ORIGINAL ARTICLE

A Study for Estimating Heat Stress and Strains in Refinery and Administrative Unit of Sarcheshmeh Copper Complex, Kerman, Iran

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ABSTRACT

Background*:* Heat Stress and strains are major workplace hazards. A wide range of complications and diseases are createdin the absence of control.

Aim: To investigate the heat stresses and strains for a five-hour working at the refinery and administrative unit of Sarcheshmeh Copper Complex in Kerman, Iran.

Methods: This study was conducted on 30 refinery workers (exposed) and 30 employees of the administrative unit (unexposed) at the Sarcheshmeh Copper Complex in Kerman, Iran. Physiological parameters (systolic blood pressure, diastolic blood pressure, heart rate, oral temperature), environmental parameters (relative humidity, dry temperature, higher temperature, radiant temperature) and WBGT, PSI, DI indexes were measured for5 hours.

Results: The results showed that the averageheat stress index ofall working hours was significantly different in the two groups. The heat strain index was significantly higher in the refinery inall hours (except 11:45). The mean score of physiological and environmental parameters for all working hours in 2 groups was statistically significant.

Conclusion: Considering the direct and significant correlation between WBGT, PSI, DI indexes, their simultaneous use in large industries (more than 1000 workers) is suggesteddue to quick and accurate evaluation of the health status of workers and workplace conditions.

Keywords: Heat Stress, heat Strains, workplace, hazard, Industry

INTRODUCTION

Heat is a harmful physical condition in the workplace that causes many diseases[1]. In many industries, such as melting metals, Building Material Production Equipment Manufacturing, and manufacturing, the heat stress, especially in the summer are major health problem for workers[2]. Muscle cramps, excessive fatigue, decreased consciousness, decreased perception, heat syncope, and death in workplaces are major complications of exposure to heat[3]. WBGT is a major index for assessing warm environments, which was presented by Hugton in 1905[4]. The American Conference of Governmental Industrial Hygienists (ACGIH) offers the WBGT to assess the heat exposure[5]. DI is also used as a supplement to the WBGT to assess warm environments. Epstein believes DI is a applicability index of Universal Thermal Climate[6].. Heat strain is a physiological response to heat stress. The PSI index is used to evaluate the heat strain. It measures heart rate and deep body temperature [including oral temperatures, tympanic, anal)[7]. Studies have evaluated the heat stress and strain in the industry at one time[8,9], while for control over the work environment, it is important to find out when stress and heat strain are at the maximum. Therefore, this study evaluated the heat stress and strains using WBGT, DI,PSI indexes in 5-hour-working at the refinery and administrative unit of Sarcheshmeh Copper Complex in Kerman, Iran.

MATERIALS ANDMETHODS

This study was an analytical descriptive type conducted in 2019 in Sarcheshmeh Copper Mine, Kerman, Iran. Sarcheshmeh Copper Mine is a large and major copper mine in the world and the largest producer of copper in Iran. More than 6,000 people are work directly working in Sarcheshme copper mine. The refinery is among the largest mining units. Refinery and administrative departments consisted of about 168and 455 employees respectively. The physiological index (heart rate per minute) was 73.8±5.4 in the Golbabayi study in order to determine the sample size.[10] The accuracy of 0.95 and an acceptable error of 28 were estimated for sample size using the following formula: n=(Z-(1-α/2)/E^2)/E^2

Thirty people out of 120 people who were interviewed at the refinery and were exposed to heat for about 5 hours a day suffered certain diseases (high stress, mental illness, infectious and febrile illnesses, high blood pressure, cardiovascular disease, diabetes, Hypothyroidism and hyperthyroidism). They did not drink alcohol in the last 12 hours. 120 employees of the administrative department were interviewed in an interview group and 30 employees were assigned to the group who were not exposed to heat. Participants were recommended not to drink, eat, and smoke30 minutes before the test.

Demographic data (age, work experience, height, weight and BMI) were achieved by interviewing and measuring. The WBGT, DI and the PSI indices were used to measure the heat strain to measure heat stress. The indices of two groups were measured 5 times in the morning shift.

The WBGT index was measured according to the ISO7243 standard and the following formula. A WBGT meter device (model; LUTRON 2010SD) made in Taiwan was used to measure the temperature.

WBGTin=0.7Tnwt+0.3Tg: The DI index was measured using the following formula. The Beurer HM16 Thermometer and Hygrometer was applied to measure the natural wet temperature (Tnwt) and dry temperature (Tdb).
DI = 0.5 Tnwt+0.5 Tdb: The PSI index was measured using the following formula. The oral temperature during exercise (Tre_1), heart rate during exercise (HRt), oral temperature during rest (Tre_0), and heart rate during rest were measured using the digital barometer of ALPK2 [Model: WS-910] made in Japan, and the digital thermometer of RELAX [Model: CE0123] made in Iran.
PSI =5(Tre_t-Tre_0) ×(39.5-Tre_0)-1+5(HR_t+HR_0)×(180-HR_0)-1
Data were registered in SPSS 19 software and analyzed by t-test and Pearson correlation.

RESULTS

29.59 years old was the average age of exposed group (4.02) and 40.9 was for unexposed group (7.02). The mean body mass index in the refinery was 24.88 ± 2.8 and was 25.1 ± 0.6 in the administrative department. (Table 1)

Table 2 indicates the physiological parameters (systolic blood pressure, diastolic blood pressure, heart rate, oral temperature) for both groups in 5 hours. Physiological parameters mean score at all working hours was significantly higher than the unexposed group in the exposed group.

Table 3 indicates the environmental variables (relative humidity, dry temperature, wet temperature, radiant temperature) for both groups in 5 hours. Environmental parameters (except for relative humidity) in exposed group were higher than unexposed group during all working hours. There was a significant difference between mean score of environmental parameters in all working hours in two groups. There was no difference between the mean radiation temperatures at the first shift in two groups.

Table 4 indicates the stress indices and heat stresses. According to the ACGIH in 2013, the authorized WBGT index, is 28 degrees Celsius.[11], the WBGT index was lower than the standard level for all working hours. The heat index was significantly higher than the unexposed group in the exposed group at all working hours. The heat strain index was higher at all refreshments (except 11:45), and this difference was statistically significant.

Table 5 indicates the relationship between physiological parameters and heat indices. Systolic blood pressure and heart rate are significantly related to all the heat indices. Diastolic blood pressure was not significantly related to any heat index. Oral temperature was significantly related to DI and PSI.

Table1: Demographic data of the study population

Group characteristic	**Expose group(n=30**		**Non-exposed group(n=30)**	
	Mean	**SD**	**Mean**	**SD**
age(y)	29.35	4.02	40.9	7
work experience (y)	6.9	3.6	14.9	5.8
height	177.07	6.57	174.6	6.6
weight	78.4	12.8	76.7	10.7
BMI	24.88	2.8	25.1	0.6

Table 2: Physiological parameters during working hours in the study group

Hour	**Exposed group(n=30)**		**Non-exposed group(n = 30)**		**P value**
	Mean	**SD**	**Mean**	**SD**	
Systolic blood pressure					
1	125.9	9.6	9.6	12.2	0.2
2	137.4	11.5	11.5	10.4	0.0001
3	139.2	10.2	10.2	7.4	0.0001
4	140.5	7.4	7.4	7.8	0.0001
5	131.7	5.7	5.7	1.3	0.004
Diastolic blood pressure					
1	78.4	6.2	6.2	10.7	0.8
2	86.1	7	7	8.8	0.01
3	87.1	6.1	6.1	6.5	0.01
4	88.8	6.4	6.4	6.1	0.01
5	82.6	3.6	3.6	6.3	0.0007
Heart Beat					
1	77.7	9.4	9.4	6.9	0.5
2	85.4	13.1	13.1	7.3	0.07
3	86.4	7.7	7.7	6.2	0.001
4	87.5	6.3	6.3	5.7	0.001
5	81.4	5.2	5.2	5.7	0.01
Oral temperature					
1	36.1	0.4	0.4	0.6	0.5
2	36.6	0.4	0.4	0.2	0.000
3	36.9	0.3	0.3	0.2	0.000
4	37	0.2	0.2	0.2	0.000
5	36.6	0.2	0.2	0.2	0.000

Table 3: Environmental parameters during working hours in the study group

Hour	Exposed group(n=30)		Non-exposed group(n = 30)		P value
	Mean	SD	Mean	SD	
RIH					
1	36.9	1.9	46.2	1.2	0.000
2	40.5	1.3	44.5	1.7	0.000
3	40.9	1.4	44	1.9	0.000
4	41	1.1	43.2	2	0.000
5	40.7	1.1	42.5	1.7	0.000
(T_{nwt})					
1	16.2	0.3	13.8	0.7	0.000
2	20.9	0.9	13.6	0.8	0.000
3	21.2	0.7	13.5	0.8	0.000
4	20.7	0.2	13.5	0.7	0.000
5	20	0.9	13.1	0.5	0.000
(T_{db})					
1	33.7	0.8	25.7	0.5	0.000
2	36.3	1	26.1	0.5	0.000
3	36.8	0.6	26.4	0.6	0.000
4	36.4	0.4	26.5	0.5	0.000
5	35.6	0.5	26	0.4	0.000
(T_g)					
1	36.1	1	26.2	0.4	0.5
2	37.9	0.9	27	0.6	0.000
3	38.3	1.2	27.2	0.6	0.000
4	38.3	1.2	27.2	0.6	0.000
5	37.7	1	26.4	0.5	0.000

Table 4: The difference in stress and heat strain indices in working hours in the study group

Hour	Exposed group(n=30)			Non-exposed group(n = 30)			
	Mean	Sd	Min-Max	Mean	Sd	Min-Max	
WBGT							
1	23.4	0.4	24.40 – 22.9	17.2	0.6	17.80 – 15.90	0.000
2	25.4	0.8	26.70 – 23.80	17.4	0.6	18.50 –16.40	0.000
3	26	0.7	27.50– 24.30	17.7	0.5	18.80–16.70	0.000
4	26.4	1	27.60 -24.50	17.7	0.5	18.70 – 16.50	0.000
5	25.3	0.5	25.80 –23.90	17.3	0.6	18.00 –16.00	0.000
DI							
1	25	0.5	25.60 – 23.75	19.8	0.4	10.78 – 6.00	0.000
2	28.6	0.9	29.65 – 26.75	19.9	0.5	11.31–6.31	0.000
3	29	0.5	29.55 – 27.75	19.9	0.7	11.09 –6.71	0.000
4	28.6	0.2	29.10 – 28.15	20	0.5	10.41 –5.21	0.000
5	27.8	0.5	28.75 – 26.50	19.6	0.4	20.50 – 18.85	0.000
PSI							
2	8.8	2	15.80- 6.52	9.2	1.2	10.78 – 6.00	0.1
3	9.2	1.9	14.54 – 6.92	8.3	1.2	11.13 – 6.31	0.03
4	9.5	1.7	14.37 – 7.28	8.6	1.2	11.09 –6.71	0.02
5	8.5	1.6	13.47 – 6.62	7.7	1.3	10.41 –5.21	0.03

Table 5: The correlation between heat stress indices and physiological parameters

Heat stress indices	WBGT		DI		PSI	
Physiological parameters	P	R	P	R	P	r
Systolic blood pressure	0.002	0.31	0.000	0.61	0.000	0.38
Diastolic blood pressure	0.4	0.07	0.2	0.01	0.009	0.1
Heart beat	0.003	0.3	0.002	0.3	0.009	0.2
Oral temperature	0.1	0.1	0.003	0.2	0.003	0.3

DISCUSSION AND CONCLUSION

In this study, heat stress and strain indices were examined in the refinery and administrative units of Sarcheshmeh Copper Complex in Kerman, Iran.

The mean score of physiological parameters (systolic blood pressure, diastolic blood pressure, heart rate, oral temperature) was statistically significant for all working hours in both groups. In a study conducted by Golbabaeion Asalouyeh petrochemical workers, the physiological parameters on the site were significantly higher than the admission site[10]. The physiological parameters in the site were more than administrative in the regular study conducted on petrochemical workers and they had significant differences[12]. Environmental parameters [except relative humidity] were significantly different with other consistent studies at all working hours in the exposed group. In the study conducted by Golbabaei, the dry site and relative humidity were higher at the reception site and this difference was significantly high[10]. In this study, the WBGT heat stress index was not more in two groups, which was not matched with other studies[13,14]. It seems that WBGT is not a proper index to measure environmental stress in large industrial units. Perhaps, more accurate results can be obtained by local measuring of the index in large industrial units. Of course, more research is needed to be conducted to prove this claim.

The mean of WBGT and DI was significantly higher in the other working hours in the exposed group, which is consistent with other studies. In the study conducted by Gobabaei, the DI and WBGT were higher than the acceptance site[10]. A similar result was obtained in the regular study[12].

The heat strain index was higher at all times (except 11:45) in the refinery, and this difference was statistically significant.

In this study, systolic blood pressure and heart rate were significantly related to all of the heat indices. Oral temperature was significantly correlated with DI and PSI. In the regular study, heart rate had the highest correlation with DI, WBGT[12]. Chen Lien-Mei indicated in a study conducted on steel mill workers that physiological parameters of heart rate, systolic and diastolic blood pressure, and skin are highly related to the WBGT index[15]. The WBGT index and the physiological strain based on heart rate can help to estimate the heat strain better in hot climates[16].

The indices of WBGT, DI and PSI are related directly and significantly that is consistent with other studies. Another study conducted by Dehghan showed that there is a direct and significant correlation between WBGT and PSI index[17].

WBGT and physiological strain based on blood pressure, heart rate and oral temperature were used in this study, which influenced significantly the determination of heat stress. The only question that poses here is the use of the WBGT index in industries above 1000. Maybe the measurement is more accurate at the height of the breast and locally.

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REFERENCES

1. Hamerezaee M, Dehghan SF, Golbabaei F, et al. Assessment of semen quality among workers exposed to heat stress: a cross-sectional study in a steel industry. Safety and health at work. 2018;9(2):232-5.
2. Hajiazimi E, Khavanin A, Solymanian A, et al. Heat Stress Control in The Foundry Platform of a Steel Plant Tehran, Iran. Journal of Health Systems Research. 2011;13(2):866-74.
3. Rowlinson S, YunyanJia A, Li B, ChuanjingJu C. Management of climatic heat stress risk in construction: a review of practices, methodologies, and future research. Accident Analysis & Prevention. 2014;66:187-98.
4. Charkhandaz Yeganeh R, ASbbasi J, Dehghan H. Evaluation of relationship among wet bulb globe temperature index, oral temperature & heat strain scoring index in bakers of Isfahan. J Health Syst Res. 2014;10(3):559-607.
5. Krishnamurthy M, Ramalingam P, Perumal K, et al. Occupational heat stress impacts on health and productivity in a steel industry in southern India. Safety and health at work. 2017;8(1):99-104.
6. Epstein Y, Moran DS. Thermal comfort and the heat stress indices. Industrial health. 2006;44(3):388-98.
7. Gao C, Kuklane K, Holmér I. Cooling vests with phase change materials: the effects of melting temperature on heat strain alleviation in an extremely hot environment. European journal of applied physiology. 2011;111(6):1207-16.
8. karim Fahed A, Ozkaymak M, Ahmed S. Impacts of heat exposure on workers' health and performance at steel plant in Turkey. Engineering science and technology, an international journal. 2018;21(4):745-52.
9. House JR, Lunt HC, Taylor R, et al. The impact of a phase-change cooling vest on heat strain and the effect of different cooling pack melting temperatures. European journal of applied physiology. 2013;113(5):1223-31.
10. Golbabaie F, Monazam Esmaieli MR, et al. Comparing the heat stress (DI, WBGT, SW) indices and the men physiological parameters in hot and humid environment. Iranian Journal of Health and Environment. 2012;5(2):245-52.
11. Hoveizi F, Ghasemkhani M. Determination and comparison of TWL and WBGT thermal stress indices of an onshore drilling rig workers in Ahvaz. Iran Occupational Health. 2015;12(4):1-10.
12. Monazam M, Golbabaei F, Hematjo R, et al. Evaluation of DI, WBGT, and SWreq/PHS heat stress indices for estimating the heat load on the employees of a petrochemical industry. International journal of occupational hygiene. 2014;6(1):6-10.
13. Cheuvront SN, Caruso EM, Heavens KR , et al. Effect of WBGT Index Measurement Location on Heat Stress Category Classification. Medicine and science in sports and exercise. 2015;47(9):1958-64.
14. Yang X, Li B, Li Y, et al. A Research on Characteristics of Human Heat Stress in Dynamic Hot Environment. Procedia Engineering. 2017;205:2749-54.
15. Roghanchi P, Kocsis KC. Challenges in selecting an appropriate heat stress index to protect workers in hot and humid underground mines. Safety and health at work. 2018;9(1):10-6.
16. Chen M-L, Chen C-J, Yeh W-Y, et al. Heat stress evaluation and worker fatigue in a steel plant. Aiha Journal. 2003;64(3):352-9.
17. Dehghan H. Survey of the relationship of heat strain scoring index and wet bulb globe temperature index with physiological strain index among men in hot work Environments. 2012.