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Abstract: Musculoskeletal disorders are the most common issues associated with poor working conditions among industrial workers of small and medium-sized industries of developing countries. This study focuses on the ergonomic considerations that are necessary to prevent and quantify problems or hazards related with MSDs in small scale companies. Analysis of MSDs was preformed through RULA, with a specific scenario of a welding firm that deviates from all these features. The study involved 10 male welders in all. The results showed that no worker received a RULA score of 1-2 (level 1), and that 90% of the workers had a score of 5-7. These findings suggested that adjustments in working postures are required to improve welder safety and comfort. The final RULA score (mean 5.91) emphasize welding workers' poor workstation design on the job. The most commonly reported areas of risk were the neck, shoulder, and lower back (trunk). Awkward posture, long duration, and repetitive activities were all substantial risk factors. The final RULA score drops to mean 2.93 with correct ergonomic interventions subsequently none of these workers have an RULA score of 5 or above, indicating that improved working posture creates less MSDs and is safe to adopt.

Keywords: Musculoskeletal disorders; rapid upper limb assessment; postural analysis; welding

1. Introduction

India is among the countries that is developing rapidly. In comparison to emerging countries, industries of developing countries' face larger occupational risks[1,2)]. Poor working conditions and incorrect postures, several researchers have determined that are the primary factors that contribute to these risks and the emergence of musculoskeletal disorders (MSDs) among the industrial workforces engaged in medium and small-scale firms of developing countries. According to the National Institute for Occupational Safety and Health, there is a substantial correlation between MSDs and working postures[3)].

MSDs caused by poor working postures are a major problem in today's world; therefore, prevention and development are critical; otherwise, it leads to multiple risk factors that can be classified as (physical, psychosocial, and individual), and there is a pressing need to quantify exposure to risk factors linked to MSDs[4)]. Observational and instrument-based techniques are two methods for quantifying discomfort and posture assessment. Instrument-based techniques used devices mounted on persons to capture deviations in body postures.

The observational approach uses perception to calculate the angular departure of a body segment from the neutral position. Due to its inexpensive cost, simplicity of usage, and absence of operator disruption, observational techniques are commonly utilised in industries[5)]. Some of the commonly used observational techniques are Ovako working posture analysis systems (OWAS)[6)], Rapid upper limb assessment (RULA)[7)], Rapid entire body assessment (REBA)[8)], Loading on the upper body assessment (LUBA)[9)], Agricultural lower limb assessment (ALLA)[10)], Novel ergonomic posture assessment (NEPRA)[11)], Task recording and analysis on computer (TRAC)[12)], Posture activity tools and handling (PATH)[13)], Occupational repetitive action (OCRA)[14)], Quick exposure check (QEC)[15)], Upper limb risk assessment (ULRA)[16)], Workplace ergonomic risk assessment (WERA)[17)], Plan for IdentifieringavBelastningsfaktorer (PLIBEL)[18)], Portable ergonomic observation (PEO)[19)], Postural targeting (PT)[20)], Hands relative to the body (HARBO)[21)]]. The analysis of several observational methods showed that they were created with different objectives in mind and, as a result, were used in a variety of professional settings[22)]. Each approach has its own posture classification system that is distinct from the others. The main goals of such assessment tools (observational approaches) are to identify and reduce levels of discomfort/poor ergonomic procedures, which have been shown to have a detrimental influence on organisation / industry productivity, safety, product quality and manufacturing expenses across a range of industries[23, 24].Improving knowledge of possible risk factors linked to the development of MSDs is essential for the development of effective preventative and reduction measures in each specific occupational group.

Several researchers conducted postural analysis on specific diverse occupational groups which includes – construction workers[25], agricultural workers[26,27], hammering workers[28], nursing staff[29,30], supermarket workers[31,32], poultry workers[33], ship maintenance staff[34], soft drinks distribution center workers[35], metal working operators[36], truck drivers[37], carpet mending workers[38], repair and maintenance workers[39], smoothing workers[40], pharmacy packaging workers[41], hospital staff[42] and have shown their relevance for postural assessments and its relation with MSDs.Most of the workers are performing their tasks under poor working conditions which further aids in the rise of various types of MSDs among workers. These illnesses develop in the bodies of workers as a result of improper working environment and repeated tasks[43].

Evaluating workers' work posture in the welding sector is the aim of the current study. Concerns about the health and safety of welders have grown recently as welding is an industrial activity that is believed to be quickly rising in emerging countries. Most of its operations involve manual labour, and many of these tasks include components that increase the risk of cumulative trauma disorders (CTDs). Welders are at a significant risk of developing musculoskeletal illness, including carpal tunnel syndrome, tendinitis, diminished muscle strength, back pain and disorders of the fingers and knees, according to the International Labour Organisation (ILO, 1960)[44]. Posture-related musculoskeletal disorders include heavy lifting, pushing, tugging, gripping, pinching, holding for prolonged periods of time and typing excessively. Although full automation is undeniably the greatest strategy to reducing worker weariness and injury, ergonomic treatments for workers are still important and useful for small-scale businesses due to the high cost of automation.

The principal aim of this study is to reduce the discomfort experienced by welding operators by the use of the RULA ergonomic evaluation tool to reduce WMSDs, or work-related musculoskeletal illnesses. Symptoms related to occupational hazards, as well as to suggest ergonomic guidelines for better working postures. This study also recommends that improved working postures will prevent MSDs caused by incorrect working postures.

2. Materials & methods

The challenges of welding workers employed in the fabrication of columns employing electric arc welding at fabrication sites are the concern of this study. Welding on a fabrication/construction site poses several ergonomic issues. Awkward postures, violent exercise, repetitive heavy work, static load, contact stress, and other extrinsic variables such as excessive temperature from direct sunshine are all common risk factors. The fundamental issue of this study is the ergonomic concerns associated with repetitive activity for long periods of time with excessive bending of the trunk and neck outside of a comfortable range of motion. Welders work in an awkward seated position with little or no support, bending and twisting their necks and trunks. The worker's posture in this study was evaluated using the RULA approach.

2.1 Subjects

The subjects chosen were ten male welding workers from a company in Uttar Pradesh, India, which specializes in the fabrication of columns using welding. A questionnaire was used to acquire the necessary information on personal details and musculoskeletal disorders, which was then mapped on a Nordic body map (NBM) by direct observation. Background information such as name, age, and employment experience were among the personal details recorded. By individual council, investigators described the study's purpose and questionnaire completion process. Workers completed questionnaires during break time that had been set aside for this purpose and returned them to the investigators. Workers' involvement in the research was entirely voluntary, and they were free to leave at any time. The overall self-reported questionnaire took about 30 minutes to complete. Before the study began, the company's management/workers gave their consent for participation in study.

2.2 RULA Score

These real-world images (inclusive working posture) were further modeled for additional study using CATIA V5 software[45]. On the upper limbs, the valid RULA approach was used to assess postural and biomechanical loads. Present study uses scores to assess the posture of several body components. The optimal or most desired posture is represented y level 1, and the poorest posture is represented level 4. Wrist, elbow and shoulder individual scores sum up to A, whereas neck, trunk and leg individual ratings will be included in B. Because of the presence of static posture or highly repeated occupational tasks, muscle utilisation for welding workers has been assigned a rating of 1. Since they are not carrying a heavy burden or handling a 1 kg load (small load) on a regular basis, they received a score of 0 to 2. To obtain scores C and D, these scores are added to scores A and , respectively. The overall score, which goes from 1 to 7, is the sum of scores C and D which indicates the musculoskeletal load associated with the worker's posture. Low grade scores (1-2) suggest that the work posture is suitable (action level 1), while grade scores (3-4) call for investigation. Further a grade score (5-6) action level 3 recommends for immediate change in the posture including it analysis. Finally, for a grade score of 7 (action level 4), urgent modifications are required[37,38].

2.3 RULA validation of working posture

In order to determine the most typical working postures and assess RULA scores for musculoskeletal disorders, welding operators' postures were tracked in real time on the job site [46]. After the postures' durations were noted, it was found that forward bending while gazing down (Fig. 1 and Fig. 2) accounts for more than 70% of the total time. The head and neck angles were measured using an online protractor angle measuring tool (lumbar + back angles) which was determined to be around 55 degrees and 12 degrees, respectively.

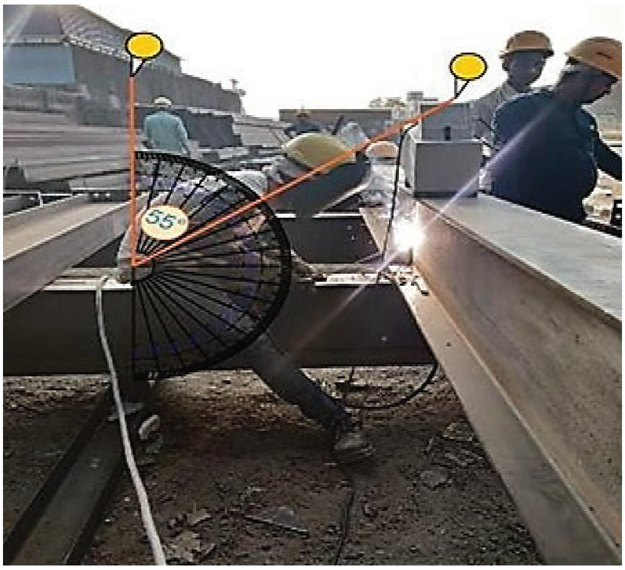

Fig. 1: Bending down posture of welding worker. (Lumbar + Thoracic angle)

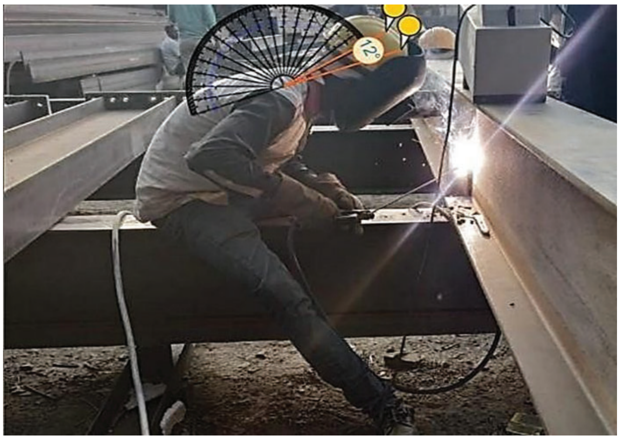

Fig. 2: Bending down posture of welding worker (Head Angle)

These real-world images were further modeled in CATIA V5 software or further analysis. Designing and modeling of working images of worker are shown in Fig. 3 and Fig. 4.. The RULA analysis was used to determine the severity of the posture analysis and is used to determine the risk factors ranging from 1 to 7[47].

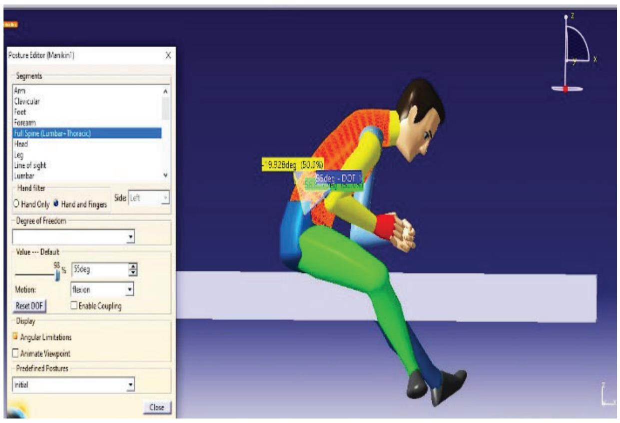

Fig 3: Modeling of bending posture showing back angle

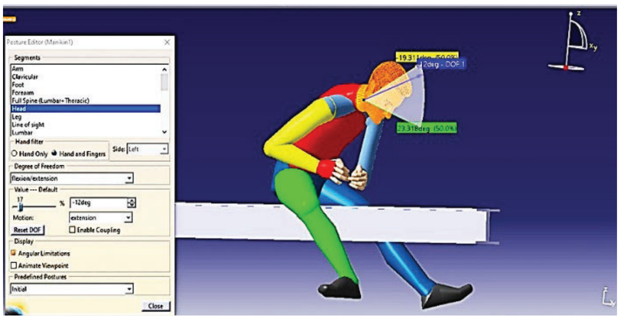

Fig. 4: Modeling of bending posture showing neck angle

3. Results &Discussions

3.1 Subjects

Workers' average age was 30.57 ± 4.54 years old, their average height was 161.78 ± 8.23 cm, and their average weight was 63.17 ± 7.43 kg. At the time of the assessment, the welding workers had an average of 8.29 years of experience.

3.2 RULA Scores

The score report (action level) of RULA analysis of one of the workers is shown tabular forms in Fig. 5. RULA analysis on welding workers (manikins) is conducted on ergonomic analysis workbench on software through virtual welding environment. Manikins can be altered and were used as virtual human bodies having anthropometric dimensions of the industrial workers[48,49] using postures editor commands and kinematics (Fig. 6). The calculated value through RULA score is obtained as 7 which clearly indicate that an urgent change is required in the working postures of the welder to reduce MSDs.

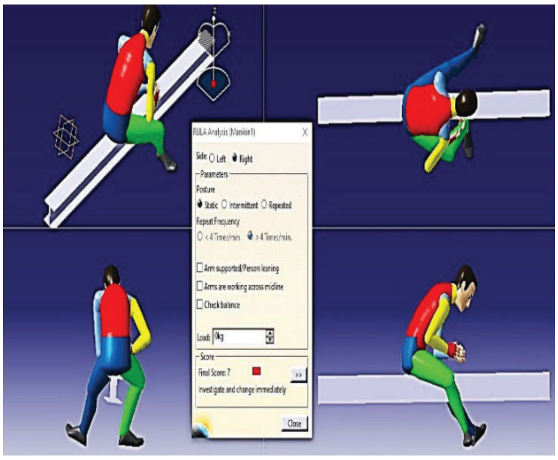

Fig. 5: RULA score of welding workers during bending posture

Further MSDs study (Fig. 7) was carried out for the remaining nine workers, and an overall analysis of the RULA score of 10 welding workers shows that 10% of the workers have scores of 3 and 4 (action level 2), indicating that more inquiry and modifications are needed. Fifty percent of the workers received scores of 5-6 (action level 3), which signifies that change in working postures and more study is recommended for such workers. Action level 4 (score 7) was gained by the remaining 40% of welding workers, indicating that urgent change and adjustments are required. MSD study clearly shows that current working postures do not provide operators with any comfort or safety, and that there is a high risk of MSDs because of these postures. Shoulders, forearms, neck, wrists, trunk, and legs are the body parts that are most susceptible to MSDs.

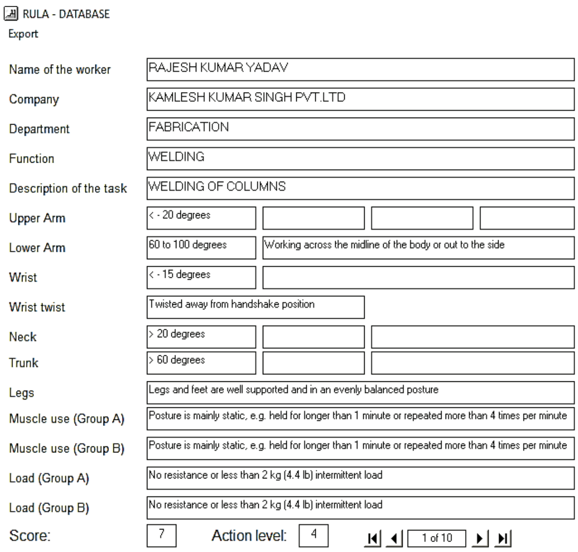

Fig. 6: RULA score =7 for 1 kg static load (right-side) operators

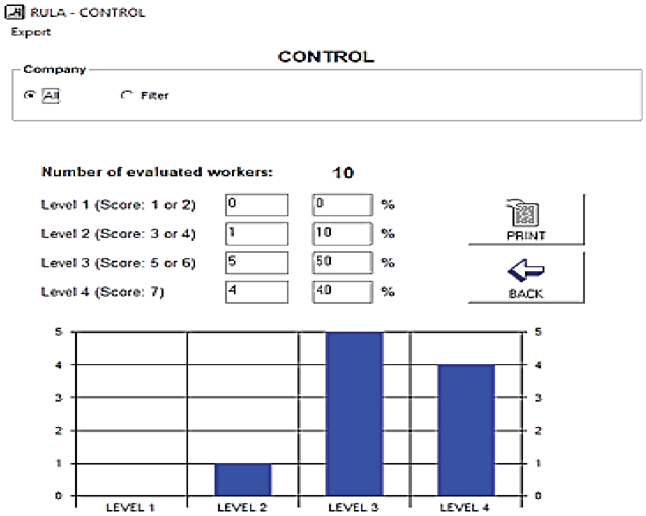

Fig. 7: Action level of MSDs risk versus number of workers

Based on the RULA score assigned to every bodily part, 64.8 percent and 74.2 percent of workers received a score of 5 or above for the neck, trunk, and accordingly. It can also be seen in Fig. 6 by the red colour zone. Scores for the remaining body parts are slightly lower, ranging from 3 to 4. The overall score of 5.91 indicates that the operators' workstation postures should be evaluated and if required postures should improved. It is important to asses operators' workplaces postures more thoroughly and, if necessary modify them. It was observed that no operators in the working condition have RULA score in the zone of 1-2. The RULA score ranged from 3 to 7 for all subjects, with 3 being the lowest and 7 being the highest (Fig. 7). The final RULA grade (mean 5.91) focuses on welding workers' bad workstation design on the job. Therefore, an urgent need is proposed for conceptual framework of quality culture development and interventions in such industry[50].

These results indicate that workplaces and working postures should be redesigned as soon as possible to reduce MSDs. According to this study, workers' posters can be corrected by using adjustable welding supports and benches. The study also recommends utilising ergonomic standards and building a workplace with the right inclination/slope surface.

3.3 Ergonomic Guidelines

The present study suggests that there is very limited awareness regarding the importance of ergonomics and safety in unorganized sectors as well as small scale industries of the nation, workers are mostly uneducated and do not consider MSDs as the major issue in their health issues. Since MSDs are a major concern therefore there is a huge need to properly implement ergonomic guidelines in any organization to reduce MSDs among the work forces. This will further help the organizations/industries to increase productivity with better quality products. This study deals with the welding workers and their working postures it was concluded that working postures are directly related with occupational injuries. The guidelines are arranged subject to the Occupational Health and Safety Association (OSHA) for welding directly to give propositions and help decline the uneasiness of operators. Simplified procedures using RULA for discomfort identification among welding workers and necessary standard ergonomic guidelines are proposed and demonstrated to reduce MSDs. It is also recommended to arrange or prepare suitable workbenches which can minimize such issues. In view of the fact that people are the most valuable resource for any industries, appropriate policies should be put in place to ensure the performance, growth and well being of operators or workers. Industries that match effectively with their human resource will do well[51,52)].

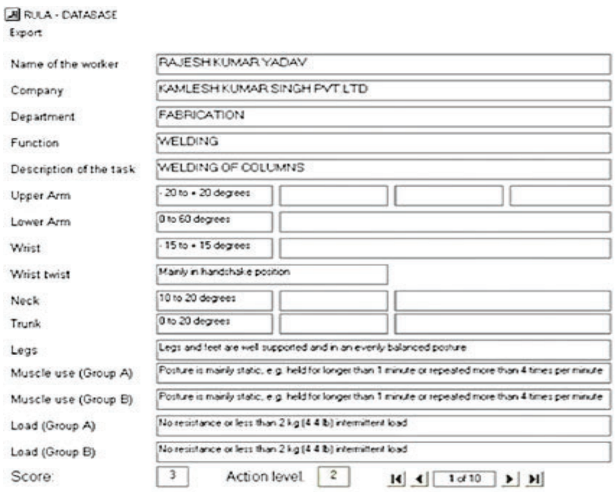

Fig. 8: RULA score after implementation of ergonomic guidelines

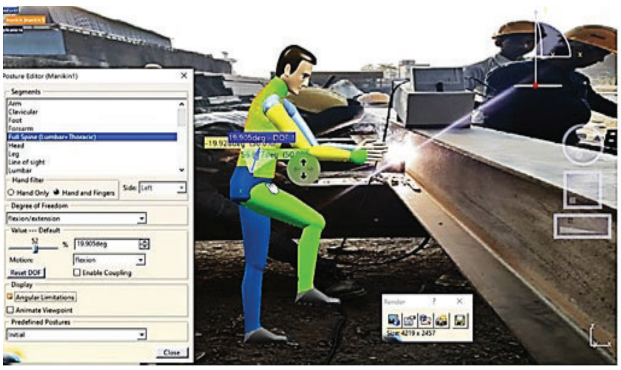

Fig. 9 (a): Visual 3D posture in correct position

Fig. 9 (b): Visual 3D posture in correct position

3.4 RULA analysis of correct posture

After reducing the angle of neck by 20^0 and making the assistance with two legs Fig. 8 illustrates how using ergonomic standards reduces pain. For ergonomic comfort and safety, the RULA score is lowered to a low of three (3) low score for ergonomic comfort and safety (Fig. 9 (a) and Fig. 9 (b)). It was observed that the risk level is reduced to 2 for almost all workers (Fig. 10) which indicate sound working conditions. Figure 10 shows the analysis of an improved RULA control graph for 10 workers.

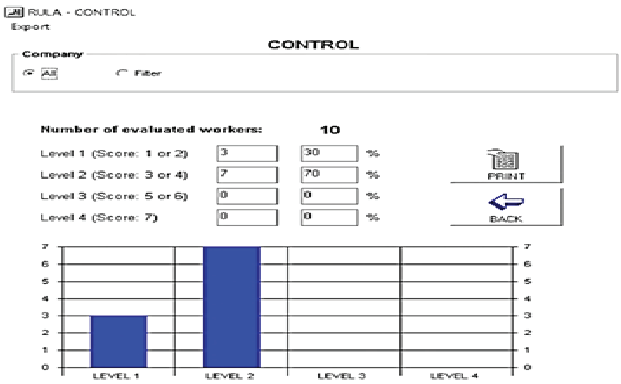

Fig 10: RULA Control graph for corrected posture

This analysis of 10 workers shows that after improving the postures of workers their discomfort levels are reduced and 70 % of the workers fall in the category of risk level 2 (RULA score 3 or 4) which indicates changes may be required and 30 % of the workers are in the risk level 1 (RULA score 1 or 2) which means good working posture (Fig. 10). The final RULA score (mean 2.93) emphasize that working posture produces minimum MSDs and it is represented by safe colour zones in Fig. 9(a) and Fig. (b).

4. Conclusions

In the welding industry, there is a lack of ergonomic awareness. MSDs can be found in the welding process, when workers are bending and kneeling, indicating that change in body postures may be required. It is approved by RULA, which gives it a 7 on the action level 4 scale, suggesting that more research and rapid improvements are required. RULA's study of the data and scores shows that almost all work conducted by the welding operators of the small welding business, regardless of the type of activity performed, has a moderate to high risk of predisposing to WRMSD. Specifically, bodily parts, and there will be a greater concern for workers in the future. Changes needed in the areas of the environment, the workplace, training, job redesign, ergonomic concepts used taking into account of biomechanical and engineering aspects into consideration in the operators' working postures will result in a reduction in the RULA score and its action level. According to the discomfort analysis, the wrist, lumbar, hand finger, and neck were the most strained portions of the body, which were dramatically reduced after following good ergonomic guidelines. The workers' neck and lumbar angles were suitably corrected, and RULA analysis on CATIA V5 gives a score of 7 on static and repetitive load for their bending posture. The RULA scores improved significantly after adequate ergonomic recommendations were implemented, i.e., 3. It was discovered that the RULA score has dropped dramatically from 7 to 3 which indicate that workers can perform the task with ease.

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