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Manual Material Handling Risk Assessment Tool for Assessing Exposure to Risk Factor of Work-Related Musculoskeletal Disorders: A Review

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Abstract: This review provides an overview of the range of method that has been available to assess Manual Material Handling (MMH) to risk factor related Work-Related Musculoskeletal Disorder (WRMDs). Electronic database was used to search for the material from 1991 until 2015. Method relevant publications on material using electronic database from 1991 until 2015 have been gathered for inclusion in this review meanwhile manual material handling, risk assessment, observational method and musculoskeletal disorder were used during the discovery process. Observational method to assess manual material handling is the purpose for this developed review based on the reliability, validity and risk factor. Two researchers conducted this evaluation process from selected publication. They identified eleven entitled observational assessment tools which were significantly used to assess exposure to MMH related to work-related musculoskeletal disorder. Posture, force, frequency, duration and environment were the risk factors involved in current method in assessing manual material handling. Only one from these eleven methods was confirmed to be reliable and graded as moderate to good. None from this review method conducted validity test. Various observational tools exist but no single tool appears to cover all of the risk factors for manual material handling. In addition, most important factors during developing tool are appropriate validation of exposure assessment method which in the existing observational method, test reliability and validity were not conducted.

Key words: Manual Material Handling (MMH), risk assessment, musculoskeletal disorders, disorder, good

INTRODUCTION

Maintaining health is important contributed from safe working posture in daily working hours (ACGIH, 2014). Exposure to particular hazardous agents in Manual Material Handling (MMH) activities among developing and develop country contributes in increasing number of cases in Work-related Musculoskeletal Disorders (WMSDs) (Choobineh *et al*., 2009; Beek and Frings, 1998; Rodriguez *et al*., 2013). MMH is defined as lifting, lowering, pushing, pulling, carrying or moving excessive load with hands or body force which is the most probable factor in resulting to WMSDs injuries because those tasks require a stable position and large degree of freedom (Kamat *et al*., 2013; Mohammadi *et al*., 2013; Salik and Ozcan, 2004).

Generally, the main concerns in observation-based method assessments are conducting assessment without disruption of working activity, early detection of WMSDs and able to complete in confined workplace (Abedini *et al*., 2013). In addition assessment on the MMH risk factor related to MSDs was conducted using more than eleven studies. RNLE evaluated lifting task for industrial worker of Shiraz City show 79.2% were at risk of back injuries (Asadi *et al*., 2015). MAC method assess lifting tasks at rubber industry (Abedini *et al*., 2013). ManTRA method conducted studies at construction industry which frequently exposed to manual material handling.

"Snook" Table method was used to reduce WMSDs in steel industry and casting workshop for MMH activity (Giahi *et al*., 2014). In addition, RNLE and 'Snook' Table were utilised in developing box widths for lifting task (Potvin and Bent, 1997) . Moreover, ARBOUW and RNLE Tool were used in case studies such as "transport, construction and dismantle of scaffolding by scaffolder" (Beek *et al*., 2005). Thus, the aim of this study is to review and identify published observational methods for

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assessing manual material handling risk factor related to WRMSDs including its reliability and validity study during development process.

MATERIALS AND METHODS

Searching methods: In order to identify the observation published methods, a list of articles dating as far back as 1991 until 2015 was compiled from PubMed, Science Direct and Google Scholar. The keywords are 'ergonomics', 'musculoskeletal disorder', 'epidemiological', 'manual material handling', 'risk assessment', 'observational method' and combinations of these terms. In addition, exposure assessment techniques were found in significant publication. Workshop discussion, conference and report from research institute which discuss the exposure assessment were used in identify the recent methods also include in this study.

Selection of references and evaluate: English language references were selected to retrieve for future studies. Observation method that still be applied and must have been published is the main criteria in selection including certain angles or body posture in each methods. One method was found hardly to use anymore and it's included in twelve systematic observation methods found. Therefore, eleven observation methods met the criteria and were included in the study. This study is completely conducted by two researchers.

RESULTS AND DISCUSSION

Figure 1 shown the eleven identified methods for assessing MMH risk factor related to MSDs. It was Liberty Mutual Snook Psychophysical Table (Snook and Ciriello, 1991) Guidance on the Manual Handling Operation Regulation Manual Handling Risk Assessment Manual Task Risk Assessment Key Indicator Method-Manual Handling Operation (Steinberg, 2012) Revised NIOSH Lifting Equation (Waters *et al*., 1993).

Published journal articles, reports and related previous case studies were chosen as the method in selecting this assessment to assess MMH. It's about 201 reference documents as reference and 50 papers were selected be the main potential references.

Table 1 shows the summary of the objectives, functions and risk factors for assessing manual material handling. Most risk factor which is force, frequency and posture cover from (RNLE, MAC and Snook). In addition

Table 2 show the basic characteristics of the MMH method. Development process, type of rating scores and potential users are the basic characteristic for each of that methods. Summary of concurrent validity and intra- and inter-rater reliability are shown in Table 3. The result is divided into three categories which are low, moderate and good. Most of the tools showed moderate result.

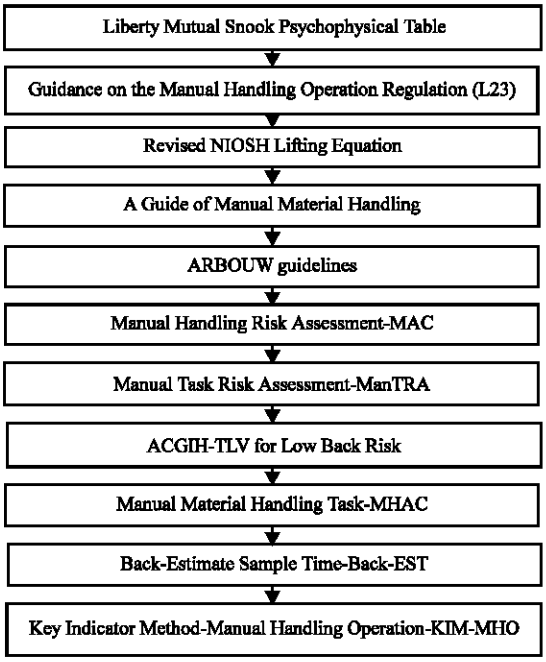

Fig. 1: Methods for assessing manual material handling

Liberty mutual Snook psychophysicalt table: The Liberty Mutual ''Snook'' tables (Snook) psychophysical based tool was developed to assist industry in the assessment and design of MMH tasks (Snook and Ciriello, 1991) A psychophysical approach was used to determine the maximum acceptable weights and forces for lift, lower, carry, push and pull tasks. Suggested parameters for handling tasks are based on experimentally determined weight selection and are displayed in the Snook tables They specify, different percentiles of male and female industrial workers. However, no validity study was found on either its association with MSD or its repeatability.

Guidance on the manual handling operation regulation (L23): The Manual Handling Regulations a MMH guideline developed by HSE, UK sets no specific requirements such as weight limits. In addition, they focus on the needs of the individual and set out a hierarchy of measures for safety during manual handling operations: avoid hazardous manual handling operations as far as it is reasonably practicable; make a suitable and sufficient assessment of any hazardous manual handling operations that cannot be avoided and reduce the risk of injury from those operations as long as it is reasonably practicable. No study was found on either its association with WRMSDs or its repeatability.

Table 1: Summary of the objectives, function and risk factor for assessing manual material handling related to WMSDs

Methods	Objective	Function	Risk factor
Liberty Mutual Psychophysical Table-Snook (Snook and Ciriello, 1991)	To provide guidance for manual material handling tasks	Whole body, Low back	F, P, Fr, G
Guidance on the Manual Handling Operation Regulation-L23	To guideline organization for reduce the risk of injury from manual handling	Regulation for manual handling associated with MSDs	F, E, I,
Revised NIOSH lifting equation (RNLE) (Waters *et al*., 1993)	To assess risk of low-back disorder in task with repetitive lifting	Assess risk factor low back	F, P, R, D
A Guide of Manual Material Handling (Mital, 1997)	To give guidance in design/analysis a workspace weight/force with	Recommendation on design related to MMH	F, Fr, L, C,
ARBOUW guidelines .	To develop guidelines instruments which enable all discipline in the construction process and improve working conditions.	Low back	P, F, Fr, D
Manual Handling Risk Assessment (MAC)	To aid health and safety inspector assess the most common risk factor in lifting, carrying and team handling operation.	Assess risks associated with WRMSDs	F, Fr, P, C, E
Manual Task Risk Assessment (ManTRA)	To assist inspectors in auditing workplaces across all industries and to make an assessment of the exposure to musculoskeletal risk factors associated with manual tasks in the workplace	Assess four body region; lower limbs, back, neck/shoulder, arm	D, R, P, Vr, S, F
ACGIH-TLV for Low Back Risk	To develop a guideline and evaluate of tasks with repetitive lifting.	Low back, shoulder disorder	P, F
Manual Material Handling Task (MHAC) (Batish and Singh, 2008)	To develop assessment tool for analyzing material handling tasks and its application for manual material handling	Screening the working population quickly for exposure to a likely risk of MSDs	F, P, Gr, I, E
Back-Estimate Sample Time (Back-EST) (Village *et al*., 2009)	To develop and evaluate the observational tool designed for documenting physical exposures to back injury risk factors related to posture, manual materials handling, and whole body vibration	Evaluate physical back injury risk factors	L, P, E,
Key Indicator Method-Manual Handling Operation (KIM-MHO) (Steinberg, 2012)	To assess the risk of manual handling of loads on a screening level	Screening level on MMH risk	L,P, F, E

Gender (G), Individual (I), Vibration (Vr), Duration (D), Frequency (Fr), Speed (S), Working Posture (P), Coupling (C), Force (F), Repetition (R), Environment (E)

Revised NIOSH Lifting Equation (RNLE): The revised NIOSH Lifting Equation (RNLE) intervention form NIOSH lifting equation,1981 based their assessment on equations which consider multipliers referring to posture, force and the time sequences of a task developed and updated in 1991. In addition this equation is an experimental method for calculating Recommended Weight Limit (RWL) and risk level using Lifting Index (LI). If value LI>1.0 its will be high risk. Back area are main concern this equation which most area in reducing the prevelance of musculoskeletal disorder. During the development process, no fromal studies were conducted to test the validity and reliability.

A guide of manual material handling: MMH recommends certain initial and sustained, horizontally exerted hand forces for different percentiles of male and female industrial workers in one and two-handed (Mital, 1997). It provides numerous studies and sources were used to compile the weight/force limit recommendations and multiplier tables for various task factors. Recommended work rate also include in this guide. However, this is a guide, no validity and reliability study were conducted. Therefore comparison on work Rate (R) are the main concern in this guide. Workstation must redesign if the R<1. The validity and reliability are not conducted for this guide.

ARBOUW guidelines: The Arbouw method was developed based on NIOSH lifting equation and standard for MMH by Arbouw Foundation for construction industry in Dutch. Its consist, the assessment of three variable only of MMH; lifted weight, horizontal distance and repeatability lifting. Lifting Index (LI) is the risk level index from ARBOUW. The Arbouw lifting guidelines can be considered as a simplified version of the NIOSH lifting equation. For all lifting situations an Arbouw LI was assessed and the resulting Lis were averaged for

Table 2: Basic characteristics of the observational methods for manual material handling

Methods	Development process	Rating score	Potential user*
Liberty Mutual (Snook Psychophysical Table (Snook and Ciriello, 1991)	Identify psychophysical risk factor Develop methodology and apparatus for experiment Establish percentage result	Recommendation load	R
Guidance on the Manual Handling Operation Regulation (L23)	Identify cause of increase number of injuries related to MSDs Comply with the regulation and review risk assessment Develop assessment tool	Regulation and guidance	O,R
Revised NIOSH Lifting Equation (Waters *et al*., 1993)	Identify the cause of low back pain injuries Determine lifting risk factor Develop lifting equation and Lifting Index (LI)	Total multiplied score, RWL and LI	O, R
A Guide of Manual Material Handling (Mital, 1997)	Identify the specify MMH task Select the percentage of the population Determine work Rate (R) Develop R level	No detail rules	O, R
ARBOUW guidelines	Identify physical workload related to construction industry Development scheme for application of guideline flowchart Develop traffic light approach for risk level	Traffic light	O
Manual Handling Risk Assessment (MAC)	Identify inspection criteria tool Review current MMH assessment tools and MHOR Develop format tool and select the risk factor Consideration discussion group and peer-review feedback Develop score system, action level and set of instruction	traffic light and total sum score	O
Manual Task Risk Assessment (ManTRA)	Identify risk factor related to manual tasks Combine physical risk component Develop suggestion threshold and risk action level	Total risk score	O
ACGIH-TLV for lowback risk	Determine task duration, lifting frequency; Review with TLV table Determine the lifting zone, horizontal location and the TLV	Threshold Limit value table	O, R
Manual Material Handling (Task-MHAC) (Batish and Singh, 2008)	Develop a survey technique. Develop a method of assessing and recording the parameters and conditions Develop a scale of action levels which provided a guide to the level of risk and the need for a more detailed assessment	Numerical score	O, W
Back-Estimate Sample Time (Back-EST) (Village *et al*., 2009)	Determine risk factor and exposure Develop sampling frequency	Time sampling	R
Key Indicator Method-Manual Handling Operation (KIM-MHO)	Determine risk factor Develop time rating point Total sum Establish risk evaluation technique Develop risk range	Total sum score	R, O, W

*Researcher (R), occupational safety and health practitioner/ergonomist (O), Supervisor/worker (W)

the job as well as for each task no studies were found on either its association with WMSDs or its repeatability.

Manual handling risk assessment (MAC): Manual Handling Risk Assessment (MAC) was developed base by HSE UK. Design as a checklist to help health and safety inspectors to assess the most common MMH risk factors in lifting, carrying and team handling operations. Observation strategy using summary score is counted from 11 items of manual handling to be evaluated according to a four-grade "traffic light to prioritize those tasks that require urgent attention and check the effectiveness of those improvements. With benchmarking against several other methods in a qualitative manner but no formal comparison on validity was found in MAC properties. The assessment has shown moderate-to-good intra- and inter-observer repeatability on observations from video recordings. In addition, a questionnaire, based on that used by was designed to elicit quantitative and qualitative feedback on the usability of the MAC.

Table 3: Summary of concurrent validity, intra- and inter-rater reliability

Methods	Concurrent validity	Reliability trials Intra-rater reliability	Inter-rater reliability
Liberty Mutual (Snook Psychophysical Table (Snook and Ciriello, 1991)	No formal study	No formal study	No formal study
Guidance on the Manual Handling Operation Regulation (L23)	No formal study	No formal study	No formal study
Revised NIOSH Lifting Equation (Waters *et al*., 1993)	No formal study	No formal study	No formal study
A Guide of Manual Material Handling (Mital, 1997)	No formal study	No formal study	No formal study
ARBOUW guidelines	No formal study	No formal studies	No formal studies
Manual Handling Risk Assessment (MAC)	No formal study	Moderate-good	Moderate-good
Manual Task Risk Assessment (ManTRA)	No formal study	No formal study	No formal study
ACGIH-TLV for low back risk	No formal study	No formal study	No formal study
Manual Material Handling Task (MHAC)	No formal study	No formal study	No formal study
Back-Estimate Sample Time (Back-EST) (Village *et al*., 2009)	Moderate-compared to inclinometer measurements	No formal studiy	Moderate >0.74
Key Indicator Method-Manual Handling Operation (KIM-MHO) (Steinberg, 2012)	No formal study	No formal study	No formal study

Manual task Risk Assessment (ManTRA): ManTRA was developed compliance with the Queensland (Australia) manual tasks advisory standard. Established to assist safety inspectors auditing workplaces across all industries task in a job related to MMH. Scoring is the observation strategy from five scale area which inclusive; total time spent, repetition, exertion, awkwardness and vibration. Conducted in specific step, could easy to take the action on risk level. High scores of individual items or a high summary score are assumed to indicate an increased risk for MSD. ManTRA showed No studies testing the validity or repeatability of the method were found.

ACGIH-TLV for low back risk: Providing guidelines for safe lifting are main concern the creating of ACGIH TLV. The TLVs estimate form the location of the handled material relative to midpoint between the ankle bones, exposure durations, frequency and daily duration and height zone refer to an anthropometric The TLVs recommend workplace lifting conditions without developing work-related low back and shoulder disorders. The method was developed to ensure a lifting guideline that was accurate, based on the latest scientific information and easy to use. The ACGIH lifting threshold limit value method has shown moderate-to-high correspondence with results obtained by the NIOSH lifting equation and Snook's psychophysical method for setting lifting limits. No studies were found on either associations with WRMSDs or repeatability

Manual material handling task (MHAC): Manual Material Handling Tasks (MHAC) was developed in a bearing industry (Batish and Singh, 2008). Low back pain and injuries attributed to manual lifting continue to be a leading occupational health and safety issue faced by the manufacturing industry. MHAC assess the most MMH task area load weight and frequency of handling, position of the upper arm asymmetrical trunk load, postural constraints, grip on load, operator's capabilities, floor surface, distance involved in the carrying task, obstacles en route and environmental factor. Total sum score could be related to risk level and action to be taken on ergonomic intervention. No validity studies were found on either its association with WRMSDs and its intra and inter-reliability.

Back-Estimate Sample Time (Back-EST): Back-EST aimed to evaluate physical back injury risk factors in demanding work environments developed by Village *et al*. (2009). In the development phase, a literature review suggested 53 relevant exposure variables; these were reduced to 20 items concerning posture, manual material handling and whole-body vibration. The items were observed once every 60 sec over a full-shift to produce data that can be analyzed according to the purposes of the individual research. The proportion of time in demanding back postures was compared with technical measures and the match was found to be moderate at best, although the finding may have been affected by the different sampling procedures of the compared tools and inter-observer repeatability has been moderate by using video recording in task.

Key Indicator Method-manual Handling Operation (KIM-MHO): KIM-MHO were drafted in the German Federal Institute for Occupational Safety and Health (Steinberg, 2012) which considered separately the posture of the back, the arms and the legs. In KIM, one of four postures was selected (Roman, 2014) KIM, the result of an

assessment is partly based on simple equations in which the scores assigned to postures are the variables. In KIM, the choice applies to what is considered as the posture of the whole body and it is only in that meaning that KIM considers the posture of the lower limbs. The other methods did not consider them. No validity studies were found on either its association with WRMSDs and its intra and inter-reliability during development process.

This studies has reviewed on method to assess MMH related to WRMSDs show eleven eligible published which various contributor risk factor. Objectives of each tool show the aim are different with not all are focus on low back pain. Most of them only focus on general ergonomics risk problem. Rather than that posture are the most risk factor include on each of tools but not in all manual material handling assessment method. The characteristics of the method to assess manual material handling are shown in Table 2. They have been included in the development process, rating score and potential user for each method. Numerical score, traffic light rating score, time sampling and multiplied score are the scoring system using most of this method. In addition, researcher, occupational safety and health practitioner or ergonomist and supervisor or worker is the main potential user for this method.

Only one method went through reliability and none completes the validity study during the development. It is most important to validate exposure methods with the most existing assessment method but in current condition, it did not show that. MAC showed moderate-good result in both inter and intra-reliability but Back-EST only showed moderate (0.74) for inter-rater reliability.

CONCLUSION

In this study, eleven observational methods to assess risk factor in manual material handling were reviewed. Result showed that from 1991 until 2015, there are eleven current published methods which still have limitation with specific work task. Although the selected methods have been tested for their reliability, they are not tested on their validity. It is also shown that no single tool covers wide range risk factor in assessing MMH. In conclusion, the findings of this review will benefit researchers in the process of understanding risk level of postures in workplace. Furthermore, it should be considered if it is possible to expand the observation methods with complete conduct validity and reliability test during the development. However, important wide range risk factor in manual material handling work should be identified early. Future work will also investigate individual, work organization and psychosocial as determinants for the suitability of this exposure assessment method.

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