

ORIGINAL ARTICLE

Work-Related Musculoskeletal Risk in Manual Layup: An Ergonomic Case Study in the Aerospace Sector

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ABSTRACT

This study investigates ergonomic risks associated with the manual hand layup process in aerospace sector, focusing on Work-Related Musculoskeletal Disorders (WMSDs). Using a structured methodology aligned with the Department of Occupational Safety and Health (DOSH) Malaysia, the assessment incorporated the Nordic Musculoskeletal Questionnaire (NMQ), Rapid Entire Body Assessment (REBA), and Assessment of Repetitive Tasks (ART). Findings revealed significant discomfort in the shoulders, lower back, and wrists due to repetitive motion and awkward postures, with ART and REBA scores indicating medium to high risk levels. Interventions including workstation redesign, use of ergonomic hand tools, job rotation, micro-breaks, and posture training were proposed to mitigate these risks. The study emphasizes the importance of integrating ergonomic principles to enhance worker safety, reduce injury, and improve productivity in composite manufacturing settings.

Keywords: Ergonomic Risk Assessment, Manual Hand Layup, Work-Related Musculoskeletal Disorders, REBA Tool, ART Tool

INTRODUCTION

Ergonomic risk is a critical concern in manual-intensive operations such as the hand lay-up process used in aerospace composite manufacturing. This task requires workers to repeatedly place prepreg materials onto moulds while maintaining awkward postures and performing repetitive motions were the key contributors to Work-Related Musculoskeletal Disorders (WMSDs) (Crowly et. al., 2016; Rayme et. al., 2018). Research has shown that a large percentage of lay-up workers report lower-back discomfort, with Rapid Upper Limb Assessment (RULA) scores consistently exceeding 6, highlighting urgent needs for ergonomic redesign of workstations (Rayme et. al., 2018). Composite materials are widely used in the fabrication of critical aircraft components due to their high strength-to-weight ratio. Among the various manufacturing techniques available, manual hand layup remains the most employed method. This process involves the manual

placement of carbon fiber reinforcement materials onto a mold surface to form the desired composite structure (Elkington et al., 2015). Manual layup, which relies heavily on Manual Material Handling (MMH), is one of the most cost-effective composite fabrication methods. However, the physical demands of MMH can significantly increase the risk of developing musculoskeletal disorders (MSDs) among workers (Deros et al., 2010). Low Back Pain (LBP) is one of the most common work-related musculoskeletal disorders (MSDs) among workers involved in the hand layup process of composite manufacturing, particularly in the aerospace industry. It is frequently associated with prolonged awkward postures and is classified alongside conditions such as Carpal Tunnel Syndrome (CTS) and Trigger Finger (Rayme, et al., 2022).

This paper presents a case study focused on ergonomic risk assessment in the manual hand layup process within the aerospace manufacturing sector. The assessment utilizes established tools recommended by the Department of Occupational Safety and Health (DOSH), including the Nordic Musculoskeletal Questionnaire (NMQ), Rapid Entire Body Assessment (REBA), and Assessment of Repetitive Task (ART). The primary objectives are to identify key ergonomic risk factors, evaluate the severity of these risks, and propose appropriate engineering and administrative interventions aimed at improving worker safety, comfort, and overall productivity.

LITERATURE REVIEW

Composite materials are extensively used in aerospace applications due to their superior strength-to-weight ratio and design adaptability (Jiao, et al., 2024; Elkington et al., 2015). The manual hand layup method remains one of the most common composite fabrication techniques, particularly for complex or low-volume parts, due to its low cost and flexibility. However, the manual hand layup process exposes workers to sustained awkward postures, repetitive hand movements, and significant physical exertion, all of which are major ergonomic risk factors that contribute to the development of musculoskeletal disorders (MSDs) (Rayme, et al., 2023). Lower back pain (LBP) is frequently documented among composite laminators, often resulting from prolonged bending during hand layup tasks. Other common MSDs in this field include carpal tunnel syndrome and trigger finger, as categorized under occupational musculoskeletal diseases (Greggi, et al., 2024). Ergonomic risk assessment tools like REBA and ART have been widely validated for evaluating body posture and repetitive task exposure in manufacturing settings. Research suggests that ergonomic interventions such as improved workstation design, vacuum-assisted systems, and worker training can substantially reduce physical strain and enhance safety outcomes. Despite this, implementation of ergonomics in many composite production environments remains inadequate, underlining the need for case-specific studies and actionable recommendations (Yusof, et al., 2023).

METHODOLOGY

This study adopted a structured ergonomic risk assessment approach guided by the Department of Occupational Safety and Health (DOSH) Malaysia. The methodology comprised three main phases: risk identification, ergonomic

assessment, and recommendation of interventions. In the first phase, the Nordic Musculoskeletal Questionnaire (NMQ) was distributed to workers involved in the manual hand layup process. The purpose was to identify areas of the body experiencing discomfort or pain within the past 12 months and 7 days, allowing the researchers to pinpoint the most affected body regions. In the second phase, two ergonomic assessment tools were employed to evaluate the severity and nature of the ergonomic risks. The Rapid Entire Body Assessment (REBA) tool was used to assess posture-related risks by observing and analyzing workers' body positions during the layup process. Simultaneously, the Assessment of Repetitive Task (ART) tool was utilized to evaluate the frequency and intensity of repetitive upper limb movements, including factors such as force exertion, posture, and recovery time. The final phase involved proposing appropriate risk mitigation strategies based on the assessment findings. These included both engineering and administrative controls, such as workstation redesign, implementation of vacuum-assisted tools, use of anti-fatigue mats, and job rotation schemes. This comprehensive methodology enabled a detailed understanding of ergonomic risks and informed practical recommendations for reducing musculoskeletal strain in aerospace composite manufacturing.

RESULT AND DISCUSSION

The initial ergonomics risk assessment revealed that the worker involved in the layup process experienced musculoskeletal discomfort, particularly in the shoulder, lower back, and hand/wrist. Table 1 summarizes the ergonomic risk factor for manual hand layup task. The symptoms were linked to repetitive motions and awkward postures observed during tasks such as ply removal, layup and cover removal, and trimming. The assessment showed that these tasks exceeded the recommended exposure thresholds for awkward posture and repetitive motion, warranting further investigation through advanced ergonomics risk assessment. In contrast, no significant risks were identified for vibration, environmental factors, or static posture. These findings highlight the need for ergonomic improvements in the layup process.

Table 1: Summary of Ergonomics Risk Factors Assessment for Manual Hand Layup task.

Task	Affected Body Parts	Ergonomic Risk Factors	Further Action
Ply removal	shoulder	Awkward posture, Repetitive motion	Advanced ERA recommended
Layup and cover removal	shoulder, lower back, hand/wrist	Awkward posture, Repetitive motion	Advanced ERA recommended
Trimming	shoulder, lower back, hand/wrist	Awkward posture, Repetitive motion	Advanced ERA recommended

The advanced ergonomics risk assessment for the manual hand layup process identified two major risk factors as summarized in Table 2 which is repetitive motion and awkward posture. According to the Washington State Ergonomics Rule (2004), tasks involving repetitive motion of the hands, wrists, or shoulders for more than three hours per day are classified as high repetition. This includes intensive use of fingers for precise placement of materials, resulting in a

high ART (Assessment of Repetitive Tasks) score of 26, which indicates a high level of risk. Additionally, the process requires the worker to perform tasks on large working table while maintaining close visual focus, forcing the worker to reach toward the center of the table. This leads to awkward postures such as elevated shoulders, forward bending of the back beyond 30 degrees, and sideways arm abduction for prolonged durations (Yale Environmental Health & Safety (n.d.), 2018). These factors contributed to a REBA (Rapid Entire Body Assessment) score of 5, which is considered a medium risk level and warrants further ergonomic intervention.

Table 2: Summary of Advanced Ergonomics Risk Assessment.

Risk Factor	Description	Assessment tool	Score	Risk Level
Repetitive motion	- Repetitive sequences > 2/min for > 3 hrs/day - Intensive use of fingers, wrists, and shoulders - Continuous arm movements with minimal pause	ART	26	High
Awkward Posture	- Large tables require reaching far - Close visual focus needed - Shoulder raised > 2 hrs/day - Back bent > 30° for > 2 hrs/day - Arm abduction > 4 hrs/day	REBA	5	Medium

To address the identified ergonomic risks in the manual hand layout process, a combination of engineering and administrative controls is proposed. Table 3 shows the summary of interventions targeting two main risk factors: repetitive motion and awkward posture. For repetitive motion, administrative controls such as job rotation and scheduled micro-breaks (1–2 minutes every 20–30 minutes) are recommended to reduce muscle fatigue. The use of ergonomic hand tools is also advised to minimize strain on fingers and wrists. For awkward posture, the need for adjustable-height tilt tables to reduce excessive reaching and bending. Posture awareness training and stretching exercises are suggested to support long-term musculoskeletal health.

Table 3: Suggested Ergonomic Interventions

Risk factor	Issues identified	Recommend Interventions	Type
Repetitive motion	- Continuous use of hands, wrists, and shoulders for >3 hours/day - High repetition rate (>2/min)	- Implement job rotation to alternate tasks and reduce cumulative load - Introduce micro-breaks (1–2 mins every 20–30 mins)	Administrative Control
		- Use ergonomic hand tools to reduce strain on fingers and wrists	Engineering Control
Awkward Posture	- Elevated shoulders, bent back >30°, arm abduction due to large table and reach distance	- Redesign workstation with adjustable-height tilt tables to minimize reaching and bending	Engineering Control
		- Provide anti-fatigue mats and adjustable seating or stools for postural support	Engineering Control

		- Conduct posture awareness training and encourage frequent stretching exercises	Administrative Control
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To support the recommendation of using ergonomic hand tools, studies show that properly redesigned tools can significantly reduce strain on the fingers, wrists, and hands. For example, the Canadian Centre for Occupational Health and Safety (CCOHS) explains that factors such as tool weight, handle size, grip shape, and fit to the user and task are crucial in preventing work-related musculoskeletal disorders (WMSDs) during repetitive tasks (CCOHS, n.d.). Likewise, a feature from Occupational Health & Safety Online highlights that ergonomic assembly tools with optimized shapes, balanced weight, low vibration, and comfortable grips help mitigate hand and arm fatigue in manufacturing environments (Occupational Health & Safety, 2019).

CONCLUSION

The serious ergonomic risks in the manual hand layup process used in aerospace manufacturing, mainly due to repetitive motions and awkward postures. Workers commonly experience discomfort in the shoulders, lower back, and wrists. High ART and REBA scores confirm the need for improvement. To reduce these risks, it is recommended to redesign workstations with adjustable tables, use ergonomic tools, and provide anti-fatigue mats. Administrative actions like job rotation, short breaks, and posture training are also helpful. These changes can improve worker safety, reduce injuries, and increase productivity. Proper ergonomic practices are essential for a safer, more efficient workplace.

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