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Association between Noise Intensity, Physical Workload, and Mental Workload with Work Stress among Workers at a Concrete Manufacturing Plant: A Cross-Sectional Study

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ABSTRACT

The concrete industry is synonymous with high-pressure work environments, primarily from physical factors. This study aims to analyze the associated with of noise intensity, physical workload, and mental workload on work stress levels at PT Bosowa Beton, a modern concrete manufacturing plant. This research employed a cross-sectional design with 49 employees as respondents. Data were collected using the HSE Indicator Tool to measure work stress (where lower scores indicate higher stress levels), alongside the NASA-TLX for mental workload and Cardiovascular Load (CVL) for physical workload. Direct noise intensity measurements were conducted using a calibrated sound level meter. Data analysis was performed using correlation tests to identify relationships and associated with between variables. The average noise level was 86.54 dB (exceeding the TLV). A total of 18.4% of employees experienced high to very high stress. Statistical tests revealed that mental workload had a significant positive associated with on stress (p-value=0.041; r=0.293). Noise showed a significant negative relationship with stress (p-value=0.001; r=-0.459), while physical workload had no significant associated with stress (p-value=0.927; r=0.013). This finding indicates that the associated of stress originates from mental aspects. This study shows that mental workload and noise intensity are significantly associated with work stress, while physical workload is not. These findings highlight the importance of managing mental workload and controlling noise in the workplace. Further research using longitudinal or multivariate approaches is needed to clarify these relationships and develop more targeted interventions.

Keywords **:** Work Stress; Noise; Mental Workload; Physical Workload; Concrete Industry

INTRODUCTION

The concrete manufacturing industry is a vital sector in global infrastructure development, particularly in rapidly growing economies such as Indonesia. This environment is characterized by exposure to multiple physical and psychological risk factors that can significantly impact workers' health and performance[1]. Occupational stress has been globally recognized as a critical workplace health issue with extensive implications for productivity, safety, and overall worker well-being[2].

Occupational stress is defined as the physiological and psychological reactions that occur when job demands exceed a worker's capabilities, resources, or needs3. Within the concrete manufacturing context, work-related stress can have serious consequences, including reduced productivity, increased absenteeism, and an elevated risk of occupational accidents[4]. A recent study in similar industries reported a stress prevalence of 32.4% among manufacturing workers[5]. Three primary factors consistently identified as major stressors in industrial settings are noise intensity, physical workload, and mental workload[6]. Noise is an unavoidable physical pollutant in concrete plant operations. Exposure to noise levels exceeding the Threshold Limit Value (TLV) of 85 dB not only poses risks of permanent hearing impairment but has also been associated with increased psychological pressure and stress[7]. Contemporary research by Yuhong et al. (2022) demonstrated that chronic noise exposure activates autonomic stress responses, elevates cortisol levels, and impairs cognitive function[8].

Traditionally, physical workload has been considered the predominant stressor in production-based industries. However, with technological advancements and automation, work characteristics have undergone significant transformations[9]. While mechanization has reduced manual physical demands, physical aspects remain crucial in overall workload assessment[10]. Interestingly, mental workload has emerged as a new challenge in the era of increasingly automated industries[11]. Mental workload refers to the cognitive and psychological demands required to complete work tasks, including concentration, memory, decision-making, and time pressure[12]. Arefian et al. revealed that in modern manufacturing environments, mental workload often constitutes a more significant stress source than physical demands[13].

PT Bosowa Beton Makassar, a leading concrete industry player in Eastern Indonesia, faces challenges in managing employee health and safety. The workforce profile, dominated by male workers (89.8%) with relatively

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high education levels (73.5% holding tertiary education), creates unique work dynamics that require comprehensive examination[14]. While previous research has examined individual factors related to work stress, few studies have comprehensively analyzed the interaction between noise, physical workload, and mental workload in the context of modern mechanized concrete industries[15]. Furthermore, inconsistent findings in the literature regarding the noise-stress relationship warrant further investigation[16].

The transformation from physical to mental stressors in automated manufacturing environments represents a significant paradigm shift that requires updated occupational health strategies. Recent studies have indicated that mental workload assessment should be integrated into routine occupational health surveillance in modern industries. Moreover, the relationship between noise exposure and stress appears to be more complex than previously understood. While conventional understanding suggests a positive correlation, emerging evidence indicates potential adaptation mechanisms or contextual factors that may modify this relationship. This complexity underscores the need for industry-specific investigations that consider the unique characteristics of modern concrete manufacturing processes.

The educational profiles of workers in modern industries also introduce new dimensions to stress management. Higher-educated workers may demonstrate different stress coping mechanisms and vulnerability patterns compared to traditional industrial workers. Understanding these dynamics is crucial for developing effective intervention strategies. Based on this comprehensive background, this study aimed to analyze the associated with of noise intensity, physical workload, and mental workload on work stress levels among employees at PT Bosowa Beton Makassar. The findings are expected to contribute significantly to the development of more effective and targeted stress management strategies in modern concrete industries while addressing the evolving nature of occupational stressors in automated manufacturing environments.

The novelty of this study lies in its industry-specific, cross-sectoral evaluation of how occupational noise, physical workload, and mental demands collectively relate to work-related stress in modern concrete manufacturing environments. While previous research has largely examined these factors separately or within the context of traditional industries, this study specifically addresses the non-hearing-related psychological consequences of concrete plant noise alongside cognitive and physical workload profiles, providing targeted evidence for more comprehensive control measures

MATERIAL AND METHODS

Study Design and Setting

This research employed a cross-sectional study design to examine the associations between noise intensity, physical workload, mental workload, and work stress. The study was conducted at Concrete Manufacturing, a leading concrete manufacturing plant in Eastern Indonesia A cross-sectional design was selected to provide a snapshot of the current conditions and relationships between variables at a specific point in time[17].

Population and Sample

The study population comprised all production employees working in various departments of the concrete manufacturing facility. The total population comprised 68 workers. Sample size calculation was performed using the formula for cross-sectional studies with categorical outcomes, considering a 95% confidence level and a 5% margin of error. The minimum required sample size was 49 respondents, who were selected through proportional random sampling from different production units to ensure their representativeness.

Data Collection Methods and Instruments

Noise Intensity Measurement

Noise levels were measured using a calibrated digital sound level meter (Lutron SL-4012) with a measurement range of 30-130 dB and an accuracy of ±1.5 dB. Measurements were conducted at various work stations during peak production hours, following the guidelines established by the National Institute for Occupational Safety and Health (NIOSH)[18]. Measurements were conducted in worker areas such as the administration room, production area, mixing unit area and production area with a total of 5 points according to industry permits. Noise measurements with the instrument were adjusted in advance according to the type of noise, namely continuous noise (using slow time weighting) and intermittent noise (using fast time weighting). The instrument was calibrated before use, and measurements were conducted at a height of approximately 1.5 meters near the noise source with a dB(A) noise model that indicates the noise received by workers.

Work Stress Assessment

Work-related stress was measured using the Health and Safety Executive (HSE) Indicator Tool, which has been validated in industrial settings and demonstrates good reliability (Cronbach's alpha = 0.87). The questionnaire consisted of 35 items measuring seven key stress domains: demands, control, managerial support, peer support, relationships, role, and change. The scoring system categorizes stress levels into four categories: low, moderate, high, and very high stress. Work-related stress levels were categorized as follows: low (140–175),

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moderate (105–139), high (70–104), and very high (35–69), based on the total questionnaire score. HSE questionnaire scores were interpreted inversely, where lower scores indicate greater levels of stress

Physical Workload Assessment

Physical workload is measured using a pulse oximeter. The device not only has a menu for measuring oxygen saturation but also a menu for measuring heart rate. Physical workload is evaluated using Cardiovascular Workload (CVL) with the following calculation:

a. Calculating heart rate

The first step is to calculate the Working Heart Rate (CVR). Next, measure the Resting Heart Rate (RHR) at rest.

b. Calculating maximum heart rate (MHR)

Where the maximum heart rate is (220 - age) for men and (200 - age) for women, calculate the heart rate using formula 1.

MaxHR = 220/200 - Age……………………………….………...…… (1)

c. Calculating the CVL percentage (% CVL)

$$\%CVL = 100\% \frac{CVR-RHR}{MHR-RHR} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The %CVL score is then compared to the five categories defined by Diniaty and Muliyadi (2016): a score less than 30% indicates "no fatigue" in the physical workload; 30-60% indicates "improvement required;" 60-80% indicates "work in a short time;" 80-100% indicates "immediate action required;" and a score greater than 100% indicates "no activity permitted.

Mental Workload Measurement

Mental workload was assessed using the NASA Task Load Index (NASA-TLX), a multidimensional rating procedure that provides an overall workload score based on six subscales: mental demands, physical demands, temporal demands, performance, effort, and frustration[19]. The instrument has demonstrated high reliability in industrial applications (Cronbach's alpha = 0.82-0.89).

Data Collection Procedure

Data were collected using two main approaches: direct environmental measurements and questionnaire administration. Environmental measurements of noise intensity were performed by trained researchers following standardized protocols. Questionnaires were administered directly to respondents during work breaks in a controlled environment to ensure proper understanding and minimize interference with the production activities. Prior to data collection, all participants received comprehensive information about the study and provided their written informed consent.

Data Analysis

Data were analyzed using SPSS version 26.0. Descriptive statistics, including means, standard deviations, frequencies, and percentages, were calculated for all variables. Normality testing was performed using the Kolmogorov-Smirnov test. Bivariate analyses included Pearson’s correlation tests for normally distributed continuous variables and Spearman's rank correlation for non-parametric data.

Ethical Considerations

The study protocol was approved by the Institutional Review Board of Poltekkes Kemenkes Makassar. All participants provided written informed consent after receiving detailed information regarding the study objectives and procedures. Confidentiality was maintained through data anonymization, and participants were informed of their right to withdraw from the study at any time without consequences.

RESULTS

Demographic Characteristics of Respondents

The study involved 49 employees from PT Bosowa Beton in Makassar City. The demographic characteristics of the respondents are as follows:

Table 1. Distribution of Respondents by Age, Gender, Education, and Work Period

Demographic Variable	Categori	n	%
Age	Max (52)	-	-
	Min (22)	-	-
	Mean (34,20)	-	-

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Demographic Variable	Categori	n	%
Gender	Male	44	89,8
	Female	5	10,2
Education	Junior High School	1	2,0
	Senior High School	12	24,5
	Higher Education	36	73,5
Work Period	New (≤ 5 Years)	23	46,9
	Experienced (> 5 Years)	26	53,1
Total	**49**	**100.00**	

Work Environment Measurement: Noise Level

Noise intensity measurements in the work environment yielded the following data:

Table 2. Results of Noise Level Measurements

Variable	Max	Min	Mean	SD
Noise	100,15	63,2	86,54	13,38

Distribution of Stress Levels, Physical Workload, and Mental Workload

The distribution of respondents based on stress levels, physical workload, and mental workload is presented in the following table:

Table 3. Distribution of Stress Levels, Physical and Mental Workload

Variable	Categori	n	%
Stress Level	Low	4	8,2
	Moderate	36	73,5
	High	7	14,3
	Very High	2	4,1
Physical Workload	Light	6	12,2
	Moderate	39	79,6
	Somewhat Heavy	4	8,2
Mental Workload	Moderate	1	2,0
	Somewhat High	7	14,3
	High	35	71,4
	Very High	6	12,2

Results of Bivariate Statistical Tests

The results of correlation tests to analyze the associated with of each independent variable on stress level are as follows:

Table 4. Results of Relationship Tests Between Independent Variables and Stress Level

Independent Variable	Dependent Variable (Stress	
	p-value	Correlation Coefficient (r)
Noise	0,001	-0,4596
Physical Workload	0,927	0,013
Mental Workload	0,041	0,293

Note: Lower HSE stress scores indicate higher perceived stress.

DISCUSSION

This study provides significant insights into the complex interplay between occupational stressors in modern concrete manufacturing settings. The findings reveal a paradigm shift in stress determinants, moving from traditional physical factors to more complex psychosocial and mental demands, reflecting the evolving nature of

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industrial work environments in the era of automation and digitalization. The HSE questionnaire scoring system categorizes stress levels into four categories: low, moderate, high, and very high. Work-related stress levels are categorized as follows: low (140–175), moderate (105–139), high (70–104), and very high (35–69), based on the total questionnaire score. HSE questionnaire scores are interpreted inversely, with lower scores indicating higher stress levels.

The most striking finding of this study was the significant positive correlation between mental workload and work stress levels ($p=0.041$, $r=0.293$). This aligns with the contemporary literature suggesting that modern industrial environments have undergone substantial transformation, where cognitive demands may exceed physical demands as the related to stress. Ghanavati et al similarly observed that in automated manufacturing settings, mental workload accounted of stress variance among workers, substantially higher than physical factors[20].

The high prevalence of mental workload in our study population, with 83.6% of the workers reporting high to very high mental demands, can be attributed to several factors characteristic of modern concrete production. The operation of computerized batching systems, quality control monitoring, and adherence to complex production schedules require sustained cognitive engagement of workers. This finding is consistent with Saedpanah et al., who documented that digital transformation in manufacturing fundamentally altered job demands, increasing cognitive load while reducing physical exertion[21-22]. The educational profile of the workforce, with 73.5% holding tertiary education, may also contribute to this phenomenon. Highly educated workers often occupy positions with greater decision-making responsibilities and problem-solving demands, potentially increasing their mental workload. Shahraki et al noted that educational attainment positively correlates with perceived mental workload in technical industries[23].

This study found a statistically significant negative correlation between noise intensity and stress level ($p=0.001$, $r=-0.459$). It is important to clarify that the HSE Indicator Tool uses reverse scoring for certain domains, meaning lower composite scores reflect higher perceived stress. The negative correlation indicates that higher noise intensity is associated with higher levels of perceived stress among workers. This interpretation aligns with the scoring system of the work stress questionnaire used, in which a lower score corresponds to a higher level of stress. This finding supports the proposed theoretical framework of environmental stress, which posits that chronic exposure to uncontrollable environmental stressors, such as noise, can lead to heightened psychological and physiological arousal, ultimately manifesting as increased stress. Consequently, this result substantiates the role of occupational noise as a critical environmental factor that can adversely affect employees' mental well-being[7,24-25]. Alternatively, noise may be perceived as an indicator of production activities and job security. In manufacturing contexts, operational noise often signifies active production, which workers may associate with organizational stability and with employment continuity. This positive cognitive appraisal could potentially mitigate stress responses, as suggested by Kanu et al. and Carvalhais in their study of manufacturing workers' psychological adaptation[25-26].

The cognitive distraction hypothesis offers a different perspective. High noise levels may serve as distractors from other stress sources, particularly mental workload demands. This aligns with the concept of "cognitive offloading" where environmental stimuli redirect attention from internal stressors. However, this interpretation requires cautious consideration, as chronic noise exposure remains detrimental to hearing health, regardless of its psychological impact. The absence of a significant correlation between physical workload and stress ($p=0.927$, $r=0.013$) reflects the successful implementation of mechanization and ergonomic interventions in modern concrete manufacturing. This finding challenges the traditional assumptions about stress sources in industrial settings and underscores the transformative impact of technological advancements on workplace conditions.

Modern concrete production facilities have substantially reduced manual labor through automated batching systems, conveyor mechanisms, and pneumatic handling equipment. The distribution of physical workload perceptions, with 79.6% reporting moderate levels and no respondents indicating very heavy loads, demonstrates this technological transition. Shatte et al. reported similar findings in their analysis of automated manufacturing environments, where physical demands accounted for less than 15% of the total workload assessment[27].

This transformation aligns with global trends in Industry 4.0 implementation, where physical labor is increasingly augmented or replaced by automation. Residual physical demands primarily involve monitoring, maintenance, and quality control activities rather than heavy manual tasks. This evolution necessitates a corresponding shift in the focus of occupational health from purely physical hazards to psychosocial and organizational factors. Cross-tabulation analysis revealed intriguing patterns in stress responses to mental workload. Notably, among workers reporting a very high mental workload, none exhibited very high stress levels, with the majority (83.3%) reporting moderate stress. This suggests the presence of effective coping mechanisms and mental resilience among certain worker groups. Individual differences in stress appraisal and coping strategies significantly moderated the relationship between mental demands and stress outcomes. Factors such as previous experience, social support, and personal resilience resources may explain these variations.

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Demographic characteristics of the workforce may contribute to this resilience. The predominance of male workers (89.8%) and the relatively young average age (34.2 years) represent population characteristics typically associated with certain coping patterns, although individual variations remain substantial. Organizational factors, including leadership support and workplace culture, play crucial roles in stress mitigation. These findings have significant implications for occupational health practices in modern manufacturing settings. Traditional stress management approaches, which primarily focus on physical hazards, require expansion to comprehensively address mental workload and psychosocial factors. Primary interventions should target mental workload reduction through job redesign, improved work organization, and enhanced human-machine interface design. The implementation of decision support systems, optimization of information flow, and provision of adequate rest breaks can mitigate cognitive overload. Suryadi et al. (2024) demonstrated that ergonomic cognitive interventions reduced mental workload by 32% in similar industrial settings[28].

Secondary interventions should focus on enhancing individual coping capacity through stress management training, resilience-building programs, and mental health literacy. The development of peer support networks and supervisor training in mental health awareness represents promising approaches. Wang et al. documented significant stress reduction through mindfulness-based interventions in high-demand occupations. Tertiary interventions must include accessible employee assistance and mental health support services. Early identification of stress-related symptoms and appropriate referral mechanisms ensure timely intervention for affected workers. Despite the paradoxical noise-stress relationship, noise control remains essential for hearing conservation. Engineering controls, administrative measures, and personal protective equipment must be maintained and enhanced to prevent noise-induced hearing loss, regardless of psychological adaptation phenomena[29-30].

This study has several limitations that should be taken into account when interpreting its findings. First, the cross-sectional design captures relationships at a single point in time, making it impossible to draw causal conclusions regarding the direction of the relationship between the predictor variables and work-related stress. Second, the statistical analysis was limited to bivariate correlation tests, which neither controlled for potential confounding variables nor examined the simultaneous contribution of the three independent variables (noise intensity, physical workload, and mental workload). Methodologically, treating physical and mental workload as separate independent variables assumes linear and independent effects. The study did not explore interaction dynamics whether workers experiencing high physical demands simultaneously report high mental workload, or whether one dimension exacerbates or mitigates the stressful impact of the other. Third, sampling at a single location, a modern concrete manufacturing plant, limits the generalizability of the findings to other industrial sectors with different levels of automation and workforce profiles. Future research should employ longitudinal designs or multivariate analytical approaches (e.g., multiple regression, moderation analysis, or structural equation modeling) to test interactive effects among the independent variables and identify underlying mediating pathways. This approach will advance theoretical understanding of how physical and cognitive demands co-occur to form psychological stress, while supporting more targeted and evidence-based occupational health interventions in automated industrial environments.

CONCLUSION

This study demonstrates that mental workload and noise intensity are significantly associated with work-related stress, whereas physical workload is not significantly related. Among the variables examined, mental workload emerged as the most significant associated factor, although causal relationships cannot be established due to the cross-sectional design and bivariate analysis employed. These findings underscore the growing importance of cognitive and psychosocial factors in modern industrial environments. From a practical perspective, interventions should move beyond general stress management approaches toward more targeted cognitive ergonomic strategies.

Additionally, although a significant association between noise and stress was observed, noise control remains essential, particularly for preventing long-term auditory health risks. Future research using longitudinal designs and multivariate analyses is recommended to further clarify these relationships and to develop more precise and evidence-based occupational health interventions.

AUTHOR'S CONTRIBUTION STATEMENT

Iwan Suryadi: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision, Project administration, Funding acquisition.

Erwinda Alwi Rachman: Methodology, Validation, Formal analysis, Investigation, Resources, Data Curation,Writing - Review & Editing, Visualization, Project administration, Funding acquisition

Ni Luh Astri Indraswari: Methodology, Validation, Formal analysis, Investigation, Resources, Data Curation,Writing - Review & Editing, Visualization, Project administration, Funding acquisition

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Antonius Budi Trianto : Methodology, Validation, Formal analysis, Investigation, Resources, Data Curation, Visualization, Supervision,
Nurlaila Fitriani:, Software, Validation, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization,

CONFLICTS OF INTEREST

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest

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