

A Review on Ergonomic Risk Assessment Tools for Manual Material Handling Tasks in Industries

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Abstract—Manual material handling tasks are unavoidable in almost every industry. Generally, these type of activities or tasks were performed repetitively, for longer duration in awkward postures without proper break schedules by workers which leads to work related issues (WMSDs). Instead of avoiding those tasks prevention is the primary thing in every sector. This review gives an organized overview of risk assessment techniques in various industries and identified the gaps in the study. This review tabulated the literature from recent years to past. This study identified various factors effecting the workers' health and safety, most of factors are showing negative impact on workers' health and causing them MSDs, Major musculoskeletal disorders are related to trunk followed by neck followed by shoulders and legs. Most of the studies included surveys, observational and direct methods as risk assessment tools and suggested some ergonomic interventions. Hence studies suggest that continuous risk assessment should be present in-order to mitigate worker related issues and to reduce claims related to WMSDs.

Index Terms— Risk assessment, Manual material handling tasks and Work-related Musculoskeletal Disorders (WMSDs).

I. INTRODUCTION

Musculo skeletal disorders are the injuries or the disorders related to the muscles, bones, joints, spine etc. If these disorders are caused due to work related issues like repetitiveness of same activity for long hours, pace of the work, forceful exertions, awkward postures etc. then these are said to be work-related Musculo skeletal disorders. Workers who perform manual material handling such as lifting, carrying, lowering etc., tasks and heavy workloads etc. are more prone to WMSDs most of the times they are involved in performing multiple material handling tasks, which leads to fatigue, pain and injuries in workers. These may affect the workers daily life where they need to stay in homes for some days, if the disorder is severe then some may take months and some may take years to get covered. Due to these sometimes companies need to pay compensation costs for the workers due to occupational hazard. Even after automation in majority of the industries they are not able to avoid manual tasks, they are still common in many industries and which leads to increase number of claims regarding musculoskeletal disorders and their resulting cost. Taking into consideration of health and welfare costs of workers all industries should compulsorily have policies to reduce or minimizing work related risks (WMSDs). Most prevalent among all Musculo skeletal disorders are low back, neck, knee, shoulder pains which are due to carrying of weight more than their recommended weight limit, repetitive task, uncomfortable postures, without

proper rest periods. To mitigate these problems right appropriate method is to assess the exposure to risk factors in the working environment and conditions. With this objective so many methods have been developed to evaluate the workers risk, all are categorized into three groups 1) Self-report methods 2) Observational methods 3) Direct methods.

II. LITERATURE REVIEW

Almost in each and every industry have manual material handling tasks such as lifting, carrying, pulling etc. Keeping workers health, safety and to run industry safely, OSHA and NOISH have released guidelines for workers' safety. As all works are mostly repetitive and performed in awkward postures so these sort of works indeed require continuous risk assessment in working environment. For ergonomic risk assessment and to mitigate WMSDs (Work related issues) issues, so many researches practiced so many methods or techniques, they have been reviewed and summarized as given below in the table.

Abiola (2020) et al., Studied the importance of risk assessment in construction workers. Cyber-physical postural training system is used for risk assessment in construction workers by integrating wearable sensors [1], virtual reality, vive tracker and machine learning to observe body kinematics. They tested this system on 10 students in laboratory. This study showed that feedback which is provided using an user interface to workers of the postural training system was considered as easy to use and correct their posture. The research also disclosed that the feedback was understandable in learning the risk associated with the posture of a participant.

As studied in the literature Harari (2020) et al., overviewed worker biomechanics during multiple-task MMH [2], and developed a prediction model for the moments acting on the worker's spine and shoulders, and the worker's kinematics, during multiple-task MMH jobs. They carried their research on 20 subjects in laboratory environment. This study revealed that removing and destination or platforms heights are more predominant factor of spinal and shoulder moments and body kinematics.

A study was conducted by Li (2020) et al., on lifting postures collected from human 3.6(human pose dataset) and from laboratory, examines by using the deep learning implementation for Rapid upper limb assessment for posture assessment. Results of this study shows that the proposed method is good for real time risk assessment in on site to mitigate work related issues (WMSD) [4].

In this document by Dianat (2020) et al., examines the, working conditions, musculoskeletal results, working postures among different agricultural workers in Iran [5]. They took data from 40 farms using questionnaire survey and by directly observing their working postures using RULA method by RULA experts. The outcome of this research highlighted the point almost all are farmers posture need an immediate change, improvement of working condition and immediate need for ergonomic interventions.

Kristina M (2020) et al., conducted research on the effect of prolonged seated work on lifting task and on age and sex on lumbar and thoracic angles [6]. They had included 34 participants for this study. This research reports says that prolonged seating shows more effect on older people during lifting tasks and in lumbar and thoracic angles and shows a significant difference in young and older people.

Jeff M (2020) et al., aim is to develop a risk assessment tool to evaluate the trunk flexion angles during sagittal plane lifting task. They developed mobile as tool for approximating the truck angles using a built-in accelerometer in mobile devices. Finally, they concluded that this tool is suitable real time assessments of lifting tasks and easy to operate by any user [7].

Based on the previous literature review Colim (2020) et al., founded that obesity is more frequent in so many workers, in this research they studied the effect of obesity on MSD and their working strategy and posture adopted during work tasks. They had included 16 novice participants (8 obese and 8 non-obese) in the experiment conducted in laboratory environment. From the results of this study they observed that obese people are more prone to MSDs than the non-obese people and they also suggest that ergonomic interventions should also consider obesity factors [8].

Several methods were proposed or used for risk assessment of construction workers, basing on those methodologies' limitations, in this research by Yu (2019) et al., has developed a non-intrusive method to assess the risk of construction workers [10]. For this they have used computer vision-based 3D motion capture algorithm using captured by RGB camera. The developed tool is showing good results for physical fatigue assessment for construction workers and increases the understanding of physical fatigue in tasks and the method is also able to predict the 3D joint locations of workers with minimum error.

Barim (2019) et al., want to improve the Revised NOISH lifting Equation by incorporating personal characteristics like L5/S1 Intervertebral Disc (IVD) cross-sectional area, age, gender and Body Mass Index (BMI). Results of the study showed that there is an improvement in risk assessment than the previous NOISH

lifting equation and also showed that IVD cross-sectional area factor had showed good improvement in results than the other factors [11].

From the previous studies Norasi (2019) et al., noted that variability in truck kinematics in repetitive tasks is one of area where most of the researches didn't explore so they considered the truck variables (average and peak velocity and acceleration of trunk) [12]. they also consider independent variables like weight of load, height of lift. This study revealed that starting height affected the trunk kinematics and ground reactions and there was no significance effect of load weight on truck kinematics.

The recent study by Harari (2019) et al., compared pace and kinematics and spinal moments of single task and multiple tasks in manual material handling tasks [13]. They found single task and multiple tasks showed a significant difference in subjects' pace, kinematics and spinal moments and they also found that tasks in multiple tasks are performed individually have a limited ability to predict variables during the multiple tasks.

Li (2017) et al., examined the workers muscle activity and assessed the muscle fatigue development for labor intensive tasks in construction works. For this they have used surface Electromyography(sEMG) and they also evaluated muscle activity by developing human body model and compared with sEMG results. In this study results showed that sEMG are good at evaluating muscle activity and muscle fatigue development and they also found that the developed human body model able to measure muscle activity and some more parameters [14].

Several methods were reported in the literature to address the risk assessment in manual material handling tasks Vignais (2017) et al., studied and analyses the challenges of risk assessment in material handling tasks in biomedical material manufacturer [15]. They had included 5 experienced workers and measured their neck, Trunk, Wrist, upper and lower arms angles with the help of IMUs, Electro goniometer, Camcorders and analysed the posture by using RULA. This study is also able to observe and analyse even the sub tasks and their posture related issues and also observed that in most of the subtasks their posture requires a immediate change.

Manghisi (2017) et al., incorporated a methodology for the risk assessment in working conditions. For this they have used a semi-automatic RULA evaluation software and motion was captured by using a Kinect V2 depth camera. This type of assessment improved the detection of critical condition in less time and they also highlighted the risk assessment with RULA by comparing with other techniques [16].

As reported from literature review constructions are facing health issues majorly due to work related musculoskeletal disorders so in this study by Antwi-Afari (2017) et al., [17] studied the effect of repetitive lifting tasks and weights they handle and posture on spinal biomechanics. To assess spinal bio-mechanics they used sEMG tool. Results showed that increase in lifting weight resulted in increase in sEMG activity of muscle and more prone to muscle fatigue development and also suggest that lifting postures, number of repetitions of tasks and muscle activity may increase the risk of developing WMSDs.

A research by Coenen (2017) et al., studied the effect of abdominal bracing on trunk muscle activity and body kinematics. They have conducted an experiment in laboratory on 14 participants [18]. Experimental results showed that there is decrease in muscle activity when compared to normal lifting with lifting with bracing.

Purpose of this research by Plantard (2016) et al., is to validate the risk assessment method [19]. For this they have used collected data with Kinect tool and modified obtained data using corrected Kinect data in laboratory conditions then they evaluated RULA score and compared with the RULA score by experts. Study revealed that Kinect is a good tool to evaluate ergonomics in working environment and also evaluated RULA grand score even in the environment with many obstructions.

Sarkar (2016) et al., overviewed the postures adopted by the workers during heavy manual material handling works and rate of MSDs occurs [20]. Results in the current study says that musculoskeletal disorders are more frequent and more reported in material handling workers, lifting task have more chance of getting back related issues and this study also suggest some ergonomic interventions which reduces the work-related issues and improves workers health.

From the previous studies M Basahel (2015) observed musculoskeletal issues are major health problems in majority of the workers [21]. He examined the effect of manual tasks on MSDs and evaluated the awkward postures with RULA and self-reports. Results of this study shows that lifting tasks impact more on body motions than any other material handling tasks mainly leads to low back pain and also highlighted risk assessment with RULA method.

Jiahong Song and Xingda Qu (2014) investigated asymmetric lifting activity and age-related issues and biomechanical differences [23]. They observed that older people are adopting safer techniques than the younger people and this study also suggest that older people require physical exercise to increase the limit of body segment parameters and younger people should be suggested with safer techniques. All this work was summarized in table I.

TABLE I. SUMMARY OF LITERATURE REVIEW

Reference	Study parameters	Focus	Gap	Findings
Abiola (2020) et al.	WMSDs in construction workers.	Creating a training environment for with use of cyber-physical training system	Construction workers were not included in the study	Feedback system helped the users to understand the risks associated with participants' posture.
Harari (2020) et al.	Risk assessment on manual material handling workers	They focused on biomechanical factors and kinematics of workers during multiple (MMH) tasks	Various MMH tasks were not included in this study.	Platform height is influencing more on spinal and shoulder moments.
Yang (2020) et al.	Occupational hazards due to MMH in manufacturing industry	This research examines 236 registered occupational incidents in vehicle manufacturing industry and conducted risk assessment	incident rates reported in this study may display a lower frequency rate	Low back pain is the most prevailing MSD among all MSDs
Li (2020) et al.	Real time risk assessment for WMSDs of MMH workers	to develop an efficient, robust, and practical method to automate RULA assessment to analyse body segments.	With more amount of data and variety of postures we need use for training the model to improve accuracy of the method.	RULA is a good tool for the real time risk assessment and to mitigate WMSDs in workers.
Dainat (2020) et al.	Evaluate the working postures and MSDs in agriculture workers	Data were collected using questionnaire and postures were analysed by RULA experts		Ergonomic interventions are required immediately to improve the working posture
Kristina M (2020) et al.	Prolonged seating effect on lifting task in workers.	Investigate effect of prolonged seating on lifting task and impact of age, gender on body segment angles	Remaining MMH tasks can also be tested.	Older people show significant difference in lumbar angle limit after prolonged seating.
Jeff M (2020) et al.	Evaluating lifting task in workers	Develop and test tool for quick evaluation of trunk kinematics	Not able to measure Trunk angles other than sagittal plane.	Developed tool is able to analyse lifting tasks in real time and is good at calculating trunk angles.
Colim (2020) et al.	Evaluating Kinematics in vertical handling task.	Analyse and compare the strategies and posture between obese and non-obese workers.	To understand the problem more clearly more no of tasks can be included	Ergonomic interventions and work place re design must also consider obese people also.
Yu (2019) et al.	Considering occupational health and safety of construction workers.	Develop a model to provide physical fatigue level assessment during the working process	Real time risk assessment was not considered in this study	Developed method could provide Joint level physical assessment and experiments showed this is a potential method
Barim (2019) et al.	Improve the revised NOISH lifting equation	Study the impact of incorporating personal characteristics into NOISH lifting equation		Overall performance has been increased by incorporating personal characteristics.
Norasi (2019) et al.	To understand the risk of low back injuries in work place	Evaluate the effects of starting height and load weight in kinematics of the body	Considerable weights were not taken in this study	Starting height differences show effect on kinematics of the body
Harari (2019) et al.	Study on body kinematics and spinal moments in manual material handling tasks	Study and compare the spinal loading, kinematics and workers pace between single and a combined task	Wide range of subjects were not included	evaluating each tasks of combined tasks separately to know the kinematics have limited capability to predict the kinematics in combined task.
Li (2017) et al.	Examined the labour-intensive tasks in construction.	To assess the muscle force and muscle fatigue development.	They didn't check in the real time environment	sEMG is capable of assessing muscle activity and muscle fatigue development.
Vignais (2017) et al.	Ergonomic risk assessment on manual	Analyse the body segment angles and their posture	Time spent in that posture cannot be determined by	Analysis allowed to recommend ergonomic

	material handling tasks	using RULA method	using this method	interventions for redesign of workstation.
Manghis (2017) et al.	Study on work related issues	Risk assessment in the posture by using Kinectv2 sensor by integrating RULA method	Hand tracking is less effective.	RULA method is good tool for risk assessment of awkward postures.
Antwi-Afari (2017) et al.	Evaluating WMSDs for construction workers.	Study the effects of repetitive lifting, weight on spinal biomechanics	Study only considered lifting activities remaining construction activities were not explored	number of repetitions of tasks and muscle activity may increase the risk of developing WMSDs
Sarkar (2016) et al.	Evaluating Awkward postures in MMH tasks	To investigate the postures adopted during heavy load handling and the frequency of MSDs among MMH workers	Didn't include non-experienced workers	MSDs are more frequent and highly reported in heavy load MMH tasks
M Basahel (2015) et al.	Examine the effects of awkward posture	Evaluate the effect of lifting and pushing tasks on MSDs	Biomechanical effects are not evaluated.	lifting task highly significantly impacted low back pain

III. DISCUSSION

Based on published papers and journals, conferences and magazines, the review process was carried out. From the literature distributed through numerous journals, published papers and conferences, it was noted that most of the works are related to manual material tasks in all most all industries. Most of the studies and the literature showed that researches were related to risk assessment of manual material tasks in construction sites, manufacturing industries and in super markets. The reason behind this is, workers who are performing manual material handling are more prone to work related issues like work related musculoskeletal disorders, so many cases have been registered or reported due to WMSDs by workers, these types of cases were loss to a company as they have to pay compensation fees to workers as they are occupational hazards. So, in industries in all developed countries which have MMH tasks there by allocating money, developing policies and maintaining a separate section for assessment of risks and reduce those risks and implementing ergonomic interventions keeping in the mind of workers health and Nations are also have standard rules and guidelines for performing these types of tasks by workers.

Among all MMH tasks these are the most prevalent MMH tasks are lifting, Lowering, Pushing, Pulling, Holding, as they perform this type of works repetitively in awkward posture they were affected by MSDs. From the Literature review of past one decade it showed many tools for risk assessments to prevent or mitigate the occurrence of MSDs. All risk assessment tools are categorized into three groups i) subjective assessments: which includes self-reports through surveys, Rating scales and interviews ii) Observational assessments: directly observing the postures and assess the risks in that posture some of the tool are (Rapid upper limb assessment (RULA), Rapid entire body assessment (REBA) etc., iii) Direct methods: in these methods they attach sensors directly to the body to get the coordinates or angles of body segments and some of them evaluate muscles activity, some of the direct measurement methods are Inertial measuring units(IMUs), surface Electromyography(sEMG), Electrogoniometer etc., Based on reviewed papers and journals most affected region of body parts are Trunk, neck, Shoulder and legs.

A closer look to the literature on risk assessments by researchers, however, reveals several gaps and shortcomings. All experiments were carried in laboratory environments and the subjects included in these studies were very less, studies are lacking in real time risk assessment. Even after specifying some ergonomic interventions, work place design and modifications are required for risk free work environment. By considering specific case studies researches had developed frameworks for assessing the postures and it is observed that researches are confined to specific tasks and their outcomes.

IV. CONCLUSIONS

Even after industries are trying to automate everything manual material handling tasks are inevitable in industries. Activities done to perform manual material handling tasks in a typical way and for long time leads to worker related issues called work related musculoskeletal disorders. For this review, data were collected related to various risk assessment tools practiced by the various researchers and analyzed efficiency and effectiveness of various risk assessment tools and developments in the past decade. It is evident from the review that variables which is need to be assessed varies from tasks they performed in that industries. From the above study, it is clear that repetitive tasks, awkward postures, handled load, work schedules etc., shows negative impact on Workers

health and safety. Risk assessments have helped industries for providing expected risks in operations or activities done by workers, also its improved knowledge and awareness in workers on risks associated while performing MMH tasks. Industries should have Continuous risk assessment in-order to know the effects and to mitigate WMSDs.

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