THE DEVELOPMENT OF ENTIRE BODY RISK ASSSESSMENT (ENBORA) METHOD FOR WORK-RELATED MUSCULOSKELETAL DISORDERS (WMSDs)

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This thesis is dedicated to my lovingly parents.

my father ; Abdul Rahman Bin Idris

my mother : Kamariah Binti Arsad

my brothers ; my sister

"Your inspiration will always with me"

Not forgotten to all my friends,

"Hope we will success in our life"

to my supervisor ;

Dr. Mohd Nasrull bin Abdol Rahman

"Thanks for the advices and cooperation" and

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ABSTRACT

The observational method remain to be the most widely used method for assessing Work-related Musculoskeletal Disorders (WMSDs) because it is inexpensive and practical in field data collection. However, several observational methods that are currently available only focus on assessing physical risk factors especially in terms of the diversity of body postures which do not encompass other factors of WMSDs including psychosocial risk factors, work organisational risk factors and individual risk factors. In addition, some of the existing methods mainly not focused on reliability and validity test during the development process. In order to improve these limitations, this study aims to develop a new observational method called the Entire Body Risk Assessment (ENBORA) method and to determine the reliability and validity of the ENBORA method. The study was conducted in three stages which include the development of ENBORA system components, the development of the ENBORA checklist (prototype), and psychometrics evaluation. In reliability testing, very good agreement was obtained for inter-observer reliability. During the training session, the majority of the participants agreed that it was easy to understand and use the ENBORA at work. In validity testing, since the ENBORA method was developed specifically for workers who work using their entire body parts, the highest risk scores were obtained by cleaners and supermarket workers in contrast to office workers according to the ENBORA assessment. The final version of ENBORA was useful for assessing the tasks in many industries as it covers the assessment of the entire body and assesses the physical, psychosocial, work organizational and individual risk factors that lead to WMSDs.

ABSTRAK

Kaedah pemerhatian tetap menjadi kaedah yang paling meluas digunakan untuk menilai kerja yang berkaitan dengan gangguan otot berangka (WMSDs) kerana ia adalah murah dan praktikal dalam pengumpulan data lapangan. Walaubagaimanapun, beberapa kaedah pemerhatian hanya memberikan tumpuan untuk menilai faktor risiko fizikal terutamanya dalam kepelbagaian postur badan yang tidak merangkumi faktor WMSDs lain antaranya faktor risiko psikososial, faktor risiko organisasi kerja dan faktor risiko individu. Di samping itu, beberapa kaedah yang sedia ada tidak tertumpu pada ujian kebolehpercayaan dan kesahan semasa proses pembangunan kaedah tersebut. Untuk meningkatkan perbatasan ini, kajian ini bertujuan untuk membangunkan kaedah pemerhatian baru yang dikenali sebagai kaedah 'Entire Body Risk Assessment' (ENBORA) dan untuk menentukan kebolehpercayaan dan kesahan kaedah ENBORA. Kajian ini telah dijalankan dalam tiga peringkat merangkumi pembangunan komponen sistem ENBORA, pembangunan senarai semak ENBORA (prototaip), dan penilaian sifat psikometrik. Dalam ujian kebolehpercayaan, hasil kebolehpercayaan antara pemerhati menunjukkan bahawa nilai persetujuan yang sangat baik. Semasa sesi latihan, majoriti daripada peserta bersetuju bahawa kaedah ENBORA lebih mudah difahami dan ia juga berguna ditempat kerja. Dalam ujian kesahan, ENBORA telah dibangunkan khusus untuk pekerja yang bekerja menggunakan seluruh anggota badan semasa melakukan kerja, skor risiko tertinggi diperolehi oleh pekerja pembersihan dan pekerja pasaraya berbeza dengan pekerja pejabat mengikut penilaian ENBORA. Versi akhir ENBORA adalah berguna untuk menilai tugas-tugas di pelbagai industri kerana ia meliputi penilaian seluruh badan dan menilai faktor risiko fizikal, psikososial, organisasi dan individu yang membawa kepada WMSD.

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LIST OF SYMBOLS AND ABBREVIATIONS

K	-	Cohen's Kappa
p_o	-	Observed agreement,
p_e	-	Expected agreement
AET	-	*Arbeitswissenschaftliche Erhebungsverfahren zur Tatigkeitsanalyse*
ART	-	Assessment of Repetitive Tasks of the Upper Limbs tool
BMI	-	Body Mass Index
CI	-	Confidence Interval (CI)
CS	-	Contact Stress
CTS	-	Carpal Tunnel Syndrome
DOSH	-	Department of Occupational Safety and Health
EAWS	-	European Assembly Worksheet
ENBORA	-	Entire Body Risk Assessment
ERIN	-	Individual Risk Assessment
F	-	Force
HAV	-	Hand-Arm Vibration
HSE	-	Health, Safety and Environment
LUBA	-	Loading on the Upper Body Assessment
MSDs	-	Musculoskeletal Disorders
NIOSH	-	National Institute for Occupational Safety and Health
OR	-	Odd Ratio
OSH	-	Occupational Safety and Health
OWAS	-	Ovako Working Posture Assessment System

P	-	Posture
PATH	-	Posture, Activity, Tools and Handling
PERA	-	Postural Ergonomic Risk Assessment
PLIBEL	-	A Method Assigned For Identification of Ergonomics Hazard
QEC	-	Quick Exposure Check
R	-	Repetition
REBA	-	Rapid Entire Body Assessment
RR	-	Relative Ratio
S	-	Stress
SD	-	Standard Deviation
SPSS	-	Statistical Package for the Social Sciences
TD	-	Task Duration
V	-	Vibration
WBV	-	Whole Body Vibration
WERA	-	Workplace Ergonomic Risk Assessment
WMSDs	-	Work-related Musculoskeletal Disorders
WP	-	Work Pace
WRUQMSDs	-	Work-related Upper Quadrant Musculoskeletal Disorders

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Work-related musculoskeletal disorders (WMSDs) may refer to muscles, tendons, nerves, blood systems or joints which are stressed, and traumatised on a repeated basis for days, months or years (Bernal *et al.*, 2014; Macdonald & King, 2014). WMSDs occur when the physical capabilities of the workers do not match the physical requirements of the job. Prolonged exposure to ergonomic risk factors can cause damage to a worker's body and lead to musculoskeletal disorders (MSDs). Common WMSDs include tendon disorders such as bursitis, tendonitis, ganglion and trigger-finger or nerve disorders such as carpal tunnel syndrome and neurovascular disorders such as Raynaud's phenomenon or white finger syndrome (Inyang *et al.*, 2012). Risk factors of WMSDs are physical factors (Gallagher & Heberger, 2013; Nunes & Bush, 2012; Widanarko *et al.*, 2014), psychosocial factors (Giorgi *et al.*, 2014; Srinivasan *et al.*, 2014), work organisation factors (Long *et al.*, 2012; Wu *et al.*, 2012) and individual factors (Bodin *et al.*, 2012; Jensen *et al.*, 2012; Nunes & Bush, 2012). For the purpose of analysing the exposure to risk factors that can cause WMSDs, Burdorf and van der Beek (1999) classified three existing methods namely;

subjective judgment (e.g., questionnaire and measurement scale), systematic observation, and direct measurement.

Self-reports from workers are useful to gather information pertaining to workplace risks whereas physical and psychosocial factors can be examined using methods that involve workers' diaries, interviews, and questionnaires (David, 2005). However, the biggest concern among these approaches is the workers' disagreement since they might consider the information to be vague and doubtful. The reports may also be varied according to the workers' level of literacy, comprehension, or interpretation of the questions provided (David, 2005; Spielholz *et al.*, 2001). Additionally, direct measurement systems are able to offer data that are highly accurate on different exposures (Juul-Kristensen *et al.*, 2001). However, they require a high initial investment for the purpose of purchasing equipment as well as the necessary sources to cover the maintenance cost (Juul-Kristensen *et al.*, 2001; Li & Buckle, 1999). Besides, highly trained and skilled technical staff are needed to ensure the successful operation of the equipment. Hence, observational methods seem to be offer an advantage because of their affordability and practicality in many types of workplaces (Chiasson *et al.*, 2012; David, 2005; Takala *et al.*, 2010).

According to David (2005), an observational tool is a systematic method to assess the exposure of risk factors at workplace and can be measured through various aspects such as work posture, frequency of movement and duration of the work involved. An observational method is an evaluation process that is lower in cost with it offers flexibilities and is practical in the field data collection (Chiasson *et al.* 2012; Rahman *et al.*, 2011; Takala *et al.*, 2010). Spielholz *et al.* (2001) stated that a simple observational method is used to identify and manage ergonomic issues at the work place. The evaluation method is normally used by experts to assess the risk factors associated with WMSDs to identify and redesign tasks or a safe working environment (Wang *et al.*, 2015). There are many observational method for assessing the exposure of risk factors associated with WMSDs which are; Ovako Working Posture Assessment System (OWAS) (Karhu *et al.*,1977), Posture Targeting (Corlett *et al.*, 1979), Keyserling's Cumulative Trauma Checklist (Keyserling *et al.*, 1993), A Method Assigned For Identification of Ergonomics Hazard (PLIBEL) (Kemmlert, 1995), Posture, Activity, Tools and Handling (PATH) (Buchholz *et al.*, 1996), Quick Exposure Check (QEC) (David *et al.*, 2008), Rapid Entire Body Assessment (REBA) (Hignett & McAtamney, 2000), Workplace Ergonomic Risk Assessment (WERA)

(Rahman *et al.*, 2011), Individual Risk Assessment (ERIN) (Rodriguez *et al.*, 2013) and Postural Ergonomic Risk Assessment (PERA) (Chander & Cavatorta, 2017) method.

1.2 Problem statement

Observational methods have been generally used to assess the exposure to risk factors of WMSDs. Examples of observational methods include OWAS (Karhu *et al.*,1977), Posture Targeting (Corlett *et al.*, 1979), Keyserling's Cumulative Trauma Checklist (Keyserling *et al.*, 1993), A Method Assigned For Identification of Ergonomics Hazard (PLIBEL) (Kemmlert, 1995), Posture, Activity, Tools and Handling (PATH) (Buchholz *et al.*, 1996), Quick Exposure Check (QEC) (David *et al.*, 2008), Rapid Entire Body Assessment (REBA) (Hignett & McAtamney, 2000), Workplace Ergonomic Risk Assessment (WERA) (Rahman *et al.*, 2011) and Individual Risk Assessment (ERIN) (Rodriguez *et al.*, 2013) and Postural Ergonomic Risk Assessment (PERA) (Chander & Cavatorta, 2017) method. The prevalence in the use of the observational methods is due to the availability of practical and cost effective methods in field data collection. Nevertheless, most of the observational tools only focus on assessing physical risk factors to evaluate WMSDs, especially in the diversity of body postures which do not encompass other factors of WMSDs. Other risk factors of WMSDs include psychosocial risk factors, work organization risk factors, and individual risk factors. Table 1.1 shows the risk factors assessed using different assessment method.

Table 1.1: Risk factors assessed by different assessment methods

Method (Author, year)	Risk factors			
	Physical	**Psychosocial**	**Work organization**	**Individual**
Ovako Working Posture Assessment System (OWAS) (Karhu *et al.*, 1977)	x	-	-	-
Posture Targeting (Corlett *et al.*, 1979)	x	-	-	-
Keyserling's Cumulative Trauma Checklist (Keyserling *et al.*, 1993)	x	-	-	-
A Method Assigned For Identification of Ergonomics Hazard, (PLIBEL) (Kemmlert, 1995)	x	-	-	-
Posture, Activity, Tools and Handling (PATH) (Buchholz *et al.*, 1996)	x	-	-	-
Quick Exposure Check (QEC) (Li & Buckle, 1998)	x	x	-	-

Table 1.1 (continued)

Method (Author, year)	Risk factors			
	Physical	Psychosocial	Work organization	Individual
Rapid Entire Body Assessment (REBA) (Hignett & McAtamney, 2000)	x	-	-	-
Workplace Ergonomic Risk Assessment (WERA) (Rahman *et al.*, 2011)	x	-	-	-
Individual Risk Assessment (ERIN) (Rodríguez *et al.*, 2013)	x	x	-	-
Postural Ergonomic Risk Assessment (PERA) (Chander & Cavatorta, 2017)	x	-	-	-

Notes.
x Risk factors covered by current observational methods
- Risk factors not covered by current observational methods

Furthermore, most existing observational methods have not gone through reliability and validity test during the development process. Table 1.2 shows the summary of reliability and validity test of current observational methods. Additionally, there is no existing observational method to evaluate the left and right body posture separately in the assessment tool.

Table 1.2: Reliability and validity analysis of the current observational method

Method (Author, year)	Psychometrics Properties	
	Reliability testing	Validity testing
Ovako Working Posture Assessment System (OWAS) (Karhu *et al.*, 1977)	x	-
Posture Targeting (Corlett *et al.*, 1979)	-	-
Keyserling's Cumulative Trauma Checklist (Keyserling *et al.*, 1993)	-	x
A Method Assigned For Identification of Ergonomics Hazard, (PLIBEL) (Kemmlert, 1995)	x	x
Posture, Activity, Tools and Handling (PATH) (Buchholz *et al.*, 1996)	x	x
Quick Exposure Check (QEC) (Li & Buckle, 1998)	x	-
Rapid Entire Body Assessment (REBA) (Hignett & McAtamney, 2000)	x	-
Workplace Ergonomic Risk Assessment (WERA) (Rahman *et al.*, 2011)	x	x
Individual Risk Assessment (ERIN) (Rodríguez *et al.*, 2013)	-	-
Postural Ergonomic Risk Assessment (PERA) (Chander & Cavatorta, 2017)	-	x

Notes.
x Reliability testing and validity testing covered by current observational methods, respectively.
- Reliability testing and validity testing not covered by current observational methods, respectively.

1.3 Objectives of the study

The objectives of this study are:

i. To develop a new observational method for assessing risk factors of work-related musculoskeletal disorders known as Entire Body Risk Assessment (ENBORA) method.
ii. To evaluate the inter-observer reliability analysis of the ENBORA method.
iii. To establish the construct validity analysis of ENBORA method using known group techniques.

1.4 Scope of the study

The scopes of this study are:

i. The pen-and-paper-based observational method has been used to develop the ENBORA method.
ii. The ENBORA method was developed to assess exposure risk factors of WMSDs and covered factors such as physical factors, psychosocial factors, work organization factors and individual risk factors.
iii. The physical factors included work posture (neck, shoulders, elbows, hands, back and legs), repetition motion, forceful exertion, contact stress, and vibration.
iv. The psychosocial factors covered the level of work stress, level of work load, work pace, social environment and the level of monotonous task involved.
v. Work schedule and task duration are the factors that are covered under work organisational factors.
vi. The individual risk factors covered the body mass index and smoking factors that affect WMSDs.
vii. The inter-observer reliability has been used to assess the reliability of the ENBORA method. Inter-observer reliability is defined as the results' level of agreement derived by numbers in monitoring similar work conditions (Park *et al.*, 2005).
viii. 16 participants participated in the inter-observer reliability and usability test including executive level (10 participants) and non-executive level (6 participants)

ix. Three tasks were assessed during the reliability and usability test comprised of Task A (lifting from pallet to conveyor), Task B (lifting creels of wire onto spindles) and Task C (bottling line inspection).

x. The Cohen's Kappa, mean, standard deviation and percentage of agreement were used for the inter-observer reliability analysis.

xi. The mean, standard deviation and percentage of agreement were used for usability analysis.

xii. The construct validity was assessed using known-group techniques to validate the ENBORA method.

xiii. The mean, standard deviation and Mann-Whitney test were used for known-group technique analysis.

xiv. The total sample size for the validity analysis was 156 participants, including cleaners (N=53), supermarket workers (N=57) and office workers (N=46).

1.5 Significance of the study

Many observational assessment tools are used to assess the exposure to risk factors, but no single tool has been developed to cover the four main risk factors that contribute to WMSDs such as physical risk factors, psychosocial risk factors, work organisational risk factors and individual risk factors (Bodin *et al.*, 2012; Gallagher & Heberger, 2013; Nunes & Bush, 2012). Most of the tools focused on postural assessment of body parts. The ENBORA method covered the four main risk factors that affect WMSDs such as physical risk factors, psychosocial risk factors, work organisational risk factors and individual risk factors. It also addresses the reliability and validity studies during the development process of the tool. In addition, none of the existing observational methods can be used as an all-purpose method. Hence, a different approach needs to be applied since different methods, and the variety of users' necessities will cause the selection of compatible tools to be more challenging. Therefore, the ENBORA method is an all-purpose method which can be applied in different tasks or industries as it covers the assessment of the entire body and assesses the four main risk factors that lead to WMSDs. Through this assessment tool, risk factors that lead to WMSDs can be reduced or prevented by redesigning tasks or creating a safe working environment.

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