RELATIONSHIP BETWEEN ENVIRONMENTAL STRESS FACTORS AND WORKER PERFORMANCE UNDER WELDING JOB ACTIVITY

M.A.M. Said[1,2], S.Z. You[1], N.K Khamis[1*], M.A.M. Sabri[1], A.R. Ismail[3], and A. Ardiyanto[4]

[1]Department of Mechanical and Manufacturing Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, Bandar Baru Bangi, 43600, Selangor, Malaysia.

[2]Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Malaysia Sarawak, Kota Samarahan, 94300, Sarawak, Malaysia.

[3]Department of Environmental Health Sciences, College of Health Sciences, University of Sharjah, 27272, Sharjah, United Arab Emirates

[4]Department of Mechanical and Industrial Engineering, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta, Indonesia

*Corresponding Author's Email: kamaliana@ukm.my

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ABSTRACT: Environmental stressors in the welding industry are a significant concern for worker safety and health. To enhance worker performance, it is crucial to create a better workplace environment that ensures safety and health standards are met. To address these issues, this study aims to identify the correlation between these stress factors and worker performance, subsequently formulating a model equation to represent this relationship. Two primary methods were employed: subjective assessment and physical assessment. For physical assessment, data related to heat stress, relative humidity stress, and lighting stress were collected. Concurrently, a questionnaire containing 56 questions was developed and distributed for subjective assessment. A total of six welding industries participated, involving 15 respondents. All collected data were then analyzed using Pearson correlation and multivariate regression analysis to determine the study's relationship. The results of the multivariate regression analysis revealed a robust correlation value (R = 0.903) and a regression value (R square = 0.816).

This variable provides a model that can be utilized to predict a worker's performance level and assess optimal job performance. In conclusion, this study can be valuable for relevant parties seeking to mitigate risks to worker safety in the workplace.

KEYWORDS: *Environmental Stress, Welding, Workers Performance, Workplace*

1.0 INTRODUCTION

Comfort working workplaces are the most important factors that need to be looked into to create a safe and low-risk working environment. A good environment also leads to the performance of the worker. In the welding industry, this job is recognized as one of the most hazardous operations in manufacturing, and prioritizing safety is paramount in every welding method or process [1]. From the previous case study, most accident that happen in the welding industry are due to safety and health issues such as physical hazard and safety hazard [1].

Nowadays, most of the welding industry operates manually and semi-automatically. Therefore, a suitable work environment is needed to increase their concentration so as not to be distracted. Researchers stated that inappropriate environmental stress can lead to low performance, and poor quality, and can even invite hazards in the workplace [2]. Workers will usually work in various workplace environmental conditions such as heat stress, relative humidity, and different lighting during the working period. These factors can indirectly affect the performance and productivity of employees. If these workplace environmental factors can be controlled, employee performance can be improved and issues related to negligence when doing tasks due to fatigue can be avoided [2]. Other research shows that the hot and humid region exhibits reduced sensitivity but heightened adaptation to elevated temperatures and humidity levels [3]. Other than that, ensuring sufficient lighting supports tasks offers visual comfort, and improves the work environment's ambiance [4]. Study also shows that hot environment workplace reduces the worker productivity [5].

Numerous studies have explored the effects of environmental stress factors, such as humidity, lighting, and noise, on employee performance, health, and safety [2, 6, 7]. Some researchers developed tools for monitoring environmental stress which as the octa hearing conservation index (OHCI) system which can be used as a hearing conservative program (HCP) monitoring tool in educational

institutions and industry workplaces to give awareness and compliance evidence [8]. Prior research highlights the importance of creating a comfortable workplace environment to enhance productivity [9]. Guidelines and international standards have been developed to safeguard workers' health in extreme conditions [10]. Another study shows that indoor environmental workplace conditions are influenced by factors directly linked to the outdoor environment [11]. The extreme weather outside can lead to high temperatures inside the workplace. This unsafe working environment can lead to job strain and reduced performance of the workers [12]. To reduce job stress and improve worker performance interventions and stress-reduction efforts have been highlighted in previous studies such as redesigning job scope [13]. Alternatively, enhanced comfort with work conditions and environment, teamwork, and tasks among employees directly elevate both job satisfaction and performance. [14].

Researchers in the past have primarily studied individual environmental stress factors' impact on worker satisfaction, health, and productivity [15]. However, fewer studies have examined the combined effect of all environmental stress variables on job performance [16]. Some of the studies combined both areas which are environmental variables and leadership behaviors [16]. Other studies focused on specific environmental factors such as heat [1] and other studies focused on workplace experiences that affect the workers [32]. In another study, the researcher only discusses the performance criteria of the workers due to the absence of specific key performance indicators that relate to the general working environment [17]. Understanding work stressors and their effects empowers employers to optimize job design and minimize stressors for employees [18]. Other than that, study shows that poorly designed workplaces can elevate the risk of workplace accidents [19]. Heat stress factors are generally considered a moderate problem, and interventions like providing drinking water, improving workers' clothing/protective equipment, and rescheduling the workday may be necessary [20]. Improve design of equipment can improve worker posture, safety, and health [21].

Environmental stressors within the welding industry have not garnered as much attention as in other sectors like construction, despite their substantial impact on worker productivity. This study investigates the relationship between worker performance and environmental stress factors, specifically heat, relative humidity, and lighting, in small and medium-sized welding industries. Given the inherent risks associated with welding, such as heat and humidity, this

research focuses on indoor workplace conditions, distinguishing itself from previous studies that predominantly concentrated on outdoor environments, particularly emphasizing heat and noise. Therefore, this study analyses the relationship between environmental stress factors (heat, lighting, and relative humidity) and worker performance in the welding industry workplace. A novel equation to predict worker environmental stress and performance levels was generated from the relationship analysis of this study.

2.0 METHODOLOGY

In this study, two methods were employed: the subjective method and the objective method. All the collected data were subsequently analyzed using IBM Statistical Package for the Social Sciences (SPSS) Statistics 22 Software to examine the relationship through Pearson Correlation and Multiple Regression Analysis. Figure 1 provides an overview of the study's process flow. Within this study, a physical assessment of specific environmental stress factors was conducted to establish their relationship with the subjective assessment. Unlike previous studies that often focused on a single environmental stress factor, such as heat [1], this research aimed to develop a novel equation for predicting worker performance levels based on environmental stress factors. This equation was derived from the multivariate regression analysis after identifying the significant variables involved.

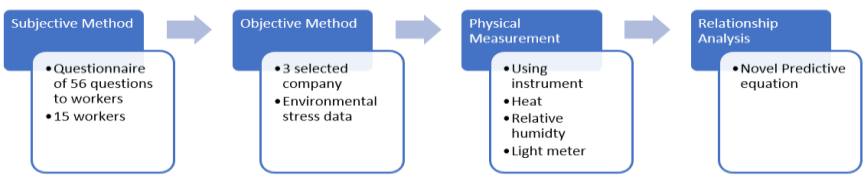

Figure 1: Process flow of this study

2.1 Subjective Method

For the subjective method, a set of questionnaires contains 56 questions divided into four parts: respondent demographics, job information, workplace stress level, and worker's performance level. It received approval from ten safety and health experts, and their feedback was considered to ensure the relevance of this questionnaire with its Cronbach's alpha of 0.871 for reliability which is considered good [30]. The questionnaire was adapted from the previous study [31]. The study involved fifteen respondents from six small medium welding industries in Johor, Pulau Pinang, and Kuala Lumpur.

2.2 Objective Method

In the objective method or physical measurement method, data related to selected environmental stress factors were collected. Three workers from the selected industries were assigned to Company A, Company B, and Company C. The companies were chosen from three locations: Johor, Pulau Pinang, and Kuala Lumpur.

2.3 Physical Measurement Equipment

The physical measurement assessment method involved using equipment to collect three environmental data points: temperature, relative humidity, and luminosity. Both environmental stress and worker data were gathered for this study. Three workers from different industries were assigned to Company A, Company B, and Company C. Figure 1(a) displays the temperature and relative humidity equipment, while Figure 1(b) shows the light meter application used in this study.

(a) (b)

Figure 1: (a) Elitech RC-4HC, (b) Light Meter Application

Environmental stress such as heat, relative humidity, and lighting stress was measured and recorded using the relevant tools. In this study, Elitech RC-4HC [22] and a smartphone with a light meter application are located at a distance of 0.8 to 1m from the welding center and 0.8m to 1m in height from the floor. Figure 2 shows the physical measurement equipment setup in this study.

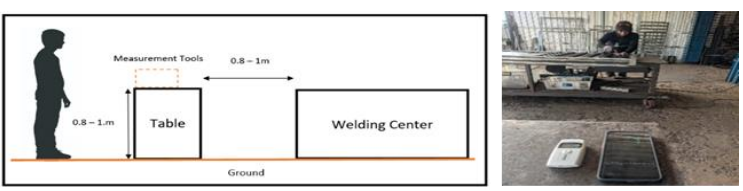

Figure 2: Physical measurement equipment setup in this study

3.0 RESULTS AND DISCUSSION

In this result and discussion section, the result was tabulated from the questionnaire and physical measurement. The data were analyzed

through correlation analysis, and multiple regression analysis using IBM SPSS Statistics 22. The findings of this study were to indicate the relationship between environmental stress factors and workers' performance.

3.1 Relationship of Environmental Stress Factors with Worker's Performance

In the subjective methods, 15 participants took part, with an average working experience of 4.13 years and an average age of 33.6 years. In the physical assessment, only three (3) participants were involved in the physical measurements. As this study is a pilot case study done in selected small medium welding industry, the participants are sufficient considered sufficient. As the adequacy of participants in a study can vary, with estimates ranging from 10 to 50 participants, depending on the nature of the research and the specific research question [33].

Tables 1 and 2 display correlations between environmental stress factors (heat stress, relative humidity) and (lighting stress) with worker's performance. A significance level of $p < 0.05$ is considered significant, while $p < 0.001$ is highly significant. Pearson correlation and Sig values are crucial for result reporting. Table 2 shows the highest correlation between heat stress and relative humidity stress with worker's performance level, exceeding 0.7. Notably, feeling confident with thick clothing ($r = -0.740$; $p < 0.001$), being informed about workplace temperature and humidity ($r = 0.715$; $p < 0.05$), feeling appreciated with comfortable dress ($r = 0.714$; $p < 0.05$), and ease in overcoming problems with thick clothing ($r = -0.707$; $p < 0.05$) have significant correlations. Pearson's correlations show feeling confident in working conditions is positively associated with wearing formal thick clothing and being informed about workplace temperature and humidity. Additionally, wearing formal thick clothing enhances ease in overcoming problems. Furthermore, worker's performance level significantly correlates ($r = 0.851$; $p < 0.001$) with comfort regarding workplace air temperature, consistent with previous studies [24] that stated knowing the workspace safe and comfortable is pertinent to ensure comfort while doing practical work in the workshop.

Table 1: Relationship between the environment of heat stress and relative humidity stress with the level of worker's performance

Environmental variables heat stress and relative humidity stress	Worker's Performance Level Variables	Correlation	Significant (2-tailed)	Strength of correlation
The air temperature at your workplace is very comfortable	The score of a worker's performance level	0.851**	0.000	High
Your clothes at work	You feel very confident	-0.740**	0.001	High

are thick	in your work			
You know about the temperature and humidity in your workplace	You feel very confident in your work	0.715**	0.003	High
Your clothes at work are very comfortable	You feel recognized by your employer	0.714**	0.003	High
Your clothes at work are thick	You feel easy to overcome and solve the problem	-0.707**	0.003	High
Your clothes at work are thick	You feel recognized by your employer	-0.628**	0.005	Medium
You feel undisturbed by the level of humidity in the workspace	You feel very confident in your work	0.681**	0.005	Medium
The air temperature at your workplace is very comfortable	You feel comfortable with your workplace environment	.644**	0.010	Medium

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 2 shows a strong correlation between lighting and worker performance (exceeding 0.7). Feeling comfortable with the workplace environment is significantly associated with suitable lighting for work activities ($r = 0.863$; $p < 0.001$). Workplace comfort also correlates positively with lighting ambiance ($r = 0.750$; $p < 0.001$). Conversely, efforts to improve skills correlate negatively with lighting, suggesting better lighting leads to a more comfortable workplace ($r = -0.632$; $p < 0.05$). Pearson's correlation analysis confirms that increased acceptance of light for welding activities enhances workplace comfort and a brighter atmosphere improves workers' comfort. Worker performance moderately correlates with acceptable lighting for work activities ($r = 0.619$; $p < 0.05$), supporting the positive impact of increased lighting, as observed by Konstantzos et al. [25], who identified horizontal and vertical illuminance as factors affecting performance.

Table 2: Relationship between the lighting environment and the level of worker's performance

Lighting stress variables	Worker's Performance Level Variables	Correlation	Significant (2-tailed)	Strength of correlation
The light in the welding workplace to perform the working activities is acceptable	You feel comfortable with your workplace environment	0.863**	0.000	High
The lighting inside the workplace makes the working environment look comfortable	You feel comfortable with your workplace environment	0.750**	0.001	Medium
The lighting inside the workplace makes working	You strive to improve your skills level	-0.632*	0.012	Medium

environment look comfortable				
The light in the welding workplace to perform the working activities is acceptable	The score of worker's performance level	0.619*	0.014	Medium
You feel bright about lighting in the welding workplace	You really satisfied with your job	-0.582*	0.023	Medium

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

3.2 Relationship Physical Measurement of Environmental Stress with Worker's Performance

Table 3 displays physical measurement results with a moderate correlation (between 0.3 to 0.7) to worker's performance. Heat stress correlates with feeling confident ($r = 0.671$; $p < 0.05$), job satisfaction ($r = -0.652$; $p < 0.05$), and on-time happiness ($r = 0.570$; $p < 0.05$). Lighting stress relates to feelings of sadness due to unexpected events at work ($r = -0.590$; $p < 0.05$). While prior studies also indicate a gap between worker perception and physical lighting stress [26-28]. Additionally, Dianat et al. [26] found that 41.5% of workplaces didn't meet noise standards, 46.9% didn't meet illuminance standards, and 54.6% didn't meet WBGT standards, aligning with workers' perceptions and low satisfaction.

Table 3: Relationship between the physical measurement of environmental stress worker's performance

Relationship between the physical measurement of environmental stress and the level of worker's performance		Physical Measurement Heat Stress Level	Physical Measurement Relative Humidity Pressure Level	Physical Measurement Lighting Pressure Level
You feel very confident in your job	Correlation	0.671**	-.157	.212
	Sig (2-tailed)	0.006	.576	.448
You feel sad if anything happens out of control about your work	Correlation	-0.104	.255	-.590
	Sig (2-tailed)	0.711	.359	0.021
You feel happy to finish your work on time	Correlation	0.570*	.190	.093
	Sig (2-tailed)	0.026	.498	.742
You really satisfied with your job	Correlation	-0.652**	-.108	.213
	Sig (2-tailed)	0.009	.701	.447

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

2.3 Relationship Analysis

In the relationship analysis, Table 4 presents the multivariate regression results, showing a moderate correlation value of R = 0.903 and a regression value of R square = 0.816 between the combined data of physical measurements and subjective assessment of environmental stress with employee performance level. The combination of these data yields a higher correlation and regression value compared to considering physical measurements or subjective assessment alone. The developed equation for the combined data is presented as equation (1) to predict the level of worker's performance.

$$y = -0.837x_1 - 4.124x_2 + 1.731x_3 - 5.004x_4 - 0.489x_5 - 3.308x_6 + 5.471x_7 - 3.107x_8 + 0.372x_9 - 9.639x_{10} + 1.134x_{11} - 0.165x_{12} - 394.417 \quad (1)$$

Table 4: Multivariate regression analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.903a	.816	-.288	5.07923

Predictor: (Constant), Physical Measurement Lighting Pressure Level, 5. The humidity level in your workplace is very dry, 18. The welding workplace in this lighting appears enough, Physical Measurement Relative Humidity Pressure Level, 16. The lighting inside the workplace makes equipment and other object look natural, 17. The light in the welding workplace to perform the working activities is acceptable, 3. You feel your workplace is comfortable, 13. You feel comfortable (visually) about lighting in the welding workplace, 7. Your cloth while working are very comfortable, 2. You feel very hot while working, 19. In general, you prefer bright lighting for welding, Physical Measurement Heat Stress Level

Model		Coefficient	Std. Error	Sig	X_n
1	(Constant)	-294.417	528.184	.633	
	2. You feel very hot while working	-.837	2.285	.749	X_1
	3. You feel your workplace is comfortable	-4.124	7.191	.624	X_2
	5. Humidity level at your workplace very dry	1.731	3.337	.656	X_3
	7. Your cloth while working very comfortable	-5.004	10.077	.669	X_4
	13. You feel comfortable(visually) about lighting in welding workplace	.489	4.728	.927	X_5
	16. The lighting inside the workplace make equipment and other object look natural	-3.308	4.332	.525	X_6
	17. The light in the welding workplace to perform the working activities is acceptable	5.471	3.125	.222	X_7
	18. The welding workplace in this lighting appears enough	3.107	8.443	.748	X_8
	19. In general, you prefer bright lighting for welding	-.372	4.560	.942	X_9
	Physical measurement heat stress level	9.639	14.356	.571	X_{10}
	Physical measurement relative humidity level	1.134	2.127	.647	X_{11}
	Physical measurement lighting stress level	-.165	.253	.581	X_{12}

According to the developed novel equation (1), the lowest value of worker's performance level indicates optimal environmental conditions with a temperature below 31°C, relative humidity below 76%, and a lighting level between 308-500 lux. However, it is important to note that the temperature value exceeds the ACGIH TLV threshold limit value of 28°C, and the relative humidity does not fall within the accepted range of 40-70% set by the Department of Occupational Safety and Health (DOSH). On the other hand, the lighting level aligns with the acceptable range of 200-500 lux as specified in the Guidelines on Occupational Safety and Health (OSH). This finding aligns with previous studies conducted by Ismail [29], which have reported significant relationships between different environmental factors, such as noise, lighting, thermal conditions, and workers' productivity in industrial settings.

4.0 CONCLUSION

In conclusion, the study revealed significant relationships between worker performance and output that obtained from questionnaires and physical measurements of heat stress, relative humidity stress, as well as lighting stress. Optimal worker performance was associated with appropriate levels of heat, relative humidity, and lighting stress. The highest correlation was found between subjective assessment data and environmental heat stress. In addition, physical measurements and subjective assessments demonstrated a strong correlation for heat stress and illumination stress, whereas the correlation for relative humidity pressure was moderate. The multivariate regression analysis revealed a strong relationship between predictors of environmental pressures as dependent variables. This study provides reliable insights into predicting the safety, health, and performance of workers who are exposed to environmental stressors in the workplace. However, future research should validate this method with various assessors from various industries, consider additional environmental stress factors, and create a comprehensive index.

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AUTHOR CONTRIBUTIONS

M.A.M. Said: Introduction, Methodology, Writing- Original Draft Preparation; S.Z. You: Methodology, Results and Discussion; N.K. Khamis: Supervision, Discussion, Reviewing and Editing; M.A.M. Sabri: Supervision, reviewing; A.R. Ismail: Supervision, reviewing; A. Ardiyanto: Reviewing.

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