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Assessing Ergonomic Risks in Laser Cutting Sheet Metal Operations Using REBA Method: A Case Study

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ABSTRACT

The laser cutting of sheet metal, which requires human participation, frequently introduces ergonomic challenges that can negatively impact both worker health and manufacturing productivity. Thus, conducting ergonomic assessments is crucial to identifying and addressing risks associated with workplace design and practices, particularly those related to lifting sheet metal and the potential for musculoskeletal disorders (MSDs). This study uses the Rapid Entire Body Assessment (REBA) method and the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) to investigate ergonomic risk assessment in laser cutting operations. Data were collected from participants familiar with the tasks through questionnaires and observations, focusing on lower and upper back disorders. The REBA analysis revealed that lifting sheet metal is linked to poor posture and a high risk of lower and upper back disorders, highlighting the need for improvements. Concurrently, CMDQ results highlighted issues related to lower back discomfort and upper back and forearm discomfort, which can detrimentally affect process efficiency. Integrating ergonomic principles into the design process can enhance worker safety and health, increasing productivity and fostering a more sustainable work environment that benefits both employees and the organization.

1. Introduction

The material handling process in sheet metal cutting operations poses significant challenges that can negatively impact worker safety, productivity, and operational efficiency. Workers frequently lift transport, and position heavy and awkwardly shaped metal sheets, increasing the risk of musculoskeletal disorders (MSDs) due to improper lifting, repetitive motions, and prolonged awkward postures [1]. Inadequate ergonomic workstation design and insufficient use of mechanical aids further heighten these risks, leading to fatigue, decreased job satisfaction, and increased absenteeism [2]. The variability in sheet metal sizes and weights complicates handling procedures, making it challenging to implement standardized safety practices. Addressing these issues is crucial for improving worker health and productivity, requiring a thorough evaluation of current practices

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and implementing ergonomic interventions [1,3]. In addition, while automation technology is rising in manufacturing, manual assembly tasks remain vital for assembling parts and creating complete products [4]. Manual assemblers utilize their unique sensorimotor skills to adapt to new processes quickly; their presence is essential for performing precise tasks [5,6]. Manual solutions are particularly beneficial for low-volume, complex tasks due to their flexibility in meeting product requirements [7]. It is essential to understand their efficiency, as assembly methods significantly affect overall production efficiency and costs [8].

Musculoskeletal disorders (MSDs) are prevalent nonfatal occupational injuries, particularly in industries where manual handling of materials is required. Such workers are at heightened risk of MSDs and associated body pains due to frequent awkward working postures and repetitive movements. These disorders are notably common across various manufacturing stages and have seen a significant increase in incidence, as reported by Malaysia's Social Security Organization (SOCSO) [9-11]. Work-related musculoskeletal disorders (WMSDs) are now recognized as widespread occupational diseases. Research by Krishnan *et al.,* [12] and Govaerts *et al.,* [13] has further reinforced this trend. While rest and sick leaves can temporarily relieve symptoms, they often recur once workers return to environments with hazardous postures [14]. The development of MSDs is significantly influenced by occupational activities, especially those involving prolonged awkward postures, heavy lifting, bending, twisting, maintaining static positions, overexertion, and exposure to excessive vibrations. These physical conditions are crucial risk factors in the workplace that markedly increase the likelihood of developing MSDs [15]. In addition to workplace conditions, personal factors play a significant role in the susceptibility to MSDs, highlighting that personal items and awkward body postures can predict musculoskeletal symptoms [16]. Research by Karwan *et al.,* [17] shows that factors such as age, smoking, physical activity, and employment duration significantly correlate with upper limb disorders. Similarly, Khanzode *et al.,* [18] emphasized that individual factors are linked to occupational injuries and accidents. Furthermore, older age, emotional exhaustion, and smoking have been identified by Oha *et al.,* [19] as significant risk factors for musculoskeletal pain across various body regions.

Besides that, regular ergonomic assessments are crucial for monitoring worker health and preventing musculoskeletal disorders (MSDs). These assessments combine self-report questionnaires and observational methods, though the latter can be subjective and lead to inconsistent risk evaluations [20]. To mitigate MSD risks, organizations should redesign workstations, minimize repetitive motions, manage load handling, educate workers on safe practices, and encourage breaks. Continuous monitoring of workplace conditions is also essential [21,22]. This includes redesigning workstations to promote neutral body postures, minimizing repetitive motions, and managing load handling to prevent overexertion [2]. The Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) is an effective tool for evaluating MSDs, as it consolidates pain frequency and intensity across 20 body regions into a single-page chart. Prioritizing worker health enhances productivity and well-being [23].

Various ergonomic assessment tools and methods are employed to identify and evaluate the key risk factors related to musculoskeletal disorders (MSDs). These assessments suggest essential actions and changes based on the identified risk levels to mitigate adverse impacts on workers. Moreover, one of REBA's primary advantages is its cost-effectiveness and simplicity. Data can be collected using pen and paper, although computer applications are also available to enhance efficiency. By providing individual scores for each assessed body part, REBA effectively identifies critical ergonomic issues, making it particularly valuable in occupational health settings for improving workplace safety and employee well-being [11,24]. Thus, REBA is widely applied across various sectors and frequently compared with other assessment methods, providing a comprehensive score that considers all body parts, load handled, and coupling types [24,25].

2. Methodology

The research will focus on a laser-cutting sheet metal process requiring human involvement. It aims to investigate the ergonomic factors related to the interaction between operators and the equipment utilized in the cutting process. The study included a sample of eight workers involved in laser cutting. Participants completed a questionnaire designed to identify ergonomic issues associated with this process. The process consists of three workers handling the sheet metal before and after the cutting operation and one worker operating the cutting machine. All individuals involved are well-trained and knowledgeable about their respective roles within the sheet metal processing area. Furthermore, video recordings were made to evaluate their working conditions for ergonomic risk assessment. The Rapid Entire Body Assessment (REBA) was performed using ErgoFellow software, effectively assessing and identifying ergonomic risks.

2.1 Process Involved

Laser cutting encompasses several processes from initiation to the production of quality parts. This procedure involves the machinery, workforce, and materials required for cutting, as outlined in Table 1. The complete process accounts for all activities involved in laser cutting, which also requires internal data collection to record the time taken. This study will focus on the GN CFD-T3015 laser cutting machine, a fibre laser system capable of 2-axis cutting designed primarily for high-power applications with a capacity of 4KW.

2.2 Selection of Process Area.

The laser-cutting process involves several stages necessary to complete the operation. This study concentrates on analyzing a specific stage chosen based on the responses from the questionnaire. The selected area emphasizes health concerns and musculoskeletal strain. Conducting an ergonomic risk analysis is essential for evaluating how these ergonomic issues affect production efficiency. The analysis area was chosen by considering the challenges associated with the tasks and the constraints that impede improvement efforts. It also mainly addresses tasks that involve lifting, which pose significant risks to the health and well-being of workers. Observations of the selected process areas indicated they required considerable human force to accomplish the tasks. The questionnaire was instrumental in identifying which aspects of the process presented the most significant difficulties in task execution.

Table 1
Detail Process involved

No.	Process Involved	Description
1	Loading raw material to bay	Loading raw materials from the materials storage by using a forklift
2	Loading raw material on the table	The sheet metal is loaded onto the machine's table using human force.
3	Machine setup	The cutting parameter is set according to the thickness and material.
4	Start cutting	The sheet metal is cut into parts.
5	Unloading parts	Unloading the cutting parts from table onto the pallets
6	Counting and Checking	Counting the quantity of cutting parts and checking the quality of parts.

2.3 Cornell Musculoskeletal Discomfort Questionnaire (CMDQ)

The CMDQ questionnaire was utilized to gather data essential for evaluating ergonomic risks. The findings assist in identifying which postures are influenced by the activities performed. Specifically designed to assess lifting activities carried out in a standing position, the questionnaire considers the weight of the materials being lifted, as greater weight is associated with increased difficulty and a higher risk of injury. Additionally, the questionnaire helps identify the postures impacted by these lifting tasks. Understanding these postures is vital for formulating strategies to alleviate discomfort and improve workplace ergonomics. The scoring results can reveal the critical body regions impacted. According to the CMDQ scoring guidelines (see Table 2) from the Cornell University Ergonomics Web [26], the overall discomfort score for a specific body part is calculated by multiplying the frequency, intensity, and interference scores.

Table 2
Rating score for CMDQ calculation [27]

Frequency of discomfort	Intensity of discomfort	Interference of discomfort
0-Never	1 = Slightly uncomfortable	1 = Not at all
1.5 = 1-2 times per week	2 = Moderately uncomfortable	2 = Slightly interfered
3.5 = 3-4 times per week	3 = Very uncomfortable	3 = Substantially interfered
5 = Every day		
10 = Several times every day		

2.4 Rapid Entire Body Assessment (REBA)

Prior to performing the REBA assessment, worker body postures during lifting sheet metal should be evaluated, taking into account factors such as the difficulty of maintaining the posture, the duration spent in that position, and the associated load, as illustrated in Figure 1. The REBA assessment assigns scores based on the arms, wrists, neck, legs, and trunk positions. These scores are instrumental in identifying potential ergonomic risks and informing interventions to enhance workplace ergonomics, reducing the likelihood of musculoskeletal disorders. This assessment was carried out using ErgoFellow software, which automatically calculates the total score for risk factor evaluation. The software also examines the posture depicted in the respondent's image in the evaluation process.

Fig. 1. Worker body posture during lifting sheet metal

2.5 Data Collection

The data collected in this study consisted of a combination of surveys and interviews conducted with a diverse group of respondents, along with their risk assessment score sheets and a thorough analysis of these scores. After completing the interviews, the working postures of each respondent were systematically observed and meticulously documented to gain a comprehensive understanding of their ergonomic practices. During this detailed observation, images of the respondent's postures were captured to aid further analysis. These images were later evaluated using ErgoFellow software, which offered valuable insights into posture-related risks. Additionally, the surveys completed by each respondent were carefully analyzed to identify critical activities within the overall process, providing a deeper understanding of the factors affecting their working conditions.

3. Results

The analysis of the REBA assessment for the process of loading material onto a table revealed a score of 10, indicating a high risk that necessitates further investigation and the implementation of changes. Figure 2 represents an image illustrating the analysis of the awkward posture angles observed while lifting sheet metal onto the laser cutting table. This analysis indicates that the working posture for lifting raw materials to the table is characterized by poor working conditions, highlighting the need for improvements.

Recent analyses of musculoskeletal disorders have revealed significant variations in impact across different anatomical regions. According to the comprehensive scoring matrix presented in Table 3, the assessment encompasses multiple parameters including frequency, severity, interference, and overall MSD scores, providing a nuanced understanding of physiological stress distribution. The findings demonstrate a notable concentration of musculoskeletal stress in the axial skeleton, particularly the vertebral regions. The lower back exhibits the highest MSD score of 21,945 (24.47%), followed by the upper back at 17,450 (19.47%). This predominance of spinal involvement suggests a significant occupational burden on the central support structures of the musculoskeletal system. The forearm region also shows substantial involvement, with an MSD score of 15,665.5 (17.47%), indicating considerable upper extremity stress. A consistent study by Punnett and Wegman [28] emphasized that low back pain is one of the most common musculoskeletal disorders among workers, often linked to physical demands and poor ergonomic practices in the workplace. Their research supports that the lower back is frequently stressed due to lifting and repetitive tasks.

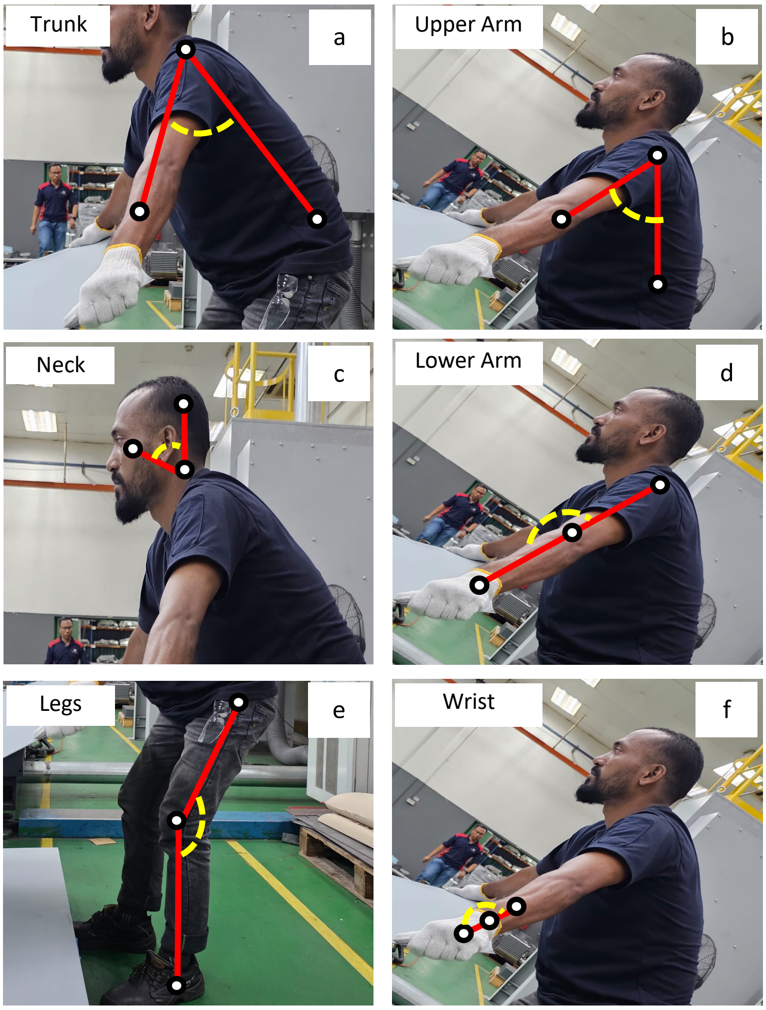

Fig. 2. REBA posture assessment during lifting sheet metal for the worker in the laser cutting department (a) trunk (b) upper arm (c) neck (d) lower arm (e) leg (f) wrist

In contrast, certain anatomical regions display remarkably lower involvement. The cervical region (neck) demonstrates minimal impact with an MSD score of 135 (0.15%), while bilateral wrist measurements indicate relatively low scores ranging from 931.5 to 1,242 points (1.04-1.39%). Bilateral shoulder assessments reveal identical scores 5,880 (0.06%), suggesting symmetrical stress distribution. The methodology employs a multi-dimensional scoring approach, with frequency measurements ranging from 1.5 to 48.5, severity scores of 9 to 19, and interference values between 9 and 21. This comprehensive evaluation framework quantifies musculoskeletal impact across various body segments. Bilateral structures demonstrate remarkable scoring consistency, reinforcing the assessment's reliability. These findings have significant implications for occupational health interventions and ergonomic modifications. The clear predominance of axial skeletal involvement, particularly in the thoracolumbar region, suggests a need for targeted preventive strategies focusing on spinal protection and postural optimization. Furthermore, the substantial upper extremity involvement indicates a requirement for comprehensive ergonomic solutions addressing both axial and appendicular musculoskeletal structures. According to Hoe et al., [29], disorders of the upper limbs and neck are common among workers involved in manual handling tasks. This indicates that ergonomic interventions should extend beyond spinal health to encompass the upper extremities to reduce the risk of developing musculoskeletal disorders (MSDs).

Table 3
MSD's scoring result frequency, severity, interference and percentage scoring at laser cutting table

Body parts	Frequency	Severity	Interfere	MSD Score	Percentage%
Neck	1.5	10	9	135	0.15
Shoulder (R)	24.5	12	20	5880	0.06
Shoulder (L)	24.5	12	20	5880	0.06
Upper back	48.5	18	20	17460	19.47
Upper arm (L)	35	15	16	8400	9.36
Lower back	55	19	21	21945	24.47
Forearm (L)	48.5	17	19	15665.5	17.47
Wrist (R)	11.5	9	9	931.5	1.04
Wrist (L)	11.5	9	12	1242	1.39
Lower leg (R)	15	12	15	2700	3.01
Lower Leg (L)	15	12	15	2700	3.01
Foot (R)	20	14	12	3360	3.75
Foot (L)	20	14	12	3360	3.75

4. Conclusions

This study examined the laser-cutting sheet metal process that involves human participation, identifying inefficiencies and ergonomic issues. The REBA assessment revealed a high risk due to poor working postures, particularly concerning lower and upper back disorders. Additionally, the CMDQ assessment indicated that workers faced lower back problems and discomfort in the upper back and forearms. Thus, modifications are needed to improve the working postures associated with lifting sheet metal. Supportive material handling mechanisms can significantly mitigate ergonomic risks and enhance workflow efficiency, optimizing labour utilization. Incorporating ergonomic principles into the design process can improve worker safety and health, resulting in increased productivity and a more sustainable work environment that benefits both employees and the organization.

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