DEVELOPMENT OF AN ERGONOMIC RISK ASSESSMENT TOOL FOR WORK POSTURES

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Dedicated to my loving family and friends,
who make all things seem possible

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ABSTRACT

The most widely used method for assessing work-related musculoskeletal disorders (WMSDs) is still the observational method, mainly because it is inexpensive and practical for use in a wide range of workplaces. However, there are no tools available that cover the wide range of physical risk factors at workplaces. Most of the existing observational methods have not been extensively tested for their reliability and validity during the development process. Therefore, the main objectives of this study are to (1) to develop a new observational technique called the Workplace Ergonomic Risk Assessment (WERA) method and (2) to determine the reliability and validity of the WERA method. The study was conducted in two phases: development of the WERA paper checklist from scientific evidence and literature review (Phase 1) and development of the WERA software program using Visual Basic programming (Phase 2). In the validity trials, the relationship of the main WERA body part scores to the development of pain or discomfort was statistically significant for the wrist, shoulder, and back regions. This shows that the WERA assessment provided a good indication of work related musculoskeletal disorders which may be reported as pains, aches or discomfort in the relevant body area. In the reliability trials, the results of inter-observer reliability demonstrated moderate agreement among the observers (K=0.41) from the feedback survey about the usability of WERA tool. On the other hand, all participants were agreed that the WERA tool was easy and quick to use, applicable to workplace assessment for the wide range of tasks, and valuable at work. The WERA tool has been developed for both paper checklist and software program use. It can be used to identify the physical risk factors associated with WMSDs at workplaces.

ABSTRAK

Kaedah yang paling banyak digunakan untuk menilai kerja yang berkaitan dengan gangguan otot berangka (WMSDs) adalah kaedah pemerhatian, ini kerana ianya adalah murah dan praktikal untuk digunakan di pelbagai tempat kerja. Walau bagaimanapun, alat yang sedia ada tidak merangkumi pelbagai faktor risiko fizikal di tempat kerja. Tambahan pula, kebanyakan kaedah pemerhatian yang sedia ada didapati tidak diuji secara meluas tentang kebolehpercayaan dan kesahihannya semasa proses pembangunan kaedah tersebut. Oleh itu, objektif utama kajian ini adalah untuk (1) untuk membangunkan satu teknik baru dalam kaedah pemerhatian yang dinamakan sebagai kaedah *"Workplace Ergonomics Risk Assessment – WERA"* (2) untuk menentukan kebolehpercayaan dan kesahihan kaedah WERA. Kajian ini telah dijalankan dalam dua fasa iaitu pembangunan kertas senarai semak WERA hasil dari bukti saintifik kajian literatur (Fasa 1) dan pembangunan program perisian WERA yang menggunakan asas pengaturcaraan visual (Fasa 2). Dalam ujian kesahihan, hubungan diantara skor WERA dengan ketidakselesaan pada bahagian utama anggota badan adalah statistik yang signifikan bagi kawasan pergelangan tangan, bahu dan belakang badan. Ia menunjukkan bahawa kaedah WERA memberikan indikasi yang baik terhadap kerja yang berkaitan dengan gangguan otot berangka yang boleh menyebabkan ketidakselesaan ataupun kesakitan anggota badan tertentu. Dalam ujian kebolehpercayaan, keputusan kebolehpercayaan antara pemerhati menunjukkan bahawa nilai persetujuan di antara pemerhati adalah sederhana (K=0.41) manakala hasil maklum balas daripada soal selidik mengenai kebolehgunaan kaedah WERA, semua peserta telah bersetuju bahawa kaedah WERA ini mudah dan cepat untuk digunakan serta sesuai dan bernilai untuk digunakan di pelbagai tempat kerja. Dengan membangunkan kertas senarai semak WERA dan program perisian WERA, diharapkan ianya boleh digunakan untuk mengenal pasti faktor-faktor risiko fizikal yang berkaitan dengan gangguan otot berangka di tempat kerja.

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LIST OF ABBREVIATIONS

Back-EST	-	Back Exposure Sampling Tool
BDS	-	Body Discomfort Survey
DOSH	-	Department of Occupational Safety and Health
LUBA	-	Postural Loading on the Upper-Body Assessment
MSDs	-	Musculoskeletal Disorders
NIOSH	-	National Institute of Occupational Safety and Health
OSHA	-	Occupational Safety and Health Administrative
OWAS	-	Ovako Working Posture Assessment System
PATH	-	Posture, Activity, Tools & Handling
QEC	-	Quick Exposure Check
REBA	-	Rapid Entire Body Assessment
RULA	-	Rapid Upper Limb Assessment
SHO	-	Safety and Health Officer
SPSS	-	Statistical Package for the Social Sciences
WERA	-	Workplace Ergonomic Risk Assessment
WMSDs	-	Work-related Musculoskeletal Disorders

LIST OF SYMBOLS

K	-	Cohen’s Kappa Coefficient
N	-	Sample Size
SD	-	Standard Deviation
X	-	Mean
°	-	Degree
±	-	Plus-Minus
%	-	Percentage
α	-	Alpha
χ^2	-	Chi Square
p	-	Pearson Chi-Square
r	-	Spearman Correlation Coefficients

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CHAPTER 1

INTRODUCTION

1.1 Overview of the Study

Ergonomics is the one of main components of safety programs around the country, and many companies have begun implementing effective ergonomic programs in their workplaces (Brodie, 2008). A basic ergonomic assessment is often the starting point for a company to approach implementing such a program due to the ergonomics hazards at a workplace (Brodie, 2008; Burdorf, 2010). This approach helps the company determine whether the jobs or tasks expose employees to risk factors that could lead to musculoskeletal disorders (MSDs). By determining how the job exposes employees to ergonomic risk factors, this approach helps the company reduce the cost of occupational injuries and work-related illnesses (Li and Buckle, 1999a; Li and Buckle, 1999b; David, 2005; Brodie, 2008; Burdorf, 2010). An additional reason to invest in ergonomics at the workplace is that it helps improve the productivity of employees, which can result in increased bottom line profits of a company (Brodie, 2008; Burdorf, 2010).

Benefits from the use of ergonomics are important to industries, so an ergonomic assessment should be the first step taken in the process of safety and health assessment (Brodie, 2008; Burdorf, 2010; Takala *et al*., 2010). The rationale for this study grew out of research needs for practical methods used to define and evaluate the ergonomics risk factors present in a job associated with work-related musculoskeletal disorders (WMSDs). It is important to identify the ergonomics stressors linked with development of WMSDs, which are key elements for any ergonomics program in developing the assessment of biomechanical exposure in workplaces (Li and Buckle, 1999a; Li and Buckle, 1999b; David, 2005; Brodie, 2008;

Burdorf, 2010). The accurate measurement of workers' exposure to the risk factors related to WMSDs are critical to both epidemiologists and ergonomists in conducting their research studies (David, 2005; Burdorf, 2010).

Work-related musculoskeletal disorders (WMSDs) are a common health problem and a major cause of disabilities (Hales and Bernard, 1996; Bernard, 1997; Kuorinka, 1998; Malchaire *et al.*, 2001). A range of physical, individual, and psychosocial risk factors are associated with the development of WMSDs. Physical risk factors are based on exposure to physical demands while performing tasks; these factors include awkward posture, forceful exertion, repetition of movement, contact stress, vibration, and task duration (Bernard, 1997; Malchaire *et al*., 2001; Aptel *et al*., 2002; Punnett and Wegman, 2004). Recent studies have shown that the effects of WMSDs result in productivity loss at work, sickness, absence, and disability (Bernard, 1997; Aptel *et al*., 2002; Punnett and Wegman, 2004). According to the Department of Occupational Safety and Health (DOSH) report on occupational accidents for the category of death until August 2010 (Figure 1.1), 51% of victims were reported by the construction industry, the highest figure. The manufacturing industry was the second highest, for which 45% of victims were reported, behind the agriculture industry (26% of victims) and the transportation industry (10% of victims) (DOSH, 2010).

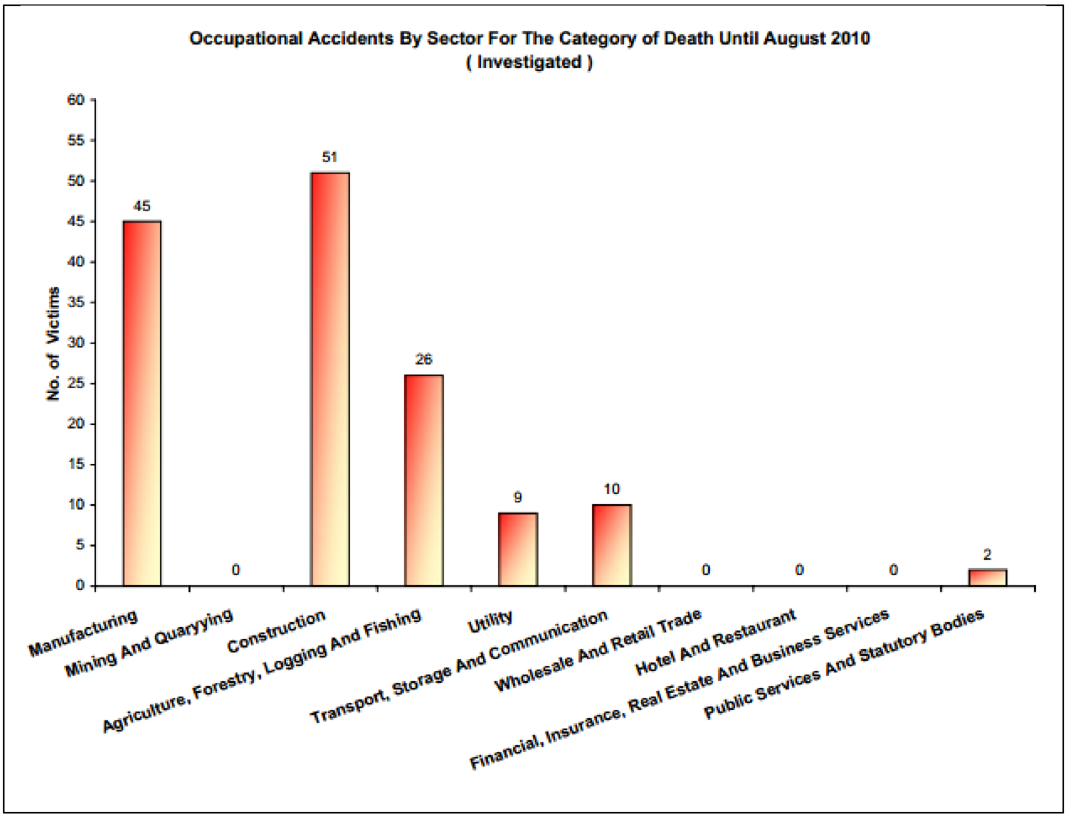

Figure 1.1 Occupational accidents by sector for the category of death until 2010

Musculoskeletal injuries begin with the workers experiencing discomfort or pain due to their tasks at a workplace (Hales and Bernard, 1996; Kuorinka, 1998; Malchaire *et al.*, 2001; Devereux *et al*., 2002; Punnett and Wegman, 2004; Khan *et al.*, 2010). Due to the risk factors present at workplaces, the discomfort will lead to an increase in the severity of symptoms and will be experienced as aches and pains (Devereux *et al.*, 2002; Punnett and Wegman, 2004; Khan *et al.*, 2010). The aches and pains may eventually result in musculoskeletal injuries such as low back pain, tendonitis, or serious nerve-compression injury such as carpal tunnel syndrome (Malchaire *et al.*, 2001; Aptel *et al.*, 2002; Punnett and Wegman, 2004).

1.2 Problem Statements

Current techniques to assess the exposure of the risk factors related to WMSDs still utilize observational methods, mainly because they are inexpensive and practical for use in a wide range of workplaces whereas using the other methods would be difficult due to the disruption they would cause (Beek and Dressen,1998; Li and Buckle, 1999a; David, 2005; Brodie, 2008; Takala *et al.*, 2010).

However, there is no tool available to covers the wide range of physical risk factors in the workplace (Table 1.1), which include posture, repetition, forceful exertion, vibration, contact stress and task duration (David, 2005; Takala *et al*., 2010). There is a need to widen the existing range of physical risk factors and to consider the interactions among them (David, 2005). Most of the observational tools available only focus on postural assessments of various body parts rather than covering the critical physical exposure factors in the workplaces (David, 2005; Burdorf, 2010; Takala *et al.*, 2010).

Table 1.1: Risk factors assessed by different assessment methods

Method (Year of First Publication)	**Risk Factors**					
	Posture	**Forceful Exertion**	**Repetition**	**Vibration**	**Contact Stress**	**Task Duration**
Ovako Working Posture Assessment System – OWAS (1977)	×	×				
Rapid Upper Limb Assessment – RULA (1993)	×	×				
Posture, Activity, Tools & Handling – PATH (1996)	×	×		×		
Quick Exposure Check – QEC (1999)	×	×	×			×
Rapid Entire Body Assessment – REBA (2000)	×	×				
Postural Loading on the Upper Body Assessment – LUBA (2001)	×					
Back Exposure Sampling Tool – BackEst (2009)	×	×		×		

(Sources: David, 2005; Takala *et al*., 2010)

Furthermore, most of the existing observational methods have not been extensively tested due to infrequent assessments of reliability and validity (Table 1.2) during the development process of the tools (David, 2005; Brodie, 2008; Burdorf, 2010; Takala *et al.*, 2010). The evaluation of reliability and validity are critical to the development of ergonomic exposure assessment tools, particularly for research that attempts to establish a causal relationship between ergonomic risk factors and musculoskeletal health outcomes (David, 2005; Burdorf, 2010; Takala *et al.*, 2010). Takala *et al.* (2010) stated that a major challenge in developing an observational tool is the validation of exposure assessment techniques. Poor performance of exposure assessment tools due to the lack of reliability and validity testing contributes to the scepticism regarding the work-relatedness of musculoskeletal disorders (David, 2005; Takala *et al.*, 2010).

Table 1.2: Reliability and validity studies of different assessment methods

Method (Year of First Publication)	**Psychometric Properties**	
	Reliability Testing	**Validity Testing**
Ovako Working Posture Assessment System – OWAS (1977)	×	-
Rapid Upper Limb Assessment – RULA (1993)	×	×
Posture, Activity, Tools & Handling – PATH (1996)	×	×
Quick Exposure Check – QEC (1999)	×	-
Rapid Entire Body Assessment – REBA (2000)	×	-
Postural Loading on the Upper Body Assessment – LUBA (2001)	-	×
Back Exposure Sampling Tool – BackEst (2009)	×	-

(Sources: David, 2005; Takala *et al.*, 2010)

Therefore, this research aims to develop a new type of ergonomic risk assessment tool that covers both the range of the physical risk factors associated with WMSDs and establishes the reliability and validity of the tool during the development process.

1.3 Objectives of the Study

The main objectives of this research are:

i. To develop a new ergonomic risk assessment technique which assesses the exposure of physical risk factors associated with WMSDs.
ii. To establish the reliability and validity of the ergonomic risk assessment tool during the development process.
iii. To evaluate the application of the ergonomic risk assessment tool on different tasks.

The specific objectives of this research are:

a. To develop the ergonomic risk assessment paper checklist (Phase 1) and to test its reliability and validity during the development process.
b. To determine the validity of the ergonomic risk assessment tool that corresponds with other valid methods in the workplace. A comparative study will be performed using the Body Discomfort Survey.
c. To investigate the inter-observer reliability of observers assessing the physical risk factors of workers performing tasks using the ergonomic risk assessment tool.
d. To develop the ergonomic risk assessment software program (Phase 2) based on the ergonomic risk assessment paper checklist in Phase 1.
e. To verify that the ergonomic risk assessment software program corresponds with other valid methods in the workplace. A comparative study will be performed using the Body Discomfort Survey.

1.4 Research Questions

1) How valid is the ergonomic risk assessment tool in the workplace? Does the ergonomic risk assessment tool correspond to the Body Discomfort Survey?
2) How reliable is the ergonomic risk assessment tool between users and observers? Do the users and observers have good, moderate, or low levels of agreement when assessing the physical risk factors of tasks using ergonomic risk assessment tool?
3) How usable is the ergonomic risk assessment tool among the users and observers? Is the ergonomic risk assessment tool easy to use, applicable to the wide range of jobs, and valuable at work?

1.5 Scope of the Study

The scope of this research encompasses the development of the observational method, which is called the Workplace Ergonomic Risk Assessment (WERA) tool. This tool covers the physical risk factors associated with work-related musculoskeletal disorders (WMSDs) at workplaces; these factors include posture, repetition, lifting the load, vibration, contact stress and task duration. This tool assessed five main body regions: shoulders, wrists, back, neck and legs. This tool did not cover the specifics of environmental factors such as noise, lighting and thermal comfort since these factors focus more on the work environment and there already exist specific tools to evaluate these factors, such as the ACGIH Threshold Limit Value for Heat Stress and Strain (2006a) for thermal comfort risk factors, the ACGIH Threshold Limit Value for Noise (2006b) for noise risk assessment and the Cornell Task Lighting Evaluation (2007) for lighting risk assessment.

During the validity test, 130 workers (Male) from the ages of 20 to 44 years have been selected to perform three jobs in the construction industry, including wall plastering, bricklaying, and floor concreting. Case Study 1 involved 115 operators (female) ranging from the ages of 20 to 35 years selected to perform three jobs at Company A located in Tangga Batu Indutrial Estate, Melaka. The jobs were also in the manufacturing industry and included wafer sawing, wire bonding, and multi-plunging. Case Study 2 involved 118 operators (Female) from the ages of 20 to 35 years selected to perform three jobs at Company B located in Senawang Industrial Estate, Negeri Sembilan. These jobs in the manufacturing industry included inspection, transaction, and packaging job. This study focused on selection of participants of the working ages of 20 to 44 because the statistical data from the Bureau of Labor Statistics (2011) reported that workers who were 20 to 44 years of age had the highest incidence rate at 134 cases per 10,000 full-time workers in the construction and manufacturing industries. Department of Occupational Safety and Health (DOSH) reported that industries with the highest occupational accidents rates included the construction and manufacturing industries (DOSH, 2010). Therefore, the validity test and case studies have been focused on the construction and manufacturing industries. This research has aided in the development of two types of the WERA tool, the WERA paper checklist and the WERA software program.

1.6 Significance of the Study

The proposed method for this study will contribute to new knowledge in the ergonomic research field, especially to knowledge of methods in ergonomic exposure assessment tools. This is because the lack of well-designed exposure assessment methods is a primary issue for epidemiological studies of work-related musculoskeletal disorders (WMSDs) (David, 2005; Burdorf, 2010; Takala *et al.*, 2010). To date, no tool has been developed to cover the range of physical risk factors related to WMSDs which carried out reliability and validity studies during the development process of the tool. This is the first ergonomic risk assessment tool that meets the research needs for practical methods to evaluate and define the ergonomics risks inherent to a job, especially factors associated with WMSDs in the workplace.

The results of this study are useful to the development of new techniques of the observational tool called the Workplace Ergonomic Risk Assessment (WERA), which covers the range of physical risk factors related to WMSDs and addresses the reliability and validity studies during the development process of the tool. Critical information may be introduced to identify the ergonomics hazards that are linked with the development of WMSDs; it is key to examine these hazards as part of any ergonomics activity in developing the assessment of biomechanical exposure at the workplace.

In addition, assessing exposure to risk factors for WMSDs is an essential stage in the management and prevention of WMDSs, and such assessment may even form part of an overall risk assessment programme in the industry (David, 2005; Brodie, 2008; Burdorf, 2010; Takala *et al*., 2010). Well-designed observational tools that assess the physical risk factors related to the WMSDs have been of vital importance to both epidemiologists and ergonomists in conducting research studies (David, 2005; Brodie, 2008; Burdorf, 2010; Takala *et al.,* 2010).

1.7 Organization of the Thesis

This thesis contains seven chapters. The chapters are arranged according to the sequence of objectives and the rationale of the research. The seven chapters are: Chapter 1 (Introduction), Chapter 2 (Literature Review), Chapter 3 (Research Methodology), Chapter 4 (Development of the WERA Method), Chapter 5 (Results), Chapter 6 (Discussion) and Chapter 7 (Summary, Conclusions and Future Works).

Chapter 1 describes the background of the research, the objectives to be achieved, the research scope, the significance of the research and the organization of the thesis. Chapter 2 gives an overview of the literature and primarily focuses on the discussion of the ergonomic methods used in assessing work-related musculoskeletal disorders (WMSDs). These methods are divided into three main categories: self-report questionnaires, observational methods, and direct measurement techniques. Chapter 3 explains the research methodology and focuses on the development of the WERA method, the validity of the WERA method, the reliability of the WERA method, development of the WERA software program and verification of the WERA software program in two different case studies.

Chapter 4 describes details of the development of the WERA method, which is divided into two phases: development of the WERA paper checklist (Phase 1) and development of the WERA software program (Phase 2). Chapter 5 shows the results of the validity and reliability testing of the WERA method (Phase 1) and verification of the WERA software program (Phase 2). It is divided into six sections: introduction, validity testing of the WERA method, reliability of the WERA method, verification of the WERA software program by Case Study 1, and verification of WERA software program by Case Study 2. Chapter 6 discusses the findings from the Chapter 5, including the results of the validity and reliability testing of the WERA method (Phase 1) and verification of the WERA software program (Phase 2).

Chapter 7 concludes with the summary, further conclusions and future work on this research.

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