Ergonomics risk assessment of postures and design of workstation in fastener industry

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Abstract

Digital Human Modeling (DHM) is one of the important tools used to simulate the workplace for providing ergonomic solutions and improved workstation design. Human manikins are built into software, easily manipulated to evaluate workstation design and prevalence of musculoskeletal disorders. The most common complaints in small scale industries are related to MSDs and mismatch between operator and work station. These issues if not resolved early, may lead to further serious problems affecting the efficiency and productivity. The present work is taken up to study and analyze working posture in nut bolt manufacturing industry by RULA assessment method (Rapid Upper Limb Assessment) using CATIA software. The manufacturing of bolts consists of cold forging, trimming, threading and heat treatment. The awkward/unnatural postures of operators are assessed for risks using RULA. The actual postures are built in CATIA software and possible changes made to show improved postures with low or negligible risks and suggest low-cost ergonomic interventions. Suggestions for improvement and low-cost interventions are based on ergonomic principles and anthropometry. The overall study highlights that working posture risks can be reduced, if proper and timely ergonomic interventions are implemented.

Key Words: CATIA, Ergonomics, Posture, RULA, Musculoskeletal disorder

1.0 Introduction

Workers in industries normally report discomfort in work and develop Musculoskeletal disorders (MSDs) over a period of time, and these are the most prevalent issues in the informal sector [Manzoor et.al.2019]. The work in the informal sector /SSIs is mainly manually done and mostly repetitive in nature with awkward/unnatural postures, frequent bending, twisting of body, stretching, vibrations etc. [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 [Sohail et.al.2020, Veeresh et.al.2022, Sampati et.al.2022, Someshwari et.al.2022]. 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 [9], 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 towards 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 [Atef et.al. 2018, Binoosh et.al.2017, Jagadish et.al.2017, Nikhil et.al. 2020]. In the present situation, the significance of ergonomics is focussed on improving productivity, health, safety and comfort issues in micro, small and medium industries [Aloorkar P. et.al..2021].However, the literature review shows that very few ergonomic studies are conducted in the fastener industry. Therefore, the main objective of the study is to find the postural risks in fastener industry, and address the MSDs and workstation design issues.

1.1 Postural Analysis

Many studies are found in the literature which discusses about the analysis of workers postures by using ergonomic assessment techniques like rapid upper limb assessment and rapid entire body assessment. The main purpose of such studies is to eliminate or reduce the musculoskeletal disorder risks due to awkward or natural postures and improve the workstation. Few papers are referred in the present study like a study on postural analysis in automotive industry (bus body building) [Qutubuddin et.al.2013], on the design of a low cost assembly workstation [Qutubuddin et.al.1013], on posture analysis of workers in sheet metal press work by Sampatibai et.al.2022. Other studies include a posture assessment and risk identification on garment industry workers [Arbaaz et.al.2021] and on small scale bolt manufacturing industry [Nikhilkumar et.al.2020]. It can be drawn from various studies that there exists a relationship between formation of musculoskeletal disorders and awkward postures.

1.2 Digital Human Modeling

Digital Human Modeling along with Simulation has emerged as a significant technology in many applications including product design, workplace or workstation design and layout design. Several ergonomic assessment techniques are incorporated in such softwares like CATIA, 3DSSP and JACK. These tools are considered to facilitate proactive ergonomic assessments. The DHM technology implementation allows the ergonomist for early and easier identification of ergonomic issues, and reduces or sometimes eliminates the need for physical and real human operator testing [Manzoor et.al.2019].

DHM technique gives a 3D visualisation of operator doing various tasks/activities and provides guidelines to analyze and design workstation ergonomically [Nikhilkumar et.al.2021]. The common capabilities and function of DHM include the ability to move the human manikins in predetermined motion, Posture analysis, reach analysis, Push/Pull analysis, and Rapid Upper Limb Analysis and building human manikin according to anthropometry data [Pooja et.al.2021].

Several studies can be found in literature on use of DHM and simulation in ergonomic assessments such as [Manzoor et.al 2019] in Shahabad stone polishing and cutting industry, by [Arbaaz et.al.2021] in small tailoring and garment industry, [Sampatibai et.al.2022] used DHM approach in CATIA to design workstation in aluminium utensils manufacturing, [Someshwari et.al. 2022] demonstrated improvement in workplace and RULA analysis in pulse processing industry and [Binoosh et.al. 2017] designed an assembly work station in submersible pump manufacturing applying DHM approach and showed improvements in RULA score.

2.0 Methodology

The methodology adapted for the work includes**;**

- Initial visit to industry for observation, and discussion with the supervisor and workers.
- Recording the images of work posture with camera
- Ergonomic risk assessment by RULA
- Modeling the actual postures in CATIA for suggesting low-cost improvements

2.1 Rapid Upper Limb Assessment

McAtamney and Corlett (1993) have developed the simple tool named RULA method for upper limb risk assessment, i.e. neck, trunk and upper limb. The tool generates an action level code to indicate the level and timing of intervention required to reduce postural risks. The RULA tool is divided into two sections A and B. In the section A, wrist, wrist twist, lower arm and upper arm are assessed looking at the posture of the worker. In section B, the neck, trunk and legs scores are obtained.
The following Table 1 gives the details of RULA action level, the risk category and a description of action to be taken.

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 investigate and change.
AL3	5 or 6	Indicates medium risk. Further investigate and change soon.
AL4	7	Indicates high risk. Further investigate and change immediate.

2.2 Preliminary Study

The flow chart in Figure 1 highlights the approach to study.

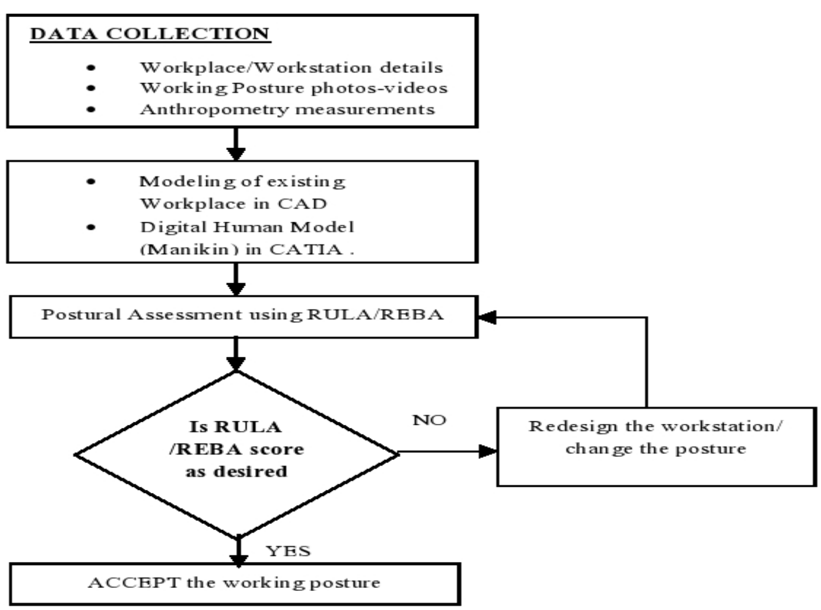


Fig. 1. Flow chart for approach to study

The study consists of three stages approach; Selection of workplace through direct observation and discussions, taking photographs and video of working postures for postural analysis and DHM using CATIA software for risk analysis and ergonomic interventions.

2.4 Digital Human Modeling using CATIA

The present work highlights the CATIA application in RULA assessments. The actual photos taken from the industry are built as 3D models using relevant anthropometry [Qutubuddin et.al.2012] dimensions [Nikhil et.al. 2020, Sampatibai et.al. 2022]. A virtual environment is developed similar to actual workplace/workstation in CATIA [Binoosh et.al.2017, Syed et.al.2021]. A virtual environment is developed in CATIA software. This technique is widely used for ergonomic assessments thus allowing the ergonomists to visualize and design an improved workplace.Some examples from literature on the use of CATIA in ergonomic assessments are quoted here, such as Binoosh et.al (2017) on virtual postural assessment of an assembly of submersible pump in small scale industry, Veeresh et.al. (2022) conducted a study on workers postures in Metal working industries by using CATIA software and RULA analysis, Atef et.al. (2017) conducted a study to evaluate workstations in mechanical manufacturing by using RULA and REBA in CATIA software. Similar studies include Sampatibai et.al. (2022) on Sheet metal utensils industry applying RULA analysis in CATIA. Another study by Someshwari et.al (2022) used the CATIA software and DHM approach to design tools used in pulse processing industry and study the postures. Arbaaz et.al. (2021) presented a interesting study using RULA analysis for postural risk assessments by CATIA software in small scale garment industries.

3.0 Results and Discussion

3.1 Bolt Manufacturing Process

Bolt is a piece of metal rod, whose one end is up settled and threaded at anotherend. The bolt making process is a high-speed multi-blow press. Firstly, 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 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. In one stroke, the wire rod is cut into required length and simultaneously hexagonal head forms at the other end. After that the material is sent to the trimming machine for cutting the edge of the bolt. The threads on bolts are cut by thread rolling machine. In the next stage, a polishing machine is used to polish the bolts, Figure 2.

Fig.2. Bolt Manufacturing Process

The current work is carried out in an informal small scale fastener industry in Gulbarga District. The small-scale industry has 20 workers, including machine operators, helpers and a supervisor. The workers were 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 were taken to find any mismatch between the work system design and operator's discomfort. Anthropometry measurements are taken to build human manikins for modelling and analysis in CATIA (Figure 3).

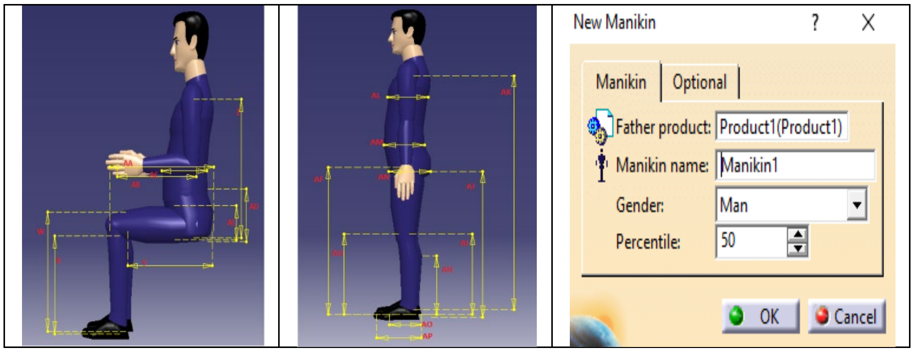
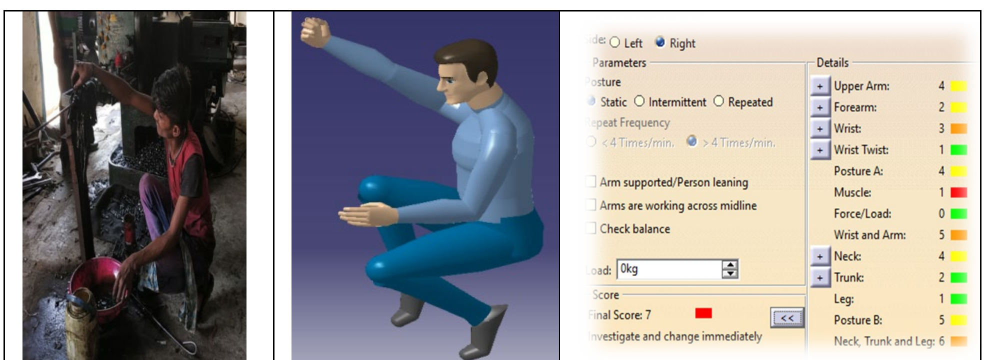


Fig.3. Anthropometric measurements in CATIA of postures

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 study is mainly focused on postures at forging and trimming machines.

3.2 Analysis of Posture 1 at Forging Machine

At the forging machine one worker is sitting on the floor in awkward position for lubricating the MS rod fed into the forging machine for bolt forming. With a cloth/cotton dipped in oil the worker is continuously applying it on the MS wire rod for smooth movement to avoid friction. The work is repetitive every 3-4 minutes and lasts for about 10 seconds Figure 4(a). This image of the worker is built in CATIA (Figure 4b) and analyzed by applying RULA technique for postural risks. The RULA score obtained for the posture (Figure 4c) is shown, indicating a score of '7' (high risk) which requires immediate action to change the posture.

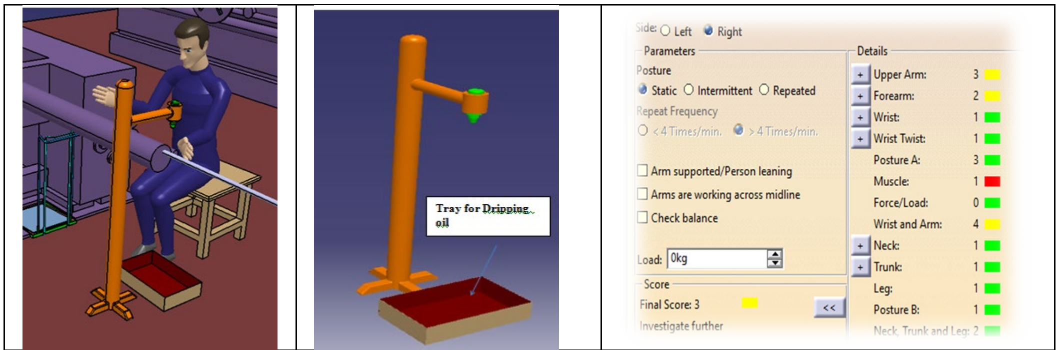


a	b	c

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

3.2.1 Low-Cost Intervention for Improvement

To overcome this drawback, a stand is designed in CATIA with a lubricant container, which can be placed near the machine. The mouth of the oil container is placed just above the wire rod such that small drops of oil fall on the rod. A small container (tray) is placed below it on the floor for collecting the drops of oil and avoids spillage of oil on the floor (Figure 5 b). A seat is provided to the worker thus changing his work posture, and also controls the flow of oil onto the rod as and when necessary. The seated posture is analyzed for postural risks applying RULA. The final score shown is '3' which indicates low category of risks Figure 5 c.

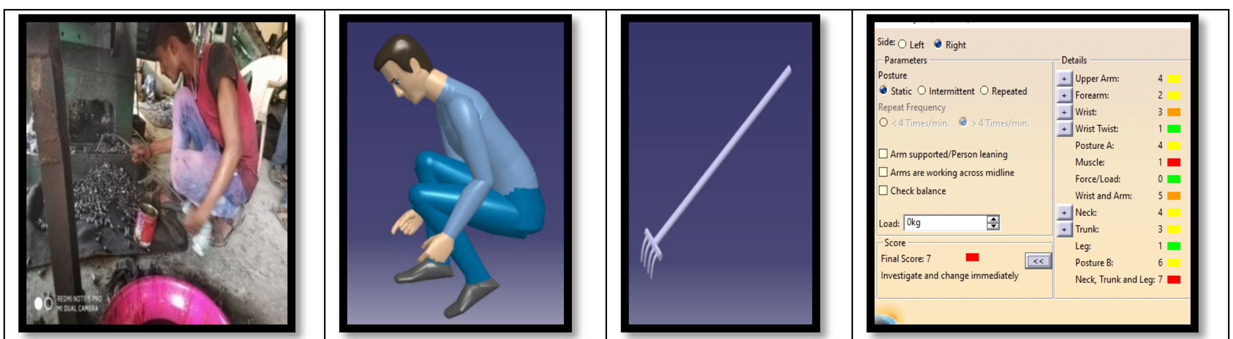


a	b	c

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

3.3 Analysis of Posture 2 at Forging Machine

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 it 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 metre distances and load it into the next machine. Overall, the work is heavy involving unnatural/awkward postures and repetitive. Figure 6 shows the worker's posture. 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 minute and duration about 2-3 minutes. An ergonomic intervention is recommended for this activity.

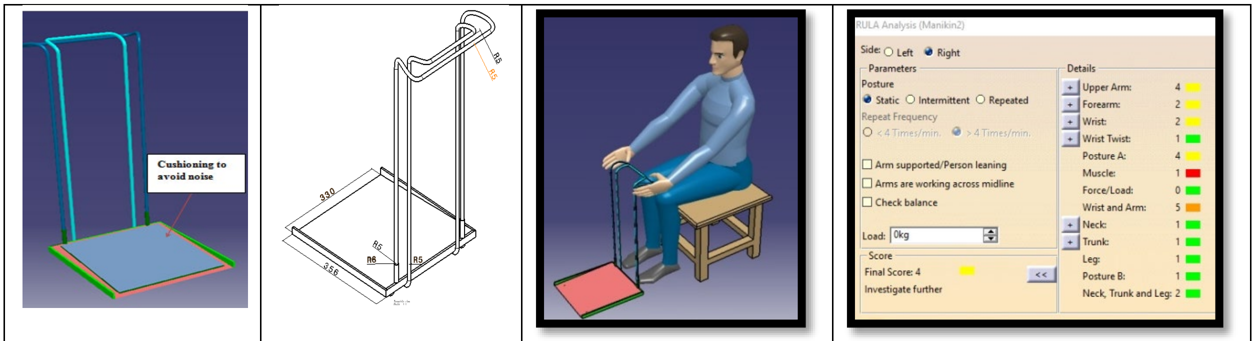


a. Removing bolts	b. CATIA model	c. Existing tool	d. RULA score sheet

Fig. 6. (a) Actual posture **(b)** CATIA model **(c)** Existing tool **(d)** RULA score sheet

3.3.1 Low-Cost Intervention for Improvement

To overcome the existing postural problems and manual handling, and discussing with the supervisor and worker, a low-cost intervention is recommended. Figure 7 (a) and 7 (b) illustrate the designed movable trolley and a bin kept on trolley for collecting the bolts. The movable trolley is designed in CATIA considering the space available under the machine. It has two handles and the wheels can be locked to avoid movement during the time it is placed under the machine. The size of the bin is about 356x330 mm, which fits the space beneath the machine and it can hold up to 12kg of bolts, depending on the size. The operator can push the tray beneath the machine space available and remove easily without bending. Proper cushioning is provided on the base of the tray to avoid noise of falling bolts on metal tray.



a	b	c	d. RULA score sheet

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

The forged bolts from the machine fall directly on the 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. The operators' posture is analyzed by RULA technique. The existing posture indicated a RULA score of '7', suggesting a change n the posture immediately due to high risk. The CATIA designed manikin is also analyzed by RULA technique which showed a final score of '4' suggesting further investigation as the risk is low.

In Table 2 the RULA final scores of the existing work posture and the recommended intervention-based posture shown. It is seen that small low-cost ergonomic interventions are necessary for the improvement of working postures. As shown in a study by [9] the posture assessment result showed more than 50% of posture under high and very high-risk categories.

Table 2. Comparison of RULA assessment scores

Posture	Description of activity	RULA score	Improvement	RULA score
01	Operator lubricating the MS rod being fed into cold forging machine. Figure 5(a)	7	A simple ergonomic intervention where a lubricant is kept on a stand. Figure 5 (b)	3
02	Operator removing semi-finished bolts from the machine using a tool. Figure 7 (a)	7	A simple tray with handle is designed. The work simplifies the operator posture. Figure 8 (a, b & c)	4

In the literature similar studies are shown to have about 30 percent high risk postures in forging industry (Nikhilkumar et.al. 2022). Several corrective measures and low cost interventions were suggested to improve postures and reduce the risks of MSDs. A study carried out by Jagadish et.al. 2018, on workers in small scale industries identified that more than 50 percent postures exhibit high risk category indicating development of MSDs if not corrected early. The present study corroborates with several studies reported in the literature by Aloorkar et. al. 2022, Sohail A et.al. 2022, Sampatibai et.al.2022, Someshwari et.al.2022 and Veeresh et.al.2022, that worker in small scale industries in informal sector are prone to high risks due to various factors like awkward posture, high handling etc. Therefore, it is necessary for the owners, managers and workers in these units to consider applying ergonomic principles to design of work and environment, and reap the benefits of higher productivity.

3.0 Conclusion

The present study was conducted at an bolt manufacturing small scale industry to find out the ergonomic risks and postural issues, which may lead to development of MSDs. Two postures which were repeatedly adapted by operator at the forging machine were selected for study and analysis. At the oiling of the MS rod and collecting the bolts from under the machine, both the postures indicated a high risk of '7'as per RULA analysis, which requires immediate correction and change to avoid further problems. Low cost ergonomic interventions were recommended as shown in Figure 6 and Figure 8. A CATIA model was built with the changed postures and RULA technique was applied to analyze the postures. The scores obtained were '3' at the lubricating station and '4'while removing the bolts from under the machine in improved designed workstation. Thus it is demonstrated that ergonomic interventions are necessary to improve the workstation and reducing the risk of developing musculoskeletal disorders. Similarly, such improvements can be possible at other workstations if interventions are designed and implemented successfully. The recommendations made can be implemented to reduce the risks, improve the productivity and efficiency.

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