Chapter 8
Analysis of Working Postures in a Small-Scale Fastener Industry by Rapid Upper Limb Assessment (RULA) Using CATIA Software

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1 Introduction

Workers in industries normally report discomfort in work, leading to the development of musculoskeletal disorders (MSDs) over a period of time, and these are the most prevalent issues in the informal sector (Manzoor Hussain et al. 2019). The work in SSIs is usually manual, basically comprises of repetitive activities involving awkward postures, frequent twisting, stretching, bending, vibrations and contact stresses (Qutubuddin et al. 2013). Several tasks also involve manual material handling, which includes lifting or lowering of loads, pushing or pulling, carrying or moving heavy loads with different kinds of postures (Deros et al. 2010; Boulila et al. 2018; Binoosh et al. 2017; Singh 2010; Kamat et al. 2017; Yadi and Meily Kurniawidjaja 2018). These are some of the signs of developing musculoskeletal disorders over a period of time and may lead to reduced work capacity and perhaps loss of function (Jagadish et al. 2018), if not corrected initially.

It is necessary for both the employers and operators/workers to promote the use of ergonomics in industry. One important step toward this is awareness, education and training. In most of the ergonomic intervention studies, it is observed that workers are unaware of the benefits of applying ergonomics, and thus become prone to various risks (Boulila et al. 2018; Binoosh et al. 2017). Over the decades, ergonomic studies and interventions have been instrumental in increasing overall effectiveness and reducing musculoskeletal disorder risk factors in various occupational settings, especially in small and medium industries (Singh 2010; Jagadish et al. 2018). However, it has been observed through literature that ergonomic studies and postural improvement to reduce risks in fastener industry are very limited. Therefore, the main objective of the study is to find the postural risks in fastener industry to reduce the risk of musculoskeletal disorders and workstation design issues.

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1.1 Postural Analysis

Several studies can be found in the literature on postural analysis by ergonomic assessment methods like RULA, REBA etc. The main purpose of such studies is to eliminate or reduce the musculoskeletal disorder risks and to find any mismatch between the worker and workstation design. Some examples of such studies using RULA are on bus body building industry (Qutubuddin et al. 2013), automotive manufacturing (Deros et al. 2010), mechanical manufacturing industry in Tunisia (Boulila et al. 2018) and in a pump manufacturing industry (Binoosh et al. 2017). Singh (2010) carried out a similar study on forging industry. It can be drawn from various studies that there exists a relationship between the formation of musculoskeletal disorders and awkward postures. The different assessment tools are used by researchers to identify the risky postures, the quantum of risks and recommend suitable measures for reducing the risks.

1.2 Digital Human Modeling as Ergonomic Assessment Tool

Virtual Ergonomics and DHM has rapidly emerged as significant technology in product design, workplace or workstation design among many of its applications (Manzoor Hussain et al. 2019). Many ergonomic evaluation methods are incorporated in software such as 3DSSPP, JACK, CATIA etc. DHM and simulation tools are considered to facilitate proactive ergonomics investigation. The uses of DHM technologies allow the researcher/ergonomist for early identification of ergonomic issues, and thereby reduce/eliminate the need for physical and real human worker testing.

DHM technique gives a 3D visualization of operator doing various tasks/activities and provides guidelines to analyze and design workstation ergonomically (Manzoor Hussain et al. 2019). The functions of DHM are many, such as analysis of posture, push–pull analysis, load analysis, and movement of human manikin in predefined motion, RULA assessment and building the manikin as per anthropometry data. Several studies can be found in literature on the use of DHM and simulation in ergonomic assessments such as (Binoosh et al. 2017) in pump manufacturing, (Kamat et al. 2017) in warehouse of aerospace industry and (Manzoor Hussain et al. 2019) in stone cutting and polishing units. Yadi et al. (2018) conducted a study on chemical industry workers and analyzed the postures using CATIA.

2 Methodology

2.1 Rapid Upper Limb Assessment

McAtamney and Corlett (1993) have developed the RULA method for upper limb risk assessment. It is a simple tool for rapid assessment of the upper limb, trunk and neck. It generates an action level list with a code indicating intervention necessary to reduce the risks of unnatural postures. It provides final posture score, movement and force required. The score are grouped into four levels, of action categories that give an indication when a risk control action should be initiated.

RULA assessment tools consist of two parts A and B. In part A, the upper arm, wrist, lower arm and wrist twist are assessed. The operator's posture is assessed through the photos taken by marking the angles and using a goniometer to measure the angles the different body parts make. Against the observations, the corresponding scores are noted down from the RULA score sheet. This gives the total part A score. In part B, the legs, trunk and neck scores are obtained in similar way. This gives total part B score. These scores are added to the score for any muscle use and force. Corresponding to the scores from A and B, from table C in RULA score sheet, the final score can be obtained. This is the score that determines the risk category and action level. The following Table 1 gives the details of RULA action level, the risk category and a description of action to be taken.

2.2 Preliminary Study

An initial observation and survey of the workplace and work environment are carried out to understand the nature of problems and issues related to the development of work-related musculoskeletal disorders and discomfort among the workers due to posture. Preliminary observations included the understanding of the work methods, compatibility between the work systems and worker anthropometry, getting feedback about pain/discomfort due to unnatural postures and the overall work environment. The study consists of three stages approach; selection of workplace through direct observation and discussions, taking photographs and video of working postures for

Table 1 RULA action level, score and brief description

Action level	Score	Summary
AL1	1 or 2	Indicates negligible risk. Posture is acceptable
AL2	3 or 4	Indicates low risk. Further investigation and change
AL3	5 or 6	Indicates medium risk. Further investigation and change soon
AL4	7	Indicates high risk. Further investigation and change immediate

postural analysis and DHM using CATIA software for risk analysis and ergonomic interventions.

2.3 Digital Human Modeling Using CATIA

In the current work, CATIA is used for RULA analysis of selected postures. For RULA analysis, photos of the posture are taken and converted into a 3D model by CATIA software. For building the human manikin in software, proper anthropometry dimensions are taken into consideration. The relevant standing and sitting body dimensions are fed into the software to build a real like manikin. Using CATIA software a virtual environment is developed. The anthropometric dimensions selected for building human manikin were 50th percentile of Indian population data (Chakrabarti 1997). The 3D human manikin built is an exact replica of the observed posture of worker. In ergonomics design and analysis of the workplace, DHM has been in use over a long time. The benefit of DHM is that it integrates dynamic simulation and ergonomics assessments enabling the designer to visualize the workplace and improve in digital/virtual environment (Boulila et al. 2018; Binoosh et al. 2017). The method for assessing the workplaces in digital environment was first suggested by Chang et al. (2007) to prevent WRMSDs. Other several benefits of DHM include (1) ergonomic assessments can be performed as early in the design process and (2) ergonomic issues/concerns and alternative designs can be communicated (Manzoor Hussain et al. 2019; Chang et al. 2007).

3 Results and Discussion

3.1 Bolt Manufacturing Process

Bolt is a piece of metal rod, whose one end is up settled and threaded at another end. The bolt-making process is a high-speed multi-blow press. First, the straight wire rod is cut into required size for bolt making. Then the MS rod is fed to cold heading machine, which is actually a high-speed multi-blow press, which makes a hexagonal head at one end. There are a series of dies in the heading machine, and the unheaded metal is forced to flow into the dies to change its shape. The machine cuts one end of the rod into required length with cutting stroke and head formation takes place simultaneously at the other end. After that, the material is sent to the trimming machine for cutting the edge of the bolt. Then the bolts are fed into a threading rolling machine for making threads. The finished bolts are polished in a polishing machine. The entire process of manufacturing bolts is shown in Fig. 1.

The round MS coil is fixed into a coil holder, the edge of the rod is ground to be fed into the forging machine. The round MS rods are passed through a set of rollers to make it perfectly straight before being fed into a cold forging machine. The high-speed cold forging machine is fully automated has one die with two strokes, which makes the head shape of the bolt. The round-headed bolts are collected manually from beneath the machine and moved to trimming machine. The next operation is threading in a thread rolling machine, where the bolt passes between two rollers. The bolts are then polished in a polishing machine and then packed for delivery to the customers.

The current work is done in a small-scale fastener industry located in Kalaburagi District. The industry employs about 22 workers, comprising of a manager, supervisor, machine operators and helpers. The industry operates in a single shift. The industry has cold forging machine, head trimming machine, threading machine, polishing machine and a facility for heat treatment. Each machine has a capacity of about 40–90 bolts per minute. The total capacity of the plant is about 400 MT per annum, and the total power required is 90HP. The finished bolts and nuts are consumed in the local and nearby markets.

The workers have explained the purpose of the study and their consent obtained orally. Several working postures were videotaped and photographed for further analysis using RULA technique. Anthropometric measurement of relevant body parts in sitting and standing positions was taken to find any mismatch between the work system design and operators discomfort. Anthropometry measurements are taken to build human manikins for modeling and analysis in CATIA (Fig. 2).

After having the discussions with the supervisor and workers, and by direct observations, some of the major areas concerning awkward postures and prevalence of MSDs were identified. The awkward postures adopted by the workers must be corrected through ergonomic assessment methods and ergonomic interventions

Fig. 1 Bolt manufacturing process

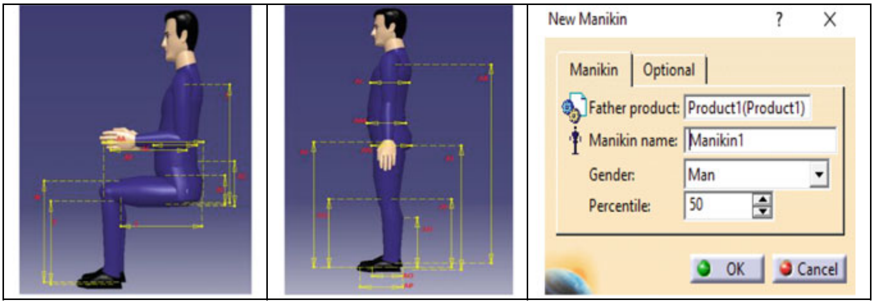

Fig. 2 Anthropometric measurements of sitting and standing posture

either through engineering controls or administrative controls. The focus of the study was the operator's postures at the cold head forging machine and trimming machine.

3.2 Postural Issue at Cold Head Forging Machine (A)

It is observed that one worker is continuously sitting in awkward posture near the machine to lubricate the wire rod, which is fed into the cold forging machine. The main task of the operator is to dip a piece of cloth in oil and wipe the MS rod which is fed into the machine. The frequency of the work is every 5 min for duration of about 10–15 s. In Fig. 3, the details of the build-up to the human manikin in CATIA and the range of motion of different body parts such as upper arm, neck, shoulder and eye sight are shown. Figure 4a shows the existing posture of operator recorded through photograph. The existing posture is modeled in CATIA human manikin and RULA analysis is done (Fig. 4b). The final RULA score obtained was 7, (Fig. 4c) which indicates high risk and needs immediate interventions to correct the posture.

To overcome this drawback, a stand is designed in CATIA with a lubricant container, which can be placed near the machine (Fig. 5a). The flow can be adjusted such that very small drops of lubricant fall on the wire rod, thus lubricating it. A

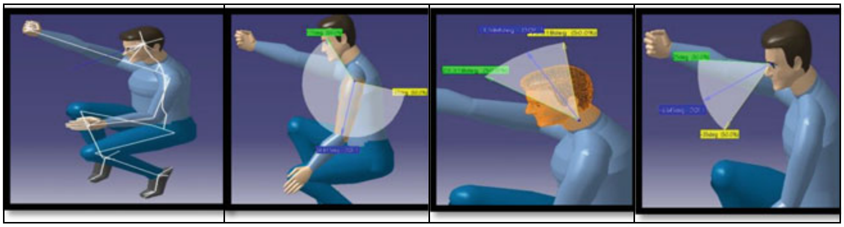

Fig. 3 Range of motion for various body parts for posture in CATIA analysis

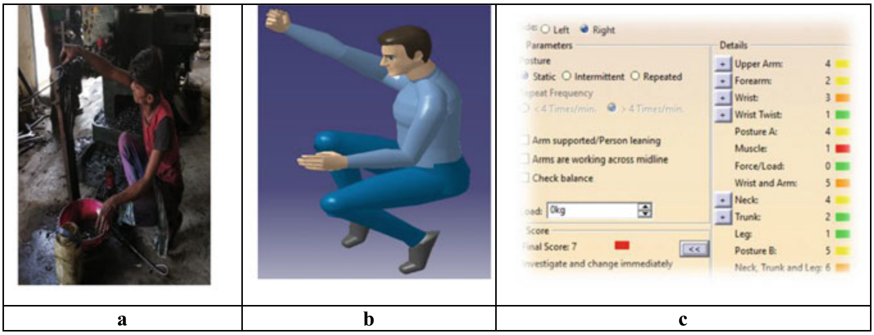

Fig. 4 Existing posture (**a**) and modeled posture (**b**) in CATIA and RULA score (**c**)

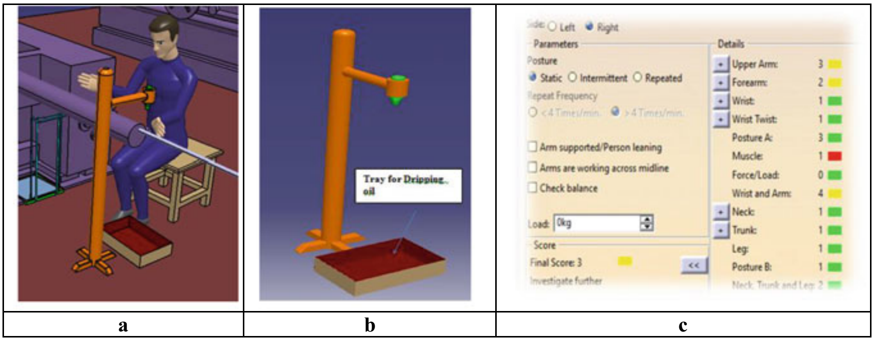

Fig. 5 Improved posture (**a**) and ergonomic intervention for lubrication (**b**) and RULA score (**c**)

small tray is placed on the floor to collect the dripping oil and avoid spillage on the floor (Fig. 5b). A sitting arrangement can be made for the worker to monitor the flow adjustments whenever necessary. The new worker posture is again analyzed in CATIA simulation using RULA assessment tool. The score obtained was 3, indicating low-risk category.

3.3 Postural Issue at Cold Head Forging Machine (B)

The main concern observed at the cold head forging machine is removing the finished bolts and rivets from beneath the machine. The machines are usually manually operated or semi-automatic, where the manual element is more, material handling is carried out manually. The movement of bolts from cold head forging machine to the trimming machine, threading machine and polishing machine is done manually. The operators use some kind of shovel to pick up the bolts from the floor and put them in a metal basket. The approximate weight of each load is about 10–12 kg. The workers lift the metal basket, carry it over a few meter distances and load it into the next machine. The work involves considerable bending, twisting, working above the shoulders and carrying loads in unnatural postures. This step is repeated frequently.

Figure 6a shows the operators present posture while performing the task of removing the finished bolts from beneath the machine. In the cold forging machine, the bolts fall to the ground and they need to be collected and moved to the next process. Depending on the size of the bolts, the work is performed frequently to remove the bolts before they get piled up. The frequency of activity is every 15 min and duration about 2–3 min. An ergonomic intervention is recommended for this activity.

After analyzing the existing posture and having discussions with the operator and supervisor, a need was felt to design a low-cost intervention, which can improve the work posture as well reduce the manual handling. A simple tray cum trolley was designed in CATIA taking appropriate measurements of available space beneath

a. Existing work of removing bolts	b. CATIA model	c. Existing tool

Fig. 6 **a** Operator removing bolts from the machine with a tool, **b** CATIA model of existing posture and **c** Existing tool used to pull the bolts from beneath the machine

the machine, as shown in Fig. 7. The tray consists of two handles and a locking mechanism to hold it stationary. It is fitted with small wheels at the bottom. The span of the tray is about 350 × 350 mm, and it can hold up to 10 kg of bolts, depending on the size. The operator can push the tray beneath the machine space available and remove it easily without bending.

The forged bolts from the machine fall directly on the tray. Proper cushioning is provided on the base of the tray to avoid the noise of falling bolts on metal tray. The operator can pull the tray once it is full so that the bolts can be removed from the tray. This activity requires very little force and the operator's posture while performing the work is acceptable. This small intervention reduces the risk to the operator's posture. RULA analysis was carried out on both the existing posture and the new improved

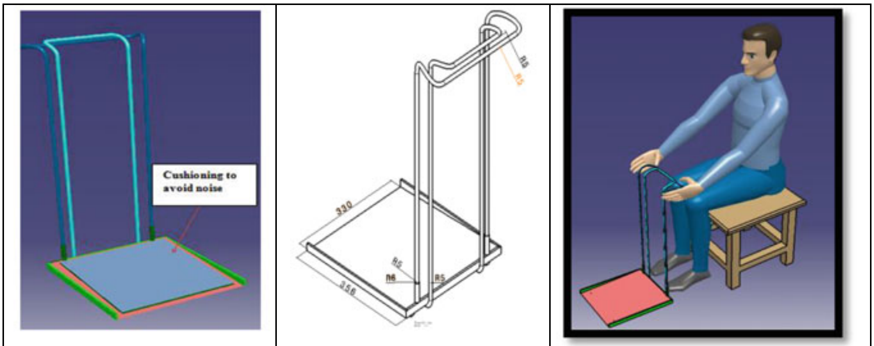

Fig. 7 Low-cost intervention for removing the bolts from beneath the machine

Table 2 Comparison of RULA assessment scores

Posture	Description of activity	RULA score	Improvement	Improved posture score
01	Operator lubricating the MS rod being fed into cold forging machine	7	A simple ergonomic intervention where a lubricant is kept on a stand (Fig. 2a)	4
02	Operator removing semi-finished bolts from the machine using a tool	7	A simple tray with handle is designed. the work simplifies the operator posture	3

posture. The existing posture showed a final score of 7, whereas the analysis on the improved posture with the ergonomic intervention has a final score of 4.

Comparison of the RULA assessment scores for the existing posture adapted by the operator and the suggested improvement score (Table 2). It is seen that small low-cost ergonomic interventions are necessary for the improvement of working postures. As shown in a study by Jagadish et al. (2018), the posture assessment result showed more than 50% of posture under high and very high-risk categories.

Similarly, some of the worst postures of the operators at the trimming and threading machines are modeled in CATIA for posture analysis. The operator has to perform activities like machine setting and adjustments intermittently. This requires the operator to adapt some awkward postures like bending at the back and neck, twisting, turning etc. Rapid Entire Body Assessment (REBA) is carried out to find out the extent of risks prevalent. All the six postures showed the (Table 3) final REBA score of 10, 11 or 12. This shows the operators' posture has a risk from high to very high signaling these postures should be changed immediately to avoid forming of MSDs. The table shows the group A score (comprising leg, trunk and neck scores) and group B scores consisting of arm and wrist scores. The final REBA scores is the summation of group A and group B scores plus the activity score.

In a similar study conducted on forging industry workers in small-scale industry, results of RULA showed about 30% of operators work in high risks due to postures adapted (Yadi and Meily 2018). Several corrective measures were suggested to

Table 3 REBA analysis scores of a few selected postures

Posture	WP1	WP2	WP3	WP4	WP5	WP6
Group A score (neck, trunk and leg)	8	9	7	8	9	8
Group B score (arm and wrist)	9	10	8	6	7	10
Final score	10	11	10	10	10	12
Risk level	High risk	Very high risk	High risk	High risk	High risk	Very high risk

improve postures and reduce the risks of MSDs. In another study by Jagadish et al. (2018) wherein RULA assessment tool was used to identify the risks in SSI workers in traditional industries like Brick industry, Pulse (dal) process industry, Saw Mill and Stone polishing industries. All the studies concluded that more than 50% of operators are prone to developing musculoskeletal disorders as a result of awkward postures. From the current study, another fact came to be known is not using safety and personnel protective equipment (PPEs). In almost every study on ergonomic evaluation or assessment of work place in SSIs, it is reported that no safety devices or protective equipment are used. The proper training and awareness about the benefits of using PPEs are recommended.

4 Conclusion

A case study of a small-scale fasteners industry (nut and bolt manufacturing) is taken up as part of the project. Several unnatural postures were identified at different machines like cold head forging machine, trimming machine and thread rolling machine. The present postures were assessed using appropriate tools like RULA and REBA. The assessments revealed a score of 7 in RULA clearly indicate high risk, meaning an investigation is required urgently and change immediately. Incorporating ergonomic considerations and engineering controls, the workstation was redesigned to eliminate the drawbacks of the present workstation. The improved posture in changed workstation was assessed again and a RULA score of '3' and '4' is obtained, meaning the posture is acceptable. Similarly, some postures were assessed by REBA and indicated high risks. If the postures are not corrected by ergonomic interventions, it may lead to the development of MSDs. Several ergonomic deficiencies were found during the study, and it was recommended to alter the workstations by having small ergonomic interventions. Such changes would definitely improve the workers' posture, increase efficacy and reduce the risks of MSD.

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