ORIGINAL ARTICLE

ERGONOMICS INTERVENTION TO IMPROVE PLASTIC ROLL HANDLING PROCESS AT PRODUCTION AREA IN PLASTIC MANUFACTURING INDUSTRY

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ABSTRACT

Improper working techniques and substandard assistive device usage during manual transportation of heavy plastic rolls from storage to extrusion machine expose workstation operators to occupational health risks in a plastic manufacturing factory. This study focuses on the redesign the existing manual lift table to improve the plastic roll handling process. The procedure was initiated with a workplace observation followed by a questionnaire survey among nineteen operators. The ergonomic risk level was analysed through Rapid Upper Limb Assessment (RULA). The improved design concept of the device was constructed and selected using House of Quality (HOQ) and Pugh method. Statistical analysis from the survey revealed that most operators experienced occasional discomfort (36.0%) at similar pain level (44.3%) at wrist/hands, upper back, lower back, and shoulder mainly caused by difficulty to transfer the plastic rolls using the existing device. This study concluded that the new design of the plastic roll handling device is able to improve plastic roll handling process with the largest RULA score improvement from 7 to 2. Actual fabrication of new design and application should be implemented in order to improve the work posture and reduce the exertion of excessive force.

Keywords: *HOQ, MSD, plastic, Pugh method, redesign, RULA*

INTRODUCTION

Manufacturing industry plays an important role in Malaysia economic growth. According to Malaysia Productivity Corporation (2015), it is identified as the second largest sector, providing 24.7% of Gross Domestic Product (GDP). Along with the rapid growth of GDP, musculoskeletal disorders (MSDs) among Malaysian workers are on the increase. Social Security Organization (SOCSO) (2015) has reported 675 cases of MSDs in 2014, revealing an exponential increase of such cases since 2005. The rise in MSDs resulted in the increasing trend of employees' compensation of occupational diseases from RM2.65 million in 2009 to RM14.05 million in 2014. The substantial financial loss showed that MSDs have a detrimental impact on the nation economic growth.

In most MSDs cases, workers generally experienced discomfort in upper body parts such as neck, shoulder, back, forearm and wrist (Rahman, 2015). The prevalence of MSDs on the different body parts depends on specific tasks in manufacturing process (Sanjog, 2015). According to National Research Council and Institute of Medicine (2001), MSD symptoms generally occurred at lower back (54%) followed by neck (43%) and shoulders (42%). Low back injury scored the highest among Malaysian manufacturing workers at 231 cases between 2009 and 2014 (Rohani, 2016). The study also showed that strenuous movements in manufacturing work were the major cause of MSDs with a record of 232 claims. Work postures such as bending forward and lifting heavy load are common practice in the industry, also leading to high stress level on the back (Zein, 2015). Intensive work load and repeated non-neutral work posture without proper ergonomics training and reliable equipment had similar effects on occupational health among Malaysian manufacturing workers (Santos, 2015).

Most ergonomic interventions involve postural analysis as one of the basic ergonomic analysis to be performed. Common postural analysis tools are Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA). Both RULA and REBA have been used by many researchers in the past (Shah, 2016). These tools were used in manufacturing industry to determine the appropriate action level to be taken

depending on the grand score of evaluated postures (Fazi, 2017). A decline of grand score from before to after ergonomic intervention indicated the effectiveness of improvement made (Kamat, 2017). In those studies RULA and REBA have been very effective and reliable in analyzing work postures quantitatively.

During the production of plastic products, transportation of heavy plastic rolls still requires manual material handling. Without any ergonomic equipment, the operators are susceptible to MSDs, negatively affecting their job performance. The purpose of this study is to redesign the existing plastic roll handling device to improve productivity and workers' occupational health in the plastic manufacturing industry.

METHODOLOGY

The study was conducted at plastic rolls handling workstation at Lum Mah Plastic & Printing Sdn. Bhd., Malaysia with written consent.

Questionnaire survey

A pilot study on six staff members was done prior to the actual questionnaire survey to assess the reliability of the survey using Cronbach's alpha test. The finalized questionnaire survey form consists seven sections from A to G. The first three sections focus on demographic information (Section A), problems and their root causes (Section B), and details of plastic roll handling activities (Section C) such types, frequency and duration of material handling. Section D is based on Nordic questionnaire to find out the impact of work practice on workers' health and discomfort level (Manitoba Aboriginal and Northern Affairs, 2012). Section E concentrates on work practice effects on productivity, product quality, health, safety and production cost to identify the most significant problem. The last two sections consist of requirements of solution to the problems (Section F) and its expectation (Section G).

Data from Section B were dichotomized as agree (strongly disagree/ disagree) or disagree (neutral/agree/strongly disagree) for analyses. Some of the twenty identified root causes from Section B were categorized into three major root causes. Five root causes were selected for analysis. From Section D, levels of discomfort for each body parts were dichotomized into discomfort (discomfort/ pain/severe pain) and no discomfort (no discomfort). The root causes and body parts with levels of discomfort were arranged from highest to lowest in order to develop the bar charts in Figure 1,2 and 3.

RULA analysis

The RULA analysis was performed via the CATIA software where the postures for each workstation were captured and recreated in CATIA software for analysis. Four checkpoints for the RULA analysis were identified, namely pulling the manual lift table with one hand (Checkpoint 1), pulling the heavy and large plastic roll onto the manual lift table (Checkpoint 2), pushing the loaded manual lift table to the machine (Checkpoint 3), and installing the plastic roll into the machine (Checkpoint 4).

Redesign of existing manual lift table

Workplace enhancement suggestions were taken from Section F of the questionnaire as customer requirements for construction a House of Quality (HOQ) matrix. Interview and discussion with the company management board members ensured the practicality of the solution. Important criteria in redesigning of the lift table were determined and incorporated into concept selection method using Pugh method. The selected concept was transferred into CATIA V5 for RULA analysis to study the effect of improvement on work posture.

RESULTS

A. Background information of respondents

Eight variables on respondent background were collected as shown in Table 1. All respondents are male. The majority of them are young workers between the ages of 19 and 25 years old Malaysian or Nepal descendants with 5 to 9 years working experience at the workstations.

The Cronbach's Alpha values on questions with Likert scale namely Section B1 (Problems), Section B2 (Root causes), Section F, and Section G are 0.7463, 0.8674, 0.7128, and 0.7183 respectively. A Cronbach's Alpha value greater than 0.7 indicates the questions are highly reliable and valid for survey (Dunne, 2014).

Table 1 Socio-demographic background

Variables	Category	n
Designation	Manager	1
	Supervisor	3
	Operator	15
Gender	Male	10
	Female	0
Age	19-25	9
	26-29	12
	30-39	4
	40 above	3
Nationality	Malaysian	8
	Nepal	8
	Bangladesh	3
Height (cm)	150-159	5
	160-169	11
	170 above	3
Weight (kg)	50-59	12
	60-69	5
	70 above	2
Working experience (years)	0-4	8
	5-9	9
	10 above	1
Education level	PMR	3
	SPM	5
	Bachelor Degree	2
	Others	9

B. Data analysis

All nineteen operators experienced some level of occupational health issues and eighteen of them agreed that there was low productivity in the workplace (Fig. 1).

From Fig. 2, majority of ninety-five percent of the operators are in consensus that the root cause of the problem is the heavy and large plastic rolls. Poor ergonomics in manual material handling (MMH) and no proper standard operating procedure (SOP) follow closely behind with percentages of eighty-five percent and eighty-two percent respectively. All operators (100%) reported to experience some level of discomfort and pain at upper and lower back, neck, and shoulders (Fig. 3). High prevalence of MSD symptoms was also revealed for thigh (95%), followed by lower legs, ankles/feet, and wrists/hands (89%).

C. Redesign of existing manual lift table

Based on the HOQ (Fig. 4), the highest importance rating for customer requirement is 4.16 where the lift trolley should be designed to reduce excessive force applied. Friction coefficient scores the top percentage importance at 22.15%. Strong relationship was deduced between less force applied and friction coefficient. The triangle roof matrix displays that friction coefficient shared positive correlations to inclination of table, and brake and barrier system. The new design was evaluated to be better than two available designs in the market from the competitive analysis. The new features of the manual lift table include ball transfer table, wheel lock, and table stoppers (Fig. 5). The table height can be adjusted accordingly to prevent workers from bending their backs when transferring any type of load to and from the table.

D. Work posture assessment

Table 2 displays reduction of RULA scores on both sides of the body for every checkpoint in the plastic roll handling and their corresponding action level. The highest RULA score decreases significantly from 7 to 3. The corresponding action level decreases from 4 to 2, which indicates immediate posture investigation and changes were taken to lower risk of MSD. Further investigation and changes are still needed based on current action level of 2.

Table 2 RULA analysis of work posture

Checkpoints	Body side	Before improvement		After improvement	
		RULA score	Action level	RULA score	Action level
1	Right	5	3	3	2
	Left	4	2	3	2
2	Right	7	4	6	3
	Left	7	4	5	3
3	Right	7	4	3	2
	Left	7	4	3	2
4	Right	7	4	3	2
	Left	7	4	3	2

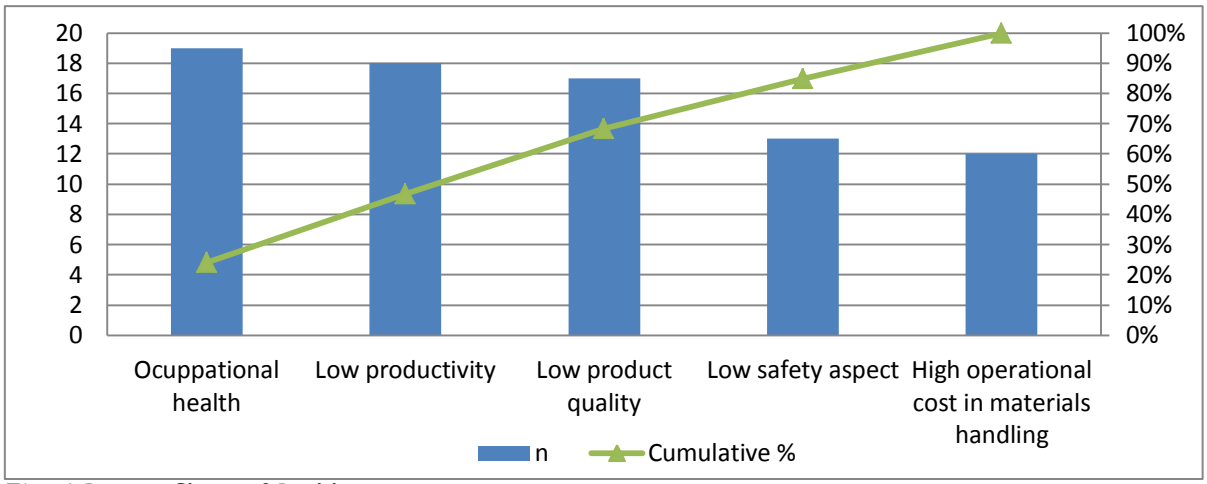

Fig. 1 Pareto Chart of Problems

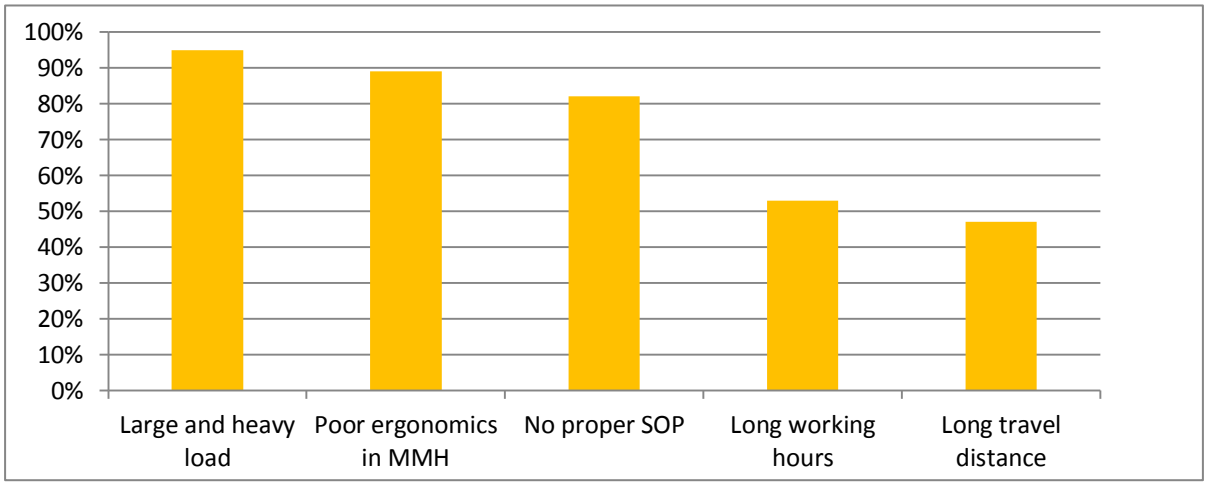

Fig. 2 Percentage of Root Causes

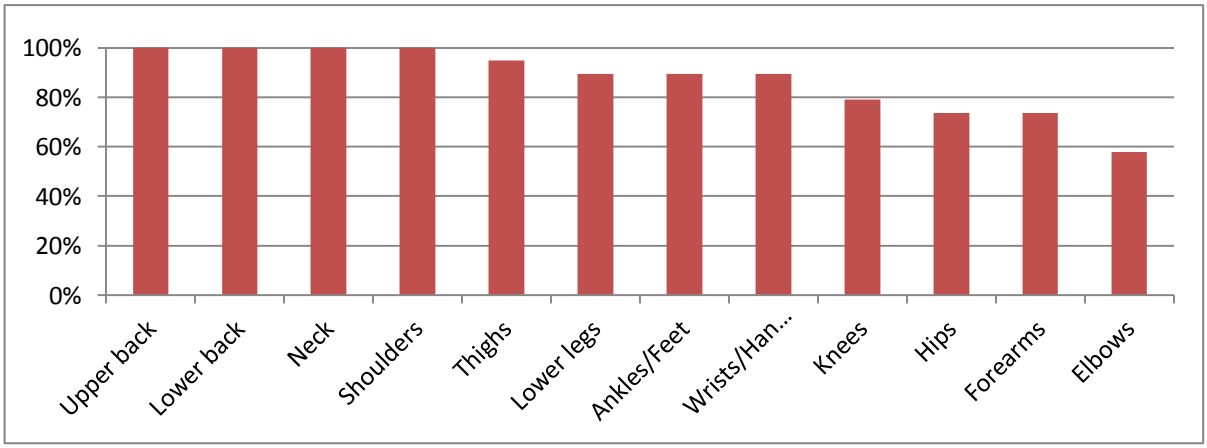

Fig. 3 Percentage of operators' discomfort

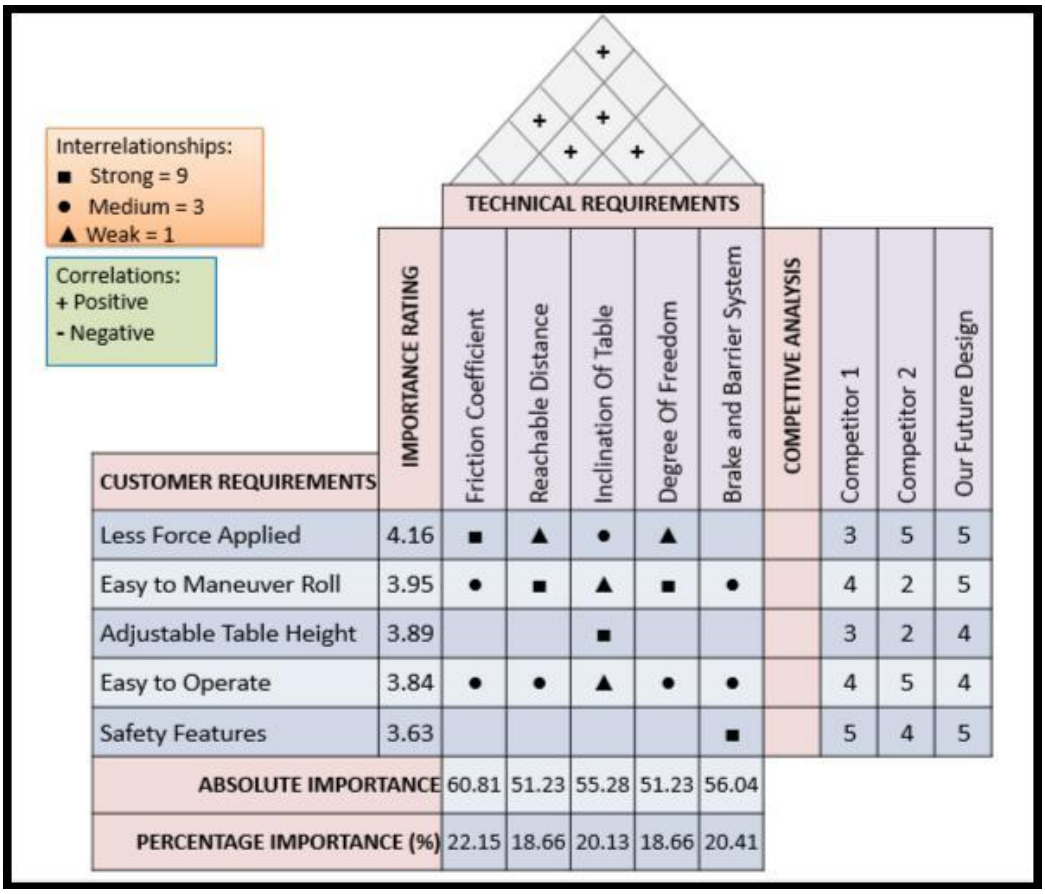

Fig. 4 House of Quality

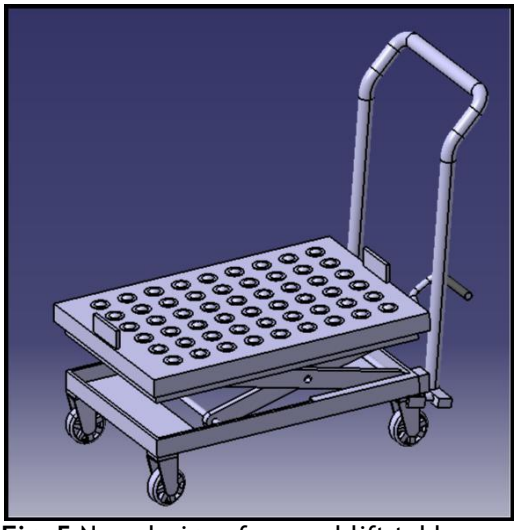

Fig. 5 New design of manual lift table

DISCUSSION

Occupational health issues addressed in this study refers any localized discomfort of varying pain level and frequency on the operator's body sites such as back pain and neck pain. Symptoms of MSD in plastic manufacturing industry are widespread among operators and start at a relatively young age. All operators reported to suffer from some level of discomfort on the upper limb especially lower back, upper back, neck and shoulders. Manual material handling and work repetitiveness are common factors of high prevalence of upper-extremity MSD among manufacturing workers (Fernandes, 2010; Sarkar, 2016). In addition to manual material handling and work repetitiveness, poor workstation design and work posture have been studied to significantly cause MSD symptoms in the same industry (Sanjog *et al.*, 2015; Punchihewa, 2016).

Referring to Figure 1, the second highest problem faced by the company is low productivity. Interview with the manager revealed that the production rate of plastic rolls is 11 plastic rolls per day, considerably lower than the production target of 15 plastic rolls per day. Limited workplace clearance and accessibility due to narrow path in between the pallets slows down the transfer of the plastic roll onto the manual lift table and the manoeuvre of the loaded lift table along the path to the processing machine. Unsafe and unhealthy workplace environment

has been confirmed to impede productivity (Ajala, 2012). The high percentage of low productivity could have a correlation to high percentage of occupational health. High prevalence of MSD has been shown to reduce productivity (Boström, 2008).

Apart from low productivity, low product quality, which is defined by high number of substandard product, produced scrap or rejected output, is the third highest percentage problem. A positive relationship between poor ergonomics and low product quality was found in previous study (Falck, 2010; Zare, 2016). High workload in MMH resulted in high quality deviations due to muscle fatigue and strains from highly repetitive awkward posture reducing job performance during manufacturing process (Ivarsson, 2016).

Low safety aspect encompasses work practices and lack of safety features such substandard assistive device in workstation which could lead to injury. The operators are required to hold the plastic roll with one hand on the manual lift table to lock it from rolling over it whereas another hand on the device as no brake system is installed on it. Most accident causation studies explained that unsafe acts of workers in combination with unsafe equipment and working conditions increased in the likelihood of workplace accidents (Enshassri, 2008; Chi, 2012). The use of proper material handling equipment with ergonomic and safety features could facilitate the manual task while simultaneously reduce workplace accidents and MSD (Patil, 2017).

Lastly, high operational cost in MMH which includes labour cost and machine maintenance cost is the least significant problems indicated by the workers as shown by the chart in Figure 1. Materials handling tasks generally account for 30-40% of production costs (Chan, 2001). Well-designed material handling systems could reduce costs and increase profits. The intervention could be done by integrating ergonomic and economic objectives, which is to improve work postures while minimizing labour costs incurred from occupational injuries and health-related absences (Battini, 2017). A cost-effective ergonomic intervention could improve wellbeing of workers which ultimately increases productivity, revenue, and reduces rejection cost (Sain, 2016).

The biggest issue highlighted by the survey was related to large and heavy loads, followed by poor ergonomic MMH principles and lack of SOP in the workplace related to MMH. The weight of heavy loads varies from 80 kg to 150 kg. Handling large and heavy loads causes force exertions which is a major ergonomics risk factor (Kamat, 2017; Palmer, 2017; Dick, 2016). Forceful exertions can lead to MSD issues such as low back pain (Andersen, 2017; Spyropoulos, 2016).

In order to address this problem, a new manual lift table design was conceptualized through HOQ method. As shown in Figure 4, friction coefficient obtained highest of absolute importance with 60.81 (22.15%) because friction between two contact surfaces will affect the force needed to apply during plastic roll handling process. A well designed lift table's table which can reduce friction between load and contact surface will ease the pushing and pulling task thus minimizes the force applied by the operator. Brake and clamping system is the second highest in absolute importance with 56.04 (20.41%). Manual material handling device should be equipped with safety features such as brake system and barrier system to avoid any injuries in manual materials handling tasks. Manual lift table that have wheel lock and table's stopper will help in loading and unloading plastic roll safely because the lift table trolley have high stability. Besides, the third absolute importance was obtained by inclination of table with 55.28 (20.13%). Lift table trolley can be designed with tilted function to allow plastic roll to be positioned at the most comfortable working height and angle. This design helps the operator installing the plastic roll to the machine holder quickly and easily without lifting, bending, stretching, or reaching. Next, reachable distance and degree of freedom were last two design requirements with same absolute importance which are 51.23 (18.66%). Reach distance and degree of freedom should be considered in designing lift table trolley to allow operator's body movements in healthy zone to minimize awkward or unhealthy positions. By improving the function and design of the lift table trolley, unnecessary movement and unsafe reach distance can be eliminated to allow safe access and circulation space.

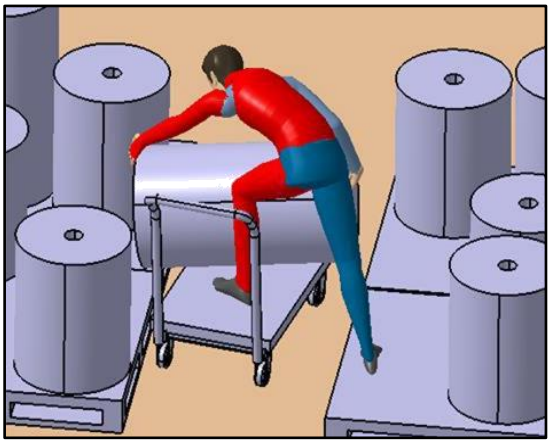

Fig. 6 Work posture at checkpoint 2 before intervention

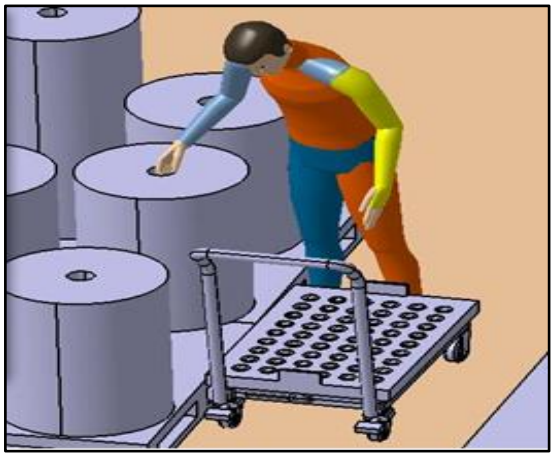

Fig. 7 Work posture at checkpoint 2 after intervention

The final modified lift table design was proposed which contains several features such as ball transfer table, wheel lock, and table stoppers. Ball transfer system lowers frictional coefficient to provide less frictional grip between the plastic rolls and the lift table during loading and unloading (Enoi, 2015; Millet, 2011). The function of wheel lock is to aid installation of plastic rolls from the table and to prevent the device from shifting around during the process. Wheel lock used as a brake system in assistive device has been shown to decrease physical demands of workers (Wiggermann, 2015). Incorporation of stoppers as a barrier system avoids the load from slipping off the table platform during transport (Suhardi, 2016). So this is evident from the RULA analysis for loading the plastic roll onto the lift table. Previously the old lift table did not have wheel lock, therefore workers have to stabilize the lift table and at the same time load the plastic roll onto the lift table. This causes awkward postures (Fig. 6) as shown by the RULA score for the task (score of 7). When the new lift table design was implemented the RULA score was reduced to 5 and 6 for left and right sides respectively. (Fig. 7) The effectiveness of the new design was evaluated through simulated RULA analysis. The new design significantly reduced the RULA scores at all checkpoints in plastic rolls handling and their corresponding action levels as shown in Table 2. The high RULA score of 7 for checkpoint 2, 3 and 4 in the plastic rolls handling before the intervention was the results of non-neutral postures, in which the upper extremity especially the back bent forward with the arms extended forward holding the load and the handle bar of the manual lift table simultaneously. The preference of using dominant right arm caused the right side scored higher than the left side for checkpoint 1 before intervention and checkpoint 2 after intervention. Improper technique of handling the manual lift table at checkpoint 1 before intervention was observed as the operator pulled the device with right arm extending back from the center of body. Pushing the device with both hands properly at checkpoint 1 after intervention lowered and evened out the RULA score for both right and left sides. Equipment redesign and proper handling technique cumulatively have been demonstrated to improve work postures and lowered risk of MSD (Ambardar, 2017; Fingerhut, 2017). Redesign fixes the ergonomic flaws in the existing workstation whereas the proper handling technique ensures workers are performing tasks in accordance to safe standard procedure which minimizes injuries. Operators should be trained to practice neutral postures and avoid previous frequent bending postures which the redesigned device could not address entirely. Training programs and utilization of proper SOP are recommended with redesign of device to increase efficiency of improvement.

CONCLUSION

This study concluded that working in non-neutral postures, absence of proper assistive device and high forceful exertions are the most contributors to ergonomics problems in plastic roll handling process. The redesigned manual lift table concept and the improved handling technique were capable to improve work postures and reduce risk of MSD among operators. Fabrication and validation of actual prototype of redesigned manual lift table using objective measures such as electromyography is recommended for future studies.

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