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The Development of Ergonomics Risk Assessment Method using Infrared Thermal Imaging

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ABSTRACT

There are at least 8 ergonomics risk assessment methods were study for comparison purpose in this paper. Based on the comparison result, there are a few limitations that can be found. The evaluation result may be dispute due to human biased. It is because, the evaluation result come from the perception of workers that taken into account. Other than that, there is limitation to observing a specific body part. Current 8 ergonomics risk assessment method had a limited to observing a body part and also the body posture of the subjects. Based on these limitations, this study explores the using of infrared thermal imaging to improve current ergonomic risk assessment method. This study also will discuss a new approach of ergonomics risk assessment method that enable to increased worker's safety through the assessment with specific feedback, due to availability of non-bias data and prevention of work-related musculoskeletal disorders (WMSD's)

Key words: Ergonomic Risk Assessment, Infrared Thermal Imaging and Work-related Musculoskeletal Disorders (WMSD's).

1. INTRODUCTION

A review from a various research are agreed that the repetitive, excessive force and work-load, vibration, awkward movements and awkward body postures contributes to the ergonomics risk factors of work-related musculoskeletal disorders (WMSD's) [1][2]. Lower back, neck, forearms, wrists, hands, shoulders and also elbow are the most often body areas that affected from these WMSD's [3]. The scientific literature shows that the best preventions from WMSD's are to reduce the exposure to the risk factors [4]. In others words, risk factors of WMSD's should be assessed especially in the work area to ensure the workers have less interaction with the risk factors of WMSD's.

There are three methods that can be used to identify the ergonomics risk factors of WMSD's [4], subjective judgement based on survey, observation and also measurement. Based on the review, measurement is the most accurate methods to identify and reduce risk factors of WMSD's but it required an investment whereas observation methods is the most commonly method used by the ergonomist [5]. Observation method is easier and less costly compared to the other method in identifying the risk factors. It is also the most flexible method when it comes to collecting data in the actual site.

There is still a continuous argument from the ergonomics practitioners to identify the most effectives ergonomics risk assessment methods for preventing WMSD's. Although there are several literature that offers the research that tested and compared current ergonomics risk assessment methods, there are still minimum information on determining which methods is the best in preventing WMSD's [5]. There is also no argument between the ergonomics practitioners as the best method to choose is to developed an experiment and compared the respective result [6][5]. Take a different path, some practitioners choose the best method from the review of the literature according to the method characteristics.

2. ERGONOMICS RISK ASSESSMENT METHOD IN PREVIOUS STUDY

In recent year, the number of published method to evaluate ergonomics risk factors has increased [7]. There are variety numbers of methods that can be used by the ergonomics practitioners and the researcher to evaluate ergonomics risk factors. Most of the methods are able to prevent WMSD's by exposed the ergonomics risk factors happened to workers so that the organization could design the method to prevent it [7]. For this paper, there are 8 current ergonomic risk assessment methods were study for comparison purpose as below:

2.1 The Quick Exposure Check (QEC)

The Quick Exposure Check or QEC are developed by Li and Buckle in United Kingdom between 1995 and 1998 [8][9].

The QEC method was developed to help ergonomics practitioners to evaluate the workers for exposure to musculoskeletal risk factors. The QEC method is an observational tool that evaluate four major arrears of the body; back of body, arm and shoulder, hand and wrist including neck, as well as vibration and work stress exposure [8][10]. This method was specifically designed to involve both the evaluator and also the subject in scoring the work task together [8][6]. The scoring shows the levels of exposure for body posture, repetitive movement, work load and duration of work task given. The scoring of levels for each exposure will be total up to get a total score for each body part, for vibration and for the work stress [8][9][6].

2.2 The Job Strain Index (JSI)

JSI or Job Strain Index is an analysis methodology that used semi-quantity analysis based on three principles which are epidemiology, physiology and also biomechanics [6][11]. JSI method normally used for evaluates the distal upper extremity body part to an exposure to risk factors. The distal upper extremity consists of elbow, forearm, wrist and hand, neck and also shoulder. Result of the JSI is shows as Strain Index (SI) that interpret the level of perceived exertion, duration of effort as a percentage of cycle time, efforts numbers, posture of hand and wrist, speed of work and length of shift [12][6]. At the end of the result, frequency and duration were obtained based on the time-motion study.

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2.3 The OCRA Index

The occupational repetitive action or OCRA is an ergonomics risk assessment method developed by Occhipinti and Colombini in 1996 [6]. The OCRA is a method that analyses the exposure of worker to work task that possible to become upper-limb injury factors. Work force and load, awkward posture, repeated movement, abnormal posture and short time recovery can become major factors besides others additional factors that can be stated on the space leave by the method for any possible factors contribute besides the original version [12][6][13]. The OCRA also known as the most complete method in ergonomics risk assessment method as the result show the analysis in details. The details consist of the evaluation result of risk factors especially for the extremity upper limbs [12].

2.4 The ISO 11228-3 Standard

The International Standard Organization (ISO) is an international independent organization that combined together experts around the world to share knowledge and experiences to developed market-relevant standards that supporting innovation and providing solutions to global challenges [14]. ISO 11228 is a standard that present a recommendation related to occupational limits of exposure to ergonomics risk factors. The ISO 11228 is divided into three main parts. Part 1: lifting and carrying, part 2: pushing and pulling and part 3: handling lows load at high frequency [14][15]. This paper is compared the used of ISO 11228-3 as method that provides guidelines on the identification and assessment of ergonomics risk factors commonly happened during handling low loads at high frequency. This method also allowed assessment that related with health risk to the working population.

2.5 The Workplace Ergonomics Risk Assessment (WERA) by DOSH Malaysia

Workplace Ergonomics Risk Assessment or WERA is created by Department of Occupational Safety and Health (DOSH) Malaysia in Guidelines on Ergonomics Risk Assessment in Workplace 2017. The purpose of these guidelines is to provide a systematic plan and to identify; assessing and controlling ergonomics risk factors associated with the work task or activity is workplace [16]. The WERA method shows the individual body part scores and the score is total up to shows the pain and discomfort happened in back body, shoulder, neck, wrist and hand [16][17].

2.6 ACGIH's Hand Activity Level threshold limit values method (HAL)

The American Conference for Government Industrial Hygienists (ACGIH) threshold limit value (TLV) for hand activity is an observation method commonly used and the method based on hand activity level (HAL) and force [18][19]. HAL method evaluate the work related based on scale between 0 and 10. This method is used to evaluate work task that related to the distal upper extremity musculoskeletal disorders (DUE MSD's). HAL is scored based on scale between 0 which stated as the idlest and 10 for the difficult to keeping up the work task [18]. The threshold limit value or TLV for hand activity also used table to measure the frequency and work task cycle, and it can be used to calculate HAL, or an equation may be used for calculating HAL using the same variables [20].

2.7 The Rapid Upper Limb Assessment (RULA)

Rapit Upper Limb Assessment or known as RULA is a method designed by Lynn McAtamney and Nigel Corlett in 1993 [21]. RULA is a very effective method for evaluate the worker to exposure of ergonomics risk factors related to upper extremity such as hands, wrist, arms, shoulders, neck, trunk and back [21]. The RULA method was designed to become less costly and easy to use. This method only used a piece of worksheet to evaluate related body posture, force and repetitive movement. The evaluator will visually assess the worker and entered the scores based on observation. There are 2 sections A and B and after data was collected for each section, the evaluator used the table on the form to combine the risk factor variable then generate result that represent the level of MSD's risk. The RULA method also one of the flexible methods in ergonomics risks assessment method as it able to be used in almost every working condition.

2.8 The Rapid Entire Body Assessment (REBA)

Rapid Entire Body Assessment or REBA was developed by Hignett and Lynn McAtamney in 2000 at United Kingdom [22]. REBA is a method that has been designed specifically to able the evaluator consider any unpredictable posture occur to the subject during the work task [22]. As same as RULA, REBA method is less costly and easy to use. This method only uses a piece of worksheet but provides easy measurement to evaluate postures that contribute for WMSD's risk factors. REBA method evaluate the subject by divides it into several body sections and independent score for each sections. The score will be given by the evaluator based on the subject body movement from the origin position, muscle activity, sudden movement, significant changing positions and several activities throughout the entire body [22].

Table 1: Summary of physical risk factors that taken into account based on identification from each method.

Methods	Physical Risk Factors								
	Posture and Movements	Work Load/ Force	Repetitive Work Task	Work Duration	Work Speed	Vibration	Rest Time	Worker Perception	Others
QEC	x	x	x	x		x		x	x^1
JSI	x	x	x	x	x			x	x^2
OCRA	x	x	x	x		x	x	x	
ISO 11228-3	x	x	x	x		x	x	x	
WERA	x	x	x	x		x		x	x^3
HAL	x	x			x			x	
RULA	x	x	x						
REBA	x	x							x^4

x^1 Visual demand, x^2 Intensity of exertion, x^3 Contact Stress, x^4 Quality of hand coupling

3. METHOD'S PHYSICAL RISK FACTORS

In the ergonomics risk assessment method, physical risk factors play an important role as it give a basic hazard exist and may be exposure individuals to the risk of injury [12][15]. The statistical literature review shows that, ergonomics practitioners used the physical risk factors to determining the best method to preventing WMSD's based on their working conditions [12][18][10][17][6]. For this study, physical risk factors is present in 8 primary risk factors (posture and movement, work load/force, repetitive work task, work duration, work speed, vibration, rest time and worker perception), as well as 4 additional factors (visual demand, intensity of exertion, contact stress and quality of hand coupling).

Between these physical risk factors, only 2 factors that used by each method; body posture and movements and work load/force whereas repetitive work task and worker perception become a second highest physical risk factors that taken into account . This shows that, WMSD's are frequently occur on the job requires these physical risk factors (body posture and movements, work load/force and repetitive work task). In a meanwhile, worker's perception also counts as one of the risk factor that taken into account. This perception is regarding to the information gain from the observation of workers activities except for the QEC method that designed to involve both the observer and the worker to scoring the assessment together. Table 1 summarizes the physical factors that taken into account based on identification from each method.

4. METHOD'S MAIN CHARACTERISTICS

To able the comparisons between the methods, which do not use the same characteristics and assessments, each of the ergonomics risk assessment method were summarize based on the method's main characteristics. It will allow the practitioner to decided or prioritize the method that suitable with the assessments situation. The main characteristics were established form the recommendations made in the literature and described in Table 2.

Table 2: Summary of main characteristics of each method based on the literature review.

Method	Main Characteristics	Body Part
QEC	Quick method that use for estimating the exposure level and it was specifically designed to involve both the observer and also the worker in scoring the assessment.	Whole body
JSI	Job analysis based on three principles, epidemiology, physiology and biomechanics.	Distal upper limbs
OCRA	The OCRA also known as the most complete method in ergonomics risk assessment method as the result show the analysis in details. The details consist of the evaluation result of risk factors especially for the extremity upper limb.	Upper limbs
ISO 11228-3	Provides guidelines and help the ergonomics practitioner to evaluate risk factors commonly happened during handling minimum loads but in highest frequency	Whole body
WERA	An observational method that use to	Whole body

	evaluate and identifying exposure of physical risk factors associated with WMSD's. This method evaluates shoulder, wrist, back, neck and leg of the subject.	
HAL	Method that measure risk of work task related to the distal upper extremity musculoskeletal disorders and scored based on scale between 0 (most idle) and 10 (difficult to keeping up).	Upper limbs
RULA	This method only used a piece of worksheet to evaluate body posture, force and repetitive movement. The evaluator will visually assess the worker and entered the scores based on observation. There are 2 sections A and B.	Upper limbs
REBA	This method only uses a piece of worksheet but provides easy measurement to evaluate postures.	Whole body

Table 3: Summary of strengths and limitations of each methods

Methods	Strengths	Limitations
QEC	QEC is easy method to used and learn. QEC focuses on exposure assessment and change in exposure. This allows the observer to assessed workstations rapidly. QEC designed to involve observer and worker to assess together.	Result of the risk assessment may be biased because worker's perception is taken into account. Assessment result level based on observer experience and perspective.
JSI	JSI can provide better understanding to the most influence risk factors and work task that become most difficult for the worker. JSI also provide strengths and weakness of interaction between worker and workstations	Time study needed and more appropriate for assessing workstations with short cycle. Result of the risk assessment may be biased because worker's perception is taken into account. Limited body posture assessed.
OCRA	OCRA can provide the result detailed analysis of the main mechanical and organizational determinants of the risk especially for the upper limbs evaluation	Time study needed. Hard to assess workstation with large sample. Result of the risk assessment may be biased because worker's perception is taken into account. Limited body posture assessed.
ISO 11228-3	Easy to use. General model of ISO 11228-3 allow using with other risk assessment method (JSI, HAL, WERA) .	Result of the risk assessment may be biased because worker's perception is taken into account. Assessment result level based on observer experience and perspective.
WERA	Easy and quick to use. WERA is useful for initial screening. Applicable to workplace assessment for the wide range of task	Result of the risk assessment may be biased because worker's perception is taken into account. Assessment result level based on observer experience and perspective.
HAL	HAL allows fairy wide range of measurement techniques by user.	Time study needed and more appropriate for assessing workstations with short cycle. Result of the risk assessment may be biased because worker's perception is taken into account. Limited body posture assessed. Assessment result level based on observer experience and perspective.
RULA	Easy and quick to use.	Not provide sub-score for different body region. Limited body posture assessed. Assessment result level based on observer experience and perspective.
REBA	Easy and quick to use	Not provide sub-score for different body region. Assessment result level based on observer experience and perspective.

5. METHOD'S STRENGTHS AND LIMITATIONS

5.1 Strengths of each method

The objective of this study is to compare 8 ergonomics risk assessment methods for determining physical risk factors for work-related musculoskeletal disorders (WMSD's). Based on the comparison, strengths and limitations of each method had been identified and summarized in Table 3. The summary will provide a better understanding of the differences between each method and able to give the useful information for the practitioners to choosing the ergonomics risk assessments method. Based on the table, most of the method (excluding JSI, OCRA and HAL) are easy and quick to use. The methods can be used by untrained employers without need skills and technique although there would be an advantage. For JSI, OCRA and HAL, the main strengths of these methods are it can provide details risk factors and work task that become most difficult to the worker.

5.2 Limitations of each method

For the limitations of each method, most of the ergonomics risk assessment method (exclude RULA and REBA) had the limitations of result may be biased because of worker's perception is taken into account. Worker's perception that taken into account during the assessment are working duration, working speed, rest time, visual demand and also worker involving during scoring the assessment (refer Table 2). Others than that, limited body posture that can be assessed also become one of major limitations of the compared methods. Methods such as JSI, OCRA, HAL and RULA only can assess upper body with a limited body posture during the process of ergonomics risk assessment.

6. INFRARED THERMAL IMAGING

There are several studies had been conducted that show the used of infrared thermal imaging in screening and detecting health diseases such as a diabetic neuropathy [23][24][25], breast tumor and cancer [13][26][27], liver diseases [28][29], personality testing and brain imaging [30][31][32] and thermal imaging in medical science [33]. It has been proved that the used of infrared thermal imaging can become a very good indicator for human health especially for early stage detection. Therefore, it is possible to use the similar process in detecting and screening using infrared thermal imaging to assess ergonomics risk factor that happened to the workers in real working situations. This new approach can become useful method to detect early problems occur to the workers that related to musculoskeletal disorders (MSD). Based on the method's limitation in Table 3, infrared thermal imaging can also become the best alternative method as is a non-contact and non-invasive process [33] compare with listed 8 comparison method that the result may be biased because of workers perception that taken into account.

6.1 Thermoregulation

Thermoregulation can be defined as core temperature that relatively constant in human body [34]. A human body temperature is normally maintain at 37°C and the higher the temperature occur to human body is critical to human health. There are two principal sources of heat that can contribute to temperature balance and maintenance of body core temperature in human body which is metabolism and flexing of muscle [33]. Metabolism is the chemical reactions occur in human body that produces heat during the use of muscle. Heat is transferred from the body core to the outer layer of human body towards blood flow through vessel. The process will reduce the heat gain from the body core and losses it at the peripheral parts of human body especially skin. The heat produce from the body core also depend on the use of muscle, forced and duration of exposure [34].

6.2 Infrared Thermography

Thermography is the process of temperature measurement [23] of any objects or subjects that produces heat. This process use infrared thermal imaging that emits an electromagnetic radiation that able to visualize the temperature distribution of the objects or subjects with a temperature greater than absolute zero (-273°C). Therefore, infrared thermal imaging is the most effective method that can be used to monitoring thermoregulation process [33][34]. In the process of thermoregulation, the skin plays an important role because it is response to the increase or decrease of internal body core. Work-related musculoskeletal disorder (WMSD's) normally happened to the workers that exposure to an excessive work-load or prolonged statics working position. This can cause a reaction of body core to produced high temperature and it can be detected using infrared thermal imaging. The ability of detecting any abnormality of human body temperature reacting to the working process or position in an early stage can prevent of work-related musculoskeletal disorder (WMSD's).

7. CONCLUSION

Nowadays, the technologies of infrared thermal imaging become more advance every year. The process of infrared thermography also become one of the most important method that been used in detecting and screening health disease for human. Based on the review, this study can conclude that there is possible to use an infrared thermal imaging as a new approach of ergonomics risk assessment method. This study also presents the result of comparison between 8 current ergonomics risk assessment method. The result of comparisons found that there are several limitations whereby the biased result becomes a major problem occur during the process of evaluation. Current ergonomics risk assessment method required human interaction between the evaluator and the subject therefore the result can be disputed.

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