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Postural Risk Analysis of Workers in Local Furniture Making Workshops using RULA and CATIA-based Digital Human Modeling

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Abstract

Workers in furniture-making workshops often perform repetitive tasks and adopt awkward postures, increasing their risk of musculoskeletal disorders (MSDs). Instead of traditional ergonomic assessments, advanced digital tools like CATIA-based Digital Human Modeling (DHM) combined with the Rapid Upper Limb Assessment (RULA) for accurate postural risk analysis. In this study, actual task data of workers performing four common furniture making tasks (i.e., wood lifting, carrying, cutting, and surface smoothing) were collected through video recordings and photographs. Additionally, virtual models were created in CATIA to assess ergonomics risk using RULA and suggest posture improvements. Results indicated that workers performing all selected tasks adopted high-risk postures, with RULA scores ranging from 6 to 7, which exceeded acceptable limits, highlighting the need for ergonomic improvements. CATIA-based simulations further confirmed that work posture modifications can effectively reduce postural risks (i.e., reducing the RULA score to '3') and improve overall ergonomic conditions. The study highlights significant postural risks among local furniture-making workers, emphasizing the need for ergonomic improvement to reduce MSDs. Implementing CATIA-based Digital Human Modeling with RULA analysis can effectively identify hazardous postures and guide working posture modifications for enhanced worker safety and efficiency.

Keywords
Posture, Musculoskeletal disorders, RULA, CATIA, Furniture making workers

1. Introduction
Workers in local furniture-making workshops are often exposed to awkward postures, repetitive tasks, and prolonged static positions, leading to a high risk of musculoskeletal disorders (MSDs). MSDs refer to pain or injuries affecting various body parts (Maher et al. 2025). Poor ergonomic conditions in these workplaces can cause discomfort, fatigue, and long-term health issues, affecting both worker productivity and well-being. In manual furniture-making activities which involve lifting, carrying, cutting, surface smoothing, handling heavy loads, and working at inappropriate workstations-may cause abnormal working postures. These are called ergonomic hazards and may lead to a reduction in work capacity and an increased rate of disability over the year, if they are not identified and corrected early. Therefore, it is essential to identify and mitigate the ergonomic hazards in the workplace.

Manual furniture-making tasks often require workers to adopt awkward and non-neutral postures, leading to increased physical strain and a higher risk of musculoskeletal disorders (MSDs) (Yang et al. 2022). Workers frequently engage in repetitive hand movements, prolonged standing, excessive bending, and overhead reaching, which can cause discomfort and long-term health issues. Unlike large-scale industrial furniture production, local workshops typically lack ergonomic workstations, forcing exertion to adjust their body positions to fit the task rather than having a workstation designed for optimal posture. Studies have shown that sustained awkward postures, particularly involving the upper limbs and lower back–significantly contribute to chronic pain, fatigue, and reduced productivity (Anjali et al. 2024; Ojha et al. 2024).

Traditional observational methods for posture assessment are often subjective and inconsistent, making it difficult to implement standardized ergonomic improvements. To address this, Rapid Upper Limb Assessment (RULA) provides a structured framework for identifying high-risk postures based on joint angles, muscle activity, and external loads. The integration of Digital Human Modeling (DHM) software, such as CATIA (Computer graphics Aided Three-dimensional Interactive Application), enhances the accuracy of ergonomic assessments by simulating real work scenarios in a virtual environment. By analyzing and quantifying postural risks, ergonomic interventions can be proposed to improve workstation design, tool ergonomics, and workflow organization. Enhancing posture analysis techniques in manual furniture-making workshops is crucial for developing sustainable ergonomic solutions that improve worker safety and efficiency.

1.1 Objectives

The main objectives of the current study were to assess the postural risks of workers in local furniture-making workshops using the Rapid Upper Limb Assessment (RULA) method, and to identify high-risk postures that may contribute to musculoskeletal disorders (MSDs). Subsequently, the study aimed to utilize CATIA-based Digital Human Modeling (DHM) to simulate and analyze workers' postures, providing a quantitative and reproducible approach to ergonomic risk assessment, and to recommend improvements in working postures and conditions.

2. Literature Review

Musculoskeletal disorders (MSDs) are one of the most common problems among manual furniture-making workers. Therefore, it is essential to investigate the factors associated with MSDs. Awkward working posture is one of the key contributors to the development of MSDs among the furniture-making workers (Thetkathuek and Meepradit 2018). Prolonged work in awkward positions can negatively impact on not only workers' health but also productivity. For example, Sianturi et al. (2025) identified awkward working postures of warehouse workers in the textile industry and concluded that such postures may lead to MSDs-related injuries. Sharma et al. (2025) conducted a study among manual waste-handling workers and found that poor working posture increased the risk of lower back MSDs and reduced productivity by approximately 50%. Thus, analyzing awkward postures among manual furniture-making workers is necessary to develop effective ergonomics interventions.

Previous studies have utilized various ergonomics assessment tools to analyze occupational postural risks. For instance, a study by Dey and Mondal (2025) used Rapid Entire Body Assessment (REBA) method to evaluate ergonomic risks associated with MSDs and explore the impact of body mass index on the posture. Aliabadi et al. (2022) utilized the Quick Exposure Check (QEC) method to evaluate awkward postures contributing to the development of MSDs among mining truck drivers and found that the body posture of drivers ranged from moderate to high risk, indicating that ergonomic interventions were urgently needed. Researchers have also used other methods such as the Ovako Working Posture Analysis System (OWAS) (Karhu et al. 1977), Rapid Upper Limb Assessment (RULA)(McAtamney and Corlett 1993), Workstation Assessment Checklist (WAC) (Hambali et al. 2019), and Novel Ergonomic Postural Assessment (NERPA) (Sanchez-Lite et al. 2013) to evaluate the postural risk factors. However, all the aforementioned methods are traditional and may introduce subjectivity into posture assessments when compared to digital techniques. Therefore, a three-dimensional ergonomic posture analysis method is required for more accurate and reliable evaluation.

This research aligns with previous studies that have utilized digital human modeling and ergonomic assessment tools to analyze occupational postural risks. For instance, a study by Hussain et al. (2019) demonstrated the effectiveness of combining RULA with digital human models to assess the ergonomic impact of work-related postures in manufacturing settings. Similarly, research by Nanda et al. (2025) highlighted the advantages of using CATIA's human modeling features to simulate and evaluate worker postures, leading to improved workplace design and a reduced prevalence of MSD.

Therefore, the authors of this study employed the Rapid Upper Limb Assessment (RULA) tool alongside CATIA's digital human modeling capabilities to evaluate the ergonomic risks associated with various tasks performed by workers in furniture workshops. By simulating workers' postures within the CATIA environment, the study identified specific movements and positions that contribute to musculoskeletal disorders (MSDs). The integration of RULA with digital human modeling provided a comprehensive assessment framework, enabling the identification of high-risk postures and facilitating the development of targeted interventions to mitigate these risks. Collectively, this study underscores the value of combining digital human modeling with ergonomic assessment tools like RULA to enhance occupational health and safety for workers in local furniture workshops in Bangladesh.

3. Methods

3.1 Data collection and processing

The study data were collected from 20 workers at several local furniture workshops in Jashore, Bangladesh. Among the various activities performed, data was collected for the following four common furniture making tasks: wood lifting, carrying, cutting, and surface smoothing. In this study, data collection was carried out by recording the workers' postures through videos and photographs while they performed the above mentioned tasks. The recorded videos and photos were then analyzed to identify critical postures, which were selected for further analysis. Additionally, the upper body joint angles were measured to postural risk analysis.

3.2 Postural analysis using Rapid Upper Limb Assessment (RULA) method

Postural analysis is considered a powerful technique for evaluating associations between body postures and musculoskeletal symptoms (Kee and Karwowski 2007). Various postural analysis techniques have been used to identify the stress of different work stages (Gangopadhyay and Dev 2014). Because of the characteristics of the subjects' awkward working postures, the Rapid Upper Limb Assessment (RULA) analysis (McAtamney and Corlett 1993) was selected for this research, where most upper body parts are used to perform furniture-making activities. RULA is a valuable and effective method for assessing body postural analysis and correcting awkward work postures. It examines the severity of the postural risk factors and provides a final score that varies from 1 to 7. Table 1 shows the details of the RULA scores, action level, the risk category, and a description of the action to be taken.

Table 1. RULA scores, risk levels, and associated actions

RULA Scores	Associated MSDs Risk levels	Actions should be taken
1-2	Negligible	No action required
3-4	Low	Change may be required
5-6	Medium	Further investigation and change soon
7≤	High	Changes are required immediately

3.3 CATIA-Based Digital Human Modeling

The current study employs the Rapid Upper Limb Assessment (RULA) to analyze workers' postures in a digital environment using CATIA-based (Computer Graphics Aided Three-dimensional Interactive Application) Digital Human Modeling (DHM). The 3D DHM manikin was created based on the participant anthropometric data. The research follows a systematic approach, beginning with data collection through direct observation and video recordings of workers performing repetitive tasks. The collected data are then used to create virtual human models in CATIA, simulating real-life working conditions. Each posture is evaluated using RULA, which assigns a risk score based on joint angles, muscle use, and external loads. The ergonomic risk levels are categorized to identify high-risk postures requiring immediate intervention. Sensitivity analysis is performed to assess variations in posture scores with minor changes in body alignment. In CATIA, the number and color code display the RULA total score. The final score causes the color to change from green for "negligible danger" to red for a level of "severe risk." If the color is green, it indicates good posture (final scores of 1 and 2) but should not be maintained for lengthy periods. The final scores of 3 and 4 (yellow color) indicate that further inquiry is needed. The orange color (final scores of 5 and 6) indicates that more research is required and that the posture should be modified as soon as possible. The ultimate score of 7 (red color) indicates that further inquiry is needed and that the posture must be changed immediately. Based on the findings, ergonomic recommendations are proposed to improve workplace safety and reduce musculoskeletal disorders.

4. Results and Discussion

4.1 Postural risk analysis of the wood lifting task

The worst working posture of the workers while performing the wood lifting task from the ground is shown in Figure 1(i). The actual picture of the workers is converted into a CATIA model (Figure 1(ii)) for postural risk analysis using the RULA method. The posture selected is prone to the development of MSDs risks. The RULA score for this posture was 7 and is represented in red color (Figure 1 (iii)). This score indicates that the posture requires further investigation and should be changed as soon as possible. Julianus found a similar RULA score among rice milling workers lifting sacks (Julianus 2019). Working in such a high-risk posture for a long time may lead to MSDs risks (Das and Gangopadhyay 2025).

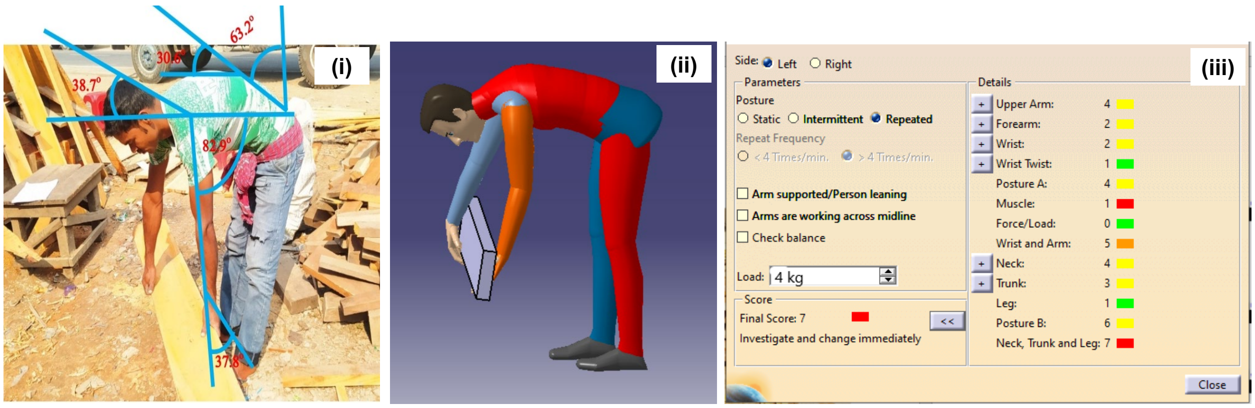

Figure 1. RULA analysis of actual working postures (i), CATIA-based modeled posture (ii), and the RULA score for the wood lifting task (iii)

4.1.1 Suggested ergonomic improvements

To overcome the drawback of the high-risk posture, a simulated working posture was created in CATIA (Figure 2(i)), and the corresponding RULA score was determined (Figure 2 (ii)). The RULA score of suggested improved posture was reduced to three, indicating a low risk category, as shown in Figure 2(ii).

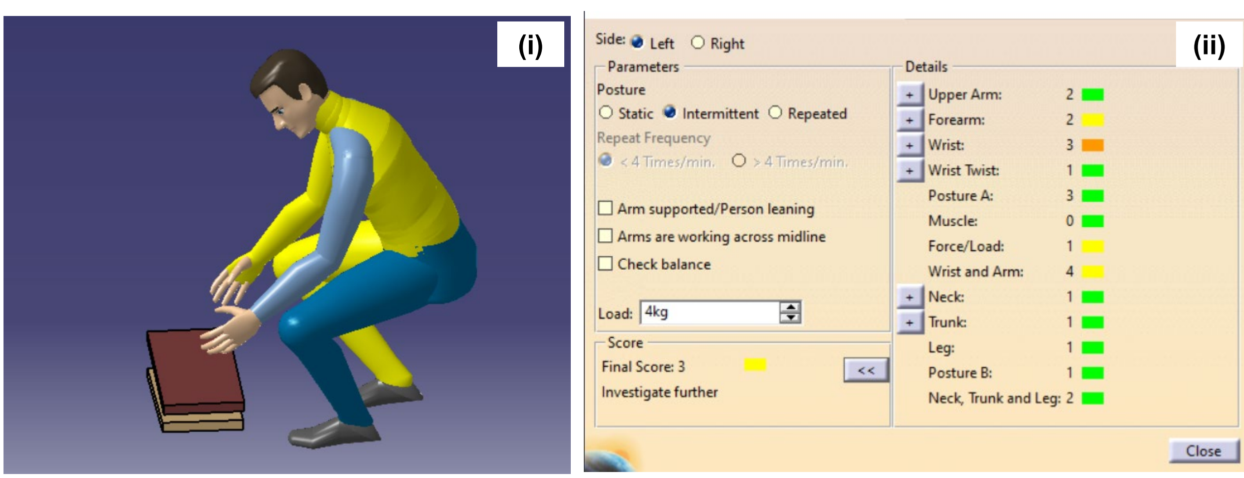

Figure 2. Suggested working posture for the lifting task in CATIA-based modeling (i), and the related RULA score (ii)

4.2 Postural risk analysis of the wood-carrying task

The actual working posture of the wood-carrying task and its digital human modeling in CATIA are shown in Figure 3(i, ii). The RULA score for this posture was 6 and is represented in orange color (Figure 3 (iii)). This score means that the posture requires further investigation and should be changed as soon as possible. Continuing this posture for a long time may lead to MSDs in the shoulder, elbow, and wrists.

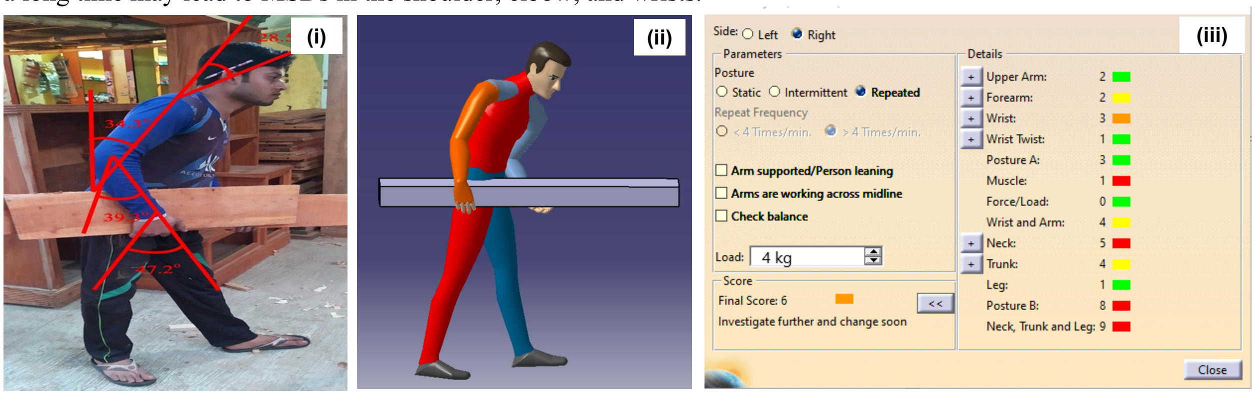

Figure 3. RULA analysis of actual working postures (i), CATIA-based modeled posture (ii), and the RULA score for the wood-carrying task (iii)

4.2.1 Suggested ergonomic improvements

To overcome the existing postural problems, ergonomic posture improvement is recommended. Figure 4(i) shows that the postural risks in a similar task can be reduced by implementing a proper working posture. The proposed posture was modeled in CATIA, and it is seen that the RULA score was reduced to 3, indicating low level of risk, as shown in Figure 4(ii). To achieve the corrected postures, worker must by trained up properly.

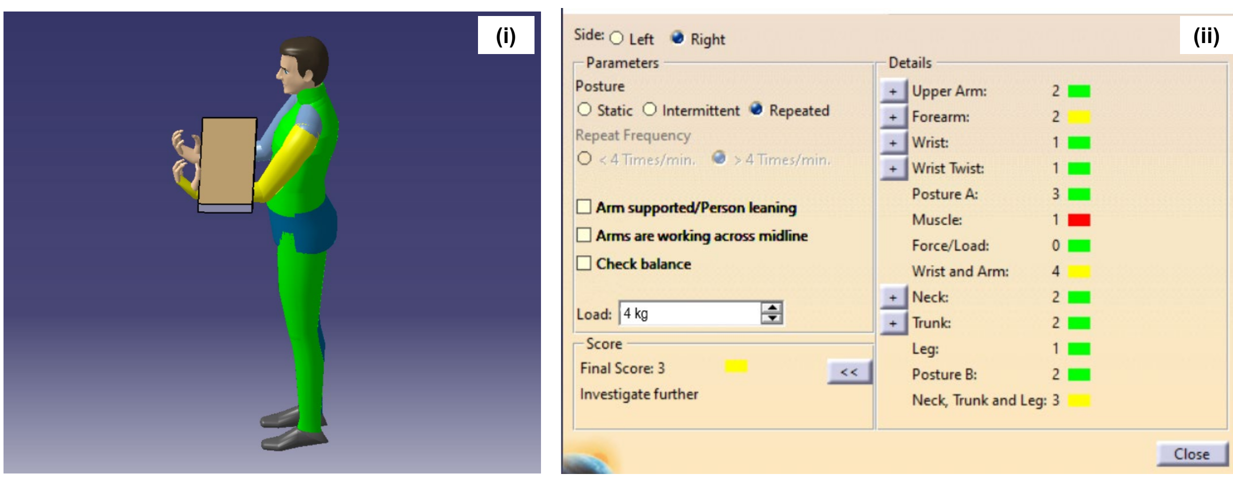

Figure 4. Suggested working posture for the wood-carrying task in CATIA-based modeling (i), and the related RULA score (ii)

4.3 Postural risk analysis of wood-cutting task

The actual working posture (Figure 5(i)), CATIA-based modeled posture (Figure 5(ii)), and related RULA score are shown in Figure 5. The RULA score of this task was 6 and orange in color, it indicates that the posture requires further investigation and should be changed as soon as possible. The possible injured body areas are the shoulder, neck, elbows, and trunk.

4.3.1 Suggested ergonomic improvements

To reduce the postural risk associated with the wood-cutting task, the recommended CATIA-based body posture and the corresponding RULA score are shown in Figure 6. The suggested improved posture received a RULA score of 3, which represents a lower risk level for the development of MSDs.

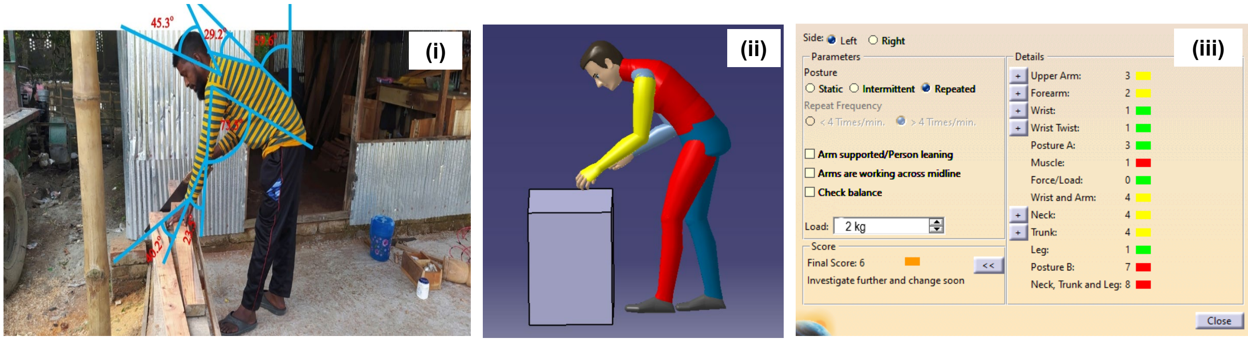

Figure 5. RULA analysis of actual working postures (i), CATIA-based modeled posture (ii), and the RULA score for the wood-cutting task (iii)

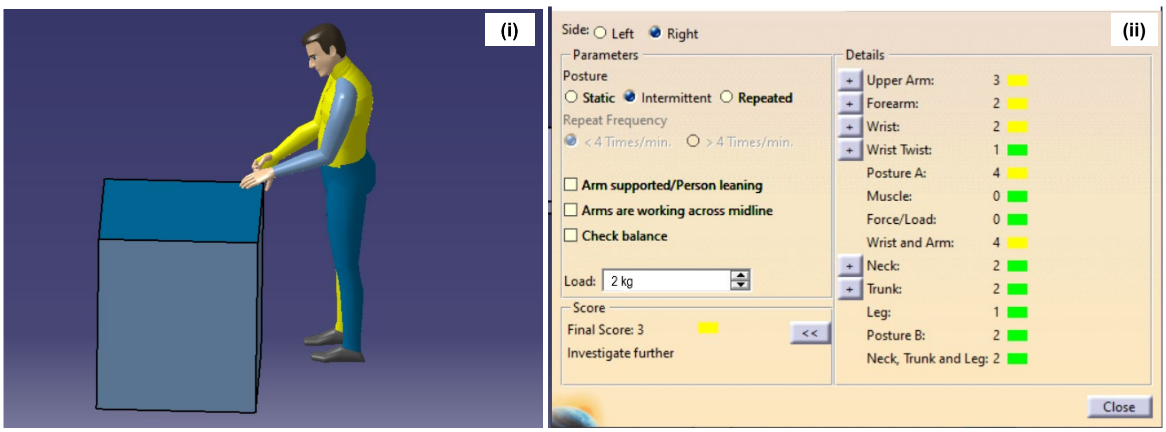

Figure 6. Suggested working posture for the wood cutting-task in CATIA-based Modeling (i), and the related RULA score (ii)

4.4 Postural risk analysis of the wood surface smoothing task

The real posture of the wood surface smoothing task and the corresponding digital human model in CATIA are represented in Figure 7(i, ii). The RULA score for this posture was 7 and represented in red color (Figure 7(iii)). This score indicates that the posture requires immediate investigation and modification. The problematic body parts are found in the trunk, upper arm, neck, and wrist.

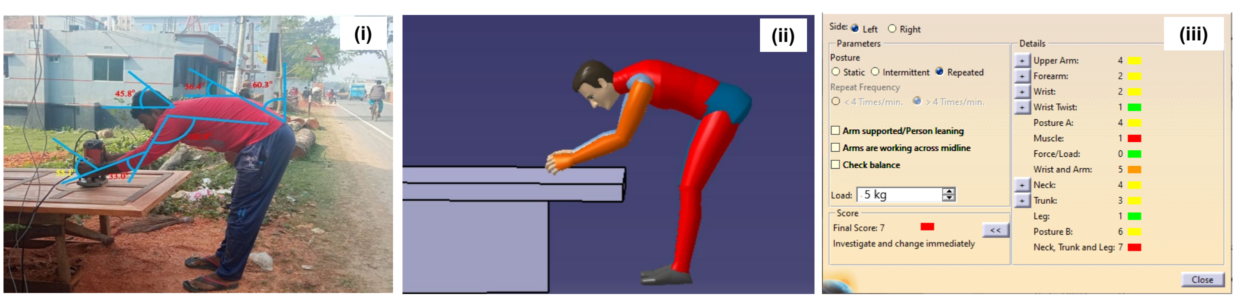

Figure 7. RULA analysis of actual working postures (i), CATIA-based modeled posture (ii), and the RULA score for the wood surface smoothing task (iii)

4.4.1 Suggested ergonomic improvements

Figure 8(i) shows that postural risks in a similar task can be reduced by implementing a proper working posture. The proposed posture was modeled in CATIA, and it is seen that the RULA score was lowered to 3, indicating a low level of risk, as shown in Figure 8(ii).

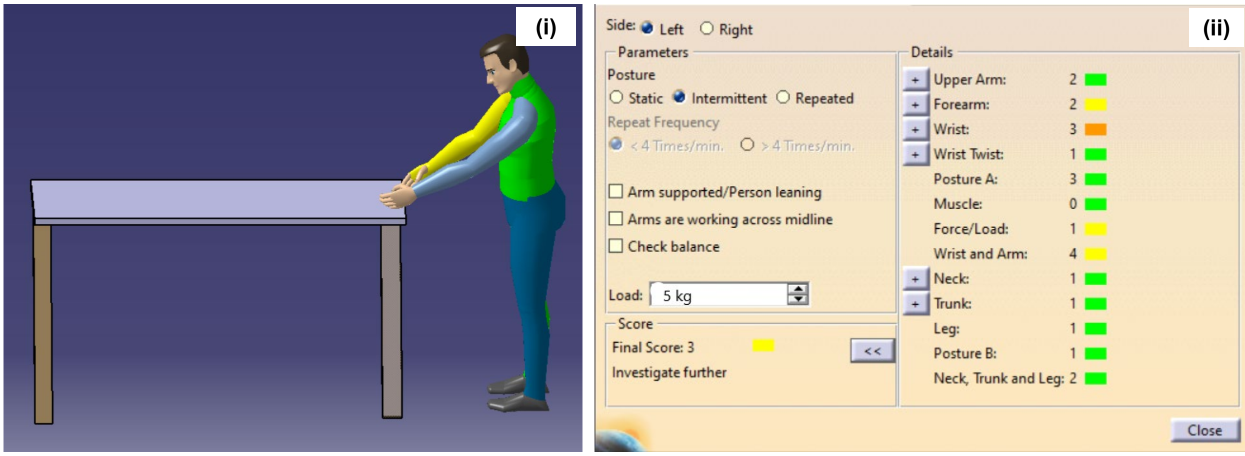

Figure 8. Suggested working posture for the wood surface smoothing task in CATIA-based modeling (i), and the related RULA score (ii)

4.5 RULA score comparisons

Figure 9 represents a bar chart comparing the RULA scores between existing and recommended postures, across four selected tasks. For all tasks, the existing posture RULA score shows significantly higher values than recommended postures. The RULA value for recommended postures remains lower and constant (i.e., 3) across four tasks, while existing posture shows a slight variation with the highest value of 7 in wood lifting and surface smoothing tasks.

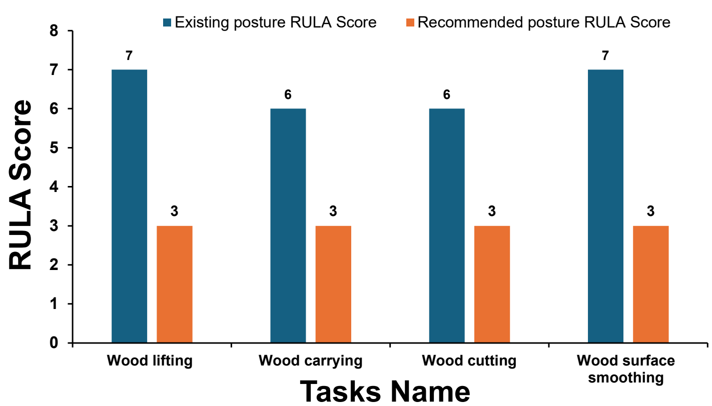

Figure 9. RULA score comparison between existing and recommended working postures

5. Limitations and future work:

This article has some limitations: firstly, authors selected only 20 workers, more workers can be included for future study. Secondly, this study was conducted four furniture making tasks others tasks can be studied. Finally, current study only conducted in a specific area in Bangladesh, participants from others areas or region can be included for future study.

6. Conclusion

This study was conducted at local furniture workshops to investigate body postural risks that may lead to the development of MSDs. The postural analysis results showed that the overall RULA scores for the selected tasks ranged from 6 to 7. It indicated that most of the workers had adopted awkward working postures. Prolonged adoption of these postures can lead to MSDs in various body parts. These findings highlight the need for immediate corrective actions to prevent problems. Ergonomic posture improvements were recommended and the revised RULA scores for all tasks were reduced to 3. Therefore, it is evident that proper working postures are essential for improving work style and reducing the risk of developing MSDs. Similarly, such improved working postures and analyzed digital method can be applied at other tasks to enhance productivity, increase work efficiency, and minimize the risk of injuries.

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