PREDICTION OF MUSCULOSKELETAL DISORDERS CASES ASSOCIATED WITH WORK-RELATEDNESS OF SEMICONDUCTOR WORKERS USING LOGISTIC REGRESSION MODEL

CHAI FONG LING

MASTER OF SCIENCE IN MANUFACTURING ENGINEERING

2020

Faculty of Manufacturing Engineering

PREDICTION OF MUSCULOSKELETAL DISORDERS CASES ASSOCIATED WITH WORK-RELATEDNESS OF SEMICONDUCTOR WORKERS USING LOGISTIC REGRESSION MODEL

Chai Fong Ling

Master of Science in Manufacturing Engineering

2020

PREDICTION OF MUSCULOSKELETAL DISORDERS CASES ASSOCIATED WITH WORK-RELATEDNESS OF SEMICONDUCTOR WORKERS USING LOGISTIC REGRESSION MODEL

CHAI FONG LING

A thesis submitted
in fulfillment of the requirements for the degree of
Master of Science in Manufacturing Engineering

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2020

DECLARATION

I declare that this thesis entitled “Prediction of Musculoskeletal Disorders Cases Associated with Work-relatedness of Semiconductor Workers Using Logistic Regression Model” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Chai Fong Ling

Date : .....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature : .....

Supervisor Name : Dr. Radin Zaid Bin Radin Umar

Date : .....

DEDICATION

I dedicate my thesis work to my family and many friends. A special feeling of gratitude to my loving parents, who rooted me throughout the entire journey with patience. My brothers, who have never left my side when I need accompaniment.

I also dedicate this thesis to my many friends who have supported me throughout the process. I will always appreciate all they have done. All of you have been my best cheerleaders.

ABSTRACT

Semiconductor industry is one of the main contributors to the economy of Malaysia. Semiconductor workers are generally exposed to various conditions at work that is likely to contribute to the development of musculoskeletal disorders (MSDs). Currently, there has been limited studies conducted to identify potential MSDs risk factors among semiconductor workers. Besides, there have been little studies categorize semiconductor workers' exposures of risk factors, and there has been a paucity of predictive model developed to predict the work-relatedness of MSDs. This study was conducted to (i) identify the potential risk factors of MSDs among semiconductor workers; (ii) construct a model in predicting work-relatedness of MSDs diagnoses based on the identified risk factors and investigate the relationship between the identified risk factors and work-related MSDs cases; (iii) validate the developed predictive model and the relationship findings statistically and through face validation by experienced experts in the ergonomic field. Risk factors from the literature searches and 277 work assessment reports of workers diagnosed with MSDs were sorted and compared. A total of 16 predictors were identified from ergonomic risk factors (ERFs), work activities, confounding factors of MSDs, and duration of employment for workers reporting the first musculoskeletal symptoms (MSS). Kurskal-Wallis one-way analysis of variance test and Kendall's tau correlation were conducted to test the significance difference of the risk factors and analyse correlation between identified risk factors and MSDs outcomes. The specific factors identified to have significant effect in predicting work-relatedness of MSDs in the developed model are ERFs such as poor posture, forceful exertion, and static posture and loading; work activities such as lifting and lowering, transferring, pushing and pulling, repairing, preventive maintenance and quality inspection; confounding factors such as age and previous injury history; and the duration of employment in reporting first MSS. Cross-validation of the developed predictive model was conducted with a new set of test data (n=30), and the accuracy of the prediction model was measured at 86.20%. Thirty experts in the ergonomics field gave promising 80% average rating agreements on the inclusion of identified risk factors and major result findings. Improvements in future research study suggest the inclusion of psychological and environmental factors in work assessments for a more comprehensive prediction process. These outcomes may help practitioners to understand the exposure components contributing to work-relatedness of MSDs cases among semiconductor workers. Ergonomists, safety and health officers, engineers and management employees can utilize this predictive model to predict the potential risk of MSDs cases and guide the process of determining appropriate control measures and future interventions.

PERAMALAN KES-KES PENYAKIT MUSKULOSKELETAL BERKAITAN DENGAN KEGIATAN KERJA DI KALANGAN PEKERJA SEMIKONDUKTOR MENGGUNAKAN KAEDAH MODEL REGRESI LOGISTIK

ABSTRAK

Industri semikonduktor merupakan salah satu sektor pembuatan yang memberi sumbangan besar terhadap perkembangan ekonomi di Malaysia. Pekerja-pekerja semikonduktor terdedah kepada situasi tempat kerja yang boleh menyumbang kepada penyakit muskuloskeletal (MSD). Penyelidikan berkaitan pengenalpastian faktor risiko kepada MSD adalah terhad. Hanya sedikit penyelidikan melibatkan pengkategorian faktor risiko dan model untuk meramalkan MSD di kalangan pekerja semikonduktor. Kajian ini bertujuan untuk (i) mengenal pasti faktor-faktor yang berpotensi menyebabkan pekerja-pekerja semikonduktor mengalami penyakit muskuloskeletal; (ii) membina satu set model untuk meramal penyakit muskuloskeletal berdasarkan faktor-faktor risiko dan mengenalpasti hubungan di antara faktor risiko dengan kes-kes penyakit muskuloskeletal disebabkan pendedahan di tempat kerja; (iii) mendapatkan pengesahan terhadap model ramalan yang dibina dengan menggunakan kaedah statistik dan kaedah pengesahan bersemuka dengan pakar-pakar berpengalaman dalam bidang ergomik. Berdasarkan kajian literatur dan kajian kes terhadap 277 laporan penilaian kerja, sejumlah 16 prediktor risiko telah dikenalpasti melibatkan faktor risiko ergonomik, aktiviti kerja, faktor interaksi, dan tempoh durasi gejala muskuloskeletal yang pertama. Ujian ANOVA Kurskal-Wallis telah dijalankan untuk menguji perbezaan secara statistik antara faktor risiko manakala ujian korelasi Kendall tau dijalankan untuk mengenal pasti hubungan antara faktor risiko dan penyakit muskuloskeletal. Antara faktor-faktor yang dikenali pasti ialah faktor ergonomik seperti postur janggal, pengunaan tenaga, faktor aktiviti kerja seperti mengangkat dan menolak, faktor interaksi seperi umur, dan faktor tempoh masa sebeleum gejala muskuloskeletal pertama dialami. Model ramalan ini diuji menggunakan kaedah pengesahan silang dengan 30 data ujian dan ketepatan model ramalan ialah 86.20%. Seramai 30 pakar ergonomik telah ditemu duga untuk mendapatkan pengesahan secara bersemuka, dan mereka memberikan purata penilaian persetujuan sekitar 80% terhadap faktor yang dimasukkan di dalam model ramalan serta hasil kajian yang lain. Cadangan penambahbaikan temasuk pertimbangan faktor psikologi dan persekitaran tempat kerja untuk proses ramalan yang lebih komprehensif. Hasil kajian dijangka dapat membantu para pengamal untuk memahami komponen pendedahan tempat kerja yang menyumbang kepada MSD berkaitan tempat kerja dikalangan pekerja semikonduktor. Ergonomis, pegawai keselamatan dan kesihatan, jurutera dan pihak pengurusan dapat menggunakam model ramalan ini untuk meramalkan jenis-jenis faktor risiko terhadap kes MSD, seterusnya memberi panduan untuk menentukan langkah kawalan dan intervensi yang sesuai.

ACKNOWLEDGEMENTS

This thesis and my study in the field of ergonomics at Universiti Teknikal Malaysia Melaka would not have been possible without Dr. Radin Zaid Radin Umar, my main advisor. He believed in me, supported, and gave me opportunities in every exposure that I can expose myself to. Without his support and encouragement at all times, I would not have completed this study. I express my deepest gratitude to him, for he has been my real teacher, guide, and mentor.

Special thanks to Dr. Jalaluddin Dahalan, who shared with me his experiences selflessly. And giving me opportunities to be involved in various ergonomics-related industrial activities. I would also like to extend my sincere thanks to Dr. Nadiah Ahmad and Dr. Isa Halim for their erudite guidance.

I wish to thank all participants for their time and patience in participating in this study. Finally, I dedicate this thesis to my parents for their unconditional support, materially, and spiritually. Without them, this would not have been a reality.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

BMI	–	Body Mass Index
DOSH	–	Department of Safety and Health
ERFs	–	Ergonomic risk factors
MMH	–	Manual material handling
MSDs	–	Musculoskeletal disorders
MSS	–	Musculoskeletal symptoms
NIOSH	–	National Institute of Safety and Health
OSH	–	Occupational Safety and Health
SOCSO	–	Social Security Organization
WMSDs	–	Work-related musculoskeletal disorders

LIST OF SYMBOLS

B	–	Unstandardized regression weight
df	–	Degree of freedom
exp	–	Exponential
$Exp\ (B)$	–	Exponential of B coefficient
H_0	–	Null hypothesis
H_1	–	Alternate hypothesis
H	–	H statistic
k	–	Number of predictors
n	–	Number of sample size
N	–	Sum of sample sizes for all samples
N_i	–	Size of the i^{th} sample
p	–	P-value
SE	–	Standard error
SD	–	Significant value
Sig	–	Significant value
T_i	–	Sum of ranks in the i^{th} sample
X_n	–	Predictor n

LIST OF PUBLICATIONS

Indexed Journal

Ling, C. F., Umar, R. Z. R., & Ahmad, N., 2020. Development of A Predictive Model for Work-Relatedness of MSDs among Semiconductor Back-End Workers. *International Journal of Occupational Safety and Ergonomics*, pp. 1-29.

Umar, R.Z.R., Ling, C.F., Abdullasim, N., Ahmad, N., Halim, I. and Hamid, M., 2019. Occupational Wrist Postural Assessment and Monitoring System: Development and Initial Validation. *Journal of Engineering Science and Technology*, 14(6), pp.3421-3436.

Conference Proceedings

Chai, F.L., Fatin, A.M.A., Ahmad, N., Halim, I., Umar, R. Z.R., 2018. Design and Development of Ergonomics Labeling Machine for Cashiers. *IRID'18 Innovative Research and Industrial Dialogue 2018*, pp. 46.

Umar, R.Z.R., Chai, F.L., Ahmad, N., Halim, I., Lee, F.A.M.A., Abdullasim, N., 2018. Initial Validation of RULA-Kinect System–Comparing Assessment Results Between System and Human Assessors. In: Proceedings of Mechanical Engineering Research Day 2018, pp.67–68.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Manufacturing industries play a crucial role in supporting most of the economics of Malaysia. In just this particular sector, manufacturing has contributed to a significant 84.4% of total export of earning on Malaysia's export components amounting to RM 614.70 billion, as reported in the website of Malaysia External Trade Development Corporation on its data of (Department of Statistics, 2019). The primary productions of the manufacturing industry includes electrical and electronics products, food, beverages and tobacco, petroleum derivatives, chemical materials, rubber and plastics components, and many more (Department of Statistics, Malaysia, 2018). The manufacturing sector in Malaysia has provided great employment opportunities and skill enhancements to Malaysian workers, and this aligned well with the country's economic growth (Chew, 2005).

Nevertheless, industrial workers often experienced musculoskeletal disorders (MSDs), such as low back pain, disc disorder, wrist and shoulder pain increases the sick leaves taken in many companies (Motamedzade et al., 2013; Hubertsson et al., 2014). Organizations in the manufacturing sector may face issues such as lack a high turnover rate or reduced manpower due to work-related musculoskeletal disorders (WMSDs) (Goetzel et al., 2002; Wan, 2016). WMSDs are the development of MSDs that is due to the exposures from work (Marcum and Adams, 2017; Yousefi et al., 2017). The causes of WMSDs are caused by unfit workplace settings towards the workers, safety and health issues or accident (Shikdar and Sawaqed, 2003).

In Malaysia, Social Security Organization (SOCSO) acts as social security protection to employees and their dependents through the 'Employment Injury Scheme and Invalidity Scheme'. Workers who were injured due to occupational related factors may apply for work compensation from SOCSO, through this scheme. A research team of National Institute of Occupational Safety and Health (NIOSH) studied the financial impact and causes of chronic MSDs cases in Malaysia based on SOCSO claims record from the year 2009 to 2014, and found that the total direct cost claims on chronic MSDs were highest from the manufacturing industry. The manufacturing related claims are approximately 50% of overall compensation claimant cost, totaling RM 5,181,282.34 payout from SOCSO (Zein et al., 2019). Industrial workers who developed chronic MSDs usually conduct industrial works that consist of various manual material handling (MMH) activities (Chew, 2005).

MMH is defined as physical activities which involves moving objects from one place to another, with the use of muscular force, with or without assistive devices (Department of Occupational Safety and Health, 2018). Examples of MMH are lifting, lowering, pushing, pulling, carrying any objects. These physically demanding work conditions usually involve force exertions in combination with body twisting or bending positions, static or repetitive tasks at a fast work pace. MMH contributed to 40% of reported MSDs cases in Malaysia (Department of Occupational Safety and Health, 2018). MMH workers with high intensity of repetitive work, added with the existence of ERFs has higher possibility to develop MSDs (Marras et al., 1995).

1.2 Background of the study

Semiconductor production in Malaysia is among the top ten industries that contributed to the economics of the country (Department of Statistics, Malaysia, 2018). In year 2017, electronic products consisted 22.8% of all the total export manufactured goods.

Among the 22.8% of the exported manufactured electronic products, 7% of the export was from the production of semiconductor. The prevalence of MSDs among semiconductor workers has increased over the years due to the increase in semiconductor productions (Aghilinejad et al., 2015; Daneshmandi et al., 2019). Besides, preliminary feedback from ergonomists and safety and health officers stated semiconductor workers often perform jobs that require physical exertion or extensive MMH activities throughout their shift, and this leads them to have a higher risk of getting MSDs at work.

The development of MSDs is multifactorial in nature. MSDs could be developed due to the exposures from work and non-work exposures. Examples of exposures from work are ERFs, stress from work, long duration of work, heavy workload and many more (Schultz et al., 2004; Winkel and Westgaard, 2008; Bugajska et al., 2013). On the other hand, non-work exposures consist of age, gender, pregnancy, alcohol consumption and smoking (Palmer and Goodson, 2015; Baker and Cornelson, 2018; Charles et al., 2018). Hence, it is difficult to clearly state the diagnoses of MSDs are solely due to working factors as confounding factors may also play a part in the role of MSDs development. In Malaysian's occupational safety context, it is important to differentiate the sources of exposures contributing to the injury outcomes. According to Laws of Malaysia, Act 514 on Occupational Safety and Health Act 1994, Malaysian employees are responsible to identify and control exposures from work that may affect workers' health conditions. In order for workers who have been diagnosed with MSD to apply for the work-compensation claim from SOCSO, evidences of exposures from work that lead to MSDs are to be established, as required by the provisions in Employees' Social Security Act 1969 and the Employees' Social Security (General) Regulations 1971.

In terms of the process to apply for SOCSO's compensation, medical doctor will conduct relevant tests before the worker is diagnosed with MSDs. The worker is entitled to request for work assessment investigation of work-related exposures of the diagnosed MSDs,

if suspected to be potentially work-related by medical doctor. The work assessment is usually conducted by experts and specialist in the area of ergonomics, and their professional assessment report will be submitted to Board of Doctors appointed by SOCSO to determine if there are enough evidences to which can become the basis for awarded compensation. The work assessment report is an assessment report that identifies workers' work exposures and ERFs that exist at their workplace. The assessment helps to examine in-depth on workers' exposures through the work activities they conducted, health conditions, and workers' personal information. The work assessment report is useful in identifying the work-relatedness of MSDs as the report includes most of the physical exposures of activities conducted by workers, ERFs, and chronology of medical reports on workers' health throughout the employment period.

Generally, there have been minimal studies attempted to investigate the risk factors that exist at semiconductor workers' workplace (Chandrasakaran et al., 2003; Chee and Rampal, 2004; Chee et al., 2004b; Abdullah and Rahman, 2009). The identification of risk factors of MSDs can provide information on the development process of MSDs. With identified risk factors, it can also become a base in predicting the development of MSDs through mathematical means. The developed predictive model of MSDs is beneficial to engineers, practitioners, and ergonomists to anticipate future MSDs cases. Through the use of predictive model, it helps to create preventive measures and improvements towards semiconductor workers' workplaces after identifying risk factors to prevent the development of MSDs.

1.3 Problem statement

The identification of risk factors of MSDs in occupational setting helps the practitioners to take precaution steps to prevent MSDs among workers. In addition, predictive model predicts the development of MSDs would be useful in aiding engineers, safety and health practitioners and managerial workers to prevent WMSD at workplaces.

Majority of the existing studies focused the risk factors that contributed towards the development of MSDs (Van Der Beek et al., 2017; Yousefi et al., 2017). Nevertheless, limited studies are focusing on the identification of MSDs, specifically in semiconductor industries (Chandrasakaran et al., 2003; Chee and Rampal, 2003). There are limited predictive models or expert system that allows accurate prediction of work-relatedness exposures as contributors to MSDs. Zong (2010) utilizes predictive model in predicting the optimal posture of manual material handler in manufacturing industry. Majority of the predictive model developed in regards to the field of semiconductor are related to control strategies for management and equipment faulty detection (Wang et al., 2007; Munirathinam and Ramadoss, 2016).

The existing MSDs studies related to semiconductor industries have few limitations that warrants a new study. Firstly, it has been more than 10 years that the MSDs studies on semiconductor workers have been conducted, and there were no new updates since then. Secondly, most of the MSDs studies focuses on MSDs symptoms instead of actual MSDs diagnosed. Hence, there is a need to conduct a new study that utilizes actual MSDs diagnosed cases among semiconductor workers (Chee and Rampal, 2004; Punnett and Wegman, 2004). This will allow a deeper understanding of the contributing factors to the development WMSDs, especially among semiconductor workers.