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Ergonomic Analysis of Welding Postures on Productivity and Weld Quality Using the REBA Method

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***Abstract*— Ergonomics in the workplace plays a vital role in reducing the risk of musculoskeletal disorders, preventing accidents, and improving both work efficiency and productivity. In shipbuilding welding activities, workers are frequently exposed to awkward and static postures that lead to fatigue, stress, and long-term injuries, which may compromise weld quality and project performance. This study aims to analyze ergonomic risks across four welding postures i.e., downhand, vertical, horizontal, and overhead, using the Rapid Entire Body Assessment (REBA) and Nordic Body Map (NBM) methods. The REBA assessment indicated that downhand welding scored 10 (high risk), vertical welding 11 (very high risk), horizontal welding 8 (high risk), and overhead welding 9 (high risk). NBM results revealed that 77.5% of welders in vertical welding reported waist pain, 72.5% calf pain, and 70% back pain; horizontal welding showed 67.5% right-hand pain and 65% right-wrist pain; overhead welding resulted in 57.5% neck and waist pain; while downhand welding still caused 70% complaints in the back and calves. These findings confirm that welding ergonomics directly affect worker health, weld quality, and productivity. The study recommends ergonomic interventions such as scaffolding, adjustable supports, arm rests, and proper work rotation to minimize strain, enhance safety, and ensure efficiency in shipyard operations.**

Keywords—REBA, welding, ergonomics, productivity, weld quality

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I. Introduction

Ergonomics has become a critical concern in industrial operations, particularly in the maritime sector, where welding plays a central role in ship construction and repair. Welding work is physically demanding, requiring workers to adopt constrained and awkward postures in confined ship compartments, which increases the likelihood of musculoskeletal disorders (MSDs), fatigue, and accidents [1][2]. Poor ergonomic conditions not only compromise workers' health but also negatively affect weld quality and overall productivity, which are essential for maintaining safety and efficiency in shipbuilding projects [3].

Several studies have demonstrated the strong relationship between ergonomics, occupational health, and productivity. According to Bridger [4], sustained exposure to poor postures significantly reduces workers' efficiency. Permana and Handayani [5] also reported that fatigue increases the risk of workplace accidents and reduces productivity. In the context of welding, García-Herrero et al. [6] found that vertical and overhead welding positions carry particularly high ergonomic risks. The application of ergonomic assessment tools such as the Rapid Entire Body Assessment (REBA) [7] and the Nordic Body Map (NBM) [8] has been widely recognized as effective for identifying ergonomic risk levels and discomfort in industrial tasks.

Despite this, research focusing specifically on welding ergonomics in the shipbuilding industry remains limited. Most studies have concentrated on general manufacturing environments [9] or construction sectors [10], with fewer addressing the unique challenges of welding in shipyards where confined spaces, varied positions, and extended working hours intensify ergonomic risks. Recent research also highlights the role of ergonomic interventions in improving productivity in maritime-related operations [11], while studies in shipyards suggest that physical workload and awkward postures are key contributors to welding defects and reduced efficiency [12]. Moreover, advancements in ergonomics are increasingly being linked to sustainable shipyard practices, where health and safety contribute to long-term productivity [13]. However, there remains a lack of integrated studies that directly connect ergonomic assessments to weld quality outcomes in shipbuilding.

Ergonomics, derived from the Greek words ergon (work) and nomos (laws), is the scientific discipline concerned with understanding the interactions among humans and other elements of a system, with the intention of optimizing human well-being and overall system performance [14]. In industrial contexts, ergonomics seeks to design tasks, workspaces, tools, and workflows that fit the capabilities and limitations of workers, thereby reducing occupational health risks and

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enhancing efficiency [15]. A well-designed ergonomic environment minimizes the occurrence of musculoskeletal disorders (MSDs), fatigue, and human errors, all of which are critical factors in high-risk occupations such as welding [16], [17].

In the maritime industry, where welding is carried out in confined and awkward spaces, ergonomic challenges are amplified. Studies have shown that ergonomic interventions not only prevent injuries but also contribute directly to improvements in productivity and product quality [18].

Furthermore, ergonomics plays a strategic role in occupational health and safety management systems, ensuring that workers' physical and cognitive capacities are balanced with job demands [19]. By integrating ergonomics into shipbuilding practices, companies can achieve safer operations, higher-quality welds, and more efficient project timelines [20].

The novelty of this study lies in its integration of REBA and NBM methods to evaluate welding postures in shipbuilding activities, linking ergonomic risks not only to worker health but also to weld quality and project scheduling effectiveness. By focusing on welding tasks performed in various positions (downhand, vertical, horizontal, and overhead), this research provides practical insights into improving ergonomic conditions, minimizing accidents, and enhancing productivity in shipyards.

Therefore, the objective of this study is to analyze ergonomic risks associated with welding postures in shipbuilding using REBA and NBM methods, to evaluate their impact on productivity and weld quality, and to propose recommendations for ergonomic improvements that support safer and more efficient shipyard operations.

II. METHOD

This study was carried out in a shipyard environment where welding is one of the primary activities in ship construction and repair. The research focused on four commonly used welding positions in shipbuilding projects: downhand welding, vertical welding, horizontal welding, and overhead welding. These positions were selected because they represent the most frequent and ergonomically challenging postures encountered by welders in confined ship compartments [2][12].

A. Participants

The participants of this study were experienced welders with practical working experience in ship construction. Each participant performed welding tasks under standard workplace conditions with appropriate personal protective equipment (PPE). The inclusion of experienced welders ensured that the data collected reflected realistic ergonomic risks in the field rather than those associated with inexperience [21].

B. Ergonomic Assessment Tools

The ergonomic assessment tools used in this study are described as follows:

1. Rapid Entire Body Assessment (REBA)
   REBA is an ergonomic assessment method designed to quickly and systematically evaluate whole-body postural risks [7]. It considers multiple body segments (trunk, neck, legs, upper arms, lower arms, and wrists), load handling, static postures, and coupling factors. Each body segment is scored based on its angle and position during welding tasks. The scores are then combined using a standard REBA worksheet to produce a final risk score, ranging from negligible to very high risk [3][22][23].
2. Nordic Body Map (NBM)
   The NBM questionnaire was administered to capture subjective musculoskeletal discomfort in 28 different body regions [8]. Welders were asked to indicate the level of discomfort experienced after completing welding tasks in each posture. The NBM complements REBA by providing direct feedback on how welders perceive their own physical strain, which is critical for validating observational findings [9][24].

C. Data Collection Procedure

The procedures included to execute this research consist of some steps as follows:

- Rapid Entire Body Assessment (REBA)
  The data collection process involved conducting posture analysis for four welding positions (downhand, vertical, horizontal, and overhead), followed by a comprehensive assessment of workers' body postures including the neck, trunk/back, legs, upper arms, lower arms, and wrists, which were then evaluated to determine the REBA score requiring Score A, Score B, and Score C, with Score A specifically derived from the neck score, trunk score, and leg score. Data collection was carried out through the following steps:
  1. Evaluating the neck score by analyzing the posture of the neck.
  2. Assessing the trunk/back posture to obtain the Trunk Score.
  3. Assessing the leg posture to obtain the Leg Score.
  4. Analyzing the neck score, trunk score, and leg score to determine posture Score A based on the standard REBA table.
  5. Considering additional scores if external loads are involved, with the following conditions:
     a. If the load < 11 lbs: +0
     b. If the load is 11–22 lbs: +1
     c. If the load > 22 lbs: +2
     d. Adjustment: If sudden shocks or rapid force increases occur, add +1.
  6. Determining Posture Score B by combining the upper arm score, lower arm score, and wrist score.
  7. Evaluating the posture of the upper arm to obtain the upper arm score.
  8. Evaluating the posture of the lower arm to obtain the lower arm score.
  9. Evaluating the posture of the wrist to obtain the wrist score through analysis.
  10. Calculating Posture Score B using the upper arm, lower arm, and wrist scores.
  11. Determining Score B by adding Posture Score B with the coupling score, based on the following conditions:

a. Good grip, acceptable coupling with moderate power: +0
b. Acceptable grip but not ideal, sufficient with support from another body part: +1
c. Poor but possible grip, inadequate: +2
d. No grip, awkward, unsafe with any body part, unacceptable: +3

12. Determining Score C by combining Score A and Score B.
13. Determining the final REBA Score by adding Score C to the Activity Score, based on the following conditions:
    a. One or more body parts are held static for more than 1 minute: +1
    b. Repeated small-range actions (more than 4 times per minute): +1
    c. Actions causing rapid, large-range posture changes on an unstable base: +1
14. Classifying the REBA scores into five risk categories as follows: negligible risk =1, low risk =2-3, medium risk = 4-7, high risk 8-10, and very high risk = 11+.

The illustration of the REBA steps is shown in **Figures 1** and **Figure 2.**

- Nordic Body Map (NBM)

Data collection was carried out through the following steps:

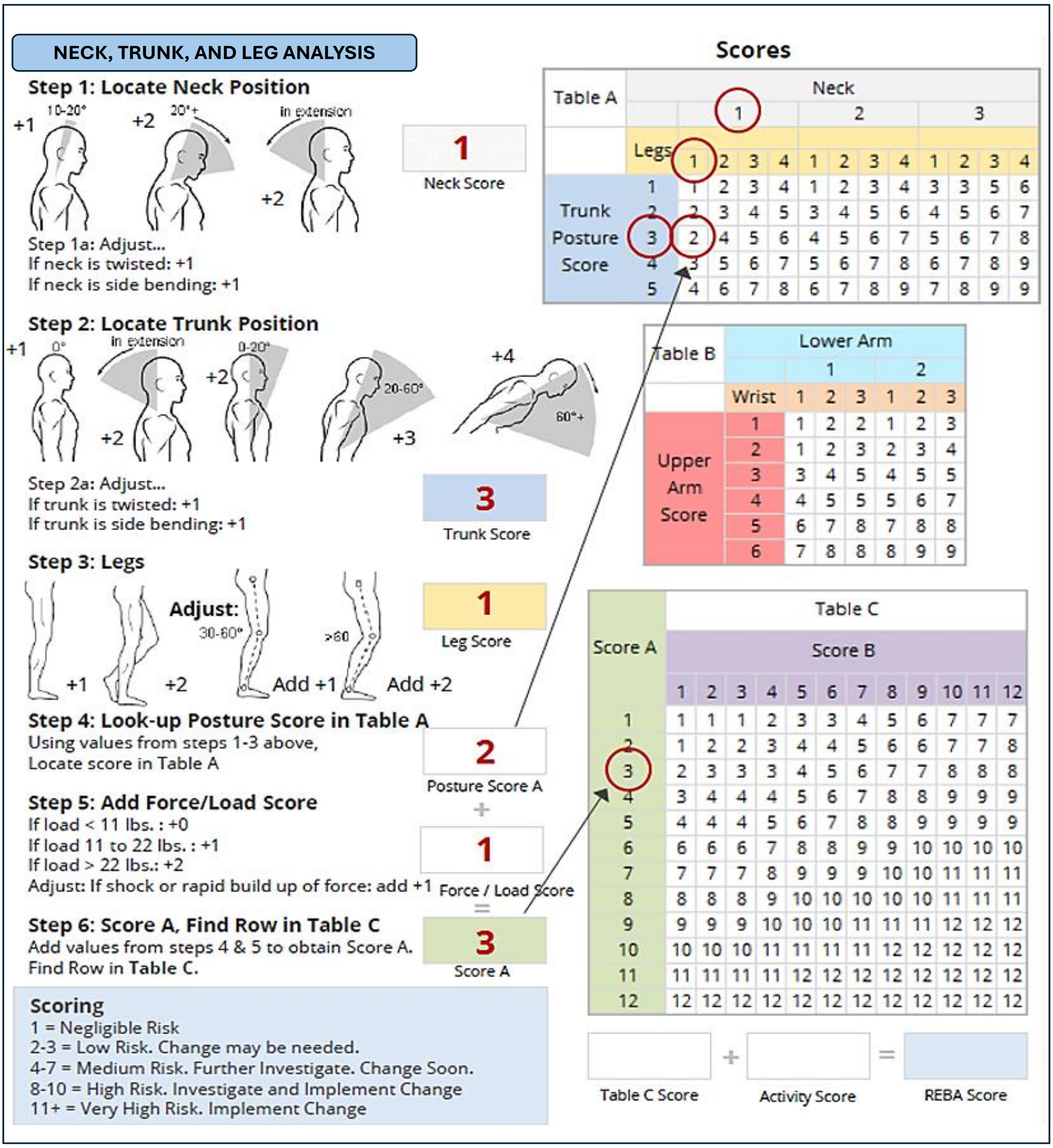
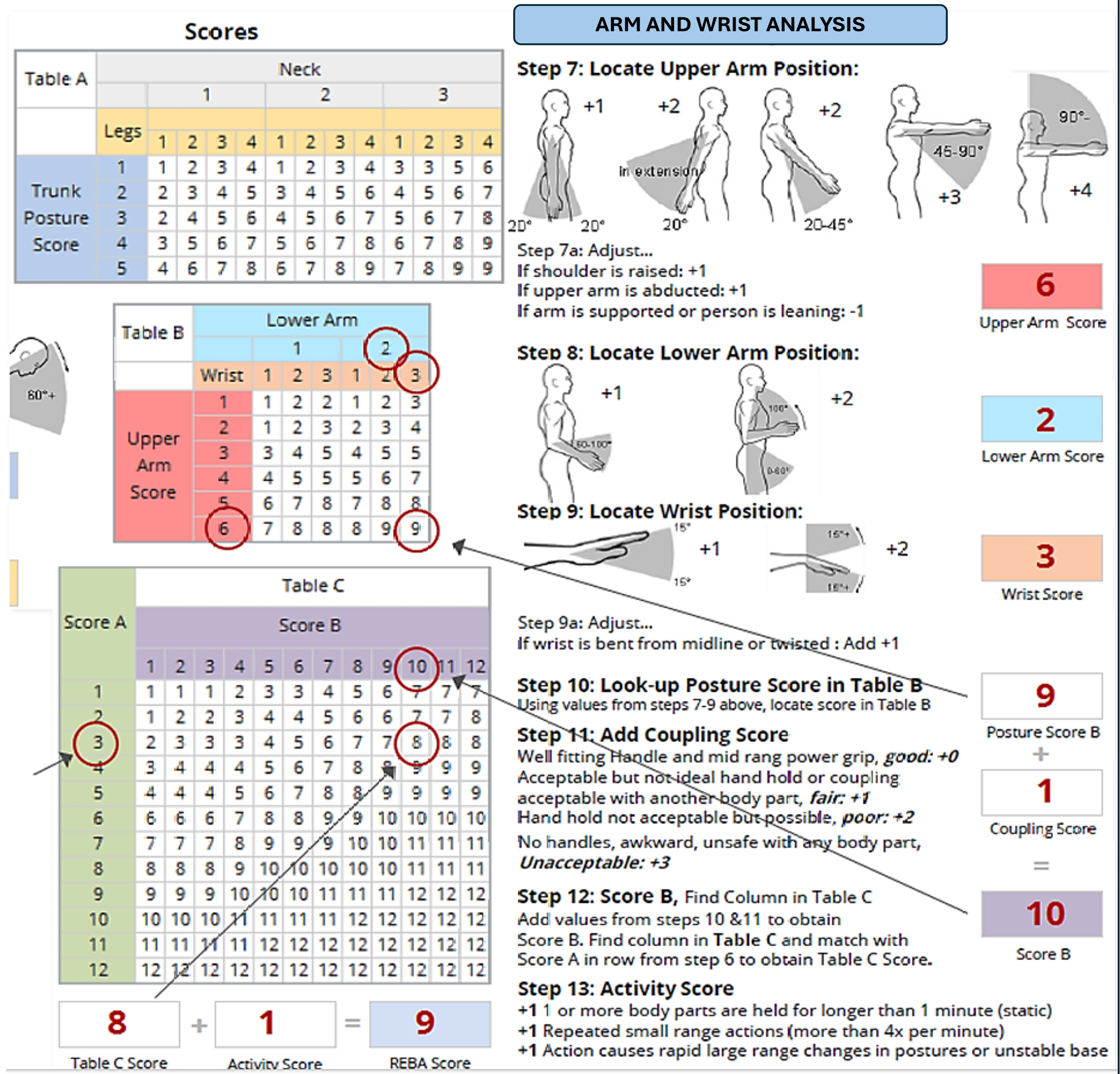


Figure. 1. Leg, Trunk & Leg Analysis Illustration [23]

1. Conducting interviews regarding workers' body discomfort using the Nordic Body Map (NBM) questionnaire as shown in **Figure 3**. Welders were asked to evaluate 28 body regions based on the following scale: 1= No. Pain, 2= Slight Pain, 3= Pain, dan 4= Severe Pain.
2. Performing visual inspection of weld results obtained from different positions, namely down hand, vertical, horizontal, and overhead.



Score	Level of MSD Risk
1	negligible risk, no action required
2-3	low risk, change may be needed
4-7	medium risk, further investigation, change soon
8-10	high risk, investigate and implement change
11+	very high risk, implement change

Figure. 2. Arm & Wrist Analysis Illustration

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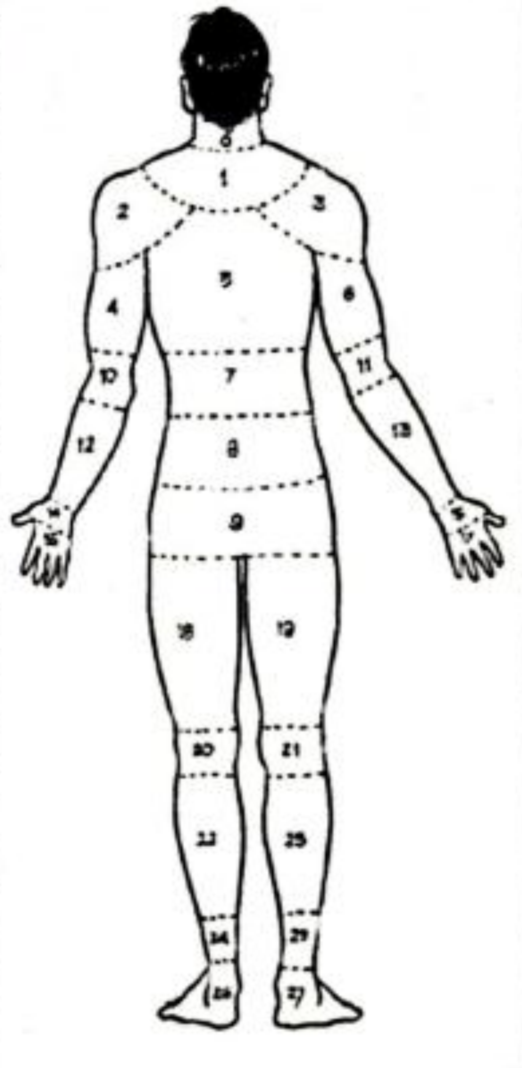
NORDIC BODY MAP QUESTIONNAIRE SHEET

Name :
Length of Service :
Working Hours :
Job/Occupation :

Please put a check mark (V) in the column according to the discomfort/pain/dependence you feel in the body part, referring to the figure provided.

No	Location	Pain Grade				Nordic Body Map (NBM)
		1	2	3	4	
0	Pain/stiff in the upper neck					
1	Pain in the lower neck					
2	Pain in the left shoulder					
3	Pain in the right shoulder					
4	Pain in the left upper arm					
5	Pain in the back					
6	Pain in the right upper arm					
7	Pain in the waist					
8	Pain in the buttock					
9	Pain in the bottom					
10	Pain in the left elbow					
11	Pain in the right elbow					
12	Pain in the left lower arm					
13	Pain in the right lower arm					
14	Pain in the left wrist					
15	Pain in the right wrist					
16	Pain in the left hand					
17	Pain in the right hand					
18	Pain in the left thigh					
19	Pain in the right thigh					
20	Pain in the left knee					
21	Pain in the right knee					
22	Pain in the left calf					
23	Pain in the right calf					
24	Pain in the left ankle					
25	Pain in the right ankle					
26	Pain in the left foot					
27	Pain in the right foot					



LIKERT SCALE NORDIC		
Likert Scale	Total Individual Score	Risk Grade
1	28-49	Low Risk
2	50-70	Medium Risk
3	71-90	High Risk
4	92-122	Veri High Risk

Figure. 3. Nordic Body Map (NBM)

III. Results and Discussion

A. Rapid Entire Body Assessment (REBA)

The REBA assessment was conducted on four welding positions, namely downhand, vertical, horizontal, and overhead. The result of REBA illustrated in **Figure 4**.

The REBA analysis revealed that all four welding positions in shipbuilding i.e., downhand, vertical, horizontal, and overhead are present high to very high ergonomic risks. The majority of welders in the downhand position were classified as high risk (36%) and very high risk (48%), with only a small proportion in the medium risk category (13%). although downhand welding is technically easier, the posture involving trunk flexion and bent legs results in significant strain on the lower back and calves. This finding is consistent with previous studies, which highlighted that trunk flexion

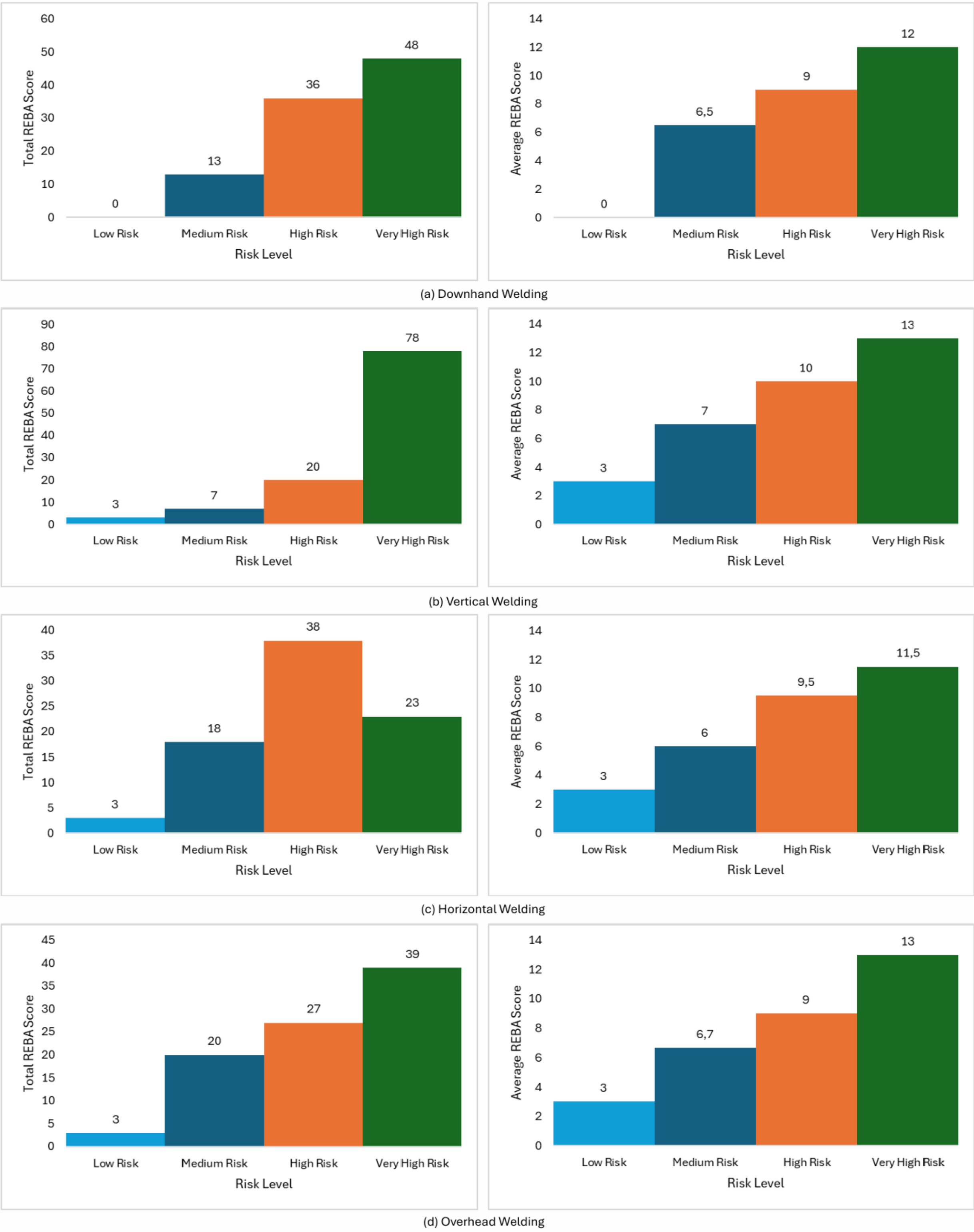


Figure. 4. Rapid Entire Body Assessment (REBA) Score

maintained for prolonged periods leads to musculoskeletal disorders in the lower back and legs.

Vertical welding showed the highest overall risk, with most welders classified as very high risk (78%) and an average REBA score of 13. This position requires welders to sustain awkward postures while applying upward force, thereby increasing stress on the neck, shoulders, and upper arms.

Horizontal welding presented a somewhat more balanced distribution, with welders falling into both high risk (38%) and very high risk (23%) categories. The average REBA score was 11.5, indicating that, despite being less demanding than vertical welding, horizontal welding still exposes workers to considerable ergonomic risk, particularly in the wrists and forearms due to repetitive and sustained movements.

Overhead welding was found to be highly demanding, with welders predominantly classified as very high risk (39%) and high risk (27%), reaching an average REBA score of 13. This position places considerable stress on the shoulders, neck, and arms due to continuous elevation of the upper limbs. Additionally, the overhead position exposes welders to increased safety hazards, such as falling sparks and fumes, which further compound physical discomfort.

B. Nordic Body Map (NBM)

Based on the analysis using the NBM method, the result is illustrated in **Figure 5**. **Figure 5** presents the comparison of musculoskeletal complaints identified using the Nordic Body Map (NBM) across four welding positions: downhand, vertical, horizontal, and overhead. The distribution of discomfort reported by welders corresponds closely to the ergonomic risk levels measured by the Rapid Entire Body Assessment (REBA).

The REBA scores previously obtained show that vertical welding carries the highest ergonomic risk (score 11, very high risk), which is consistent with the NBM results, where welders reported the highest prevalence of complaints in the waist (77.5%), calves (72.5%), and thighs (70%). These findings confirm that vertical welding is the most hazardous posture in terms of musculoskeletal strain.

Overhead welding also reflects high REBA scores (9, high risk), and the NBM results support this, with complaints concentrated in the neck (57.5%), waist (57.5%), and shoulders (50%), highlighting the cumulative effect of prolonged arm elevation and upward head posture. Horizontal welding, with a REBA score of 8 (high risk), shows complaints most concentrated in the right hand (67.5%) and right wrist (65%), underscoring the link between repetitive hand-intensive tasks and localized strain. Downhand welding, although categorized with a high REBA score of 10, remains the least ergonomically demanding compared to other positions, yet still demonstrates significant discomfort in the back and calves (70%) due to sustained bending.

The alignment between REBA and NBM outcomes indicates that welding postures with higher ergonomic risks are also those where workers report the greatest musculoskeletal discomfort. This has direct implications for productivity: welders experiencing pain and fatigue are more likely to slow down, lose concentration, and commit errors, leading to lower weld quality and higher rework rates. Over time, such conditions can increase absenteeism due to musculoskeletal disorders (MSDs), disrupt project schedules, and reduce overall efficiency in shipbuilding operations.

Therefore, the combined REBA and NBM analysis emphasizes that ergonomic interventions are not only necessary for health and safety but are also critical for maintaining productivity and weld quality in shipyards.

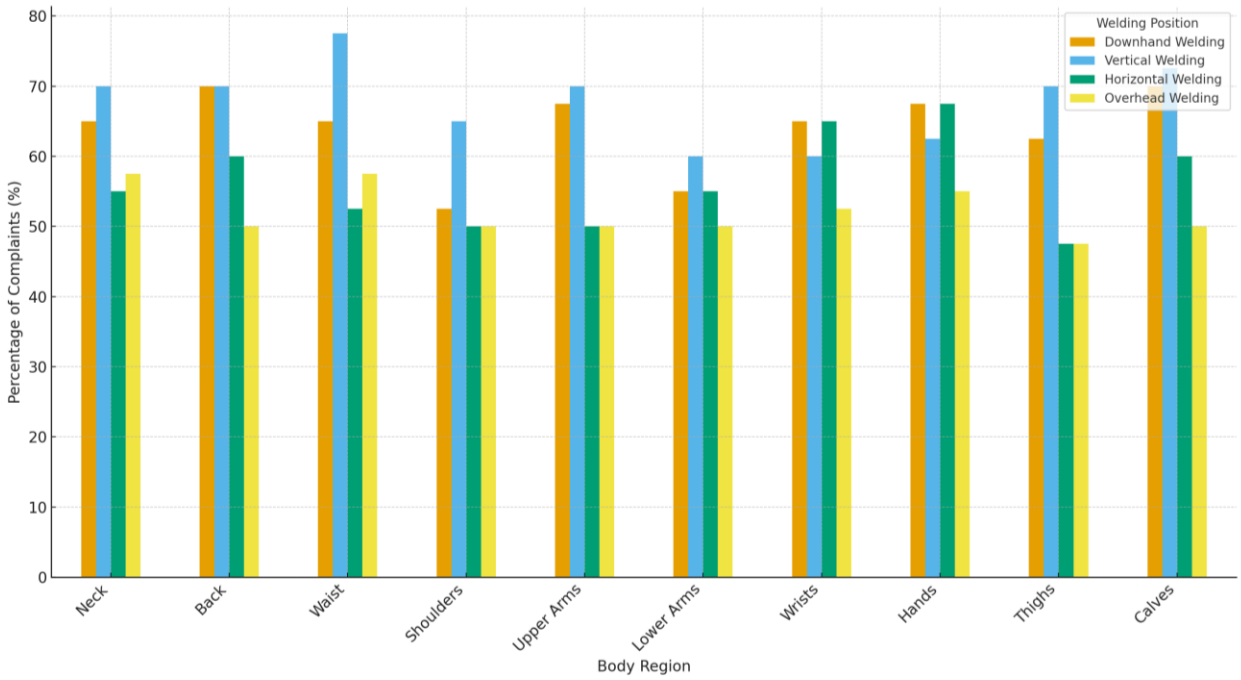


Figure. 5. Comparison of NBM Complaint Across Welding Positions

Ergonomically optimized working conditions, such as the use of scaffolding, adjustable supports, or mechanical aids, can significantly reduce physical strain, thereby enhancing efficiency and ensuring timely project completion.

IV. CONCLUSION

This research concludes that welding postures in shipbuilding, i.e., downhand, vertical, horizontal, and overhead, pose significant ergonomic risks, as indicated by REBA scores in the high to very high-risk categories (scores 8–11) and supported by NBM findings. Vertical welding showed the most severe impact, with 77.5% of welders reporting waist pain, 72.5% calf pain, and 70% back pain, while overhead welding led to 57.5% complaints in the neck and waist and 50% in the shoulders. Horizontal welding was dominated by upper extremity strain, with 67.5% of welders experiencing right-hand pain and 65% right-wrist pain, whereas downhand welding, though relatively less demanding, still caused 70% of welders to report back and calf pain. These results confirm that poor ergonomics not only increases musculoskeletal disorders but also reduces weld quality and productivity. Therefore, ergonomic interventions such as scaffolding, adjustable supports, mechanical aids, worker training, rotation schedules, and routine ergonomic assessments are essential to minimize risks, enhance safety, and maintain efficiency and competitiveness in shipbuilding operations.

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