SHORT COMMUNICATION

Heat stress and physiological changes among workers at steel manufacturing industry in Shah Alam, Selangor

Syakimatun Aliah Mohd Daud, Nurul Imanina Azalan, Rodziah Ismail, Mohd Pozi Mohd Tahir, Ahmad Razali Ishak*

Centre of Environmental Health and Safety, Faculty of Health Sciences, Universiti Teknologi MARA Kampus Puncak Alam, Selangor, Malaysia.

***Corresponding Author**

Ahmad Razali Ishak, PhD
Email: ahmadr2772@uitm.edu.my

Abstract:

Heat stress is recognized as a severe physical hazard which can cause health related problems at workplace. Theoretically, the effect of heat stress tends to cause physiological changes such as raising body temperature and also increase both heart rate and blood pressure. The purpose of this study was to determine the heat stress level among workers at a steel manufacturing industry in Shah Alam. A total of 71 workers from six workstations were included in this study. The level of heat stress was identified using Heat Strain Score Index (HSSI) questionnaire while the ambient temperature at various workstations was measured using Wet Bulb Globe Temperature (WBGT). Based on the HSSI, 60, 30 and 10% of workers in the steel manufacturing industry were working in the red, yellow and green zones respectively. However, no correlation was observed between ambient temperature and physiological response among them. Although these findings showed no extreme environmental heat stress experienced by the workers, mitigation measures should be taken to control future heat exposure.

Keywords: Heat stress, HSSI, physiological changes, WBGT

1. INTRODUCTION

Heat stress is a physical hazard which may cause health effects, either directly or indirectly to employees. It occurs when the body failed to regulate its internal temperature and unable to lose the heat after continuous labor [1]. It can increase stress and fatigue, thus enhancing the likelihood for accidents to occur at workplace [2].

Workers in steel making industries are prone to heat stress during their working period due to the various processes in steelmaking such as extraction, tapping, burning a scrap, casting and molten steel production [3]. The workers who are exposed to heat stress might lose their focus during work and experience heat-related illness symptoms such as muscle cramps, heat rash, fainting, fatigue, nausea, and headache [2]. Heat stress can also cause physiological and psychological discomforts, and these changes would affect the worker's performance. It may increase the thermoregulatory, cardiovascular and perceptual strains on the body that will promote body confusion, irritability and other emotional stress [4].

This study was intended to identify the exposure of the workers to heat stress and their physiological changes during 8 hours working period in a steel manufacturing industry. Physiological parameters such as core body temperature, pulse rate, and blood pressure are used as indicators to determine the environmental thermal effects. The data obtained from this study would be used as a baseline data for the implementation of preventive control measures in the industry.

2. MATERIALS AND METHODS

2.1 Study location

A cross sectional study on heat stress was conducted in a steel manufacturing plant in Selangor. Six sampling points were chosen as the location for heat stress assessment which include (A) Small press, (B) Manual welding line, (C) Automated welding line, (D) Assembly line, (E) Riverting area and (F) Kawake area.

2.2 Heat stress screening

Heat Stress Screening Checklist (HSSC) was used as a pre-assessment method to evaluate the condition of workplace before the monitoring took place. The checklist was adopted from Guideline of Heat Stress Management at Workplace [2].

2.3 Ambient temperature monitoring

Environmental temperature was measured using Wet Bulb Globe Temperature (WBGT) QUESTEMP °36 Thermal Environment Monitor, QUEST Technologies, USA. The WBGT monitor was fixed on a tripod at 1.1 meter in stand position supported with photographic tripod. The WBGT was placed near the heat source as well as near to the worker's activity. The measurement was taken for eight hours of working shift and the data was recorded automatically in data logger.

2.4 Determination of Heat Strain Score Index (HSSI) and physiological changes among workers

A total of 71 workers from six different work areas were selected as respondents. The adopted HSSI questionnaire from Dehghan et al. [5], was distributed to each of the participants prior to taking the physiological measurement. The physiological responses measured were core body temperature, pulse rate, and blood pressure. The measurement was taken before and after working hours.

3. RESULTS AND DISCUSSION

3.1 Heat Stress Screening Checklist (HSSC)

In this study, HSSC was used to evaluate the subjective score of the following parameters; air temperature, radiant temperature, air velocity, humidity, clothing and metabolic rate. Table 1 showed the risk score obtained from the HSSC. Higher score indicated higher risk of heat stress. It was found that there were 4 parameters which exceeded the score more than 1; air temperature (2), radiant temperature (2), air velocity (2) and clothing (2). These findings indicated the presence of potential heat stress risk among workers in this industry and require further evaluation for heat stress.

Table 1: HSSC Risk Score.

Parameters	HSSC Score									
	-3	-2	-1	0	1	2	3	4	5	6
Air Temperature										
Radiant Temperature										
Air Velocity										
Humidity										
Clothing										
Metabolic Rate										

3.2 Environmental temperature measurement

There are a total of six work stations set-up in this steel manufacturing industry. The highest temperature of 29.6 ˚C was recorded at automated welding station while the lowest of 27.7˚C was obtained at small press area. Manual welding, assembly line, Kawake and Riveting station recorded the temperature of 28.7˚C, 28.5˚C, 28.0˚C and 27.8˚C respectively (Table 2). As for relative humidity, the highest reading was found at automated welding area and assembly line which was 67% while the lowest of 62.5% was recorded at small press area. The relative humidity of other work station; Riveting, Kawake, manual welding and automated welding area were 66.7%, 65% and 63% respectively. All workers were exposed to a consistent high temperature during their working duration especially at the assembly line, manual welding area and automated welding. At this station, the workers were exposed with the heat continuously throughout 12 hours of working period. In Kawake, Riveting and Small Press station, the workers were not exposed to a consistent heat due to the nature of work which did not require the workers to work continuously. In the steel manufacturing industry, the workers are usually exposed to a high temperature for eight hours working shift via various process [3]. They are being exposed to a high level of heat from hot machines, furnace, oven and molten metals [6]. The recommended WBGT TLV and Action Limit by ACGIH are 28˚C [7]. In this industry, the result of WBGT was in the range of 27.7°C to 29.6°C. 3 out of 6 stations were slightly exceeded the ACGIH standard which were Automated welding, Manual welding and Assembly stations. These findings require some corrective control measures so as to avoid heat stress exposure to the workers

Table 2: Average WBGT at different work station.

Station	Average WBGT	Relative Humidity
A Small Press	27.7	62.5
B Manual Welding Line	28.7	67
C Automated Welding Line	29.6	63
D Assembly Line	28.5	67
E Riveting Area	27.8	66.7
F Kawake Area	28.0	65

3.3 Workers perception towards heat stress at their workplace

HSSI questionnaire consisted of 18 questions related to the perception of workers towards heat stress at their workplace. The HSSI were classified into three categories which were Green zone or safe level, Yellow zone or alarm level, and Red zone or danger level. The score less than 13.5 indicated the workers were in the green zone which contribute to low heat strain index. Meanwhile, the score 13.5 to 18 indicated the yellow zone which showed that the workers has a potential of heat –induced illness. The HSSI score more than 18 represent the onset of heat-induced illnesses [5]. In this study, the results showed that 60% of the workers have the total score greater than 18. Majority of the workers in this industry perceived to be working in the red zone or danger level. Meanwhile another 30% perceived that they were working at the yellow zone with the total score of 13.6 to 18. The remaining 10% of the workers perceived that they were working in the green zone or safe condition.

3.4 Workers physiological response before and after work activity

Table 3 showed the physiological response; oral temperature, systolic, diastolic pressure and pulse rate before and after working activity. The pair sample T-Test indicated significant different ($p<0.05$) of all physiological parameters before and after working activity. All the parameters showed slight increment after the work started. The mean systolic pressure of the workers increased from 123.1 before work to 131.2 after working period. There will be a change in physiological due to the changes of human metabolism during any physical activity. The blood pressure and pulse rate tend to increase due to the higher rate of respiration for the purpose of removing excess heat from the body. This finding was in agreement with Goh et al. [8] that indicated significant difference between body temperatures and pulse before and after working period. Environmental heat stress during working activity might contribute to the changes of physiological parameters. It may increases the sweat rate, core body temperature and pulse rate among workers that are exposed to the health hazard [9]. In another study by Ahasan et al. [10] also reported the increased of body temperature detected in the workers due to the heavy work load and exposure to environment heat that originates from steel industry.

Table 3: Worker's physiological response before and after work activity.

Physiological Response	***n***	**Mean ± SD**		***p*-value**
		Before	After	
Oral Temperature	71	36.4 ± 0.5	36.8 ± 0.5	< 0.01
Systolic Pressure		123.1 ± 11.2	131.2 ± 11.5	
Diastolic Pressure		72 ± 8	80 ± 7	
Heart Rate		76 ± 10	84 ± 11	

3.5 Correlation between physiological responses with environmental temperature

No correlation was found between physiological responses According to Pearson correlation test (Table 4). Normally, the body temperature will increase when the workers work in a high heat environment. However, the highest WBGT found in this study was 29.6 ˚C which is in moderate condition. Meanwhile, the average body temperature of the workers were below 36.8°C. Thus, it could not be used as indicator of physiological strain since all the worker's body temperature was below than 38°C [3]. No correlation also was found between averaged WBGT with blood pressure and pulse rate.

The *p*-value of the physiological response was found to be higher than 0.05. The strength of the correlation (*r*-value) also showed a poor correlation between heat stress and physiological changes for oral temperature, systolic blood and diastolic blood pressure and pulse rate. These finding were in agreement with findings from other previous researchers; Hasan et al. [3] and Shamsul et al.[11].

Table 4: Correlation between physiological responses with average WBGT.

Physiological Response	***r*-Value**	***p*- value**
Oral Temperature	0.188	0.117
Systolic Blood Pressure	0.053	0.662
Diastolic Blood Pressure	0.145	0.227
Pulse Rate	0.212	0.076

4. CONCLUSION

The averaged WBGT temperature at this steel manufacturing plant was found to be 29.6°C and could be categorized as mild heat stress condition based on the Threshold Limit Value (TLV) for WBGT(in) guideline ACGIH [7]. Although the HSSI score showed 60% of the workers was in the Red zone, no correlation was found between physiological response with ambient temperatures. The present study found that workers at this steel manufacturing industry did not have serious heat-related illness due to acute heat exposure. However, continuous improvement of workplace condition should be taken to minimize the risk of heat stress among workers.

ACKNOWLEDGEMENTS

The authors are grateful to the management of the steel manufacturing industry for giving the permission and their kind cooperation to conduct this study successfully.

REFERENCES

[1] Tymvios N BehmM., Jia Y., and Johnson K., "Heat Stress in the US Construction Industry," *University of North Carolina at Charlotte,* 2016.

[2] DOSH, Guidelines on Heat Stress Management at Workplace 2016.

[3] Hasan N, *et al*., "The evaluation of heat stress on steel mill workers through monitoring of environmental and acute physiological changes," *Advances in Environmental Biology,* 8(15):177-183, 2014.

[4] Ghanbary S.A., Palyzban F., Abedi M., and ShovkatiH., "Heat stress assessment according to the wet-bulb globe temperature (WBGT) index among workers of a steel mill in 2014," *Journal of Occupational Health and Epidemiology*, 6 (3):165-170, 2017.

[5] Dehghan H. *et al.*, "Validation of a questionnaire for heat strain evaluation in women workers," *International journal of preventive medicine,* 4(6): 631, 2013.

[6] Xiang J, *et al*.,"Health impacts of workplace heat exposure: an epidemiological review," *Industrial health,*52(2):91-101,2014.

[7] American Conference of Governmental Industrial (2012). Threshold Limit Values for Physical agents. Retrieved March 20, 2018 from https://www.acgih.org

[8] Ben G.S, Hashim Z., and Hamzah R., "Occupational heat stress of workers in a plastic industry, Selangor," *Journal of Occupational Safety and Health,* 95(56): 59-66, 2004

[9] Krishnamurthy M., *et al.*, "Occupational heat stress impacts on health and productivity in a steel industry in southern India," *Safety and health at work,* 8(1): 99-104, 2017.

[10] Ahasan et al. “Monitoring thermal stress of steel re-rolling mill workers” *Ergonomic international journal* 2.1(1-9), 2018

[11] Shamsul B., and Dubashini N., "Occupational heat stress and physiology parameters of male workers in a steel plant factory at Pasir Gudang, Johor," *Journal Of Occupational Safety And Health*, 11(2):63, 2014.