DEVELOPMENT AND EVALUATION OF ERGONOMICS AND PSYCOSOCIAL ASSESSMENT METHOD FOR ASSESSING WORK-RELATED UPPER LIMB DISORDERS

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Every challenging work needs self-efforts as well as guidance of elders especially those who were very close to our heart.

My humble effort I dedicate to my sweet and loving

Abah & Mama,

Whose affection, love, encouragement and prays of day and night make me able to get success and honor,

Along with all hard working and respected Supervisors.

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ABSTRACT

The observational methods have been considered as the most widely used for assessing work-related upper limb disorders (WULDs) because it is inexpensive, practical to use, and flexible to use in a wide range of workplaces. However, the existing methods have a specific purposes and do not universally ideal for all risk factors. Most of the existing methods only focus on assessing physical risk factors of WULDs especially in body postures and do not considered other factors of WULDs such as psychosocial, work organizational, and individual risk factors. Nowadays, psychosocial work characteristics are recognized as important risk factors. Besides that, during the tool development process, it was found that some of the existing observational methods have limited work perform the reliability, usability, and validity analysis. In order to improve these limitations, this study aims to develop a new observational method known as Upper Limb Risk Assessment (UPLIRA) tool and to determine the reliability and validity of the UPLIRA tool. The initial development of UPLIRA tool was conducted in three stages including the development of the UPLIRA system components, development of the UPLIRA checklist (prototype), and psychometric properties evaluation (reliability and validity). In reliability trials, the results of inter and intra rater reliability shows good (K = 0.802 - 0.806) to very good (K = 0.811 - 0.833) agreement among the observers. Meanwhile, the usability trials shows that the UPLIRA tool was applicable to wide range of jobs/tasks, valuable at works, and action level is easy to understand (mean 4.17 $\pm$ 0.753). Whereas, in validity trials the highest risk scores were obtained by cashier workers contrast to office workers according to the UPLIRA assessment. Based on the results so far, it can be concluded that the UPLIRA tool was found to be practically reliable and applicable to a wide range of workplaces.

ABSTRAK

Kaedah pemerhatian dianggap sebagai yang paling banyak digunakan untuk menilai gangguan otot berangka (WULDs) kerana ia murah, praktikal untuk digunakan, dan fleksibel untuk digunakan dalam pelbagai tempat kerja. Walau bagaimanapun, kaedah yang sedia ada mempunyai tujuan tertentu dan tidak meliputi semua faktor risiko WULDs. Kebanyakan kaedah yang sedia ada hanya memberikan tumpuan untuk menilai faktor risiko fizikal WULDs terutamanya dalam postur badan dan tidak menganggap faktor WULDs lain seperti faktor risiko psikososial, organisasi kerja, dan individu. Pada masa kini, ciri-ciri kerja psikososial juga diiktiraf sebagai salah satu faktor penting. Di samping itu, semasa proses pembangunan kaedah, didapati beberapa kaedah pemerhatian yang sedia ada terhad dalam melakukan analisis kebolehpercayaan dan kesahihan. Untuk memperbaiki kekurangan ini, kajian ini bertujuan untuk membangunkan kaedah pemerhatian baru yang dikenali sebagai kaedah *Upper Limb Risk Assessment* (UPLIRA) dan untuk menentukan kebolehpercayaan dan kesahihan UPLIRA. Peringkat awal UPLIRA dijalankan dalam tiga tahap termasuk pembangunan komponen sistem UPLIRA, pembangunan senarai semak UPLIRA (prototaip), dan penilaian sifat psikometrik (kebolehpercayaan dan kesahihan). Dalam ujian percubaan kebolehpercayaan, keputusan kebolehpercayaan inter and intra pemerhati menunjukkan persetujuan yang baik (K = 0.802-0.806) dan sangat baik (K = 0.811-0.833) di kalangan pemerhati. Sementara itu, ujian kebolehgunaan menunjukkan bahawa UPLIRA boleh digunakan untuk pelbagai pekerjaan/tugas, berguna di tempat kerja, dan tahap tindakan mudah difahami (min 4.17 ± 0.753). Manakala dalam ujian kesahihan, skor tertinggi diperolehi oleh pekerja juruwang berbeza dengan pekerja pejabat mengikut penilaian UPLIRA. Berdasarkan keputusan setakat ini, dapat disimpulkan bahwa UPLIRA adalah praktikal dan dapat diterapkan pada berbagai tempat kerja.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Upper limb disorders (ULDs) are disorders that represent the upper body part including neck, shoulders, elbows, wrists, fingers, and upper back (Garg and Kapellusch, 2011). The symptoms or disorders of ULDs include swelling, pain, numbness, stiffness, loss of strength, clumsiness, tingling, and caused limitations in activities either at work or even during leisure time (Bongers *et al*., 2002a). Lomond and Cote (2011) stated that muscle fatigue is a complex phenomenon that has been suggested to be an important precursor for work-related upper limb disorders (WULDs) such as non-neutral posture, high force exertion, and highly repetitive movements that may be associated with WULDs (NIOSH, 1997; Da Costa and Viera, 2010). Risk factors of ULDs are physical factors (Da Costa *et al.*, 2010; Takala *et al*., 2010; Gallagher and Heberger, 2013; Widanarko *et al.*, 2014), psychosocial factors (Tinubu *et al*., 2010; Niedhammer *et al*., 2015; Harvey *et al*., 2017; Milner *et al*., 2017), work organizational factors (Long *et al.*, 2012; Petit *et al.*, 2015) and individual factors (McCauley, 2011; Jensen *et al*., 2012; Nunes and Bush, 2012).

The posture and movement of a worker are important in determining the risk of musculoskeletal injury in the workplace (Vieira and Kumar, 2004). Different

methods and tools have been developed to assess the exposure of risk factors for WULDs. They can be categorized in three different groups according to the measurement technique, which are direct measurement, self-report, and observational methods (Li and Buckle, 1999; David, 2005). Self-report methods are useful to measure many various forms such as questionnaires, checklists, and interviews. The advantages of these methods are that they are straightforward to use, applicable to a wide range of workplace, and low-cost. However, they are not always reliable and could lead to biased interpretation (Wiktorin *et al.,* 1995). In addition, the difficulties with self-reports may vary from worker's level of literacy, comprehension, or question interpretation (David *et al.,* 2005) and the levels of reliability and validity of self-report methods are too low to use as the basis of ergonomics intervention (Li and Buckle, 1999). On the other hand, direct methods were used to collect data directly from sensors attached to the workers' body to measure the exposure factors at workplace are difficult to implement in real work situations (Li and Buckle, 1999; David *et al*., 2005). Although direct measurement methods can provide highly accurate data on a range of exposure variables, they are however very expensive and need an employment of highly trained and skilled technical staff to run the system (David *et al.,* 2005). Meanwhile, the observational methods consist of directly observing the workers doing their jobs at their workplace (Plantard *et al.*, 2017). Moreover, the accuracy and validity of the results obtained by observational methods directly depend on the input information collected (Fagarasanu and Kumar, 2002). The observational methods have the advantages of being inexpensive and can be used in a wide range of workplaces (David *et al.,* 2005; Takala *et al.,* 2010; Chiasson *et al*., 2012) and are suitable for any work case and simultaneously remain a practical way to estimate the risk (Plantard *et al.,* 2017). Although numerous observational methods have been reported in documenting levels of posture, forceful exertions, and repetitiveness have appeared in the literature, comparisons between studies involving physical exposure continue to be limited by a lack of standardization among methods of assessing exposure (Lowe, 2004). Since postural analyses of industrial work are often conducted by visual observation from a video-recording of the work activities, and the limitations of visual observation for posture analysis have not been well defined, the lack of standardization is understandable (Lowe, 2004).

Different tools have been developed in assessing exposure to risk factors for WULDs. About eight eligible pen-and-paper-based observational methods assessing

WULDs have been recognized. First, Rapid Upper Limb Assessment (RULA). RULA is designed for assessing the severity of postural loading and is particularly applicable to sedentary jobs. The exposure factor covered by RULA are posture (head, trunk, upper and lower arm, and wrist) and forceful exertion (McAtmney and Corlett, 1993). Second, Job Strain Index or Strain Index (JSI/SI). JSI was originally designed for mono-task jobs which is there is only one repeated motion, or very similar motions throughout the job. JSI measuring six different parameters include intensity of exertion, duration of exertion, efforts per minute, wrists/hand posture, speed of exertion, and duration of task per day (Moore and Garg, 1995). Third, Occupational Repetitive Activities (OCRA). The key features of OCRA methods is to measure the body postures and force for repetitive tasks. The posture covered by OCRA are shoulder, elbow, and hand (Occhipinti, 1998). Fourth, Cumulative Trauma Disorders (CTD). CTD uses quantitative data such as hand motion frequencies and forces together to obtain a frequency factor score that is reflective of the strain imposed on the muscles and tendons of the wrists (Seth *et al*., 1999). Fifth, Loading on the Upper Body Assessment (LUBA) (Kee and Karwowski, 2001). LUBA is technique for postural loading on the upper body assessment. The method was based on experimental data for the composite index of perceived discomfort, expressed as numerical ratio scores for a set of joint motions, including the hand, arm, neck, and back, and the corresponding maximum holding times in static postures (Takala *et al.*, 2010). Sixth, Upper Limb Disorders (ULDs) Health and Safety Guide (HSG-60) provide a method for identifying and assessing risk in the form of two checklist. The risk factors covered by these methods are physical (repetition, fingers, hands, wrists, arms, shoulders, force, working environment), psychosocial, and individual risk factors (Health and Safety Executive, 2013). Seventh, American Conference of Governmental Industrial Hygienists Hand Activity Level (ACGIH HAL). ACGIH HAL have been developed to quantify the repetitive hand, wrists, and forearm activity (Armstrong, 2006). Lastly, Assessment of Risk Task (ART) Tool. Art tool was designed to assess repetitive tasks involving force, head/neck, arm, back, wrist, and hand/finger grip (Ferreira *et al.,* 2009). From the objective for each tool, it can be concluded that the aim was not entirely focused on assessing the WULDs. Most of them only focused on general ergonomic risks (Rahman and Razak, 2016). Therefore, this research describes the development of the Upper Limb Risk Assessment

(UPLIRA) tool for assessing WULDs associated with work-related upper limb disorders.

1.2 Problem Statement

It is evident that various methods are available for the assessment of exposure to work-related upper limb disorders (WULDs), which include the pen-and-paper-based observational method. Observational methods are mostly often used by practitioners because they are inexpensive and flexible to use in a wide range of workplaces (David *et al*., 2005; Takala *et al*., 2010; Burdorf, 2010).

Work-related upper limb disorders (WULDs) have a multi-factorial origin. Previous research has identified the physical (Winkel and Mathiassen, 1994), psychosocial (Hutson, 2014; Sposato *et al.,* 2017), work organization (Huang *et al.,* 2002; Petit *et al.,* 2015), and individual (Burt *et al.,* 2011) as a risk factors that lead to upper limb disorders (ULDs). Physical risk factors at workplace can be categorized as awkward posture, repetitions, forceful exertions, vibration etc. (Da Costa *et al*., 2010). In Social Security Organization (SOCSO, 2015) annual reports, the numbers of injuries in elbows (404), hand (6427), shoulders (2781), wrists (1480), and fingers (8483) were reported (SOCSO Annual Report, 2015). From a physical point of view, an ergonomic intervention aims at detecting and evaluating the disequilibrium between workplace requirements and workers physical abilities in order to prevent WULDs (Vignais *et al.,* 2017). Nowadays, psychosocial work characteristics are recognized as important risk factors. The previous study (Bongers, Kremer, and Laak, 2002b; Karwan *et al.,* 2015) has concluded that the large majority of the studies reported an association between at least one work-related psychosocial factor and adverse upper limb disorders, symptoms, or signs. Although a growing number of studies on occupational stress, the relationships between ULDs and psychological factors at work remain unclear (Harris-Adamson *et al.,* 2013). Work organization factors normally relate to the structural task and organizational level aspects of the work process (Huang *et al.,* 2002). In the study of Petit *et al.* (2015), found that several factors related to the work organization such as work pace, payment on a piecework, overtime hours etc., were associated with Carpal Tunnel Syndrome (CTS) even though after adjustment for individual factors and biomechanical risk factors. This study confirms that in addition

to physical exposure, work organizational constraints should be an important target for strategies for the prevention of ULDs. Meanwhile, personal, or individual risk factors can influence the tendency of musculoskeletal injury. These factors diverge to the study include age, gender, anthropometry etc. (McCauley, 2011). The study by Dianat *et al*. (2015) indicated that gender was a significant factor for upper back symptoms as the differences in working habits between genders. The other two studies reported a significant association between age and upper back symptoms in workers involved in sewing activities (Öztürk and Esin, 2011; Dianat and Salimi, 2014). Therefore, these findings highlight the need for consideration of individual factors such as age gender, anthropometry etc. of musculoskeletal complaints among this working population.

However, the existing tools have specific purposes and most of the tools are not universally ideal for all risk factors. There are four types of risk factors that usually lead to upper limb disorders (ULDs) such as physical risk factor (awkward posture, forced exertion, vibration, temperature, noise level, and lighting level), psychosocial risk factors (social support from supervisor, workload, work schedule, and training), work organizational risk factors (relationship between employees, wage incentives), and individual risk factors (smoking, previous health history). ART tool was also lacking in parameters to assess the risk factors at the workplace such as the environment, which includes lighting, noise, and temperature.

In addition, the crucial part in developing an assessment tool is to validate the exposure assessment techniques. However, some of the existing tools were not fully tested for psychometric tests, which are reliability and validity. The lack of reliability and validity testing can cause poor performance of exposure assessment tool (Burdorf, 2010; Takala *et al.,* 2010). Based on previous study, only three tools were found to have examined both reliability and validity tests, which are RULA, SI, and ACGIH HAL. Furthermore, the existing tools did not cover the right and left sides of the body part. Takala *et al*. (2010) found that there are no methods available to combine the scores of right and left body parts because most of the tools assess the body parts separately. Besides that, some of the tools do not consider the duration of exposures. Tomaschek *et al*. (2018) found that there are only a few of observational methods that sufficiently assess both psychosocial and physical risk factors at work. Thus, developing supportive tools for the identification and assessment of potentially hazardous tasks and postures appears crucial for ergonomic research. Table 1.1 shows the comparison between the previous research method and UPLIRA method.

Table 1.1: Comparison between the previous research method and UPLIRA tool

Method (Year of First Publication)	Risk Factors			
	Physical	**Psychosocial**	**Work Organization**	**Individual**
Rapid Upper Limb Disorders (RULA) – (McAtmney and Corlett, 1993)	×			
Job Strain Index (JSI) – (Moore and Garg, 1995)	×			
Occupational Repetitive Actions (OCRA) – (Occhipinti, 1998)	×			
Cumulative Trauma Disorders Risk Index (CTD) – (Seth *et al*., 1999).	×			
Loading on the Upper Body Assessment (LUBA) – (Kee and Karwowski, 2001	×			
Upper Limb Disorders Health & Safety Guide (ULDs HSG-60) - (Health and Safety Executive, 2013	×	×		×
American Conference Governmental Industrial Hygienists Hand Activity Level (ACGIH HAL) – (Armstrong, 2006).	×			
Assessment of Repetitive Task (ART) – (Ferreira *et al.*, 2009)	×	×		
Upper Limb Risk Assessment – UPLIRA (2017)	×	×	×	×

1.3 Objectives of Study

The main objectives of this study are:

i. To develop a new observational method known as Upper Limb Risk Assessment (UPLIRA) for assessing risk factors of work-related upper limb disorders (WULDs)

ii. To evaluate the inter- and intra-rater reliability for UPLIRA tool.
iii. To establish the construct validity analysis of UPLIRA tool.

1.4 Scopes of Study

The scopes of this study are as follows:

i. The pen-and-paper-based observational method was used to develop UPLIRA tool.
ii. This UPLIRA tool covers risk factors like physical (awkward posture, force, vibration, temperature, noise level, lighting level), psychosocial, work organizational, and individual risk factors.
iii. The physical risk factors include awkward postures (neck, shoulders, elbows, wrists, and back), repetitive motion, forceful exertion, temperature, noise level, and lighting level.
iv. The psychosocial risk factors cover the social environment, workload, and work schedule.
v. The work organizational risk factors cover skills from previous experience and wage incentive.
vi. The individual risk factors cover smoking habits and previous job accidents at the workplace.
vii. UPLIRA tool covers both right and left sides of the body part.
viii. The items selected were based on strong and moderate scientific evidence with (OR > 2.00) and strong and moderate association ($1.01 < OR \leq 2.00$).
ix. The development of a scoring system for UPLIRA tool uses the sum score of weighted items.
x. Inter- and intra- rater reliability assessments were used to assess the reliability trials of UPLIRA tool.
xi. The training for inter and intra rater reliability was conducted among six students (three undergraduate students and three postgraduate students) of Mechanical Engineering students who conducted research in the ergonomics field.
xii. Three different jobs including packaging operator, cashier, and accountant have been assessed in order to determine the reliability among six participants.

xiii. Cohen's Kappa coefficient was used to assess the level of agreement for inter and intra rater reliability using 25 items and 36 sub-items of the UPLIRA checklist.

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

xv. The construct validity using known-groups technique was used to assess the validity of UPLIRA tool.

xvi. The total sample size for validity trials is 126; 56 workers from selected grocery supermarket and 70 workers from selected office workstation.

1.5 Significance of Study

The proposed tool for this study contributes to the new knowledge in ergonomic exposure assessment tools especially in work-related upper limb disorders (WULDs). This is because the risk factors may lead to ULDs if the exposure assessment method is not well-designed (Takala *et al.,* 2010). Based on previous studies, it was shown that no tools/methods have been developed to cover all the risk factors for WULDs. Moreover, the reliability and validity testing of these tools were conducted during the development process of the tool. Therefore, this UPLIRA tool meets the research needs to evaluate all the risk factors in the workplace.

The results of this study are useful to develop and evaluate new observational tools that are capable of evaluating ergonomic risks related to ULDs. Therefore, a new tool was developed from this study, which is called Upper Limb Risk Assessment (UPLIRA) that covers all the risk factors that might lead to ULDs such as physical, psychosocial, work organizational, and individual risk factors. The reliability and validity tests were conducted during the tool development process. Furthermore, UPLIRA tool is applicable to a wide range of task and is valuable at work. UPLIRA tool was designed to be user-friendly without the need to use expensive equipment and the new user only needs a minimal training to carry out the assessment.

An assessment conducted at a field study is important to identify the risk contributing to WULDs such as carpal tunnel syndrome (CTS). The ergonomic risks are able to be identified by using the new tool, which is designed specifically for WULDs. This new tool is useful for future research related to ergonomic risk evaluation related to ULDs. In fact, a well-designed observational tool that assesses

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