangkat dan memasang produk perkayuan. Oleh itu, cadangan untuk kajian ini adalah untuk mereka bentuk produk untuk mengawal bahaya. Reka bentuk dan pembangunan stesen kerja antropometri dalam urutan fasa ketiga dan keempat telah dijalankan menggunakan data antropometrik yang diperoleh daripada pekerja perkayuan yang menjalankan tugas mengangkat produk. Kajian ini mengukur dimensi antropometri enam pekerja lelaki perindustrian. Empat ukuran antropometrik termasuk ketinggian perawakan, rentang lengan, jangkauan tangan ke hadapan dan ketinggian pinggang telah diambil. Purata ketinggian pada persentil ke-50 telah dipilih untuk mereka bentuk troli ergonomik perindustrian untuk industri perabot kayu.

Pada akhir, validasi reka bentuk troli ergonomik perindustrian telah dinilai melalui REBA, QEC dan sesi temu duga. Sepuluh pekerja lelaki perindustrian yang menjalankan tugas yang sama telah terlibat dalam eksperimen ini. Keputusan menunjukkan bahawa troli ergonomik perindustrian sebagai reka bentuk yang baik untuk pekerja perindustrian mengurangkan pergerakan postur badan dalam aktiviti mengangkat harian mereka. Secara keseluruhannya, kajian ini mencapai matlamat untuk mereka bentuk dan membangunkan model stesen kerja antropometrik yang dapat meningkatkan persepsi keselesaan, meningkatkan kualiti dan produktiviti pekerja perindustrian.

Kata kunci: penilaian ergonomik, gangguan *muskuloskeletal* yang berkaitan dengan pekerjaan, antropometrik, industri kerja kayu, reka bentuk produk

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Peace be upon our prophet, **Muhammad S.A.W.**, His family and His companions.

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LIST OF ABBREVIATIONS

WMSDs	Work-related musculoskeletal disorders
MSDs	Musculoskeletal disorders
LBP	Lower back pain
REBA	Rapid entire body assessment
QEC	Quick exposure check
MSS	Musculoskeletal disorders symptom
IBM SPSS	Statistical Package for Social Science
cm	Centimeter
mm	Millimeter
ft.	Feet
Inch.	Inches
WHO	World Health Organization
OSH	Occupational Safety and Health
DOHR	Department of Human Resources
DOSH	Occupational Safety and Health Department
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Association
SOCSO	Social Security Organization
UNESCO	United Nations Educational, Scientific and Cultural Organization
MIDA	Malaysian Investment Development Authority
MCO	Movement control order
COVID-19	Coronavirus disease 2019
GBD	Global burden of disease
SOP	Standard operation procedure

PPE	Personal protective equipment
MDF	Medium-density fibreboard
ABS	Acrylonitrile butadiene styrene
VDT	Video display terminal
OEM	Original equipment manufacturer
ODM	Original design manufacturer
UPM	Universiti Putra Malaysia
PhD	Doctor of Philosophy
3D	Three dimensional
2D	Two dimensional
CAD	Computer-aided design

CHAPTER 1

INTRODUCTION

1.1 Background of study

The workplace is the most important environment for a worker. The World Health Organization (WHO) stated that 2.9 million workers across the world are exposed to hazard risks in the occupational sector. Work-related musculoskeletal disorders (WMSDs) are the second highest cases of occupational disease and poisoning as reported by NIOSH (2018). As mentioned by the Occupational Safety and Health Department (DOSH, 2018), 35,460 workers in Malaysia are reported to have an accident in the workplace with a risk rate of 2.40 per 1000 workers. In 2018, the national employment total of accidents indicates that the highest number of accidents is from the manufacturing sector, followed by the construction and services sector. This increase in the accident rate in manufacturing, construction, and services sectors highlights the need to conduct a significant study on ergonomic intervention to reduce the number of accidents in a particular workplace.

Most industries worldwide often adopt the use of machinery and tools in their work. The design of tools and equipment for a worker to perform their work should not disregard the physical and mental state of the workers. In various industries, it is very common for individuals working in one job field to be considered as valuable for companies. Therefore, workers are always exposed to same working condition for a long period. Industrial workers are often exposed to working situations that involves hazard. There are five main hazards which are ergonomics, biological, chemical, physical and physiological (Bridges et al., 2000). Nevertheless, ergonomic hazard was found to be the most challenging for early detection since it does not give immediate strain and harm to the body. Ergonomics are commonly known to be related to job task and human health. In short, ergonomics examines the capabilities and limitations on the behavioral, psychological and physiological state of humans (Jaffar et al., 2011). Through an effective ergonomic, workers shall not be exposed to work stresses which can affect their safety and health as well as productivity for companies. Thus, it is clear that ergonomics intervention could provide a productive and quality workplace for workers and can thus help to fulfill the companies' objectives and goals as well (Lenkeit, 2013). The implementation of ergonomics in the workplace should consider the human quality, productivity, and safety in terms of fitting products, task and environment instead of forcing them to adapt to the work. Ergonomists need to consider the worker, workplace and work task in order to create a good work environment between the person and their task (Kolgiri et al., 2016).

The woodworking industry has evolved from being a lodge-based, skill dependent industry into a highly mechanized and labor-intensive industry that

operates in high-volume production (Rampal & Mohd Nizam, 2006). In Malaysia, a study of ergonomics within the woodworking industry concluded that there is scientific proof that the woodworking and sawmill industries can expose one to many ergonomic risks (Jamaludin et al., 2022). The work environment in the woodworking industry has always been regarded as an environment that is dirty, dangerous, and degenerative. Therefore, woodworkers are often exposed to many risk factors that could affect their safety and health, such as air-borne dust, manual handling, chemical exposure, and noise emission (Ratnasingam et al., 2010). Among that, manual handling is an example of an activity that exposes one to ergonomic issues that bring discomfort, which can then lead to fatigue and back pains that could affect the productivity of workers (Shikdar & Sawaqed, 2003).

Woodworking compared to other industries involve various stages to get to the final product, where most involve manual handling. For that reason, the woodworking industry is known to be one of the industries with the highest accident rates in the manufacturing sector (International Labour Organization (ILO), 2015). Manual handling in woodworking involves the use of the human body to manage heavy loads, which can lead to difficulty in gripping, excessive use of force, repetition, twisting, and other awkward postures. Prolonged manual handling to conduct woodworking activities such as cutting, nailing, assembling, and painting may lead to work-related injuries that include work-related musculoskeletal disorders (WMSDs), which are disorders of the muscles, skeleton, and related tissues. WMSDs are among the most common occupational disorders around the world (Baek et al., 2017; Bandyopadhyay et al., 2012; Chandrasakaran et al., 2003; A. Yusof & Shahida, 2021) and is particularly evident in the woodworking industry (Akanmu et al., 2020; Lemasters et al., 1998; Nejad et al., 2013; Ooneklabh et al., 2020). According to the Global Burden of Disease (GBD) study in 2010, back pain is reported as one of the most prevalent conditions globally, with a global point prevalence of 9.4% (Hoy et al., 2014). Such exposure may be present among workers due to the nature of work that requires them to bend, crouch, and stoop for long periods.

In abovementioned situation, the study, analysis and prevention of musculoskeletal disorder among woodworking workers need to be sought in order to reduce the number of occupational accident and disease in occupational safety and health sector. Therefore, the purpose of this study is to develop an anthropometric workstation design model that could reduce the WMSDs for woodworking workers. Through this study, preventive action to maintain workers' working ability for a long period and to increase the safety, quality, and accessibility as well as productivity of company with an ergonomic input is proposed.

1.2 Background of the Problem

In every industry sector, WMSDs continue to present a major challenge to workers and their employers. Many disciplines have been involved in providing

advice and have worked on interventions to prevent or reduce their consequences. Job-related accidents and diseases that happen in the industrial sector such as in manufacturing, construction and many more are normally due to human-related issues. Manual handling, fatigue due to overload, long duration of exposure to sunlight, job dissatisfaction, and prolonged awkward postures in handling work may be among the factors that contribute to the aforementioned issues. These factors are simply addressed as human factors and ergonomics by many researchers. Although the term is widely accepted, an understanding of the two terms would be beneficial for researchers to conduct more impactful research in this field. In job handling, the most significant ergonomics risk factors are awkward posture in handling a job task, force, and repetition of specific movements including vibration. Other ergonomics risk factors include uncomfortable static position, contact stress of muscles and tendon, and extreme temperature conditions.

The woodworking industry in Malaysia has continued to develop due to the country's economic growth. According to the Manufacturing Statistics Malaysia, furniture manufacturing is among the three top industries that has the strongest year-on-year growth with export-oriented industries in Malaysia (Department of Statistics Malaysia, 2023). The WMSDs statistics on occupational health and diseases, especially in back pain, rank high among workers, proving that there is still lack of research carried out particularly in the anthropometric workstation design model that could reduce or prevent WMSDs for woodworkers. Previous studies have shown that lower back pain is one of the most common MSDs reported. In addition, it also has been proven that back pain MSDs also occur among woodworkers (Adeyemi et al., 2017; Mitchual et al., 2015).

Based on literature, one of the causes of occurring symptom of WMSDs is due to inappropriate workstations. This study was suggested that ergonomics workstation should be considered to improve occupational health (Hong et al., 2022). According to Janet I. Minshew, WMSDs and their associated high costs are a major cause for concern in any workplace (Janet I. Minshew, 2008). In addition, a safe working environment must be created, and all workers must understand, accept, and use the principles of ergonomics in order to reduce any potential occupational injuries. As a reason for that, extended research is needed concerning the safety and health of workers, ergonomic factors, significant factor on prevention of WMSDs and its best recommendation in enhancing comfort perception among woodworking worker.

1.3 Research need

The main idea for this research had been inspired by the facts that industrial workers are likely to exposed to occupational hazards and are at risk of having occupational disease or injury. Based on previous finding , WMSDs appear to be one of main health problem among workers in Malaysia in the past five years (Awaluddin et al., 2023). In addition, those who worked in a factory were exposed to MSD due to ergonomic factors such as repetitive activities (Anwar et al., 2019;

F. A. Aziz et al., 2017; Yahya & Zahid, 2018). DOSH report also stated that the highest number of workers was from manufacturing workers. Hence, there is strongly need to explore this research.

This study aims to improve the performance of industrial workers in their working environment. More research has been conducted on the problem of WMSDs, however, little attention and focus have been given to ergonomic interventions to reduce WMSDs injuries among industrial workers (Dale et al., 2012; Kramer et al., 2010; Yazuli et al., 2019). Consequently, the study would provide information in design and development of an industrial trolley which is not currently mainly use in woodworking workstation.

1.4 Research questions

The main research question of the study is how to develop an anthropometric workstation design that could reduce the WMSDs in order to enhance comfort perception among woodworking workers performing their task? Therefore, below are the research questions for this study:

1. What is the present state of safety and health among industrial workers in Malaysia?
2. Which ergonomic factor affects the WMSDs of woodworking workers while performing their task?
3. What is the significant factor to prevent WMSDs in anthropometric workstation design which enhances comfort perception among woodworking workers when they perform their task?
4. What is the recommendation for ergonomic interventions that could enhance comfort perception to improve the quality and productivity of woodworking workers?

1.5 Research Aim and Objectives

The general aim of the study is to develop an anthropometric workstation design model that could reduce the WMSDs in order to enhance comfort perception among woodworking workers performing their task. Below are the research objectives for this study:

1. To identified the present state of safety and health among industrial workers in Malaysia.
2. To evaluate the WMSDs risk factor that affects the woodworking workers in performing their task.
3. To determine the anthropometric workstation dimensions that are significant to WMSDs risk factor.
4. To design and validate the anthropometric workstation design model that could enhance comfort perception for improving the quality and productivity of woodworking workers.

1.6 Research Strategy Table

Table 1.1 : Research question methodological strategy of study

Construct	Research Question Construct Description	Research Question/ Research Objective	Methodological Strategy	Analysis	Output
WHO	Industrial worker	Sub RQ1: What is the current state of safety and health among industrial workers in Malaysia? RO: To understand the present state of safety and health among industrial workers in Malaysia	Literature review Observation Interview	Analyse the task: Comparison between the critical task	Documentation of demography information on industrial workers in Malaysia. Documentation of issues and problem related to industrial workers. Identification on critical working conditions to support quality working among industrial workers.

Table 1.1 : Research question methodological strategy of study (continued)

WHAT	Ergonomic	Sub RQ2: Which ergonomic factor affects the WMSDs of woodworking workers while performing their task? RO: To evaluate the WMSDs risk factor that affect the woodworking workers in performing their task	Observation (Video recording) Rapid Entire Body Assessment (REBA) Quick Exposure Check (QEC)	Analyse the MSDs on industrial worker: Rapid Entire Body Assessment (REBA) Quick Exposure Check (QEC)	Identification on the common types of tasks for woodworking workers. Categories of tasks for ergonomics measurements. Identification of ergonomic variables affecting task performance among woodworking workers.

Table 1.1 : Research question methodological strategy of study (continued)

HOW 1	Enhance comfort	Sub RQ3: What is the significant factor to prevent WMSDs in anthropometric workplace design which enhances comfort perception among woodworking workers when they perform their task? RO: To determine the anthropometric workplace dimensions that significant to WMSDs risk factor	Anthropometric measurement	SPSS: The dimensions of proposed workplace design	Categorisation of significant factors enhancing comfort perception among woodworking workers Identification of significant factors enhancing comfort perception among woodworking workers

Table 1.1 : Research question methodological strategy of study (continued)

HOW 2	Improve workplace design	Sub RQ4: What is the recommendation for ergonomic interventions that could enhance comfort perception for improving quality and productivity of woodworking workers? RO: To validate the anthropometric workplace design model that could enhance comfort perception for improving quality and productivity of woodworking workers	Develop the ergonomic workplace design model based on anthropometric dimensions	Analyse finding from validation: Rapid Entire Body Assessment (REBA) Quick Exposure Check (QEC) Questionnaire on worker's preferences	Recommendation of design guideline and task performance for woodworking workplace Proof of concept prototype of proposed design for workplace.

1.7 Scope of the Study

Ergonomic study is a combination of numerous disciplines that cover many areas such as psychology, sociology, biomechanics, engineering, industrial design, anthropometry, interaction design, visual design, user experience, and many more. Therefore, in order to accomplish the objective of this thesis, it is necessary to affirm the scope so that it will not go beyond of the limitation. The focus of this work is mainly on development ergonomic workstation designed for woodworking industry. In this study, the inclusion criteria include local and migrant workers aged between 20 to 50 years old who are working in factories in peninsular Malaysia. The semi-direct method was used in this study to identify ergonomic risk factors. Generally, woodworkers perform four main activities, which are cutting, lifting, assembling, and finishing products. However, only lifting was chosen for further development of product enhancement in this study. Hence, the design guidelines were based on lifting activities in a woodworking area. In addition, it focused on the response of workers while operating the developed product. Even though this research focused on the workstation design, it also gathers some information on Malaysia's industrial workers in terms of the prevalence of WMSDs, the social activities, and their issues on performing common daily working tasks and identification of major factors associated with MSD symptoms as well as development of guidelines for workstation design in order to improve quality and productivity of workers in woodworking industry.

1.8 Significance of the Study

This study intends to improve the quality and productivity of woodworkers by instigating the ergonomic aspect of their workstation design. The findings of this study can contribute to the Department of Occupational Safety and Health, Malaysia (DOSH) in minimizing the percentage of occupational incidents among workers, especially in the manufacturing field. Moreover, this study also can be beneficial to the worker to maximize efficiency, quality, and quantity of work while minimizing WMSDs, fatigue, and overexertion.

1.9 Flowchart of the Study

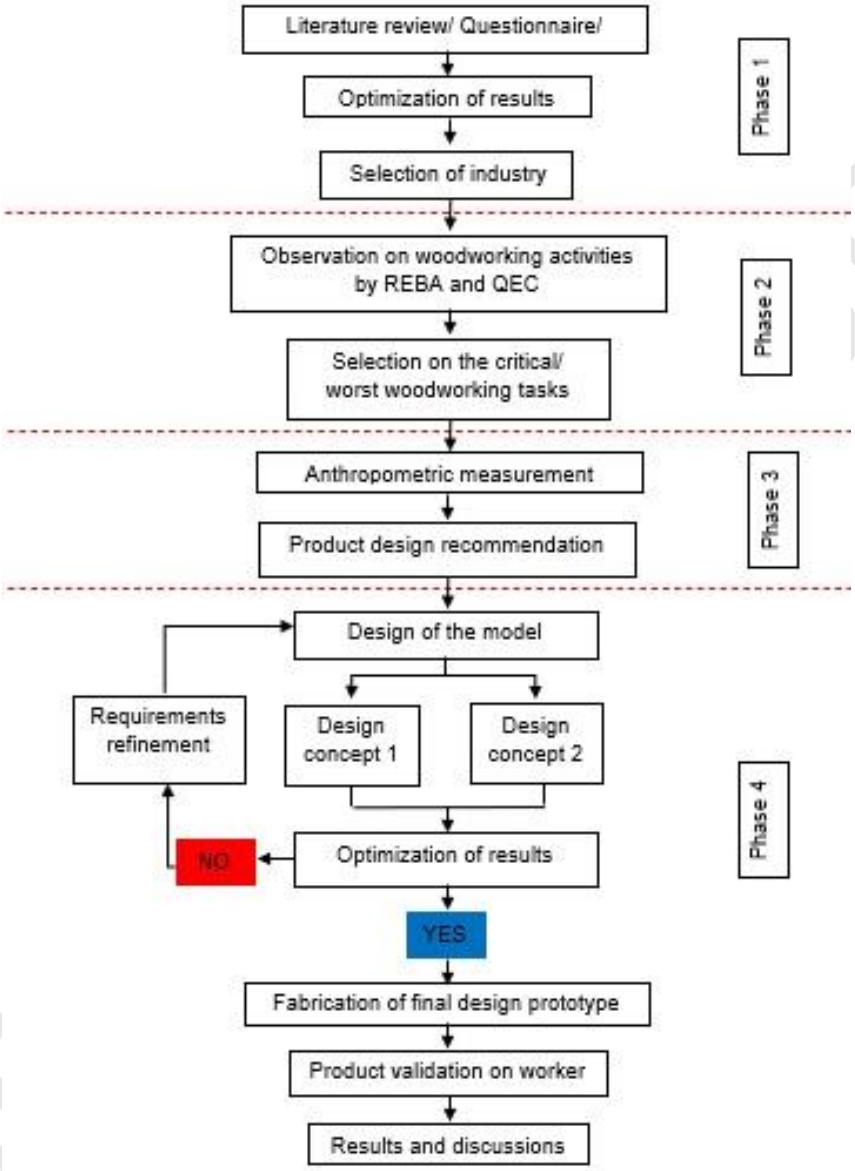

Figure 1.1: Flowchart of the study
(source: author)

1.10 Chapter Overview

Chapter 1
This chapter offers a general introduction to the purpose of the study, the problem statement, as well as the objectives, scope, and significance of the study.

Chapter 2
The second chapter will briefly explain the analysis of literature review based on current studies.

Chapter 3
The third chapter reveals the research material and methodology for this study. This includes the explanation of the selected method for developing the questionnaire, survey and the proposed table research framework. The chapter proceeds with the description on conceptual design task and selection on final concept of proposed design. Further details description was explained in development process of proposed ergonomic industrial trolley. Finally, the required evaluation to verify the developed prototype based on ergonomic risk assessments and user evaluation is presented.

Chapter 4
The fourth chapter reveals the findings for the overall study. In order to understand the current situation of industrial workers, the first part of the chapter provides an analysis of the risk factors of musculoskeletal symptoms among industrial workers, followed by a survey on musculoskeletal pain and discomfort associated with work condition, sleep health, and social-life. This research identified the necessities of the woodworkers in their workplace. This chapter also presents the developed design concept for an industrial ergonomic trolley-lifter based on the problem discussed previously in the literature and analysis results from the REBA and QEC findings. This research sought to uncover the most critical tasks that can contribute to an anthropometric design criterion in order to design an industrial ergonomic trolley-lifter for woodworkers. Finally, the conceptual design, fabrication, and validation of prototype of the industrial ergonomic trolley-lifter were proposed. This chapter then covered the evaluation of the final design concept. An evaluation was also conducted to appraise the comfort, usability, and convenience performance of the developed industrial ergonomic trolley-lifter for woodworkers.

Chapter 5
The fifth chapter reveals the discussion for the overall study. This chapter presents the details finding from previous chapter.

Chapter 6
The sixth chapter, which is the final chapter, concludes the research outcome and discusses the contributions and limitations of the research. It also provides further recommendations for future works.

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