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Exploring The Pathways Of Various Risk Factors Influencing Musculoskeletal Disorders In Dockworkers: Evidence From Soekarno Hatta Port, Makassar

Rais Munajat[1,3]*, Atjo Wahyu[1], Syamsiar S. Russeng[1], M. Furqaan Naiem[1], Masyitha Muis[1], Irwandy[2], Wahyudi Hidayat[4]

[1]Department of Occupational Health and Safety, Faculty of Public Health, Hasanuddin University, Makassar 90245, Indonesia;

[2]Department of Hospital Management, Faculty of Public Health, University of Hasanuddin, Makassar 90245, Indonesia;

[3]Doctor of Balangnipa, Sinjai District Health Office, Sinjai 92614, Indonesia; [4]Health Quarantine Centre, Makassar 90552, Indonesia

***Corresponding author:**

Rais Munajat,

Department of Occupational Health and Safety, Faculty of Public Health, Hasanuddin University, Makassar 90245, Indonesia.

Email ID: rais.munajat@yahoo.co.id

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ABSTRACT

Objectives: Dockworkers are at high risk of developing musculoskeletal disorders as a result of the cumulative effects of various interacting factors, ranging from personal attributes to the demands of the job itself. These factors can trigger physical fatigue, which acts as a mediator in the onset of musculoskeletal disorders. Understanding the relationships between these variables is essential in preventing long-term health consequences for port workers.

Methods: This study employed an analytical observational design with a cross-sectional approach. The sample consisted of 113 active dockworkers at Soekarno-Hatta Port. The causal relationships between the independent variables (age, length of service, working posture, and physical workload), the intervening variable (fatigue), and the dependent variable (musculoskeletal disorders) were analysed using path analysis with the assistance of AMOS version 24 software.

Results: The path analysis results indicated that, among the four independent variables—age, length of service, working posture, and physical workload—only physical workload had a significant direct effect on fatigue ($\beta = 0.086$; $p = 0.011$). Although physical workload did not have a direct effect on musculoskeletal disorders, it exerted an indirect effect through fatigue, which acted as a mediator due to its significant influence on musculoskeletal disorders. Furthermore, the musculoskeletal disorder variable, as the final endogenous variable, showed significant relationships with age, length of service, and working posture, indicating that it serves as the end node receiving influences from various pathways within this model related to musculoskeletal disorders.

Conclusions: These results indicate that there is an indirect effect of physical workload on the development of musculoskeletal disorders, mediated by workers' fatigue. Meanwhile, the variables of age, length of service, and working posture have a direct effect on the onset of musculoskeletal disorders.

Keywords: *Musculoskeletal Disorders, Working Posture, Physical Workload, Path Analysis, Fatigue*

1. INTRODUCTION

Although increased workload at ports aims to boost productivity, it has the potential to exacerbate ergonomic risks that may seriously affect workers' health and long-term operational efficiency. More than 30% of the global population experience musculoskeletal pain [1], with approximately 1.71 billion individuals diagnosed with such conditions [2], an estimated 50-70% of whom are workers [3]. Lower back pain is the most common complaint [2], making work-related musculoskeletal disorders a significant challenge that continues to threaten health and productivity in the workplace.

The high incidence of work-related musculoskeletal disorders is influenced by the complexity of risk factors such as individual characteristics [4], high pressure to achieve production targets [4–6], non-ergonomic working positions [6–9], combined with repetitive work cycles, causing fatigue that is not balanced with adequate recovery [4,10] such as dockworkers who routinely perform heavy physical tasks. As a result, these conditions can worsen musculoskeletal disorders, leading to decreased productivity, increased sick leave, and the risk of serious functional disability [10–13].

The prevalence of musculoskeletal disorders among port workers in one study reached as high as 88.6% [4] highlighting the significant health impact in this sector. At Makassar City Port, 46.4% of respondents reported high levels of musculoskeletal complaints, while 37.9% fell into the very high category [7]. Study of Zanatelli [13] noted that 17% of 82 workers observed at Santos Port experienced lower back pain. Back discomfort is also a common issue among part-time dockworkers in Nigeria [5].

Fatigue factors among dock workers can also worsen the risk of existing musculoskeletal disorders. Bonow [14] showed that tired workers tend to experience decreased focus and performance, which can increase the risk of injury. Bonfiglioli et al [15] emphasized that although musculoskeletal diseases are not life-threatening conditions, they can cause pain, limited mobility, and dexterity, resulting in early retirement from work, low quality of life, and reduced ability to participate fully in society.

The nature of work-related musculoskeletal disorders is highly complex, making local research essential for developing effective protection systems [16], As increasing attention is given to occupational and ergonomic risk assessments, along with the various factors that worsen working posture during production tasks, the progression of musculoskeletal diseases can be prevented [17]. Soekarno-Hatta Port in Makassar was chosen as the research site as it is one of the largest cargo ports in Eastern Indonesia.

This port plays a crucial role in the regional economy and facilitates the movement of goods and passengers, including cargo from Makassar and international vessels. With a high physical workload, particularly among dockworkers handling heavy loads, the port provides an ideal setting to study ergonomic risks and musculoskeletal disorders. Therefore, this study aims to explore the relationship between individual characteristics, working posture, and physical workload on work-related musculoskeletal disorders through the condition of fatigue, specifically at Soekarno-Hatta Port in Makassar.

2. MATERIALS AND METHODS

Observation Subject

This study is a quantitative explanatory research aimed at analysing the direct and indirect effects of several independent variables on the dependent variable through a mediating variable. The research design employed is cross-sectional, whereby data were collected at a single point in time. The study was conducted at Soekarno-Hatta Port, Makassar City, from November 2024 to March 2025.

The study subjects were selected using purposive sampling, meaning participants were chosen based on specific criteria relevant to the research objectives. The sample comprised 113 dockworkers at Soekarno-Hatta Port who met the inclusion criteria, including a minimum age of 19 years, active employment as port workers at Soekarno-Hatta Port, and a minimum length of service of three months at the port. The exclusion criteria consisted of female dockworkers present at the research site. Data collection was conducted through direct observation of working posture and measurement of health parameters such as pulse rate before and after work to assess physical workload, following standard operating procedures, as well as structured interviews with the dockworkers.

Instruments and Data Collection

The data in this study were collected through a combination of direct observation techniques, structured interviews, and the use of standardized questionnaire instruments. The instruments used included individual characteristics questionnaires, Rapid Entire Body Assessment (REBA) to assess work posture quickly and comprehensively, Fatigue Assessment Scale (FAS) to measure fatigue levels, and Nordic Body Map (NBM) to identify and assess musculoskeletal disorder complaints in workers. In addition, pulse measurements were taken using an oximeter. All data were coded and analyzed using SPSS software for initial statistical assumption tests, followed by modeling causal relationships between variables using path analysis in AMOS.

Research Variables and Model Specification

This study employs a quantitative approach with path analysis conducted using AMOS software. The conceptual model tested includes three groups of variables: independent variables, consisting of age (X1), length of service (X2), working posture (X3), and physical workload (X4); the intervening (mediating) variable, fatigue (Y); and the dependent variable, musculoskeletal disorders (Z). The relationships among variables in the model are assumed to be causal and are represented through path coefficients (standardised regression weights). Data were collected through a combination of direct observation, objective pulse rate measurements, and the use of validated standardised questionnaires to assess fatigue, working posture, and musculoskeletal complaints.

Statistical analysis

All data were first coded and analyzed using IBM SPSS software to conduct initial statistical assumption tests. Then continued with path analysis with the help of AMOS software to evaluate the causal relationship between variables in the research model. Data analysis was carried out in two stages, the descriptive stage to describe the characteristics of respondents and the distribution of variable data, and the path analysis stage to identify direct and indirect influences between variables and the total contribution of the path to the dependent variable. Before interpreting the results, the path model was tested for goodness of fit using the chi-square test, if the probability value is greater than 0.05. This indicates that the model is acceptable and the path coefficient results can be used for further interpretation.

Ethical considerations

This research had ethical approval from the Ethics Commission of the Faculty of Public Health, Hasanuddin University, with the protocol number was 11024062306 and the letter number was 2959/UN4.14.1/TP.01.02/2024

3. RESULTS

Table 1 Distribution of Respondents Based on Characteristics

Characteristics	Overall	
	n	%
Age Group		
20-29 Years	8	7.1
30-39 Years	19	16.8
40-49 Years	40	35.4
50-59 Years	37	32.7
60-69 Years	8	7.1
70-79 Years	1	0.9
Education Group		
Didn't finish elementary school	6	5.3
Elementary school	56	49.6
Junior high school	28	24.8
Senior high school	23	20.4
Years of service		
≤10 Years	26	23.0
>10 Years	87	87.0

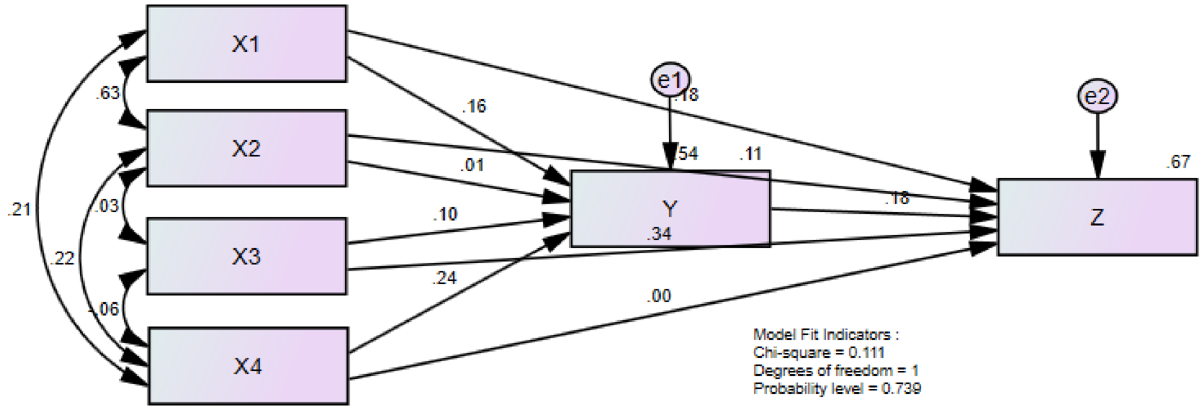
The results of the study conducted on dockworkers at Soekarno Hatta Port, Makassar City showed that the 40-49 age group is the highest age group of workers 40 people (35.4%), then the 50-59 age group 37 people (32.7%), and the lowest age group 70-79 years (0.9%). The highest education among workers is the elementary school graduate group 56 people (49.6%), and the lowest is not in school / not finished elementary school 6 people (5.3%). As for the work period, the dominant workers have worked for more than 10 years, namely 87 workers (87.0%) out of 113 respondents.

Table 2. Summary of Descriptive Statistics of Questionnaire Scores and Observation Variables

	Mean	Median	Std. Deviation	Minimum	Maximum
Age	45.97	46.00	10.05	23	72
Years of service	19.42	20.00	10.69	1	51
Working Posture	11.91	12.00	1.22	9	14

Physical Workload	17.49	17.86	12.95	0	111
Fatigue	15.13	14.00	4.74	10	34
Musculoskeletal Disorders	13.19	13.00	3.78	2	22

Table 2 showed that the average age of the workers was 46 years, ranging from 23 to 72 years. The average length of service was 20 years (minimum 1 year, maximum 51 years). The observed working posture score averaged 12, with a weighted range from 9 to 14 points. Based on the analysis, the average physical workload was recorded at 17.86% of the maximum Cardiovascular Load capacity. For fatigue, the average score obtained was 14 points, with a weighted range of 10 to 34 points. Meanwhile, the average musculoskeletal disorder score was 13 (minimum 2, maximum 22).



Gambar.1 Path Diagram

The path analysis model in Figure 1 shows that the error variance for variable Y is 0.11, indicating that 89% of the variance in Y can be explained collectively by its predictors (X1, X2, X3, and X4). Similarly, the error variance for variable Z is 0.67, indicating that 33% of the variance in variable Z can be explained by its influencing variables), both indicating a high level of explanation of the endogenous variables by the model.

Regarding the direct effects on the mediating variable (Y), variable X4 exhibited a substantial positive effect (standardised coefficient = 0.24). Variables X3 and X2 showed positive but non-substantial effects on Y (standardised coefficients = 0.10 and 0.01, respectively), while variable X1 demonstrated a weak positive effect on fatigue (standardised coefficient = 0.16). Furthermore, variable Y had a weak positive effect on Z (standardised coefficient = 0.18).

For the direct effects of the independent variables on musculoskeletal disorders, X1 (standardised coefficient = 0.18) showed a weak positive effect, X2 (standardised coefficient = 0.54) showed a very substantial positive effect, and working posture demonstrated a moderate or fairly substantial positive direct effect on musculoskeletal disorders (standardised coefficient = 0.34). However, physical workload (standardised coefficient = 0.00) showed no direct effect on the dependent variable.

Correlation between exogenous variables varies: weak positive correlations were observed between age and physical workload (0.21), work period and physical workload (0.22), positive and very weak correlations between work posture and physical workload (0.06), work period and work posture (0.03), but positive correlations and large effects on age and work period (0.63). Path analysis also identified the presence of a mediating effect of fatigue, the indirect effect of physical workload on musculoskeletal disorders through fatigue (physical workload → fatigue → musculoskeletal disorders) was estimated at 0.24 x 0.18 = 0.0432, meaning that increasing physical workload tends to increase fatigue, and increasing fatigue then also increases the risk of musculoskeletal disorders. The value of 0.0432 shows the magnitude of the contribution of the mediation effect of fatigue to the relationship between physical workload and musculoskeletal disorders, although the value is relatively small, some of the impact of physical workload on musculoskeletal disorders occurs due to increased fatigue, in other words, every one unit increase in physical workload will increase musculoskeletal disorders by 0.0432 units through the fatigue mediation pathway.

Table.3 Direct Effects of Independent Variables and Dependent Variable through the Intervening Variable

			Estimate	S.E.	C.R.	P	Label
Y	<---	X1	.074	.055	1.360	.174	Not significant
Y	<---	X2	.006	.051	.108	.914	Not significant
Y	<---	X3	.402	.348	1.155	.248	Not significant
Y	<---	X4	.086	.034	2.557	.011	Significant
Z	<---	Y	.147	.046	3.158	.002	Significant

Based on the model estimation results using AMOS in Table 3, variable X4 was found to have a significant effect on the intervening variable Y, with an estimated value of 0.086 and a significance level (p) of 0.011. This indicates that X4 statistically contributes to the formation of variable Y. Meanwhile, variables X1, X2, and X3 did not show significant effects on Y, with p-values of 0.174, 0.914, and 0.248, respectively. Therefore, only the path from X4 to Y was proven significant in this model, followed by the path from Y to Z, which was also statistically significant ($p = 0.002$).

Table.4 Indirect Effects of Independent Variables on the Dependent Variable

			Estimate	S.E.	C.R.	P	Label
Z	<---	X1	.068	.027	2.527	.012	Significant
Z	<---	X2	.193	.025	7.645	***	Very significant
Z	<---	X3	1.056	.172	6.151	***	Very significant
Z	<---	X4	.000	.017	.003	.997	Not significant

In the endogenous variable Z, the estimation results show that the paths from X1, X2, and X3 to Z are statistically significant. X1 to Z is 0.068 with $p = 0.012$, X2 to Z is 0.193 with $p < 0.001$, and X3 to Z is 1.056 with $p < 0.001$. On the other hand, the path from X4 to Z is not significant ($p = 0.997$). Thus, in this model structure, it can be concluded that variables X1, X2, and X3 have a significant direct influence on Z, while X4 only has a significant influence on Y, not directly on Z.

Discussion

The results of the path analysis showed that among the independent variables (X1, X2, X3, and X4), only X4 had a significant direct effect on Y ($\beta = 0.086$; $p = 0.011$). This indicates that X4 has an important contribution in explaining changes in the Y variable, while the effects of X1, X2, and X3 are not statistically significant. This finding indicates that in this simple linear structural model, only one valid direct path to Y is valid, and practically indicates that X4 needs to be prioritized in prevention strategies related to increasing Y values.

In addition, although X4 does not have a significant direct path to Z, an indirect effect through Y can be identified because Y is proven to significantly affect Z. Thus, Y acts as a mediator in the relationship between X4 and Z. Furthermore, the variable Z as the final endogenous variable shows a significant relationship with other variables, namely Y, X1, X2, and X3, which indicates that Z is the final node that receives influences from various input paths in this analysis in this case musculoskeletal disorders.

According to the theory of mechanical and metabolic energy, heavy physical workload requires substantial energy, increasing muscle metabolism and oxygen demand, which implies a linear relationship between mechanical load and physiological response—where higher loads elicit greater responses [18]. When these demands are not adequately met, muscle fatigue occurs, reducing physical capacity and triggering poor working posture, thereby further increasing the risk of musculoskeletal disorders [6–9], This study also confirms that working posture has a highly significant effect on musculoskeletal disorders.

The fatigue failure theory describes how muscle and bone tissue can fail or become damaged when repeated physical loads are applied without adequate rest, in other words, intense and repeated muscle use causes a decline in performance known as muscle fatigue. Many muscle properties change during fatigue, including action potential, extracellular and intracellular ions, and various intracellular metabolites [19]. The combination of these theories explains that physical workload and fatigue are interrelated, and if physical workload is excessive without proper fatigue management, it can be a key factor in the development of musculoskeletal disorders in dockworkers.

Although statistically, physical workload does not show a significant direct effect on musculoskeletal disorders, it is important to understand that as work activities involving excessive physical load make workers in the port sector very susceptible to musculoskeletal disorders, which have the potential to cause serious functional disabilities and increase absenteeism reports [12,13]. Therefore, reducing heavy physical workload and early treatment of musculoskeletal pain are very important, because they can significantly improve workers' physical work ability [20].

The findings of this study appear to contrast with those of Li, Li and Crag (2019) who identified physical workload as a primary factor contributing to musculoskeletal disorders among port workers. However, this discrepancy is largely due to Li, Li, and Crag's study not considering intervening variables. Furthermore, findings by Li, Li and Crag (2019) tidak meninjau menggunakan variabel intervening. Lebih lanjut dalam temuan Cezar-Vaz *et al* (2018) among dockworkers in the state of Rio Grande do Sul, Brazil, reported a high prevalence of lower back pain and dorsalgia closely associated with heavy physical workloads, such as repetitive lifting of goods in non-ergonomic postures.

Other findings on the subject of port stevedore by Robinson (2019) who evaluated the risk factors of biomechanical load in officers showed that very high risk levels were recorded at the beginning and end of the task, with scores of 4.22 and 8.50 respectively. Correlation analysis identified a direct relationship between vertical lifting distance, torso torque, and increased musculoskeletal injuries in port workers, emphasizing the need for interventions to reduce the risk of biomechanical load-related injuries. Based on previous findings and this study, it is known that physical workload is still a consistent problem that is easily identified among dockworkers. So that related parties need to follow up on these findings, provide the best interventions in occupational safety and health such as proportional physical workload management, active rest scheduling, and increasing workers' physical capacity through fitness training are needed to prevent further impacts in the form of musculoskeletal disorders.

Limitations and recommendations

The limitations encountered by the researchers during data collection included limited time, with some respondents having to be interviewed hastily due to tight schedules. At times, respondents were less focused or provided inaccurate answers due to physical fatigue during work shifts. Additionally, there was a lack of openness from respondents regarding health complaints due to concerns about potential impacts on their employment or management. Therefore, future studies should consider conducting interviews at respondents' homes with appropriate variables to enable them to focus better and minimise bias.

Conclusion

We found that fatigue mediates the effect of physical workload on musculoskeletal disorders. The indirect mediation effect indicates that an increase in physical workload may exacerbate musculoskeletal disorders; however, the role of fatigue as a mediator is important to consider in efforts to prevent musculoskeletal disorders among dockworkers.

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Conflict of interest

No potential conflict of interest was reported by the authors.

Authors contributions

R.M., A.W., and S.S.R. designed the research and wrote the paper. M.F.N., M.M., and I.D. made substantial contributions to the study design, while W.H. assisted during data collection in the field. They were responsible for all aspects of the work to ensure the accuracy and integrity of every part of the research, including data analysis. All authors provided comments and approved the final draft.

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