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Optimizing Welders' Posture: A Study on Ergonomic Solutions to Mitigate MSDs

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Abstract

This study explores the implementation of ergonomic interventions in a welding workshop to reduce the risk of musculoskeletal disorders (MSDs) among welders. The objective is to assess the incidence of MSDs and develop tailored ergonomic solutions to enhance safety and productivity. Ergonomic assessment tools such as Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), and Ovako Working Posture Analysis System (OWAS), along with advanced simulation software like CATIA was used to create accurate postural models. The findings reveal significant ergonomic risks in welding operations, leading to the development of optimal working postures to minimize injuries and risks. Customized interventions, including enhanced sitting and standing postures with ergonomically built furniture, led to a decrease in RULA scores from 6 to 3, REBA scores from 8 to 2, and OWAS scores from 3 to 1. These enhancements underscore the effectiveness of focused ergonomic interventions in reducing MSD risks, improving worker well-being, and increasing workshop productivity.

Keywords: Welding workers, Musculoskeletal Disorder, Posture Modelling, Biomechanical Analysis.

1. Introduction

Ergonomics, derived from the Greek words “Ergon” (work) and “Nomos” (principles), aims to optimize human well-being and system performance by designing tasks, workspaces, and tools that suit workers' physical and cognitive abilities [1] . Globally, ergonomic principles are crucial in reducing work-related injuries, improving productivity, and lowering costs. In Bangladesh, where the metal products manufacturing industry is crucial to the economy, ergonomic challenges are particularly severe, especially for welding workers. This sector, which employs over 409,000 workers, is vital but faces a high prevalence of MSDs due to physically demanding tasks and the absence of ergonomic protocols [2] [3].

Welding, a key process in metal fabrication, involves prolonged periods of awkward postures, repetitive motions and exposure to vibrations, all of which significantly increase the risk of MSDs. Welding workers in Bangladesh often perform tasks such as lifting heavy objects and maintaining awkward positions like bending and twisting, leading to pain, stiffness, and, in severe cases, permanent disability [4] . These issues not only impact individual workers but also reduce workplace productivity, increase absenteeism, and elevate healthcare costs, ultimately affecting the industry's overall efficiency and economic contribution [5] .

This study focuses on addressing the ergonomic challenges faced by welding workers in Bangladesh’s metal workshops. The primary objectives are to assess ergonomic risks specific to welding tasks and to design and implement targeted interventions to reduce MSDs among these workers. Given the essential role of welding in metal manufacturing, improving ergonomics for welding workers is critical for enhancing safety, reducing absenteeism, and boosting productivity. To achieve these objectives, the study will utilize comprehensive ergonomic assessments and data collection, including tools like RULA, NIOSH guidelines, and simulation software such as CATIA. These will help identify risks and develop ergonomic solutions tailored to the needs of welding workers. By implementing these interventions, the study aims to achieve substantial improvements in worker health and safety, thereby contributing to the sustainable growth and success of Small to Medium Sized Enterprises in Bangladesh's metal industry.

Ultimately, by focusing on welding workers, this research seeks to reduce MSDs, improve overall worker comfort and safety, and enhance the productivity and operational efficiency of metal workshops in Bangladesh.

The findings will not only benefit individual workers but also support the broader economic stability and growth of the industry

2. Literature Review

In today's industrial landscape, worker safety and well-being are critical. Ergonomics, the science of designing work environments to align with natural human movements, is essential in reducing MSDs and boosting productivity. Numerous studies have evaluated ergonomic hazards across industries, proposing interventions to improve working conditions. This essay explores key research on ergonomic concerns in various occupational settings, emphasizing the importance of ergonomic assessments in enhancing worker well-being.

In a study in 2022 Dedhia et al. focused on the ergonomic evaluation and workstation redesign for Tambat Ali artisans in India. The researchers used observational methods and ergonomic assessments to identify postural and environmental hazards faced by these traditional metalworkers. By redesigning the workstations to better accommodate the artisans' physical needs, significant improvements in worker comfort and efficiency were achieved. The study highlights the importance of tailored ergonomic interventions in enhancing the productivity and well-being of workers in traditional craft industries [6].

Palikhe et al. [7] assessed the ergonomic risks associated with MSDs among aluminum form workers at construction sites using simulation methods. The study employed ergonomic risk assessment tools and simulation software to identify and analyze hazardous postures and movements. The findings revealed significant ergonomic hazards in the construction workstations, leading to recommendations for interventions to reduce the risk of MSDs. The study emphasizes the value of simulation in predicting and mitigating ergonomic risks in the construction industry.

Das et al. [8] conducted an ergonomic evaluation of welders, focusing on their work posture and postural stresses. The study utilized observational techniques and postural analysis tools to assess the physical strain on welders during various tasks. The results indicated that welders are exposed to significant postural stress, leading to a high risk of MSDs. The study underlines the need for ergonomic interventions, such as improved workstations and posture training, to reduce the physical strain on welders.

Singh and Singhal [9] assessed the risk of work-related MSDs for different welding positions and processes. The study employed ergonomic assessment tools to evaluate the risk levels associated with various welding tasks. The results highlighted that certain welding positions, particularly those involving awkward postures, posed a higher risk of MSDs. The research suggests that ergonomic improvements, such as optimizing welding positions and processes, can significantly reduce the risk of MSDs among welders.

Zhang et al. [10] study focused on the ergonomic evaluation of welders' standing postures using Jack simulation software. The researchers conducted a detailed analysis of postural risks associated with prolonged standing during welding tasks. The simulation provided insights into the physical strain and potential musculoskeletal risks faced by welders. The findings highlighted the importance of improving workstation design and posture management to reduce the risk of injury. The study demonstrates the effectiveness of using advanced simulation tools like Jack for ergonomic assessments in industrial settings.

The research proposed by Lara-Lezcano et al. [11] a Dysergonomic Risk Management Model aimed at improving welding productivity in the metal-mechanic sector in Lima, Peru. The study utilized the Nordic Questionnaire, along with REBA and NIOSH methods, to assess ergonomic risks and identify areas for improvement. The model focused on reducing MSDs by optimizing work conditions and processes. The study's findings suggested that addressing dysergonomic factors can significantly enhance both worker well-being and productivity in welding operations.

Suman et al. [5] [12] conducted a postural stress analysis of welders, focusing on MSD symptoms and the redesign of workstations. The study employed observational methods and ergonomic assessment tools to identify postural stresses associated with welding tasks. The findings indicated a high prevalence of MSD symptoms among welders, emphasizing the need for ergonomic interventions. The study proposed workstation design improvements to mitigate these risks, highlighting the critical role of ergonomic redesign in reducing physical strain on welders.

This review highlights the critical need for ergonomic interventions in physically demanding industries such as welding. The insights gained helped identify the high-risk postures and informed the development of targeted solutions to address the ergonomic challenges faced by welders.

3. Research Methodology

This study explores ergonomic interventions in metal welding workshops to identify the best posture for reducing MSD risks among welders. It aims to develop customized ergonomic solutions to improve both safety and productivity. The methodology involves using RULA, REBA, and OWAS assessment tools, along with CATIA simulation software, to model and identify the most ergonomic welding postures.

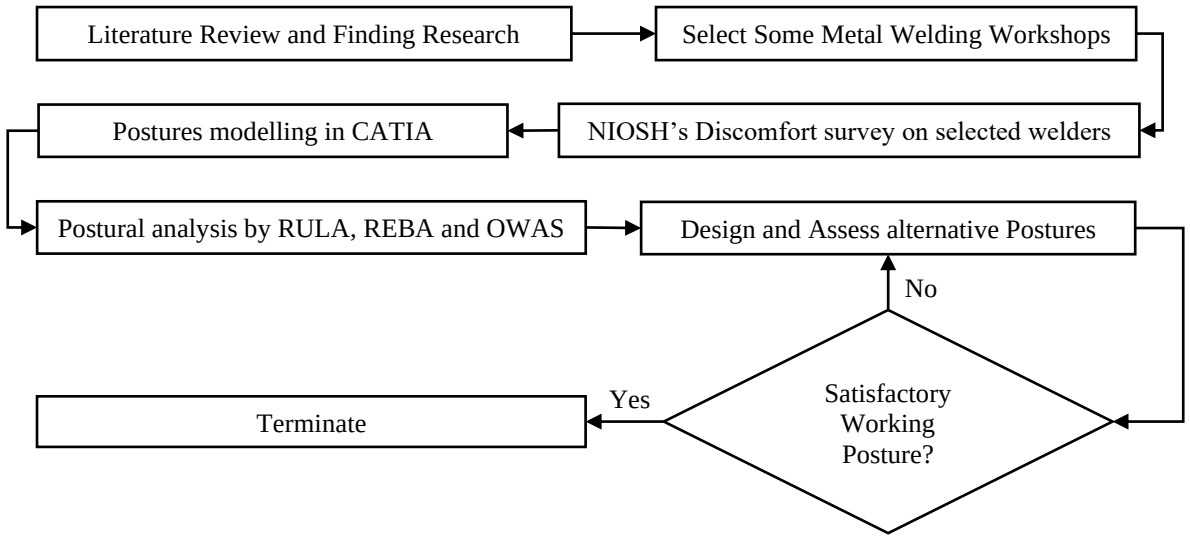


Fig. 1. Flow diagram of Research Methodology

Research Steps

The research's methodology shown in Fig. 1 was meticulously structured to evaluate ergonomic hazards faced by welders and to design strategies for enhancing their work postures. The process started with the identification of research gaps and the selection of workshops, subsequently followed by ergonomic evaluations using diverse techniques. Alternative postures were developed, evaluated, and adjusted to enhance worker comfort and safety based on these assessments. The essential stages are defined below:

Step 01: Initially, a review of recent literature was conducted to identify research gaps. Based on these gaps, the objectives of the study were formulated.

Step 02: Several metal welding workshops were randomly selected to ensure the avoidance of bias.

Step 03: The NIOSH Discomfort Survey was administered to a group of welders to assess the severity of MSDs.

Step 04: The current welding posture was then modeled using 'CATIA' Simulation software. This modeling allowed for the visualization and analysis of ergonomic hazards, thereby improving the understanding of specific areas requiring attention.

Step 05: Various postural analyses were conducted during this phase using RULA, REBA, and OWAS tools. These tools helped evaluate ergonomic risks associated with different worker postures in the metal welding workshops. RULA and REBA were used to assess the likelihood of developing MSDs in the upper limbs and whole body, respectively, while the OWAS system classified working postures that posed potential health risks.

Step 06: At this stage, two alternative welding postures were developed and assessed using ergonomic tools.

Step 07: The alternative postures were found to be more comfortable than the current posture, concluding the process.

4. Experimental Result Analysis

This section explores various ergonomic assessments of body postures during welding processes. Ultimately, optimal body postures are recommended to enhance worker comfort and safety.

NIOSH's Discomfort Analysis

The NIOSH discomfort survey was utilized to identify and map the areas of pain and discomfort experienced by welders during welding tasks. The analysis was performed using the Ergo-Fellow software. The survey was conducted with five workers, each having a minimum of five years of experience in metal workshops. The demographic details of these workers are presented in Table 1.

Table 1. Demographic data of the workers (n = 5)

Variables	Workers (±SD)
Mean Age (years)	26.50 (±8.5)
Height (cm)	166.50 (±4.24)
Mean working experience (years)	6.5 (± 2.85)

Fig. 2 depicts the correlation between a worker's bodily discomfort and the number of working hours. By the 8th hour, discomfort sharply increased due to extended periods in an uncomfortable posture. While the discomfort experienced during the first hour was manageable, it escalated to severe levels because of improper body positioning. The data indicate that the upper body of the welder is most affected during the final hour of work. Here, Evolution level 1 means no discomfort, 2 means mild discomfort, 3 means moderate discomfort, 4 means severe discomfort, 5 means insupportable discomfort.

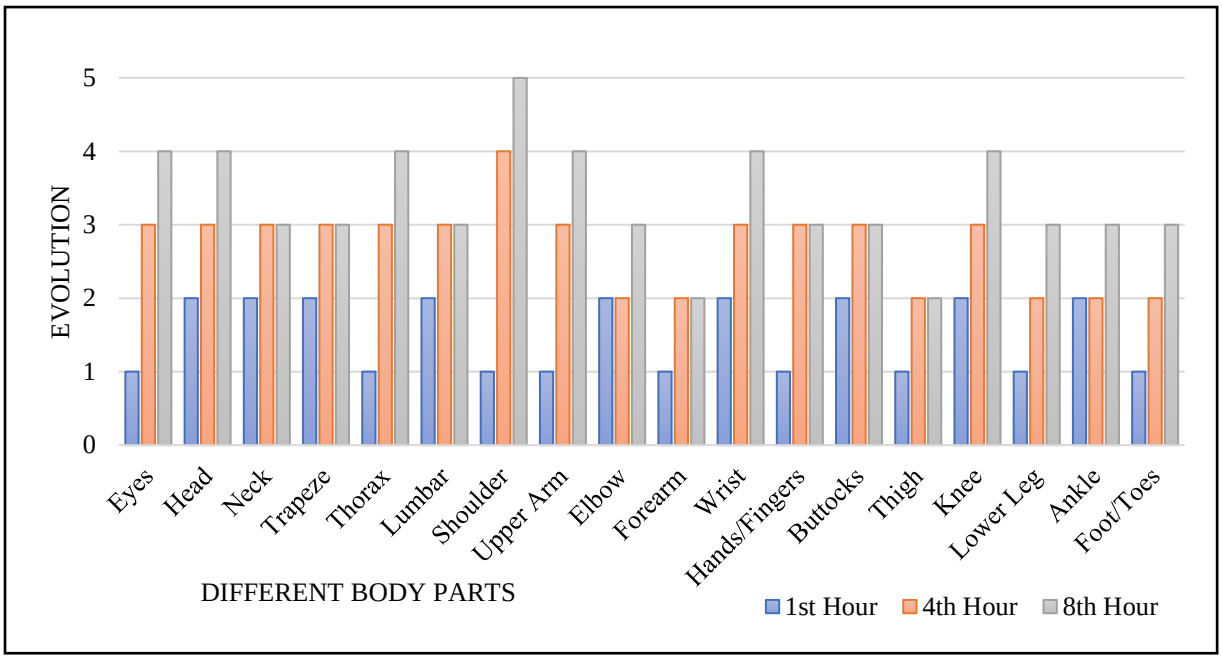
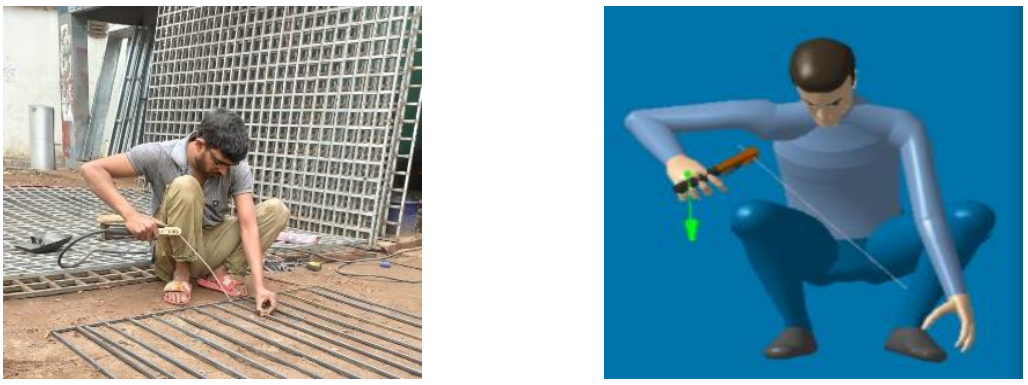


Fig. 2. Discomfort evolutions in different body parts of worker-01

Different Ergonomic Assessment for Welding Operation

Welders typically work in a deep squatting position, kneeling on their feet for extended periods, as seen in Fig. 3. This posture places significant strain on the lower body, leading to discomfort and increasing the risk of MSDs [8] . To address this, this study proposed a sitting posture using an ergonomically designed chair and height-adjustable workbench, which reduces strain on the legs and promotes better posture. Additionally, this height-adjustable workbench allows welders to alternate between sitting and standing, minimizing fatigue and further reducing the risk of MSDs while maintaining productivity and comfort.

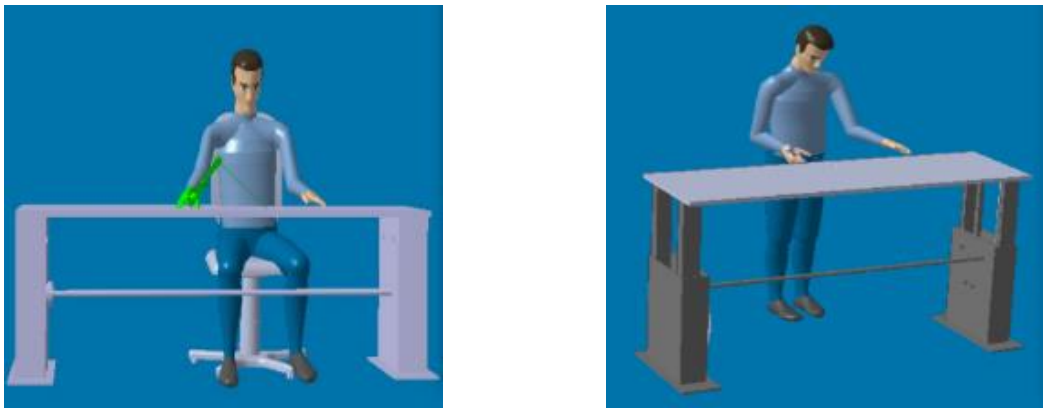


a b

Fig. 3. Original working posture of welders and Modelling in CATIA [a,b]

Initially, the current deep squatting posture used by welders was modeled using 'CATIA' to visualize and analyze ergonomic hazards. In addition to this, two alternative postures were developed: a sitting posture and a standing posture. The sitting posture was designed with an ergonomically optimized chair and workbench to reduce stress on the lower body, while the standing posture featured a height-adjustable workbench to allow flexibility in movement and posture, as illustrated in Fig. 4. All three postures—the deep squatting, sitting, and standing—were then subjected to ergonomic assessments using RULA, REBA, and OWAS tools. These tools

were utilized to evaluate the risks of MSDs associated with each posture. The results of these analyses are summarized in Table 2, providing a clear comparison of the benefits and drawbacks of each posture in terms of worker safety and comfort.



a b

Fig. 4. Sitting and Standing Posture for welders with proper ergonomic chair and workbench [a,b]

Table 2. Comparison of RULA, REBA and OWAS score for three different welding postures.

Working Posture	RULA Score	REBA Score	OWAS Score
Deep squatting	6	8	3
Sitting	4	5	2
Standing	3	2	1

Table 2 describes Deep squatting is associated with the highest risk across all three tools. The RULA score of 6 indicates a high risk of upper limb disorders, suggesting the need for ergonomic improvements. The REBA score of 8 reflects a high risk for overall musculoskeletal issues, highlighting the necessity for significant ergonomic interventions. The OWAS score of 3 also points to a moderate risk, emphasizing the need for adjustments to reduce the likelihood of work-related MSDs.

Sitting presents a relatively lower risk compared to deep squatting. The RULA score of 4 suggests a low risk of upper limb disorders but indicates that some ergonomic refinements might still be beneficial. The REBA score of 5 denotes a moderate risk of musculoskeletal issues, implying that some ergonomic modifications could improve comfort and reduce risk. The OWAS score of 2 supports this by indicating a low risk of MSDs, though further optimization could enhance ergonomics.

Standing is evaluated as the most favorable posture in terms of risk. The RULA score of 3 and the REBA score of 2 both indicate a low risk of upper limb and overall MSDs, respectively. The OWAS score of 1 reinforces this by showing a very low risk, suggesting that standing is ergonomically the most advantageous posture among the three.

Result Discussion

The ergonomic scores improved significantly post-intervention, with RULA scores decreasing from 6 to 3, REBA scores from 8 to 2, and OWAS scores from 3 to 1. These changes represent a substantial reduction in ergonomic risks, indicating practical improvements in worker safety and posture. ‘Sitting’ and ‘Standing’ are preferable to ‘Deep squatting’. Sitting offers a lower risk of MSDs compared to deep squatting, with moderate risk scores indicating that ergonomic improvements are beneficial but less critical. Standing is the most favorable posture, with consistently low risk scores across all tools, suggesting minimal ergonomic concerns. Therefore, transitioning from deep squatting to sitting or standing is recommended to enhance worker comfort and reduce risk. Additionally, interchanging between sitting and standing when needed can provide further ergonomic benefits and prevent fatigue.

5. Conclusion

This study tackles the significant ergonomic challenges faced by welders, particularly the high prevalence of MSDs caused by poor working postures. Using a combination of ergonomic tools such as RULA, REBA, and

OWAS, along with CATIA simulation software, the research aimed to identify optimal postures to reduce the risk of MSDs. The analysis revealed that the deep squatting positions typically adopted by welders contribute to significant physical strain. In response, the study developed alternative postures, including a sitting and standing position with a height-adjustable workbench. These adjustments showed a marked improvement in reducing the ergonomic risks, enhancing both worker safety and productivity.

On a practical level, this research holds substantial benefits for the welding industry. By incorporating these ergonomic solutions, workshops can significantly improve worker comfort, minimize injuries, and enhance productivity. Reduced absenteeism due to injury and increased efficiency in daily operations are expected outcomes. This is especially vital in developing countries where ergonomic practices are not fully embraced, leading to avoidable health risks and economic losses.

However, this study has limitations. The sample size was small, focusing on only five welders, which may limit the generalizability of the findings. Additionally, the research concentrated on postural improvements, without considering other ergonomic factors which can also influence worker health.

Looking ahead, Future research could explore broader ergonomic factors, such as environmental conditions and tool design, to develop more comprehensive solutions. This could include designing ergonomically optimized chairs and workbenches based on anthropometric data to suit the physical dimensions of welders. By tailoring these designs to the specific needs of workers, the industry could achieve even greater improvements in both safety and productivity, leading to more sustainable work environments.

6. Ethical Considerations

Informed consent was obtained from all participating welders before data collection. They were informed about the study's objectives, procedures, and their right to withdraw at any time without repercussions. Confidentiality and anonymity were maintained throughout the research, and all ergonomic assessments were conducted in a manner that ensured the safety and well-being of the participants.

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