



Research

The Relationship between Exposure to Hand-Arm Vibration (HAV) and Work Fatigue in Tailors in Makassar

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ARTICLE INFO

Keywords:

hand-arm vibration (HAV), work-related fatigue, seamstresses, informal sector

History:

Submitted: 27 July 2026

Reviewed: 31 July 2026

Accepted: 6 August 2026

Competing Interests:

The authors declare no conflicts of interest related to this work.

ABSTRACT

Encountering mechanical vibration represents a notable physical occupational risk that can lead to work-related health issues, including occupational fatigue, especially in jobs that require the repetitive operation of vibrating equipment, such as tailoring in the informal sector. This research sought to investigate the correlation between hand-arm vibration (HAV) exposure and work-related fatigue among informal-sector tailors in Makassar City. A quantitative, cross-sectional methodology was utilized, incorporating 30 participants chosen via simple random selection. Vibration exposure was quantified in m/s^2 using the ISO 5349-1:2001 standard, whereas occupational tiredness was evaluated via the tiredness Feeling Measurement Tool Questionnaire (KAUPK2). Bivariate data examination was performed via Fisher's Exact test. A significant portion of participants experienced minimal vibration exposure and indicated modest degrees of work-related weariness. Statistical examination indicated no significant correlation between hand-arm vibration exposure and work-related weariness ($p > 0.05$). The results indicate that minimal vibration exposure might not be adequate to substantially provoke occupational tiredness in the studied group. The lack of a statistically significant correlation suggests that alternative factors might have a more considerable influence on the emergence of work-related weariness among tailors, especially considering the minimal vibration exposure noted in this environment. Additional investigation utilizing a longitudinal framework and an expanded sample population is advised to thoroughly assess the impact of vibration exposure and ergonomic elements on work-related weariness.

1. Background

Occupational diseases (OCD) are health disorders that arise as a result of exposure to work conditions and environments. Various potential hazards in the workplace can impact worker safety

and health, including chemical, physical, ergonomic, biological, and psychological factors. One physical factor that affects health is vibration (Abikenova et al., 2023; Singh et al., 2024).

Mechanical vibration is a vibration generated by work equipment or machinery, where some of the vibration energy can be transmitted to the worker's body (Darmawan & Pattipawaej, 2016). Long-term exposure to vibration can cause various health problems in workers (Putri et al., 2022). Mechanical vibration is divided into two, namely hand-arm vibration and whole-body vibration. Hand Arm Vibration (HAV) is a vibration transmitted to the hands and arms due to the use of vibrating work tools (Dwinaffebri et al., 2021). Hand-arm vibration (HAV) can occur in all industries, especially those carrying out activities that cause vibrations to the body due to the use of tools that emit vibrations (Andianingsari et al., 2023). Vibration exposure is one of the physical hazards that is still often found in various work sectors, especially in jobs that involve the continuous use of vibrating machines or equipment. The high risk of occupational hazards is also reflected in the prevalence of work accidents among informal workers, which reached 70.49 million cases, although most of these incidents were not optimally recorded (Pratama & Delima, 2024).

Sewing involves repetitive hand use, static work positions, and exposure to physical factors such as vibrations from sewing machines. These working conditions can increase the workload on hand and arm muscles, potentially leading to various occupational diseases in the long term (Ramadani et al., 2025).

Mechanical vibrations experienced by the body, whether in the form of hand-arm vibration or whole-body vibration, can cause various occupational health disorders (Gerhardsson, 2024). According to ILO data, tens of millions of workers worldwide experience occupational diseases related to exposure to physical hazards, including exposure to vibrations such as HAVS. Long-term exposure to vibration is known to impact the musculoskeletal, vascular, and neurosensory systems, which can ultimately reduce workers' work capacity and trigger work fatigue (Dong et al., 2021). Home-based clothing production businesses (tailors) have a variety of potential occupational hazards, including electrical, mechanical, physical, ergonomic, chemical, and psychosocial factors such as work fatigue (Hanani, 2021). Work fatigue itself is a condition of decreased physical and mental efficiency that can increase the risk of work errors, accidents, and reduced productivity. Sewing work in the garment industry involves static work postures and repetitive hand activities with exposure to machine vibrations, which can increase muscle workload and contribute to worker fatigue (Sukmawati, 2020); (Syafitri et al., 2023). Furthermore, several studies have shown that chronic exposure to vibration can accelerate fatigue through mechanisms such as impaired blood flow, increased muscle workload, and decreased peripheral nerve function (Krajnak, 2018b).

Besides work fatigue, exposure to hand-arm vibration is also known to be a major factor in the development of Hand-Arm Vibration Syndrome (HAVS). HAVS is a collection of symptoms that include vascular, neurosensory, and musculoskeletal disorders, such as tingling, numbness, pain, and decreased hand strength and function. This condition not only impacts workers' health but also has the potential to reduce work endurance and accelerate fatigue (Dermawan, 2016). Research conducted by (Chani & Kurniawan, 2018) shows that repeated exposure to mechanical vibration is

associated with vascular and neurosensory complaints in industrial workers, which further contributes to decreased work ability and increased fatigue.

Globally and nationally, various data and studies indicate that vibration exposure remains a significant occupational health problem. International occupational health and safety organizations emphasize that vibration is a physical risk factor that needs to be controlled due to its impact on worker health and fatigue. A study found that workers exposed to hand-arm vibration and noise simultaneously significantly increased muscle fatigue and mental fatigue, especially at high intensity and frequency exposures. This finding strengthens the evidence that vibration is an important determinant of work fatigue (Hojat et al., 2023). Another study on informal sector workers also found a significant relationship between the intensity of hand-arm vibration exposure and HAVS complaints, indicating that the risk of vibration exposure occurs not only in large industries, but also in small-scale and informal jobs (Dwinaffebri et al., 2021).

Although numerous studies have demonstrated a link between vibration exposure and health disorders such as HAVS, most studies have focused on clinical complaints or musculoskeletal disorders, while studies specifically examining the relationship between vibration exposure and occupational fatigue are still relatively limited, particularly in specific work contexts. Furthermore, differences in job characteristics, exposure intensity, and work duration allow for variations in fatigue levels that have not been fully explained in previous studies. Therefore, this study is important to fill this gap by analyzing the relationship between vibration exposure and occupational fatigue more specifically, thus hopefully providing a scientific contribution to efforts to prevent occupational fatigue and control vibration risks in the workplace.

2. Method

This study used a quantitative design with a descriptive-analytical approach to describe hand-arm vibration exposure and analyze its relationship to work fatigue levels among informal sector tailors. The study was conducted on December 5–8, 2025, at several informal sector tailoring businesses in Makassar City. The locations and research subjects were chosen because informal sector tailors generally use mechanical or electric sewing machines repeatedly for long work durations and have not yet implemented optimal occupational safety and health standards.

The study population comprised all informal sector tailors in Makassar City. A sample of 30 respondents was selected using a simple random sampling technique. Inclusion criteria included active tailors who had worked for at least six months and routinely used sewing machines in their daily activities. Subject selection was based on the assumption that work duration and repeated exposure allow for the accumulation of hand-arm vibration exposure.

Literature sources and research information were obtained from national and international scientific journals discussing hand-arm vibration exposure, work ergonomics, work fatigue, and occupational health in the informal sector. Additionally, references from international organizations such as the WHO and ILO served as a theoretical basis and support for interpreting the research results.

The research procedure began with field observations to identify the tailors' work activities. Data on respondent characteristics was then collected using a structured questionnaire covering age, gender, length of service, daily work duration, smoking habits, medical history, and exercise habits. All respondents were given an explanation of the research objectives and signed informed consent prior to data collection.

Hand-Arm Vibration (HAV) exposure was measured using a vibration meter in accordance with the ISO 5349-1:2001 standard placed on the sewing machine part that interacts directly with the worker's hands. Vibration values were recorded in m/s^2 . The level of work fatigue was measured using the Work Fatigue Feelings Measurement Questionnaire (KAUPK2) which consists of 17 questions with "yes" and "no" answer options. This instrument has been used as a work fatigue measurement tool in various previous studies in Indonesia and has been proven suitable for measuring subjective perceptions of work fatigue in workers (Parmasari & Kunci, 2024).

Data obtained through questionnaires and measurements were processed through editing, coding, and data entry into statistical software. Descriptive analysis was used to describe respondent characteristics, vibration exposure levels, and work fatigue levels. Inferential analysis was conducted to determine the relationship between hand-arm vibration exposure and work fatigue using the Chi-square test or Spearman correlation according to the data distribution. The results of the analysis are presented in tabular and narrative form for ease of interpretation.

3. Results and Discussion

a. Results

Table 1 Characteristics of Individual Workers

Variable	Frequency (f)	Percentage (%)
Age		
<35	7	23.3%
36-55	17	56.7%
>55	6	20%
Gender		
Man	9	30%
Woman	21	70%
Work Period		
<=5 Years	14	46.7%
6-10 Years	3	10%
>10 Years	13	43.3%
Work Duration		
8 Hours	22	73.3%
>8 Hours	8	26.7%

Table 1 show the characteristics of workers in this study were dominated by the 36–55 age group (56.7%), while the <35 and >55 age groups -accounted for 23.3% and 20%, respectively. The majority of respondents were female (70%), while males accounted for 30%.

The largest number of respondents with a working period of ≤ 5 years (46.7%), followed by >10 years (43.3%) and 6–10 years (10%), reflecting a combination of new and experienced workers. In terms of work duration, the majority of workers worked for 8 hours per day (73.3%), while those who worked >8 hours were 26.7%.

Table 2Frequency distribution of vibration and work fatigue

Variable	Frequency (f)	Percentage (%)
Vibration		
Low ($< 2\text{m/s}$)	29	96.7%
Moderate ($\geq 2\text{m/s}$)	1	3.3%
Work Fatigue		
Not Tired	26	86.7%
Tired	4	13.3%

After measuring vibration on respondents using a vibration meter that measures Hand Arm Vibration (HAV), it was found that vibration exposure in workers was generally in the low category, namely 96.7% of respondents with vibration intensity $<2\text{ m/s}^2$, and only 3.3% were in the moderate category ($\geq 2\text{ m/s}^2$). The condition of work fatigue seen based on the questionnaire filling score (KUPK2) illustrates that most workers did not experience fatigue (86.7%), while 13.3% of respondents experienced fatigue (see Table 2).

Table 3Relationship between Vibration and Work Fatigue

Vibration	Work Fatigue				Percentage (%)		P Value
	Not Tired		Tired				
Low	26	89.7	3	10.3	29	100	0.133
Currently	0	0.0	1	100	1	100	
Total	26	86.7	4	13.3	30	100	

After testing the data through the SPSS application using the Fisher exact test to see the relationship between vibration levels and work fatigue and the test results showed that in the low vibration group, most workers were not tired (89.7%) and only 10.3% were tired. In the moderate vibration group, all workers (100%) reported experiencing fatigue, but the number was very small (1 person) so it was not statistically significant. The Fisher exact test obtained a p value = 0.133 ($p>0.05$) which showed that there was no significant relationship between vibration levels and work fatigue (see Table 3).

Table 4Relationship between Vibration and Work Duration

Vibration	Work Duration				Percentage (%)		P Value
	8		>8				
Low	21	72.4	8	27.6	29	100	0.733
Currently	1	100	0	0	1	100	
Total	22	73.3	8	26.7	30	100	

Furthermore, data testing was also conducted to see the relationship between vibration levels and work duration. The test results showed that in the low vibration category, workers with a work duration of 8 hours reached 72.4%, while those working >8 hours were 27.6%. In

the moderate vibration category, all workers had a work duration of 8 hours, and there were no workers with a work duration of >8 hours in this category. The p-value from the Fisher exact test for the relationship between vibration and work duration was 0.733 ($p>0.05$), which indicated there was no significant relationship between vibration levels and work duration (see Table 4).

b. Discussion

Exposure to hand-arm vibration in sewing workers has the potential to affect the vascular, neurological, and musculoskeletal systems, which can further contribute to the onset of work fatigue through physiological and psychological mechanisms (Ahn, Rhie, Kim, et al., 2022). Work fatigue can decrease performance, reduce work enthusiasm, and impact productivity and increase work errors (Izzati & W, 2018). The results of the study showed that the majority of respondents experienced low vibration exposure, with a low prevalence of work fatigue, and no significant relationship was found between hand-arm vibration exposure and work fatigue. The results of this study differ from the study by (Pramuditta & Kunaefi, 2016) who found a significant relationship between exposure to machine vibration and work fatigue in precast concrete industry workers. This difference in results is thought to be caused by differences in vibration intensity, where in that study vibration exposure was at a high level and occurred continuously during working hours. This finding indicates that at a certain level of exposure, the worker's body is still able to make physiological adaptations so that fatigue does not appear significantly.

Hand-arm vibration (HAV) is transmitted through work tools such as sewing machines and can trigger various physiological responses, including peripheral vasoconstriction and impaired sensory function of peripheral nerves (Qamruddin & Ali, 2019). This mechanism is described in the ISO 5349-1:2001 standard, which states that vibration with a frequency of 5–1500 Hz can cause the accumulation of mechanical energy in soft tissue, trigger microinflammation, and reduce local blood flow, thus potentially accelerating muscle fatigue (Ahn, Rhie, Kim, et al., 2022). The results of this study align with this theory, as although low vibration exposure predominated, one case of moderate exposure accompanied by complete exhaustion was found. This condition reflects an individual's biological threshold for accumulated vibration exposure.

In tailoring workers, the effects of HAV do not stand alone but interact with other ergonomic factors such as repetitive movements and static working postures. This combination can exacerbate the effects of vibration through local hypoxia and decreased neuromuscular efficiency (Schulze et al., 2023). An international study showed that chronic HAV exposure increased the prevalence of occupational fatigue by 30.5% in at-risk workers, compared with 15.9% in unexposed workers (Ahn et al., 2022). The lack of a significant association in this study does not contradict theory but rather indicates that exposure has not reached a critical dose capable of triggering fatigue effects in the general population. This is consistent with the ACGIH TLV dose-response model, which sets the HAV exposure threshold at 5 m/s^2 (Qamruddin &

Ali, 2019). This finding is supported by (Burstro et al., 2017) who stated that the health impacts of hand-arm vibration exposure tend to be more pronounced at medium to high exposure levels, while at low exposure the effects are often not statistically significant. Krajnak (2018) also shows that vascular, neurological, and musculoskeletal disorders generally develop progressively and are closely related to the intensity and duration of exposure, so that workers with low exposure tend not to show any obvious manifestations of work fatigue.

The results of this study are inconsistent with the findings of Ahn et al. (2022) in Korea, which reported a significant association between occupational vibration exposure and job fatigue (OR = 1.99), especially in workers with exposure duration exceeding 30% of weekly work time. This difference can be explained by the intensity of vibration exposure in tailors in Makassar, which was mostly below 2 m/s², much lower than the exposure intensity in the Korean study which approached or exceeded the threshold of 5 m/s². In contrast, the results of this study are consistent with the study of Qamruddin & Ali (2019) in tire repair workers in Malaysia, which found that high exposure (>5 m/s²) increased neurological and musculoskeletal symptoms by up to 62.89%, while the group with low exposure showed relatively minimal levels of fatigue. Research conducted by Aeni et al. (2022) in Indonesia also showed a similar pattern, where complaints due to hand-arm vibration were more common in workers with high vibration exposure, while workers with low exposure showed minimal or statistically insignificant symptoms.

However, these results are inconsistent with research by (Rahimimoghadam et al., 2023), which stated that simultaneous exposure to vibration and noise increases work fatigue through oxidative stress mechanisms and cumulative effects, particularly in repetitive tasks. This discrepancy suggests that the context of multiple exposures plays a significant role in increasing the risk of fatigue.

Respondents' demographic characteristics also contributed to the low prevalence of occupational fatigue. The majority of respondents were women aged 36–55 years with more than five years of work experience. (Ahn, Rhie, Kim, et al., 2022) stated that women have a higher risk of fatigue due to HAV (OR = 1.21), but at low exposures, women tend to show better physiological adaptation, although they remain psychosocially vulnerable.

Workplace vibration has long been known to decrease workers' physiological and motor performance and cause persistent musculoskeletal tiredness (Krajnak, 2018a). Numerous studies show a favourable link between vibration intensity and fatigue symptoms, however the effects of daily exposure and cumulative work length need more study (Ahn, Rhie, Kim, et al., 2022). Individual variation and job dynamics often result in an insignificant relationship between total work duration and reported fatigue levels (Rahimimoghadam et al., 2023). Yung et al. (2017) found that daily work duration and vibration exposure intensity predict transitory tiredness better than overall work duration. By limiting daily labour length, this study intends to systematically explore the association between vibration acceleration levels and job weariness (Ahn, Rhie, & Kim, 2022; Lai et al., 2019).

The insignificant relationship between vibration exposure and work duration ($p = 0.733$) in this study aligns with the findings of Mwaitenda & Musonda (2024), who stated that an eight-hour workday does not necessarily trigger HAVS if the vibration magnitude is low. However, this condition still requires attention through the implementation of ergonomic interventions. Furthermore, the relatively stable work environment of tailors with low noise and heat levels also plays a role in reducing additional physiological burdens that can accelerate fatigue (Fang et al., 2025; Morina, 2026).

The type of sewing machine used is also an important factor. Sewing machines with modern electric motors produce more stable and lower vibrations than conventional mechanical machines. Modern sewing machines equipped with electric motors are generally designed with more stable components, vibration isolation, and the possibility of implementing damping elements to reduce vibration and noise levels compared to traditional mechanical sewing machines. This is in line with research conducted by Fayziev & Haydarova (2022) which states that sewing machine designs that consider damping structures and elastic elements can reduce the transfer of vibration forces to the machine frame and operator, indicating a better approach to controlling vibration in modern sewing machines. This condition reflects the application of indirect engineering controls, which can reduce occupational health risks. From a work physiology perspective, exposure to low vibration allows the body to maintain homeostasis mechanisms, such as improving microcirculation and neuromuscular adaptation, especially in workers with long working hours (Zuccarelli et al., 2023).

The test results showed no significant relationship between exposure to hand-arm vibration and work fatigue. This is due to natural ergonomic controls, such as spontaneous work breaks taken by tailors. This condition is consistent with Karasek's Job Demand Control model, which states that greater job control can reduce the impact of physical demands on fatigue (Ahn, Rhie, Kim, et al., 2022). Furthermore, this finding is relevant to EU Directive 2002/44/EC, which sets an action value of 2.5 m/s^2 as a monitoring threshold, thus remaining within the range of primary prevention.

Overall, this study concludes that low exposure to hand-arm vibration in sewing workers is not sufficient to significantly trigger occupational fatigue. This is in line with the previous researches Innah et al. (2021), which states that occupational fatigue can be influenced by other factors such as work duration, workload, sleep quality, and nutritional status. However, the presence of moderate exposure cases indicates the potential for risk escalation if exposure increases or becomes cumulative. Comparison with five major studies from 2019–2024 emphasizes the importance of implementing national exposure limits based on ACGIH and routine monitoring using vibration meters. This study's recommendations include occupational health surveillance, periodic KUPK2 examinations, and work ergonomics education through a promotive-preventive approach such as GERMAS to prevent future increases in fatigue.

The strength of this study lies in its quantitative descriptive-analytical design, which allows for a comprehensive description of hand-arm vibration (HAV) exposure and analysis of its relationship to occupational fatigue among informal sector tailors in Makassar City. Direct

measurements using an accurate vibration meter in m/s^2 were used to capture objective data on accumulated vibration from mechanical and electrical sewing machines. A simple random sampling of 30 respondents from a population of active tailors with a minimum of six months of service ensured the representativeness and relevance of the subjects, supported by strict ethical procedures including informed consent and initial field observations for validation of work activities. The use of KAUPK2 as a standard instrument with 17 yes/no questions offered high reliability in measuring subjective fatigue perception, while bivariate analysis using Chi-square or Spearman rank correlation tests according to data distribution provided strong inferential power, complemented by theoretical foundations from national and international scientific journals as well as WHO and ILO for evidence-based interpretation. This approach also contributes to filling the knowledge gap regarding ergonomics in the informal sector, which lacks OSH regulations.

However, there are also limitations of this study, including the small sample size ($n=30$) which limits the generalizability of the results to the entire population of informal tailors in Makassar or other regions, the potential for recall bias in the subjective nature of the KAUPK2 questionnaire data, and the lack of in-depth measurement of confounding variables such as daily cumulative vibration intensity or environmental factors (e.g., working posture and room temperature) that may influence fatigue. The use of a cross-sectional design does not allow for longitudinal causal inference, while data processing with basic statistical software without multivariate adjustment may overlook interactions between variables. This study was also limited to a specific location during December 5–8, 2025, thus seasonal fluctuations or sewing machine variations were not widely captured, suggesting replication with a larger sample and cohort design for further validation.

4. Conclusion

The conclusion of this study is that exposure to hand-arm vibration among tailors in the informal sector of Makassar City is generally low and does not have a significant relationship with work fatigue. The results of statistical tests indicate that the level of vibration exposure experienced by respondents is still below the recommended threshold, so it is not enough to trigger significant work fatigue. This condition indicates that at low exposure, the worker's body is still capable of physiological and neuromuscular adaptation, especially in workers with long working periods and relatively stable work environments. However, the discovery of cases of moderate exposure accompanied by total fatigue indicates a potential increase in risk if vibration exposure increases or continues cumulatively. Therefore, handling or control is still needed to prevent severe and continuous fatigue.

As a follow-up effort, regional and central governments are expected to improve OSH guidance and supervision in the informal sector by developing work ergonomics guidelines and encouraging the use of low-vibration work equipment. Sewing institutions or workplaces are advised to implement technical and administrative controls, such as regular sewing machine maintenance, setting rest periods, and providing occupational ergonomics education to prevent increased

vibration exposure. For future researchers, it is recommended to develop studies with a longitudinal design, a larger sample size, and considering cumulative exposure variables and other ergonomic factors so that the relationship between work vibration and fatigue can be analyzed more comprehensively.

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