

Evaluating and Mitigating Musculoskeletal Risks among the Operators: A Case Study in a Small-Scale Automotive Repair Workshop

Rini Oktavera^{1*}, Muh Ilal Sarifudin¹, Wahyu Eko Cahyono¹, Moh. Ainul Fais¹, IGA Sri Deviyanti²

¹ Department of Industrial Engineering, Engineering Faculty, WR Supratman University, Surabaya, Indonesia

² Department of Industrial Engineering, Faculty of Science and Technology, Institut Sains dan Teknologi Surabaya, Surabaya, Indonesia

Received: December 10, 2024

Revised: February 16, 2025

Accepted: April 25, 2025

Published: April 30, 2025

Corresponding Author:

Rini Oktavera

rini.oktavaera@gmail.com

DOI: [10.29303/jppipa.v11i4.10682](https://doi.org/10.29303/jppipa.v11i4.10682)

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Abstract: Musculoskeletal Disorders (MSDs) are a prevalent issue among lathe operators in small automotive repair workshops, largely due to repetitive movements, prolonged static positions, and awkward postures. This study employed the Nordic Body Map (NBM) and Workplace Ergonomic Risk Assessment (WERA) to evaluate ergonomic risks and identify affected body areas among lathe operators at XYZ workshop. Results indicate significant discomfort in the lower back, neck, shoulders, and wrists, linked to static postures and repetitive motions required for lathe operations. WERA scores revealed moderate ergonomic risks, particularly involving shoulder posture and work duration. Visual summaries in the form of bar and radar charts illustrate key risk factors. To mitigate these risks, the study proposes low-cost ergonomic interventions such as workstation adjustments, anti-vibration gloves, regular breaks, posture training, and rotational work schedules. These interventions not only address immediate discomfort but also have long-term potential for reducing MSDs when integrated into worker training programs. Moreover, the study's findings can be utilized as contextual learning materials within applied science education (IPA terapan) at vocational schools (SMK), fostering ergonomic literacy among students and educators. This study fills a significant gap in ergonomic research in informal micro-industry settings and offers actionable insights for both occupational health improvement and science-based curriculum development in vocational education.

Keywords: Ergonomic risk; MSDs; small workshop; WERA; applied science education

Introduction

The prevalence of Musculoskeletal Disorders (MSDs) has become a central issue in occupational health, especially in industrial sectors that involve repetitive, high-intensity physical tasks. Particularly in small-scale workshops, such as automotive repair and machining operations, lathe operators are highly susceptible to MSDs due to the physically demanding nature of their work. These operators frequently engage

in prolonged static postures, repetitive tool manipulation, and awkward body positions, which intensify ergonomic risks and lead to various musculoskeletal complaints (Chourasia et al., 2022). The primary areas affected include the lower back, neck, shoulders, and wrists – regions subjected to continuous stress and strain due to suboptimal working conditions and lack of ergonomic adjustments (Qibtiyah et al., 2023). Increased awareness of these ergonomic risks has spurred the development of assessment tools such as the

How to Cite:

Oktavera, R., Sarifudin, M. I., Cahyono, W. E., Fais, M. A., & Deviyanti, I. S. Evaluating and Mitigating Musculoskeletal Risks among the Operators: A Case Study in a Small-Scale Automotive Repair Workshop. *Jurnal Penelitian Pendidikan IPA*, 11(4), 372-381. <https://doi.org/10.29303/jppipa.v11i4.10682>

Nordic Body Map (NBM) and Workplace Ergonomic Risk Assessment (WERA), which are widely used to identify and evaluate occupational risks that contribute to MSDs.

Despite significant attention in larger manufacturing settings, ergonomic assessments and interventions are less frequently applied in smaller workshops due to financial and resource constraints. Studies in similar industrial environments underscore that smaller enterprises often lack structured ergonomic programs, which further exposes workers to MSD risks (Nejad et al., 2013). However, research also shows that even low-cost ergonomic interventions can have substantial effects on reducing discomfort and enhancing worker productivity. For example, targeted improvements in workstation design, task rotation, and use of supportive tools have been shown to reduce ergonomic strain and improve posture among workers in various settings (Dewangan & Singh, 2015). These findings suggest that effective ergonomic interventions can be beneficial even in small workshops by focusing on practical, affordable adjustments that reduce physical strain without requiring significant structural changes.

Several studies have demonstrated that ergonomic improvements can significantly mitigate MSD risks across different industries and occupational roles. For instance, a participatory ergonomic approach among childcare workers led to notable reductions in physical exertion and musculoskeletal discomfort, with 50-58% of participants reporting improved comfort and performance following the intervention. Similarly, an ergonomic program implemented for video display terminal operators resulted in sustained reductions in low back pain over a three-year period, underscoring the long-term benefits of ergonomic training and workstation adjustments (Pillastrini et al., 2010). The success of these interventions highlights the value of involving workers in the ergonomic assessment process, allowing for adjustments that directly address the most pressing discomforts and enhancing overall adoption of ergonomic practices.

Lathe operations in particular involve repetitive and high-force tasks that increase MSD risk, often necessitating a focused ergonomic assessment to identify specific areas of improvement. (Chourasia et al., 2022) emphasize that lathe operators, similar to those in the XYZ workshop, often face higher ergonomic risks due to awkward postures and repetitive actions. Furthermore, a study by (Park & Kim, 2020) found that prolonged exposure to improper ergonomic practices can exacerbate musculoskeletal symptoms, with increased risk of chronic pain and physical limitations. These findings support the necessity for ergonomic

interventions in lathe work, especially in settings with limited ergonomic infrastructure.

To address ergonomic risks systematically, the NBM and WERA are often applied. NBM is particularly effective for identifying specific areas of discomfort, providing a clear visualization of MSD risk across various body regions. Meanwhile, WERA offers a structured risk evaluation based on factors like posture, force, and repetition, making it a comprehensive tool for analyzing specific job tasks (Baydur et al., 2016). In small automotive workshops, adapting these tools to the specific context can yield valuable insights into the physical demands faced by lathe operators, guiding tailored interventions. However, while the use of WERA and NBM is well-established in ergonomic research, their application in smaller, resource-constrained environments remains limited, which this study aims to address.

The purpose of this study is therefore twofold: to assess the ergonomic risks of lathe operators in a small automotive repair workshop using NBM and WERA, and to propose low-cost, practical ergonomic interventions based on the identified risk factors. This research seeks to bridge the gap in ergonomic practices between larger manufacturing environments and smaller workshops by demonstrating that even minimal adjustments, such as posture training, anti-vibration gloves, and workstation improvements, can significantly reduce MSD symptoms among lathe operators (Ranavolo et al., 2020). These interventions, guided by assessment results, are intended not only to improve immediate operator comfort but also to foster a sustainable culture of ergonomic awareness within small workshops.

In summary, this study contributes to a growing body of knowledge on ergonomic risk management in labor-intensive occupations, particularly in small-scale environments. By focusing on accessible and cost-effective ergonomic solutions, this research highlights that it is possible to achieve meaningful reductions in MSDs without extensive resources. The findings aim to inform small workshop managers, occupational health practitioners, and policymakers about practical ergonomic adjustments that can enhance worker safety, well-being, and productivity, ultimately creating a foundation for further ergonomic advancements in resource-limited settings.

Methods

This study utilizes ergonomic assessment tools – the Workplace Ergonomic Risk Assessment (WERA) and Nordic Body Map (NBM) – to evaluate musculoskeletal disorder (MSD) risks among lathe

operators in a small automotive repair workshop. The methodology combines systematic sampling methods with tailored adaptations of these tools to address the specific ergonomic demands of automotive repair environments. The Workplace Ergonomic Risk Assessment (WERA) instrument used in this study has been validated in previous research and demonstrated high internal consistency. According to Baydur et al. (2016), the WERA tool achieved a Cronbach’s alpha above 0.80, indicating strong internal reliability in evaluating ergonomic risk factors in manual and repetitive occupational tasks. This supports the instrument’s methodological robustness and its appropriateness for use in small-scale and informal industrial settings, such as the current study’s automotive workshop environment. Key stages of the methodology are outlined below.

Study setting and participants

The study was conducted at XYZ automotive repair workshop, located in Sidoarjo. The workshop specializes in engine repair and machining tasks, where operators frequently perform high-risk tasks such as bending, lifting, and handling heavy tools. The sample consisted of five lathe operators selected through convenience sampling, representing the specific population of workers engaged in physically demanding roles (Jarius et al., 2023). Convenience sampling is effective here as it ensures access to participants directly involved in tasks relevant to ergonomic risks.

Sampling and data collection techniques

A participatory ergonomic approach was adopted, emphasizing the active involvement of lathe operators to ensure accurate ergonomic assessments. This approach, as discussed by (Baydur et al., 2016), highlights the value of engaging workers in identifying their ergonomic challenges, allowing for a more thorough analysis of task-specific risk factors. Operators were guided to complete self-assessment questionnaires (NBM) and engage in observational assessments for WERA, enhancing ergonomic awareness and enabling feedback mechanisms (Partido, 2017). Visual aids, including photographic records of work postures, were also utilized to complement self-assessment and facilitate postural analysis.

Tools and instruments

Workplace Ergonomic Risk Assessment (WERA): WERA was employed to evaluate the ergonomic risks associated with specific lathe tasks, such as prolonged standing, bending, and repetitive movements. Each task was scored based on six primary factors – posture, repetition, contact stress, force, vibration, and duration. This scoring method, as used in small-scale manual

labor settings, requires adaptations for specific work tasks, such as lathe operations, which involve repetitive tool handling and high-force exertions (Baydur et al., 2016). This structured scoring allowed for an objective assessment of ergonomic risks and facilitated targeted recommendations. Nordic Body Map (NBM): The NBM questionnaire was used to assess areas of the body experiencing discomfort or pain, capturing self-reported data on MSD complaints among operators. Since NBM is primarily a subjective assessment tool, modifications were made to address the specific tasks involved in automotive repair. These adjustments included emphasizing the upper and lower limb regions frequently affected in lathe operations (Fowler, 2020). The NBM assessment data were crucial in identifying which body areas were most impacted by specific tasks and provided a baseline for evaluating the effectiveness of proposed ergonomic interventions.

Data collection process

The data collection process included the following stages (Figure 1):

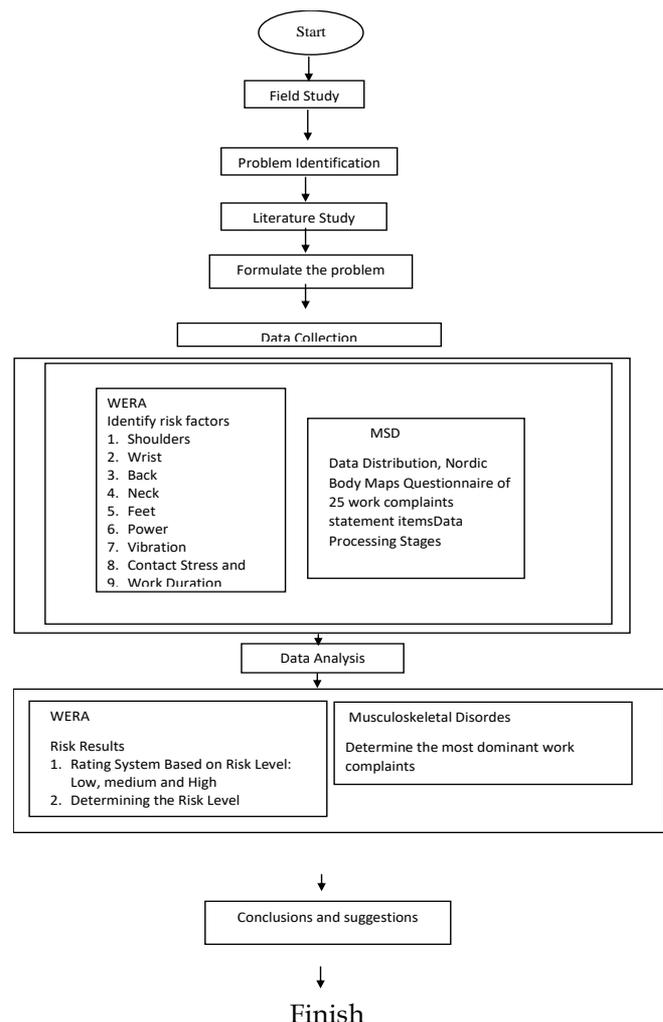


Figure 1. Flow chart of research

- Baseline Observation: A preliminary observation documented tasks and postures in lathe operations at the XYZ workshop. Following the approach described by (Partido, 2017), photographic records and operator feedback visually documented typical work postures.
- NBM Self-assessment: Operators filled out the NBM questionnaire, indicating the frequency and severity of pain or discomfort in various body areas. This self-assessment helped operators reflect on and report discomfort patterns.
- WERA Assessment: Trained researchers completed WERA assessments through observations and operator feedback. Each task was scored on a scale of 0 to 3, with higher scores indicating increased risk. Adjustments for task-specific demands, such as sustained exertions and repetitive tool manipulation.

Data analysis

NBM Data Analysis

Self-reported NBM data were analyzed by categorizing complaints into high-risk areas (e.g., back, wrists, shoulders), highlighting patterns of discomfort specific to lathe operations. A frequency analysis was conducted to determine the most common pain points among operators, which informed the ergonomic recommendations.

WERA Scoring and Interpretation

The Workplace Ergonomic Risk Assessment (WERA) tool was selected due to its structured evaluation criteria and validated use across various occupational settings. WERA assesses ergonomic risk based on six domains: posture, repetition, force, vibration, contact stress, and duration. Previous studies, such as Baydur et al. (2016), have confirmed **high internal consistency and reliability** of WERA scores (Cronbach’s alpha > 0.8), indicating strong instrument validity in occupational ergonomics research.

This justifies the use of WERA in micro-industry settings such as the current study’s automotive workshop environment. The WERA scores for each task were compiled to create a risk profile for each posture and task. Each factor—such as repetitive motion or awkward posture—was scored independently to determine the ergonomic risk levels associated with each task. The scoring system, adapted as per (Baydur et al., 2016), provided a clear assessment of ergonomic risks, helping prioritize interventions for the most critical areas.

Integrative Analysis

Data from NBM and WERA assessments were combined to identify correlations between self-reported discomfort and observed risk factors. This integrative approach allowed for a comprehensive understanding of the ergonomic challenges specific to lathe operations, supporting evidence-based recommendations.

Data processing results

The following are the results of the NBM questionnaire and data from employees of the car engine repair workshop which can be seen in the Table 1 and 2.

Table 1. Lathe Operator Data

Full Name	Gender	Length of Service (Years)
Murianto aminullah	Male	6
Muhammad hikam arofi	Male	3
Kusnadi	Male	6

Table 2. Results of the Frequency of Worker Complaints

Complaint Position (Respondents 1, 2 And 3)	Frequency of Worker Complaints
Upper neck	2
Left side of neck	1
Left shoulder	1
Right forearm	1
Right upper arm	1
Back	4
Right elbow	1
Right hand	2
Right wrist	1
Left Hand	1
Left wrist	1
Waistband	1
Left thigh	1
Left knee	3
Right thigh	1
Right knee	2
Left Calf	2
Right Calf	1
Buttocks	1
Left ankle	1
Left Foot	3
Right foot	3

The following is a checklist for turning work pieces using a lathe which can be seen in Table 3 and Figure 2.

Table 3. Work Posture Risk Assessment

Risk Factors		Risk Level		
		Low	Med	Hig
Shoulders	Posture		✓	
	Repetition		✓	
Wrist	Posture		✓	
	Repetition	✓		
Back	Posture		✓	
	Repetition	✓		

Risk Factors		Risk Level		
		Low	Med	Higl
Neck	Posture		✓	
	Repetition	✓		
Feet	Posture		✓	
	Repetition	✓		
Load		✓		



Figure 2. Work posture

The following are the results of the combination and calculation of the final score on turning activities which can be seen in Figure 3. Assessment of work posture in shoulder posture: a) Moderate risk level, b) Moderate repetition. So that the value in the table becomes as follows.

The level of risk obtained from the calculation of all data by means of and The level of risk obtained by work postures can be seen in Table 4.

$$\text{WERA} = \text{Shoulder Risk Level} + \text{Wrist Risk Level} + \text{Back Risk Level} + \text{Neck Risk Level} + \text{Foot Risk Level} + \text{Load Risk Level} + \text{Vibration Risk Level} + \text{Stress Risk Level} + \text{Work Duration Risk Level}$$

$$\text{WERA} = 4 + 3 + 3 + 3 + 3 + 3 + 3 + 3 + 5 + 3 = 30$$

WERA scores were interpreted using a standardized ergonomic risk scale, with thresholds as follows: 18–27 = Low Risk, 28–44 = Medium Risk, and 45–54 = High Risk. These ranges are commonly used in ergonomic assessments to guide necessary interventions. The final WERA score in this study (30) fell within the medium risk category.

Standard WERA Risk Score Interpretation Scale



Figure 3. Standardized interpretation scale for WERA (Workplace Ergonomic Risk Assessment) scores. The low-risk range (18–27) indicates acceptable working conditions; the medium-risk range (28–44) suggests that work requires further investigation and modifications; and the high-risk range (45–54) signifies that the task is unacceptable and must be redesigned. ((Baydur et al., 2016)(Baydur et al., 2016)Baydur et al. (2016) and Rah, and Rahman et al. (2013)

Tabel Sistem Penilaian Posur 01														
1a. Postur Bahu				2a. Postur Pergelangan Tangan				3a. Postur Punggung						
1b. Pengulangan	Level Risiko	Rendah	Sedang	Tinggi	2b. Pengulangan	Level Risiko	Rendah	Sedang	Tinggi	3b. Pengulangan	Level Risiko	Rendah	Sedang	Tinggi
	Rendah	2	3	4		Rendah	2	3	4		Rendah	2	3	4
	Sedang	3	4	5		Sedang	3	4	5		Sedang	3	4	5
	Tinggi	4	5	6		Tinggi	4	5	6		Tinggi	4	5	6
Hasil				Hasil				Hasil						
4a. Postur Leher				5. Postur Kaki				6. Beban						
4b. Pengulangan	Level Risiko	Rendah	Sedang	Tinggi	9. Durasi	Level Risiko	Rendah	Sedang	Tinggi	3a. Postur Punggung	Level Risiko	Rendah	Sedang	Tinggi
	Rendah	2	3	4		Rendah	2	3	4		Rendah	2	3	4
	Sedang	3	4	5		Sedang	3	4	5		Sedang	3	4	5
	Tinggi	4	5	6		Tinggi	4	5	6		Tinggi	4	5	6
Hasil				Hasil				Hasil						
7. Getaran				8. Hubungan stress				9. Durasi Kerja						
2a. Postur Pergelangan Tangan	Level Risiko	Rendah	Sedang	Tinggi	2a. Postur Pergelangan Tangan	Level Risiko	Rendah	Sedang	Tinggi	6. Beban	Level Risiko	Rendah	Sedang	Tinggi
	Rendah	2	3	4		Rendah	2	3	4		Rendah	2	3	4
	Sedang	3	4	5		Sedang	3	4	5		Sedang	3	4	5
	Tinggi	4	5	6		Tinggi	4	5	6		Tinggi	4	5	6
Hasil				Hasil				Hasil						

Figure 4. Work posture assessment

The level of risk obtained by work postures can be seen in Table 4.

Table 4. Risk levels

Risk Level	Final Score	Action	Results
Low	18-27	Acceptable work	30
Medium	28-44	Work needs to be investigated and changes made	
High	45-54	Work not accepted, replaced immediately	

From the assessment results, the final score is 30 which has a medium risk level so that the work needs to be investigated further and changes are needed.

Ethical considerations

Participant confidentiality and informed consent were prioritized throughout the study. Operators were briefed on the study's purpose, procedures, and data confidentiality measures. Consent was obtained for all photographic documentation and questionnaire responses, ensuring compliance with ethical research standards.

Limitations

The primary limitation of this study is the small sample size, which may affect the generalizability of findings. Additionally, due to the convenience sampling method, results may not fully represent all lathe operators in similar settings. However, the study's targeted approach provides specific insights into ergonomic risks at XYZ, serving as a basis for further research and practical applications.

This methodology incorporates both structured ergonomic assessments and participatory elements, creating a comprehensive approach to evaluating and mitigating ergonomic risks in automotive repair workshops. The chosen methods and tools offer replicable insights, addressing MSD risks and fostering ergonomic improvements tailored to small-scale, resource-limited environments.

Results and Discussion

Results

The study results reveal the prevalence and specific patterns of Musculoskeletal Disorders (MSDs) among lathe machine operators at the XYZ automotive workshop. Using the Nordic Body Map (NBM) and Workplace Ergonomic Risk Assessment (WERA), data were collected to analyze the ergonomic risks and the areas most affected by discomfort. These assessments highlight the ergonomic challenges posed by static

postures, repetitive movements, and awkward positioning inherent in lathe operations.

NBM results: Areas of discomfort

The NBM questionnaire, completed by the lathe operators, identified key body areas experiencing discomfort. The most common complaints were reported in the lower back, neck, shoulders, and wrists, consistent with findings in similar machining environments (Qibtiyah et al., 2023). The following specific trends were noted in discomfort frequency: (1) Lower Back: Nearly all operators reported lower back discomfort, attributed to the prolonged static posture required during machining tasks. This position, compounded by the lack of back support in their standing position, contributed to significant discomfort; (2) Neck and Shoulders: Operators experienced neck and shoulder strain due to continuous forward bending and reaching motions while adjusting the lathe and handling tools. Frequent neck strain was often linked to an awkward forward-leaning posture maintained over extended periods; (3) Wrists and Hands: Operators reported wrist and hand discomfort, particularly after repetitive tool handling and gripping activities. The strain in these areas was likely due to sustained, forceful grip motions and repetitive fine adjustments required during machining.

These findings align with those of (Qibtiyah et al., 2023), who found that static positions and repetitive tool use in lathe operations predominantly affect these areas, leading to chronic MSD complaints among operators.

WERA scores: Ergonomic risk levels

The WERA assessment quantified the ergonomic risks associated with specific lathe tasks, highlighting postures and movements that elevate MSD risk levels. Scores for each task ranged from low to high, with higher scores indicating greater ergonomic risk. Significant observations include: (1) High-Risk Postures: Tasks that required operators to reach forward excessively or twist their torso scored higher on WERA, suggesting these postures increase the risk of MSDs. As noted by (Chourasia et al., 2022), excessive reaching and twisting contribute to discomfort and musculoskeletal strain; (2) Static Positioning: Operators' static standing positions, often maintained without support, resulted in moderate to high WERA scores. Prolonged static postures have been shown to increase muscle fatigue and contribute to lower back pain (Dewangan & Singh, 2015); (3) Repetitive Motions: Tasks involving repetitive wrist and hand movements, particularly those required for precision adjustments, also scored high in WERA. The lack of task variability and frequent fine-motor tasks elevated the scores for these movements, consistent with

findings by (Chourasia et al., 2022) on the impacts of repetitive tasks.

The combined analysis of WERA scores and NBM data indicated that prolonged exposure to awkward and repetitive postures significantly increases the ergonomic risks among operators, validating the need for intervention. To complement the ergonomic assessment, the summarized WERA scores are visualized in a bar chart (Figure 5), providing a clear comparative view of risk intensities across factors. The highest scores were observed in shoulder posture and work duration, highlighting the need for prolonged posture management and break optimization.

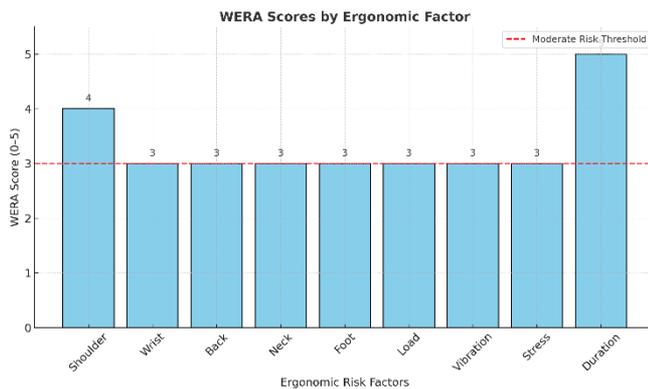


Figure 5. Summarize of WERA Scores

In the long term, interventions such as posture training programs and rotational work schedules can significantly reduce the risk of MSDs. Posture training increases workers' awareness and ability to maintain neutral body positions, especially during repetitive or prolonged tasks. Meanwhile, rotational work schedules reduce muscle fatigue by alternating task types, which has been shown to prevent overuse injuries and improve overall productivity.

Implementing these strategies as part of workplace training modules or integrating them into vocational education (e.g., SMK workshops) can build sustainable ergonomic habits in young workers. Longitudinal studies are recommended to evaluate the effectiveness of these strategies over extended operational periods.

Proposed ergonomic interventions

Based on the results from the NBM and WERA assessments, several ergonomic interventions are recommended to mitigate the identified risks. The interventions align with effective practices documented in existing research [1, 9], emphasizing workstation adjustments, supportive equipment, and training: (1) Workstation Adjustments: Redesigning workstations to support a neutral posture can reduce strain on the lower back, neck, and shoulders. Adjustable seating or standing supports would allow operators to alternate

between sitting and standing, minimizing prolonged static postures; (2) Supportive Tools and Equipment: Introducing anti-vibration gloves and ergonomic hand tools could alleviate wrist and hand discomfort by reducing the impact of repetitive gripping and precision tasks (Qibtiyah et al., 2023). Additionally, supportive seating or stools for resting could help minimize lower back strain; (3) Regular Breaks and Training: Instituting scheduled breaks to encourage movement and reduce static positioning is essential in alleviating muscle fatigue. Training programs focused on proper posture and lifting techniques could further help operators avoid awkward postures and mitigate MSD risk (Aisha et al., 2019).

These interventions are expected to lower WERA scores by promoting ergonomic best practices, enhancing operator comfort, and potentially reducing the incidence of MSDs.

Summary of findings

The results indicate a high prevalence of MSDs among lathe operators due to sustained awkward postures and repetitive hand movements, consistent with MSD trends in similar manual labor environments [1, 2]. The NBM and WERA assessments provided clear insights into the specific areas of discomfort and risk, with findings showing that lower back, neck, shoulders, and wrists are most affected. Ergonomic adjustments, combined with targeted equipment and training interventions, are recommended to alleviate these risks. These findings underscore the importance of ergonomic assessments in guiding low-cost, high-impact improvements for small workshops like XYZ, demonstrating that even modest adjustments can significantly reduce MSD risks and improve worker well-being.

Discussion

Comparison with similar work environments

The findings of this study indicate a high prevalence of Musculoskeletal Disorders (MSDs) among lathe machine operators in small automotive repair workshops, which aligns with existing research across both small workshops and larger manufacturing settings. In smaller workshops, such as those in the furniture industry, workers frequently perform repetitive manual tasks under unstructured conditions, leading to awkward postures and prolonged static positions (Nejad et al., 2013). Similarly, lathe operators at XYZ workshop experience significant ergonomic strain due to prolonged static standing and repetitive actions required for machining tasks. Conversely, larger manufacturing environments benefit from more structured workflows and access to ergonomic interventions, though these settings still pose MSD risks

due to high task repetition and occasionally suboptimal workstation design (Hawari et al., 2023). These comparisons highlight that while resource limitations can make ergonomic improvements more challenging in small workshops, both small and large settings are subject to similar ergonomic risks, necessitating tailored solutions for MSD prevention.

Effectiveness of ergonomic interventions

This study's proposed ergonomic interventions – such as adjustable workstations, anti-vibration gloves, and scheduled breaks – are supported by research demonstrating the effectiveness of similar approaches across a range of occupational settings. Participatory ergonomic interventions, which actively engage workers in identifying ergonomic risks and implementing solutions, have shown to reduce physical exertion and pain, with positive changes reported by 50-58% of participants in studies involving childcare workers and other physically demanding roles (Gupta et al., 2022; Rasmussen et al., 2020). Similar long-term benefits were observed in video display terminal operators, where ergonomic interventions reduced low back pain and improved posture over a three-year period (Pillastrini et al., 2010). The applicability of these interventions to lathe operations at XYZ suggests that even low-cost, targeted adjustments – such as improved workstation layouts and proper posture training – can help minimize MSD risks in small workshops.

Limitations of ergonomic interventions in small workshops

Despite the proven benefits of ergonomic interventions, certain limitations can restrict their effectiveness, especially within small workshops. Factors such as inconsistent worker engagement, limited access to ergonomic resources, and traditional workflows often complicate the adoption of ergonomic practices. Without structured ergonomic support or regular training, operators may revert to improper postures, diminishing the long-term effectiveness of interventions. Similar limitations were observed by (Ranavolo et al., 2020), who noted that limited data on individual worker habits and task variability could hinder the sustainability of ergonomic adjustments. Furthermore, budget constraints in small workshops may limit access to higher-cost ergonomic tools, necessitating the implementation of cost-effective and innovative solutions tailored to specific job demands.

To mitigate these limitations, fostering a culture of continuous ergonomic improvement and involvement among workers is crucial. Establishing ergonomic committees, conducting regular training sessions, and implementing feedback mechanisms can enhance worker engagement and support sustainable ergonomic

practices (Nejad et al., 2013). A participatory ergonomic approach, which involves workers in evaluating and adjusting their work environment, can empower operators to maintain and improve ergonomic practices, even within budget constraints.

Implications for future interventions

The results from this study suggest that future ergonomic interventions in small workshops could benefit from incorporating technology and structured ergonomic programs. For instance, digital human modeling and sensor-based assessments have proven effective in providing precise ergonomic data, enabling personalized interventions (Sanchez-Lite et al., 2013). Although these technologies may currently be less accessible in small workshops, their cost is decreasing, and they could soon provide valuable insights for targeted ergonomic improvements in resource-constrained settings.

Additionally, implementing structured ergonomic programs with ongoing evaluation could reinforce a systematic approach to reducing MSD risks. Integrating ergonomic training into onboarding processes, along with periodic refresher courses, can promote proper posture, lifting techniques, and overall ergonomic awareness. Visual aids and self-assessment tools could further facilitate ergonomic best practices, reducing MSD prevalence by helping workers recognize and adjust poor postures (Partido, 2017). These steps can establish a foundation for a safer and more productive work environment, even with limited resources.

Limitations of the current study

This study has several limitations that may affect the generalizability of the results. The small sample size and convenience sampling method limit the scope of findings, which may not fully represent the ergonomic challenges faced by all lathe operators in similar environments. Additionally, while the study provides insights into ergonomic risks and recommended interventions, it does not measure the direct impact of these interventions. Future research could employ a longitudinal design to implement and evaluate these ergonomic adjustments, assessing their effectiveness in reducing MSD symptoms over time.

Conclusion

This study identified moderate ergonomic risks associated with lathe operations in small-scale automotive repair workshops, with MSD complaints most commonly reported in the lower back, shoulders, neck, and wrists. The use of validated tools – Nordic Body Map (NBM) and Workplace Ergonomic Risk

Assessment (WERA)—enabled a dual-perspective analysis of self-reported discomfort and observed task risks. Visual data, including bar charts, helped summarize ergonomic risk levels, emphasizing the highest strain associated with shoulder posture and prolonged work duration.

The recommended interventions include low-cost and practical measures such as workstation adjustments, anti-vibration gloves, posture training, scheduled breaks, and rotational work schedules. These strategies aim not only to address immediate physical strain but also foster long-term ergonomic resilience, particularly when embedded into routine operator training or integrated into structured workplace programs. Additionally, the study highlights the educational value of ergonomic data, suggesting its applicability as contextual learning material within IPA Terapan (applied science) curricula in vocational high schools (SMK). By integrating case-based ergonomic analysis into science education, vocational learners can gain hands-on insights into biomechanics, body mechanics, and occupational safety.

This research contributes new insights to the underexplored area of informal micro-industrial ergonomics while offering replicable, affordable, and pedagogically valuable approaches to reducing MSD risks in small-scale technical environments.

Acknowledgments

We would like to thank all parties involved in the completion of this research.

Author Contributions

R.O.: Coordinating writing and editing the manuscript; R.O., M.I.S: conceptualization of ideas, data processing, writing, and editing the manuscript; W.E.C., M.F., ISD: Collecting data, data processing, and writing the manuscript.

Funding

This article did not receive any external funding.

Conflict of Interest

In writing this article, the authors do not have any conflict of interest.

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