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Upper Limb Analysis of Work-Related Musculoskeletal Disorder Among Transformer Industry Worker Using DELMIA

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ABSTRACT

This paper presents the Upper Limb analysis of Work-Related Musculoskeletal Disorders (WRMSDs) among Transformer industry worker using DELMIA Software. This health issue can have a long-term impact on the quality and productivity of production. Therefore, this study is to evaluate the risk level of industrial workers in the assembly of transformer industry using the DELMIA V5R20 software with RULA evaluation. DELMIA V5R20 used to reconstructed working posture and then evaluated with RULA. Result from RULA analysis, find awkward postures were identified to be high risk. Based on RULA observation, the workstation score in action level 3 with grand score mean (6.2), SD (0.42) which is required further investigation and change soon the procedure or workstation design. Finding show, RULA assessment able to detect the risk posture and further improvement should conducted to avoid impact of discomfort and health compilation among worker.

Key words : Awkward Posture, DELMIA, RULA, Assembly

1. INTRODUCTION

Safe working conditions in most small and medium-sized industries (SMIs) in Malaysia are a critical contributor to ideal occupational health[1]. The efficiency of the operations and the quality of the goods in the industry can be improved by occupational health. It is easier for industrial employees to be exposed to body pain and discomfort at work. Occupational risk factors are the most important factors for these health problems and can be seen in any industry[2]. MSDs can degrade the health of the workers and thus reduce the quality of the workers in carrying out their tasks. Nevertheless, since SMI is a highly competitive environment, businesses need to be more creative in obtaining tools to improve performance, handle improvements and facilitate customer demand.[3]

Multiple research indicated that workers ' effects of low performance could have major economic and social implications[4], [5]. Previous studies showed that SMIs that face common hazard in the workplace called musculoskeletal disorders (MSDs) if occupational health is not taken into consideration[6]. Working posture has a massive impact on ordinary life and health issues[7]. Therefore, computer simulation able to integrate the finding with real visual and rapid result from the study[8]. The purpose of this study is to evaluate the industrial workers posture in the transformer industry using the RULA evaluation in the DELMIA V5 R20 software.

2. LITERATURE REVIEW

The Social Security Organization of Malaysia (SOCSO) has reported the severity of workplace accidents due to poor occupational health [9]. The annual reports revealed that industrial workers suffered severe wounds to the head, chest, spine, upper limb and lower limb, upper back and lower back. Table 1 shows a list of injury-related accidents for the years 2014, 2015, 2016 and 2017 reported in Malaysia. The location of injuries is divided into nine categories. For example, the highest category of injury concerned the upper limb and this trend continued for the whole four- year period.

Table 1 : Location of injuries in part body

Location of Upper Limb Injuries	Year			
	2014	**2015**	**2016**	**2017**
Neck	264	224	264	276
Back	2347	2218	2307	2042
shoulder	2987	2781	2728	2780
Upper Arm	53	80	175	109
Elbow	421	313	327	356
Forearm	383	296	386	267
Wrist	1438	1480	1580	1429
Hand	7103	6427	6140	6357
Fingers	8884	8483	8466	7932
TOTAL	**23880**	**22302**	**22373**	**21548**

2.2 Observational Method

A fundamental job function analysis may rely on questionnaires, interviews and video analysis. In addition, various measures commonly known as the assessment tool

can be used to determine the physical risk of work activities, typically unique to a part of the body or a type of work. There are various methods for ergonomic assessment of manual tasks on the market. For example are the RULA, REBA, OWAS, LUBA, QEC, PATH and PEO method [10], The Rapid Upper Limb Assessment (RULA) index is one of the most frequently cited and used methods to assess the ergonomic risk of WMSDs associated with work [11]. RULA is a subjective observational posture analysis approach that focuses on the upper part of the body with special attention to the neck trunk and upper limbs [12], [13]. Observational approaches based on videotaped work tasks to evaluate different types of manual tasks with certain tools are now commonly used due to their practicality and affordability [14]

2.3 Digital Human Modelling (DHM)

Another alternative when designing a new project is to use virtual human models (DHM) for ergonomic analysis, by using DHM, motion and posture can be observed, interpreted and visualized in a user-friendly three-dimensional graphical interface. It software often allows designers or ergonomists to incorporate ergonomic criteria on human subjects without the need for direct measurement in the early design process [15]. Several studies have shown that the findings of DHM use with different tools in postural analysis are fairly accurate[16].

Pro / ENGINEER Manikin Analysis, SAMMIE, JACK, CATIA-HUMAN Design and Analysis Tools, RAMSIS and SANTOS are examples of DHM software packages used for ergonomic assessment[17].Through this study, DELMIA software is chosen for RULA assessment method in order to analyze the posture of the selected worker[18]. Table 2 shows the cases of WMSDs invalidity reported in Malaysia (SOCSO, 2017). The number of cases reported increased drastically from 708 reported 2015 to 1354 cases in 2017. This pattern must be controlled, and effective action must be taken to establish a harmonious and healthy work environment.

Table 2 : Work-related Musculoskeletal Disease (2012-2017)

Year	Work-Related Musculoskeletal Disorders (WRMSDs)
2012	448
2013	517
2014	675
2015	708
2016	1006
2017	1354
TOTAL	**4708**

3. METHODLOGY

Figure 1 below show the steps involved during this research. Detail explanations of this method discussed from step 1 until step 5.

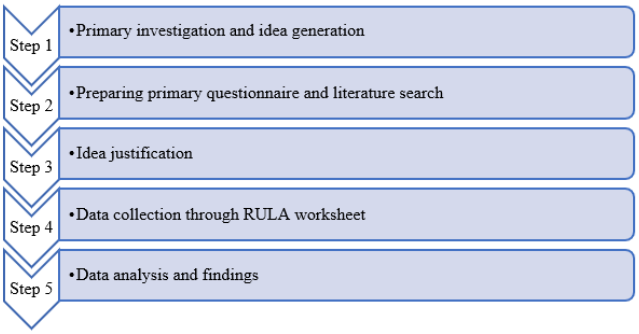


Figure 1: Research frame methodology

Step 1: Study and brainstorm prior research-related information such as forms of musculoskeletal disorders. Search and study on manual material handling and risk factors involved in transformer industry. Idea produced from collecting all the data and selecting the best idea for this study.

Step 2: The questionnaire was then prepared to gather the necessary information and previous literature as a source for this study. Ten questionnaires prepared for ten worker for evaluating and checked for literature review on articles related to awkward postures, risk rate and several more specific journals.

Step 3: The idea gathered from the brainstorming, analysis and questionnaire must be explained either by adding more elements of maintaining the current condition. Moreover, the idea of the methodology to be used in this research was justified and which sectors were chosen as the main target or elements in this research.

Step 4: Data collected at EWT Transformer Sdn. Bhd. by company visit and personal interview done to gather information about their demographic variables and working postures for every ten workers. Data collected using the RULA worksheet and several pictures captured to show the working postures for subsequent analysis.

Step 5: RULA analysis used as to estimate the level of risk for any postures. This provides a quick and efficient assessment of working positions. This analysis resulted in a RULA score resulting in improvements the level of risks of working postures. The action levels gives the urgency of the changes to reduce the dangerous postures of the body to more appropriate and safer condition. the results of RULA were analyzed using of the Statistical Package for Social Sciences (SPSS) version 25 and descriptive statistics were collected and also measured the distribution of frequencies, mean and standard deviation.

4. CASE STUDY

This research was conducted in a transformer industry, under EWT Transformer Sdn. Bhd. located in Nilai, Negeri

Sembilan. This company is one of the vendor or the trusted producer of high-quality, and cost efficient distribution transformers, serving all utilities in Malaysia including the Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn. Bhd. (SESB), Syarikat SESCO Berhad, and the Waterworks Companies.

During the observation throughout this research, manual material handling was identified as the major contributor to occupational risk factor for human which resulting the musculoskeletal disorders (MSDs). Manual material handling (MMH) such as lifting heavy products, reaching materials, bending forward their back when doing tasks, and pushing pulling excessive loads because those tasks require a stable position and large degree of freedom. Pushing and pulling activities are one of the activities for MMH that can increase the risks of back pain problem [20]. In other words, MMH could be defined as the unaided moving of objects, often combined with twisting and awkward postures, and eventually contributing to musculoskeletal disorders.

In the company, ten workstations were identified such as; assembly 1, assembly 2, assembly 3, assembly 4, top yoke 1, top yoke 2, top yoke 3, top yoke 4, transfer parts, and tap selector process in producing transformers that contributed to the highest risk to the assemblers or workers. Fig. 2 shows an example of common working postures oriented by the workers in this company especially in top yoke assembly process.

Figure 2 : Worker needs to raise his arms and bend his trunk to reach the material

5. RESULT

5.1 Description of subjects

Assembly job in produce transformer has been evaluated and assess during this study, total response are 10 workers, the age range from 21 to 54 years (mean 33.3±4.16). The working experience ranges were from less than a year to 25 years (mean 5±4.24). Table 3 shows the demographics of the workers in assembly which is related to the effect of musculoskeletal disorder of their body part.

Table 3:Demographics of the workers in assembly

Job	Age (year)			Working experience (year)		
	Mean	SD	Average	Mean	SD	Average
Assembly workers	33.3	4.16	32.6	5	4.24	5.7

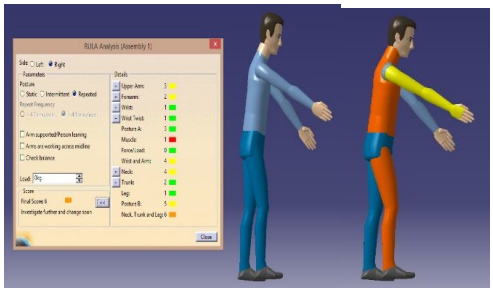
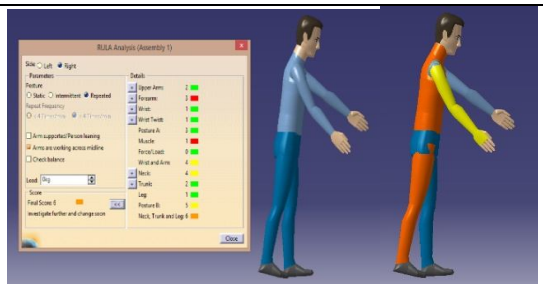
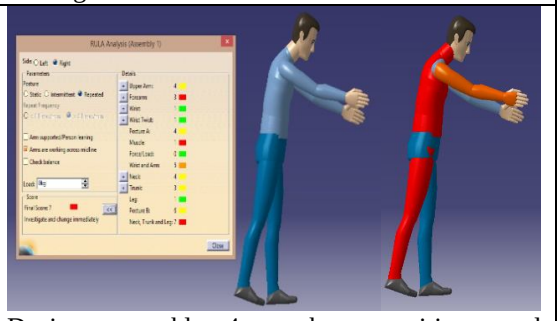
5.2 Result and Analysis

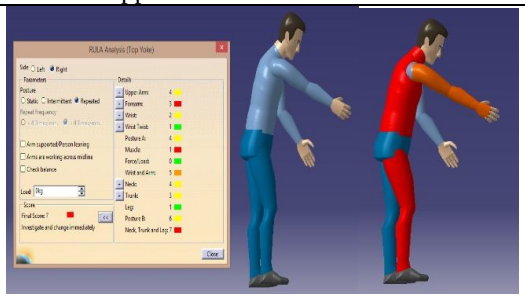
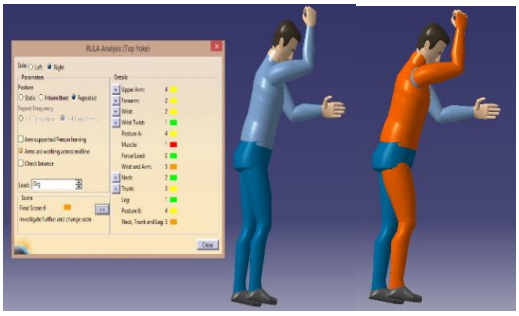
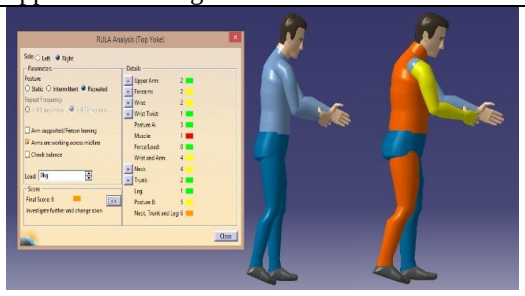
Workers from assembly and top yoke workstations face the highest musculoskeletal disorders (MSDs) due to the value of their final score, risk level and action level obtained from each posture result generated by DELMIA software as shown in Table 4 below. It appears in the norm of the condition of the worker such as working postures, final score and upper limb segment that has exposed to musculoskeletal disorders (MSDs). Finding from the result, show workstation is considered critical. It required immediate investigation and changes to prevent musculoskeletal disorders (MSDs) occur continuously.

Overall Analysis results of all ten positions involved in the RULA review are summarized and shown in Table 5. Each sample produces a difference RULA Grand Score with the highest score is 7 for sample number 4 & 5 because the height of the workstation did not fit to the worker. Therefore, each workstation required further investigation by considering the height of the worker and process to complete this assembly task.

Table 4: Description on working postures and its RULA Analysis in DELMIA Software

Postures	Digital Human Model (DHM)
Assembly 1	 Working cycle during this task, which is to assemble the individual parts into laminated transformer core bundle. From the RULA analysis, it reveals that the posture level is 6 and in orange colour. This means that investigation and changes are required soon. The problem parts are detected in around the upper arm, forearm, wrist, trunk, neck, and leg. Working cycle during this task, which is to assemble the individual parts into laminated transformer core bundle. From the RULA

	analysis, it reveals that the posture level is 6 and in orange colour. This means that investigation and changes are required soon. The problem parts are detected in around the upper arm, forearm, wrist, trunk, neck, and leg.
Assembly 2	 For this posture, worker need to assemble parts of core. At this condition, the worker must take parts from higher parts storage to lower main core frame where the assembly process takes place. From RULA analysis shows that this posture level of risk is 6 and in orange colour. Therefore, investigation and changes are required soon. The problem parts are detected in around the neck, trunk and leg.
Assembly 3	 This assembly 3 is the state where the worker positions the parts into their core frame. This condition occurs the worker to bend their back. RULA analysis shows that the posture level is 6 and in orange colour with yellow colour in the forearm and upper arm. This means that investigation and changes are required soon. The parts of issue are found around the neck, trunk, and leg.
Assembly 4	 During assembly 4, worker transitions and tightens the entire parts of the core frame. This process requires that the worker bend their neck and trunk beyond normal condition. For this

	posture, RULA analysis shows that the level is 7 and red in colour. This indicates that investigation and changes are required immediately. The problem parts are detected around the neck, trunk and leg. It also shows orange colour at the worker's upper arm and forearm.
Top Yoke 1	 Top yoke 1 is when subject starting to arrange parts one by one with same distance from one another. Worker needs to repeat this role for more than ten times for one transformer. RULA analysis shows that the posture level is 7 and in red colour. This means that investigation and changes are required immediately. The leg, trunk and neck are the problems. It also shows orange colour at the forearm and upper arm of the subject.
Top Yoke 2	 For top yoke 2, worker is tapping parts with a rubber hammer as to insert another element into the process. This condition needs worker to raise arm above his shoulder. From RULA analysis, it can be seen that the posture level is 6 and in orange colour. This indicates that investigation and changes are required soon. The problem parts are detected around the neck, trunk, forearm, upper arm and leg.
Top Yoke 3	 Top yoke 3 is the working condition where the subject is setting parts neatly between the primary and secondary winding. RULA analysis shows that the posture level is 6 and orange colour at the

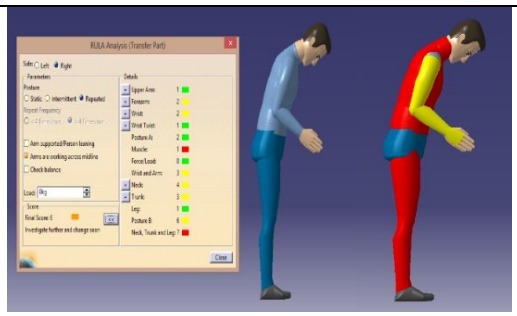
	neck, trunk, and leg. Other than that, yellow colour found at the forearm and upper arm. From the posture level, investigation and changes are required soon.
Top Yoke 4	 During top yoke 4, worker with more height inserting parts into the "closed-core" transformer where the primary and secondary are wound outside and surround the core ring. From RULA analysis, it can be seen that the posture level is 6 and in orange colour. This indicates that investigation and changes are required soon. The problem parts are neck, trunk, leg, upper arm and forearm.
Transfer Part	 The transfer part is the working state where subjects transferring various types of core from forklift to a low storage area. The subject needs to lower his trunk and neck to put the core to the lower place, but this condition is not repeated more than five times a day due to the minimum quantity of parts transferred. The posture level of RULA analysis is 6 but in red colour at the neck, trunk, leg and yellow colour at the upper arm and forearm because it is an intermediate state of work. This means that investigation and changes are required soon.
Tap Selector	 During tap selector, subject is trying to install parts by using screwdriver and regulate the output voltage of a transformer. It does this by altering the number of turns in one winding and thereby changing the turn ratio of the transformer. RULA analysis of tap selector shows that the posture level is 6 and in orange colour. This indicates that investigation and changes are required soon. Around the forearm, upper arm, chest, trunk and foot, the problem pieces are found.

Table 5: Result of RULA Analysis for every workers

Sample (n)	Final Score Part A	Final Score Part B	RULA Grand Score	Sign
1	5	5	6	(iii)
2	5	5	6	(iii)
3	5	5	6	(iii)
4	6	6	7	(iv)
5	6	6	7	(iv)
6	5	5	6	(iii)
7	5	5	6	(iii)
8	5	5	6	(iii)
9	4	6	6	(iii)
10	5	5	6	(iii)
Mean	5.1	5.3	6.2	
SD	0.57	0.48	0.42	

Legend

(i) : Indicates that postures is acceptable if it is not maintained or repeated for long period.
(ii) : Further investigation is needed and changes may required.
(iii): Investigation and changes are required soon.
(iv): Investigation and changes are required immediately.

Source: McAtamney, L. and Corlett, E. N., 1993.

6. CONCLUSION

As a conclusion from this research, it's found that DELMIA as computer-aided analysis software provides a rapid and proven assessment of the loads on the musculoskeletal system of workers due to muscle function, the forces they exert and mostly related with working posture. It function as to examine, score and simulate on the condition or situation of workers that may be exposed to musculoskeletal disorders in the present and future. This computer-aided analysis software fulfills the role of providing a method for screening the whole body and evaluate a large number of workers quickly efficiently. Final score, Mean (6.2), SD (0.42) results show this process required further investigation. Therefore, it also indication of the level of

loading experienced and the level of musculoskeletal disorders risk by the individual body parts. Improvement the height, arrangement workstation design, and body exercise are important in reducing risk levels among workers.

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