IDENTIFICATION OF LATERAL TRANSFER DISTANCE THAT MINIMIZES TWISTING AND BENDING MOTIONS IN WORKSTATION DESIGN

This report submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering
(Department of Manufacturing Design)(B.Eng)

by

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DECLARATION

I hereby, declared this report entitled "Identification of Lateral Transfer Distance that Minimizes Twisting and Bending Motions in Workstation Design" is the results of my own research except as cited in reference.

Signature :

Author's Name : LEE POH YAN

Date : 17 JUNE 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Department of Manufacturing Design) (B.Eng).
The member of the supervisory committee is as follow:

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Dr. Radin Zaid bin Radin Umar

ABSTRAK

Matlamat kajian awal ini adalah untuk mengenal pasti potensi jarak pemindahan sisi yang meminimumkan pusingan dan bengkokan badan dalam reka bentuk stesen kerja. Pendedahan dan pemahaman melalui aplikasi ergonomik dengan mewujudkan keselesaan antara stesen kerja dan pekerja boleh meningkatkan produktiviti dan mewujudkan persekitaran kerja yang selamat. Jarak sisi yang optimum boleh mengurangkan pendedahan kepada postur janggal terutamanya pusingan dan bengkokan yang melampau. Projek ini mengkaji dengan terperinci kesan jarak pemindahan sisi kepada darjah pusingan dan bengkokan pada belakang badan. Empat jarak pemindahan sisi dibincangkan dalam kajian ini iaitu 50cm, 75cm, 100cm dan 125cm. Sebanyak 10 sukarela lelaki telah mengambil bahagian dalam eksperimen ini projek ini. Mereka memakai Xsens MVN, satu Mocap system yang membenarkan proses pengumpulan data pergerakan. Mereka perlu mengangkat kotak seberat 10.9kg secara manual antara semua jarak pemindahan yang telah dinyatakan. Jarak pemindahan sisi pendek antara 50cm dan 75cm menyebabkan nilai darjah pusingan yang lebih tinggi manakala jarak pemindahan sisi jauh antara 100cm dan 125cm menyebabkan nilai darjah bengkokan yang lebih tinggi. Oleh itu, kajian awal ini mengenal pasti bahawa potensi optimum jarak pemindahan sisi yang mengimbangi pusingan dan bengkokan adalah pada sekitar jarak 100cm. Lanjutan terperinci dan analisis perlu dilakukan untuk menjadikan jarak ini sebagai garis panduan untuk rekabentuk stesen kerja populasi Malaysia.

ABSTRACT

The goal of this preliminary study is to identify the potential lateral transfer distance that minimizes both twisting and bending motions of the spine in workstation design. The exposure and understanding through ergonomic intervention by creating fit between workstation and worker could increase productivity and develop safe working environment. This report further discusses the effect of lateral transfer distance on the degree of twisting and bending. Four lateral transfer distances explored in this study which is 50cm, 75cm, 100cm and 125cm. Total of 10 voluntarily male subjects were recruited to participate in this experiment of this project. The subjects wore the Xsens MVN full-body, a wearable motion capture (Mocap) system allowing data collection process. They have to manually carry a 10.9kg box with a handle over the specified distances. The shorter lateral transfer distance of 50cm and 75cm resulted higher value of twisting degree while the longer lateral transfer distance of 100cm and 125cm resulted higher value of bending degree. Therefore, the preliminary results of this project identify that the potential optimum lateral transfer distance that balances the twisting and bending motions of the spine is at the distance of 100cm. Future study and analysis need to be made in order to apply this guideline for the Malaysia population.

DEDICATION

Only

my beloved father, Lee Chee Meng

my appreciated mother, Khor Sew Tiam

my adored sisters, Poh Ching, Poh Yin, Poh Wei and Poh Sheen

for giving me moral support, money, cooperation, encouragement, and also understandings

Thank You So Much

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I would also like to thank the experts who were involved in the exploitation use of the human motion capture system in this study, Encik Nazreen. Without his willingness partaking and sharing, the experiment could not have been successfully conducted.

Last but not least, I am grateful with the cooperation given by the technician of the ergonomics lab for providing me an ambient room to conduct the experiment comfortably. Also, to all of the volunteers for agreed to be the subject of this study to ensure the experiment could be conducted.

Finally, I would like to show my appreciation to everybody who had support or motivates me to complete this study. Many valuable suggestions and comments had been received throughout this study.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

HFE	-	Human Factors Engineering
MMH	-	Manual Material Handling
MSD	-	Musculoskeletal System Disorder
NIOSH	-	National Institute of Occupational Safety and Health
OWAS	-	Ovako Working Posture Analysing System
SOCSO	-	Social Security Organisation
WMSD	-	Work-related Musculoskeletal System Disorder

CHAPTER 1
INTRODUCTION

1.1 Background

Work-related Musculoskeletal Disorders (WMSDs) are defined as the pain, injury, or damage particularly on the muscular system (i.e. muscles, tendons, ligaments, bones, nerves, veins, disks, etc.) and that influence body motion due to work (Wang, D., Dai, F., & Ning, X., 2015). The common WMSDs are muscle/ tendon strain, ligament sprain, back and neck pain and hand tendonitis. Workers that repeatedly involve with manual material handling (MMH) are vulnerable to the risk of WMSDs.

Every organization needs to aware of the potential risk factors of WMSDs at their workstation as the number of recorded cases has been rising in Malaysia. Total of 14 recorded cases in the year of 2006 and has risen sharply to 238 recorded cases in the year of 2010 (Sharifah Raini, 2013; Xiang Yun, 2012). In the same article, National Institute of Occupational Safety and Health (NIOSH) chairman Tan Sri Lee Lam Thye state that the number continue to rise to 268 recorded cases on the following year, 2011. There are many aspects of studying in order to reduce the risk of WMSDs. Despite, the proper design of workstation layout is crucial as many other factors might affect along too.

Moreover, a total of 675 accidents associated with occupational musculoskeletal disorders reported in the annual report year 2014 by Social Security Organisation Malaysia (Social Security Organisation[SOCSO], 2014). In addition, it compromises total of 416 reports and 259 reports, for male workers and female workers respectively. It shows that the rate of WMSD among Malaysian workers is in high rate and needs immediate action to be taken.

There is a strong relationship between workstation layout and musculoskeletal disorders. It is demonstrated as shown as Figure 1.1.

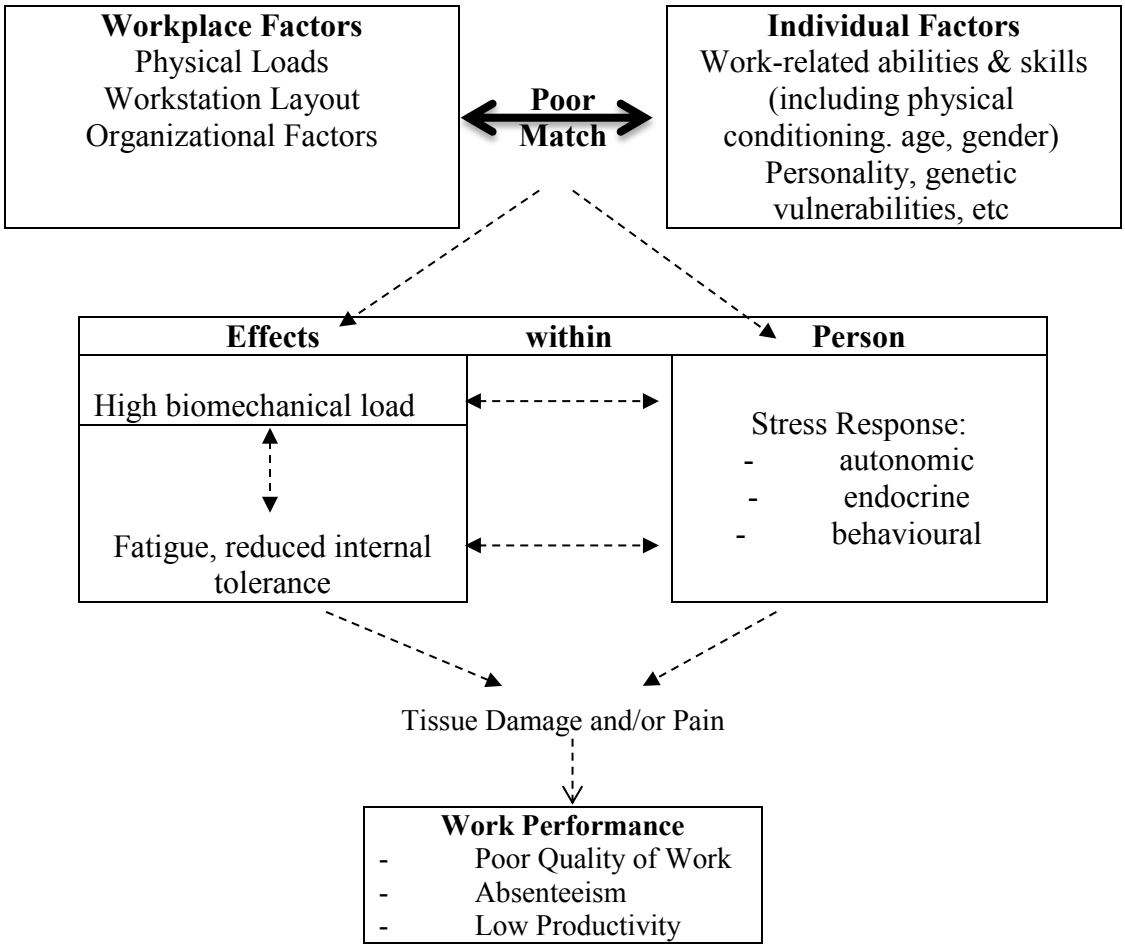

Figure 1.1: Relationships workplace factors, individual factors, and effects within-person

Workplace factors are subdivided into physical loads, workstation layout, and organizational factors. If these factors do not match with the worker's traits, it may lead to tissue damage and/or pain. These damages could bring major adverse effect the performance and quality of work. The fundamental principal in workstation design is to fit the layout to the workers (Anshel, 2005). Good design of workstation layout is a way to increase productivity, improve quality, and promote worker health and safety. It also reduces the exertion force needed of the worker to support their task.

The variables of workstation layout include the structure and range of gesture, the height of the load to reach or to be performed, the space of workplace, the reach distance, sitting or standing position etc. (United States Department of Labor, n.d.). WMSDs risk can be reduced provided that the design of workplace allows the worker to perform their task without excessive bending, twisting nor stretching. The too small gap will drive the

worker to possess twisting posture. Contradictory, the worker might possess bending posture if the gap is too big.

Both twisting and bending posture are the two main contributors to WMDSs in manual handling tasks (Zein, R. M. et al., 2015). The awkward postures like bending and twisting are the major cause of strains and sprains of the back, arms, and shoulders (Bending, Twisting & Reaching, 2011). Proper design of workstation layout promote good postures and thus the alignment of the bone is upright as well as the muscles, joints and ligaments could work at its nature state without sprain or strain (Chris Woolston, 2016). Long term of experiencing pain due to sprain and strain could adverse body health and lead to permanent WMSD.

1.2 Problem Statement

Ideally, the most ergonomic workstation is a fully adjustable workstation as it fit everyone regardless the physique size or shape (Anshel, 2005). However, in a certain situation, the workplace is challenging to be fully adjustability due to cost and design constraints. The parameters of the workplace layout must be set at the beginning before the operations start. Most of the job routine involves transfer process of loads. Thus, lateral transfer distance is one of the vital parameters in the workstation design. Neither research was performed that able to state the optimum lateral transfer distance that minimizes twisting and lateral bending motions of the spine in workstation design in Malaysia.

There's a study effects of transfer distance on spine kinematics for de-palletizing task. A study by the Journal of Occupational and Environmental Hygiene (JOEH) needs to be replicate among Malaysian population. It is because the physical traits such as interscye breadth, hand length etc of Malaysian populations is differing from the people in the Ohio State. Therefore, the recommended gap distance of the Ohio study is not applicable for Malaysian population.

1.3 Objectives

a) To understand design parameter in the workstation layout affecting the posture of workers in manual material handling.
b) To explore the effect of lateral distance to the working posture in manual material handling.
c) To identify the potential optimum lateral transfer distance that minimizes twisting and bending in Malaysia workstation design.

1.4 Scopes

The study is an approach towards the design of the workstation layout. The research would focus on how the lateral distance affects the postures of human body particularly on twisting and bending posture. Adhering to the objective stated, the subjects involved in the study are Malaysian only. Only subjects that do not experience any back pain or related MSDs injury are eligible to perform the experiment.

The study is performed in the experimental based whereby the setup will imitate the desired workstation layout of manual material handling. Both, the weight of the load and the height of the destination conveyor act as the controlled variables. The dimension of the box will also be constant and is not the manipulators in this study.

1.5 Significant of Study

The finding of this study could balance between the degree of twisting and bending posture during manual material handling. It is an empirical approach to implementation of ergonomic consideration in the design of workplace specifically for Malaysian when designing a workplace that engages with MMH activities. This not only benefits the employee but also to the company where the MMH activities are highly dependable on the workforce productivity. Thus, creating a safe and comfortable environment is important in order to form a productive workforce. It also reduces the turnover rate in a company by keeping the employee in good health condition to be able of performing their task.

Determining the optimum lateral transfer distance could reduce the outstanding expenditures of WMSDs that result from poor ergonomics. Thousands of compensation claims being made each year. The reduction of the WMSDs severity due to the ergonomic interventions could reduce the injury cost (Goggins, R. W. et al, 2008). Optimum lateral transfer distance could minimize the risk of injury, sprain or strain of the musculoskeletal system as it manipulates the posture of the workers. The outcome is beneficial in a varied aspect in the terms of ergonomic in the workplace.

1.6 Organizations of Report

Chapter 1: Introduction

This chapter provides general information regarding the context of the whole study about. It provides a clear statement of the subjects, problems or controversy arise in this study. It also states the reason for this study undertaken and the objectives to be achieved in the end. The extent of the contents or focus to be covered will be specified at this part. It states the areas and limitations in this study context. The outcome of the study is also express.

Chapter 2: Literature Review

This chapter discusses the theories, ideology, and understanding of any relevant information concerning the study. Bounteous sources studies acquire from the past such as journals, books, articles, research papers, etc in order to gain knowledge on this study. Annotations and the relationship between WMSDs and workplace are being resolved at here. The explanatory notes on the design of experiment in this study are being clarified as well.

Chapter 3: Methodology

This chapter presents the sequential, methodical and organized procedure on how this study will be conducted. It constitutes the independent, dependent and controlled variables of the design of the experiment. It provides details information and the checklist to be prepared before conducting the experiment. It provides insight of this study.

Chapter 4: Results & Discussion

This chapter presents the results or findings obtained from the experiment. It comments on the results obtained and interpreting what the results mean. These data is present in the statistical chart to ease the comparison and the explanation of any results. The discussion section of the reports woven the findings together and the major issues/ themes are identified and discussed. It aims to distinguish the main project findings with the results obtained.

Chapter 5: Conclusion and Recommendations

This chapter concludes the topic raise in this report. It synthesizes the hypothesis, to present the importance of the contents discussed, and to drive reader to a new perspective of the topic. In the recommendation section, it proposes the potential positive changes and continuity improvement in this project. It probably could solve or overcome the limitations of this project.

CHAPTER 2
LITERATURE REVIEW

2.1 Work related Musculoskeletal Disorders

Workers that engage to (MMH) in their job routine are in the risk exposure to injuries. The Canadian Centre for Occupational Health and Safety (MMH - Health Hazards, 2013) explain MMH whereby the transferring or handling materials process is by lifting, lowering, pushing, pulling, carrying, holding or restraining. The works involve manual labour rather than automated system Continual high exposure MMH that exceeds one's capabilities may develop into work-related musculoskeletal disorders (WMSDs) over time.

The term of musculoskeletal disorders (MSDs) signify ache, soreness, sprain or strain endure at the joints, ligaments, tendons, muscles or bones including the associated circulatory system and neurology (Seim, 2015). WMSDs imply developing of MSDs by the cause of the task itself or the workplace. The main contributors to WMDSs are repetitive motion, heavy lifting, forceful exertion, awkward posture and expeditious hand and wrist motion (Shamsuddin, K. A. et al., 2014). The correlation of these factors with the workplace design (e.g. workstation height, space, distance to travel, the angle of movement, etc.) is strong.

Injuries at the musculoskeletal system have been aware by the Malaysia government. The number of cases reported is increasing from year to year. There are several locations of injuries that are related to the musculoskeletal system such as neck, trunk, upper limb and lower limb. The annual report disclosed by Malaysia's Social Security Organisation (SOCSO) recorded the numbers of injuries/ accidents on the location of WMSDs as shown in the Table 2.1.

Table 2.1: Number of accidents by the location of injuries for the year 2010, 2011, 2012, 2013, and 2014.

Location of Injuries		Years				
		2010	**2011**	**2012**	**2013**	**2014**
Neck		189	235	280	249	264
Trunk	**Back**	1,388	1,510	1,805	2,011	2,347
	Pelvis	246	296	306	339	282
	Trunk, multiple locations	1,136	713	613	1,009	2,174
	Trunk, unspecified location	124	161	226	418	466
Upper Limb		22,798	23,520	23,696	23,442	21,512
Lower Limb		14,678	14,727	15,241	15,799	15,501

Adapted from: SOCSO Annual Reports (SOCSO 2010, SOCSO 2011, SOCSO 2012, SOCSO 2013)

The Table 2.1 listed the locations of injuries related to WMSDs which are the neck, trunk, upper limb and lower limb. Mainly numbers of cases reported from SOCSO increases from the year 2010 to the year 2014. The obvious continually increasing trend from the statistic data are injuries at the back and trunk (multiple locations and unspecified location). The average percentage of increment number of injuries at the back from the four years is up to 14 percent. While, the total number of cases reported regarding injuries at the trunk, both, multiple locations and unspecified location rise drastically from year the 2012 to 2013. These numbers indicate the severity of related WMSDS injuries among Malaysian workers and its risk to the worker's health and their productivity.

WMSDs may develop into permanent health problems among the workers in the industry. The presence of this syndrome will result into adverse effect on the occupational health and certainly developing into workers disability and lost wages (Isa Halim et al., 2005). When a WMSD injury happens, the organization needs to pay for the direct cost of worker's compensation, medication fees, and legal charges. Indirect cost includes off-track production rate, manpower shortage, overtime wages, repairment of equipment/ building, etc. As WMSD injury only noticeable after a certain period of time, many fail to notice (McCauley-Bush, P., 2011). WMSDs are the least favourable cost in an organization and it is a pricey expense in a business (Islam, M. M. 2012; Middlesworth, 2015). Thus, it is disadvantaged in term of competitive and productivity to an organization.

2.2 Awkward Posture

Posture defines the position or the pose of the body when executing the job duty. Awkward posture is whereby the body joint is diverging from its ordinary or neutral position that leads to injury risk (Michael, 2002). Higher deviation will lead to a high potential risk of injury, especially towards the musculoskeletal systems. Thus, the fundamental guideline in MMH is by which the workers should perform their task in the neutral joint posture. Awkward working posture like bending, twisting, overstretch along with repetitive motion will develop WMSDs (Raemy et al., 2015). Continually and repeatedly exposure to awkward posture evolves into few possibly paralyzing injuries and musculoskeletal systems disorders.

MMH activities require great strength from the muscles. However, the muscles will have lesser strength when a joint is in an awkward posture in comparison with a neutral posture. It will have to work with closer to their maximal strength or effort. The person tends to feel fatigue subsequently in a continuous awkward working posture (Rosnah et al., 2013). The common warning sign that indicates a worker experiencing muscle fatigue is the weakness. The workers suffer insufficiency energy or the incapability to perform the works due to the insufficient stream of blood flow to the extremities (Stern, 2014). The drawback of this state will reduce their efficiency and productivity. The interpretation of awkward posture as shown as Figure 2.1.

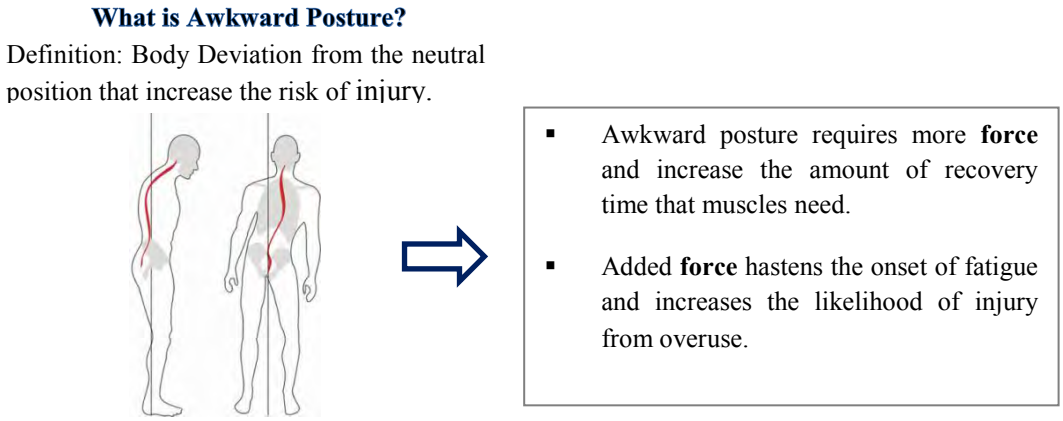

Figure 2.1: Awkward Posture Modal
Adapted from: (Awkward Postures – Safety Talk, n.d.)

As previously stated, when working in an awkward posture, the efficiency of the muscles is greatly reduced other than exerting large physical force to perform the work.

This extra exertion causes muscle-tendon to exhaust and injured. It reduces the output forces in doing work (Awkward Postures – Safety Talk, n.d.). If the worker sustains the awkward postures when performing the work, the tension on the muscles and tendons may trigger inflammation and irritation of the ligaments and muscles. (Awkward Postures, n.d.). It explains that the increased stress on nerves and blood vessels, contracting the blood supply to the working tissues and ligaments. Awkward posture such as bending and twisting is the main ergonomic risk factor to whereby the workers are exposed to WMSD.

2.2.1 Back Bending and Twisting

Bending or twisting during MMH tasks illustrates as an improper posture. The twist is identified when the absolute angle of the shoulders in conjunction with the pelvis go beyond 20^{o}. The similar measure is used to identify lateral bending by the relative angle of the torso (the cord from L3 to C7) in conjunction with the vertical of the anterior plane (Neumann, W. P. et al, 2001). There are four classification back postures in the Ovako Working Posture Analysing System (OWAS), which are straight, bend, twisted (or bend sideways), and both (bend and twist) (Karwowski & Marras, 2003). Thus, it has the option of 1 to 4 to be the first digit in the posture code of the back as shown in the Figure 2.2.

1 BACK STRAIGHT

"Back straight" means that worker's back is less than 20° (the angle of the lines which go between head–hips and legs) bent forward or sideways or less than 20° twisted (the angle between shoulders and hips).

2 BACK BENT

"Back bent" means that worker is in a posture in which the upper body is bent forward or backward 20° (the angle of the lines which go between head–hips and legs) or more.

3 BACK TWISTED (OR BENT SIDEWAYS)

"Back twisted" means that the back is twisted 20° or more (as defined above) or bent sideways 20° or more.

4 BACK BENT AND TWISTED

"Back bent and twisted" means a situation where back is bent (like in case 2) and simultaneously twisted (like in case 3).

Figure 2.2: Definition of Four Codes for the Back Postures in the OWAS System (Karwowski & Marras, 2003).

OWAS system uses the trunk angle to differentiate between the straight or bending posture that distinct by the joining fragment angle of the hip-right and hip left joints, and