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Heat Stress among Steel Workers in Al Jubail, Saudi Arabia

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Abstract

Background: Workers working in the steel industry has commonly exposed to heat which lead to health risk. The objective of this study was to assess heat stress among steel production workers. **Materials and Methods:** It is a cross sectional study, 186 workers were selected through simple random sampling. There are two groups of workers staff and line production. The Wet Bulb Global Temperature (WBGT) index was measured from Heat Stress Monitor (Casella Micro herm WBGT) and Heat Strain Score Index (HSSI). Spearmen correlation for determine the correlation between WBGT and HSSI and association between risk factors and HSSI determined through logistic regression. **Results:** The mean and SD values of the wet bulb global temperature was 32.46 (2.01) and these values exceed Threshold Limit Values (TLV by American Conference of Governmental Industrial Hygienists (ACGIH) standard and HSSI scores showed that 24.3% of the exposed workers were in red dangerous zone (severe heat strain). The WBGT and HSSI values are positively correlated (r = 0.85) (P = 0.001). Risk factors associated with heat stress after adjustment are age 19-35 years (OR 6.07, CI 1.78-21.90), years of experience >10 years (OR 4.67. CI 1.23-18.42), ever smoking (OR 1.58, CI 1.08-4.57) and overweight (OR 1.56, CI 1.20-12.48). **Conclusion:** The finding of this study showed that heat stress is common hazard among steel workers and the heat conservation planning intervention action should be conducted to reduce exposure.

Keywords: Heat, Health, Steel, Stress, Workers, Zone

1. Introduction

Heat is considered as one of the most hazardous physical agents that can cause multiple health problems in the workplace[1]. Abnormal working environment might create negative consequences both on workers' health and productivity. Long term occupational exposure to heat which can results in heat related disorders, such as dehydration, rash, fatigue, cramps, syncope, and heatstroke[2,3].

Steel industry workers exposed to many hazards and heat stress one of the common hazards[4]. They are exposed to a high temperature exposure during the various processes of steel manufacturing such as extraction, tapping, burning a scrap, casting and molten[4]. High temperature caused various health effects such as fatigue, lethargy, dizziness, heat rashes, unstable movement and heat collapse[5].

Result of the previous study found that workers working in the steel industry exposed to heat which lead to heat stress and WBGT values from 31 to 33°C[6]. In the previous study found that human body thermal sensation has high sensitivity during high temperature and advised to reschedule their activity to prevent thermal shock[7]. Eye dryness was common among workers in steel industry[8].

Saudi Arabia (SA) is one of the hottest countries in the world and eastern region where many industrial units are working and there are many steel industries in this region[9]. During high temperature various health hazard on the human body and various health disorders were found among workers in this high temperature[10,11]. Industrial workers in steel company are frequently exposed to severe heat stress during their duty, which may strongly decrease work efficiency and affect their health and survival[12]. In the best of our knowledge there is no previous study conducted in eastern region of Saudi Arabia to determine the heat stress among steel workers. This study will help to identify the factors which contribute to heat stress among steel workers and determine the prevalence of street stress among steel workers. Research objective of this study is to assess the heat stress among steel workers in Jubail, KSA.

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2. Methods

2.1 Study Setting, Study Design and Inclusion and Exclusion Criteria

The study was conducted in a steel industry located in a Jubail city. Study subjects represents as a total of n = 186 including administration employee n = 79 and line production workers n = 107. It's a cross-sectional study and eligibility for inclusion of study as line production workers exposed to heat during their working, the administrative workers were not exposed to heat and excludes those workers who works as maintenance and workshop warders that not regularly exposed to heat.

2.2 Sample Size, Data Collection Tool Study Variables

A sample size was calculating from EPI info calculator. Total 186 steel workers is needed to detect an odds ratio of 4, assuming heat related illness of 76% in group WBGT below TLV (Threshold Limit Values) with a power of 80% and the significance level at 5%.

2.3 WBGT

In the steel factory work environment, Wet Bulb Globe Temperature (WBGT) index were used to assessment heat stress. Wet Bulb Globe Temperature included dry bulb (air) Temperature (Tdb), natural wet bulb Temperature (Tnwb) and globe Temperature (Tg).

The formula of WBGT in solar radiation (outdoor) is = 0.7 × Tnwb + 0.2 × Tg + 0.1 × Tdb and in indoor is = 0.7 × Tnwb + 0.3 Tg.

The Study instruments was used (Quest Technologies, WI, USA) it included sensors which measure relative humidity (RH), Tg and Tdb. Validation of these instruments to measure and record WBGT according to ISO 7243 standards[14]. The observed values of WBGT in the steel mill plant practice 75% work and 25% rest in work-rest regimen scales according to ACGIH standards.

Self-administrated reliable and validated Heat Strain Score Index (HSSI) questionnaire was distributed among steel workers (n = 186) to collect data from worker and analyze Heat Strain score Index. The questionnaire was included demographic data (Age, nationality…etc.), years of experience, level of education, smoking, workload and all other variables. The HSSI scale includes 17 items, observation and questions relating to heat stress were also included. There are three levels of risk, no heat strain (score less than 13.5), the low heat strain (13.6 to 18) and high heat strain (>18.1).

2.4 Ethical Approval

Study protocol was approved from the Institutional Ethical and Review Board (IRB) of IAU. Informed written consent was obtained before the start the data collection.

2.5 Statistically Analysis

Study data analyzed by using the Statistical Package for Social Sciences (SPSS) version IBM 24. The characteristics of the steel workers are described using means, standard deviation and proportion were calculated. Chi-square test used to compare the proportions between the groups. Multinominal tegression analysis was used for studying the impact of heat stress and other related variables on the heat disorder illness among steel workers. A p-value <0.05 will be considered statistically significant.

3. Results

Mean age of study participants (line production and administrative) are of 33.66 (SD±6.82), and 38.32 (±9.52), respectively. The characteristics of administrative and line production employee difference are age, nationality, working hours and daily shift, these differences were statistically difference (p-value <0.05) (Table 1).

The prevalence of heat stress is 14% who were in the red zone (danger level), 12.4% of the respondents were in the yellow zone (alarm level) (Table 2).

The prevalence of the heat stress among the two groups of the study participant are 2.5% of the administration staff were in the yellow area compared to 19.6% of the line production staff. Only 24.3% of the line production staff was in red zone (Table 3).

Table 4, shows the Univariate analysis for risk factor of heat stress among steel worker. In the red zone, subjects aged 19-35 years are 3.19 times more likely to have heat stress, (OR 3.19 and 95% CI 1.2-8.43). Non Saudi participants and those who are working >8 hours were 1.65 and 3.45 times to get heat stress in the red zone, respectively. Additionally, overweight subjects were 1.7 times at risk of heat stress with OR (95% CI) at 1.7 (1.16-17.24).

Table 5, for the multivariate analysis, the low risk association between heat stress and day duty shift remained statistically significant in the yellow zone (OR 0.19, with 95% CI of 0.05-0.77). In the red zone, the increased risk of heat stress remained significantly associated with age, working >8 hours, ever smoking and overweight staff, with OR (95% CI) of 6.07(1.68-21.90), 3.26 (1.18-8.98), 1.58 (1.08-4.57) and 1.65 (1.20-12.84), respectively.

There is positive correlation of WGBT and HSSI (Table 6).

Table 1. Demographic characterized of study participate n = 186

	Administration employee n = 79		Line production employee n = 107		
Characterized	**Frequency n**	**Proportion %**	**Frequency n**	**Proportion %**	***p value**
Age (years) (Mean ± SD)	38.32 ± 9.52		33.66 ± 6.82		
19-35	32	40.5	73	68.2	0.01
>35	47	59.5	34	31.8	0.01
Nationality					
Saudi	72	90.1	105	98.1	0.028
Non-Saudi	7	8.9	2	1.9	0.028
Marital status					
Single	13	16.5	19	17.8	0.4
Married	63	79.7	87	81.3	0.4
Divorced	3	3.8	1	0.9	0.4
Years of service					
<5 years	13	16.5	23	21.5	0.69
05-10 years	47	59.5	60	56.1	0.69
>10 years	19	24.1	24	22.4	0.69
Working Hours					
8 hours	56	70.9	48	44.9	0.01
>8 hours	23	29.1	59	55.1	0.01
Educational Level					
Secondary School	15	19	30	28	0.15
Higher education	64	81	77	72	0.15
Duty shift					
Day	72	91.1	70	65.4	0.01
Afternoon	4	5.1	17	15.9	0.01
Evening	3	3.8	20	18.7	0.012
Smoking					
Non-smoking	27	34.2	36	33.6	0.94
Current smoking	40	50.6	60	56.1	0.94
Ex-smoking	12	15.2	11	10.3	
****BMI**					
Underweight	2	2.5	2	1.9	0.15
Normal	18	22.8	30	28	0.15
Overweight	59	74.7	75	70.1	0.15

*Chi-square test**Body Mass Index (BMI): Underweight <18.5 kg/m^2 Normal 18.5- 24.9 kg/m^2 Overweight ≥ 25 kg/m^2.

Table 2. Prevalence of heat stress among study participant

Classification	Frequency n	Proportion %
Green (normal)	**137**	**73.6**
Yellow	**23**	**12.4**
Red	**26**	**14.0**
Total	**186**	**100.0**

Heat Strain score Index: Green Zone is <13.5, Yellow Zone 13.6 to 18 Red Zone >18.

Table 3. Prevalence of heat stress among two groups of study participants

	Administration employee		Line production employee	
Classification	**Frequency n**	**Proportion %**	**Frequency n**	**Proportion %**
Green (normal)	**77**	**97.5**	**60**	**56.1**
Yellow	**2**	**2.5**	**21**	**19.6**
Red	**0**	**0**	**26**	**24.3**

Heat Strain score Index: Green Zone is <13.5, Yellow Zone 13.6 to 18 Red Zone >18.

Table 4. Risk factor of heat stress among steel worker (Univariate analysis)

	Yellow zone		Red zone	
	Odd Ratio (OR)	**95% Confidence Interval (CI)**	**Odd Ratio (OR)**	**95% Confidence Interval (CI)**
Age (years)				
19-35	1.79	0.71-4.5	3.19	1.2-8.43
>35	1	1	1	1
Nationality				
Saudi	1	1	1	1
Non-Saudi	1.09	0.99-2.99	1.65	1.07-5.38
Marital status				
Single	1	1	1	1
Married	1.46	0.40-5.34	0.92	0.31-2.69
Years of service				
<5 years	1	1	1	1
05-10 years	1.57	0.38-6.43	1.01	0.24-4.12
>10 years	1.56	0.48-5.10	1.52	0.51-4.46
Working Hours				
8 hours	1	1	1	1
>8 hours	1.18	0.48-2.88	3.45	1.40-8.51
Educational Level				
Secondary School	1.62	0.61-4.33	1.97	0.79-4.87
Higher education	1	1	1	1
Duty shift				
Day	0.24	0.07-0.75	0.22	0.07-0.71
Afternoon	0.28	0.04-1.69	0.84	0.21-3.38
Evening	1	1	1	1
Smoking				
Ever smoking	1.62	0.60-4.39	1.56	0.61-3.96
Never smoking	1		1	
***BMI**				
Normal	1		1	
Underweight	0.72	0.25-2.10	0.82	0.3-2.23
Overweight	1.45	1.01-12.89	1.7	1.16-17.24

*Body Mass Index (BMI): Underweight <18.5 kg/m^2 Normal 18.5- 24.9 kg/m^2 Overweight ≥ 25 kg/m^2.

Table 5. Risk factor of heat stress among steel worker (Multivariate analysis)

	Yellow zone		Red zone	
	Odd Ratio (OR)	**95% Confidence Interval (CI)**	**Odd Ratio (OR)**	**95% Confidence Interval (CI)**
Age (years)				
19-35	2.13	0.62-7.34	6.07	1.68-21.90
>35	1		1	
Nationality				
Saudi	1		1	
Non-Saudi	1.03	0.98-8.99	1.86	0.17-18.79
Marital status				
Single	0.32	0.05-1.74	0.92	0.21-4.04
Married	1		1	
Years of service				
<5 years	1		1	
05-10 years	3.87	0.64-23.27	1.22	0.21-7.11
>10 years	2.67	0.68-11.07	4.76	1.23-18.42
Working Hours				
8 hours	1		1	
>8 hours	1.08	0.39-2.97	3.26	1.18-8.98
Educational Level				
Secondary School	1.86	1.62-5.53	2.62	1.88-7.76
Higher education	1		1	
Duty shift				
Day	0.19	0.05-0.77	0.4	0.10-1.56
Afternoon	0.21	0.03-1.52	1.06	0.21-5.35
Evening	1		1	
Smoking				
Ever smoking	1.96	0.66-5.76	1.58	1.08-4.57
Never smoking	1		1	
***BMI**				
Normal	1		1	
Underweight	0.49	0.14-1.71	0.52	0.15-1.75
Overweight	1.01	0.63-5.65	1.56	1.20-12.84

*Body Mass Index (BMI): Underweight <18.5 kg/m^2 Normal 18.5- 24.9 kg/m^2 Overweight ≥ 25 kg/m^2.

Table 6. Spearman Correlation Coefficient (r) between HSSI and WBGT

Heat Stress Score Variable	**HSSI**	
	P-Value	**r**
WBGT	P<0.001	0.85

4. Discussion

This study found the high prevalence of heat stress among steel workers specifically line production workers. There are various factors which contributed to heat stress.

The results of the present study revealed that most of the steel workers in the current study were in the green zone (save

level), this was followed by who were in the red zone (danger level). The result of this study is in consistence with past study where the HSSI values were in red zone among production workers. 98.62% of the workers are in red zone and 1.38% in yellow zone[13]. In the present study, the average WBGT record among line production workers and administrative employees were 27.5 and 37.40 respectively. WBGT in this study shows positive correlation with heat stress. In Dehghan, et al. study on workers in Hot/Humid working conditions (WBGT>30°C), the heart rate of subjects was increased and the overweight workers was showed cardiac strain higher in compared with that in normal weight workers which is same with the findings of the present study[14].

The study of Peiffer and Abbiss conducted on miners working in an iron ore mine in northwest of Australia and the results showed that deep body temperature of the workers was higher at the end of shift work (37.6°C) than in the beginning of the shift work (37°C)[15]. The study by Falahati, et al., the result found that there was a significant correlation between heath indices with deep body temperature. Moreover, WBGT was the most accurate index for estimating heat stress in employees[16].

The result of this study showed that the level of heat stress indices was higher in work state. The maximum WBGT values recorded in this study is 30.76°C which is higher compared to ISO 7243 recommended limits (<30°C). The result is consistent with the other study[17]. In another study, workers experienced had positive correlation between WBGT and aural temperature[18].

In previous study[19], determined the relationship of heat stress and thermal hazard in a steel mill. They found that workers employed in the steel industry are exposed to heat stress and heat protection methods should be carried out for workers. This result was same with this study. In the present study, overweight subjects were 1.7 times at risk of heat stress with OR (95% CI) at 1.7 (1.16-17.24).

Overweight participants had high heat stress due to physiological and thermal response. Moreover, Tuomaala et al. determine correlation between HSSI and BMI >25. Result showed that no relationship. These result not in line with this study[20].

5. Conclusion

Steel workers have high level of heal stress with WBGT positive association with physiological parameters. It is recommended with HSSI screening with WBGT preventive measure for continuous monitoring heat stresses among exposed workers. Collaborated action is required to mitigate the effects of occupational heat strain.

6. References

1. 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; 9:10–6. PMid: 30363068 PMCid: PMC6111124. https://doi.org/10.1016/j.shaw.2017.04.002
2. Kjellstrom T, Holmer I, Lemke B. Workplace heat stress, health and productivity - An increasing challenge for low and middle-income countries during climate change. Global Health Action. 2009; 2:1. PMid: 20052422 PMCid: PMC2799237. https://doi.org/10.3402/gha.v2i0.2047
3. Luo H, Turner LR, Hurst C. Exposure to ambient heat and urolithias is among outdoor workers in Guangzhou, China. Science of the Total Environment. 2014; 472:1130–6. PMid: 24361748. https://doi.org/10.1016/j.scitotenv.2013.11.042
4. Xiang J, Hansen A, Pisaniello D, Bi P. Perceptions of workplace heat exposure and controls among occupational hygienists and relevant specialists in Australia. PLoS ONE. 2015; 0(8):1–12. PMid: 26287608 PMCid: PMC4546008. https://doi.org/10.1371/journal.pone.0135040
5. Kishor PB, G.L. Ashok GL, et al. Heat stress and its effect in glass factory workers of central India. IJERT. 2012; 1(8):1–13.
6. Al-Bouwarthan M, Quinn MM, Kriebel D, Wegman DH. Assessment of heat stress exposure among construction workers in the hot desert climate of Saudi Arabia. Ann Work Expo Health. 2019 May; 63(5):505–20. PMid: 31051037 PMCid: PMC6527521. https://doi.org/10.1093/annweh/wxz033
7. Abdel-Ghany M, Al-Helal IM, Shady MR. Human thermal comfort and heat stress in an outdoor urban arid environment: A case study advances in meteorology:1- 7. 2013; 2013:693541. https://doi.org/10.1155/2013/693541
8. Fagehi R, Ghazalm H, Alrabiah S, et al. Ocular dryness assessment in Saudi employees working indoors and outdoors. Clinical Optometry. 2018; 10:51–6. PMid: 30214342 PMCid: PMC6095570. https://doi.org/10.2147/OPTO.S163303
9. Al-Otaibi ST. Male infertility among bakers associated with exposure to high environmental temperature at the workplace. J Taibah Univ Med Sc. 2018; 13(2):103–7. PMid: 31435311 PMCid: PMC6695025. https://doi.org/10.1016/j.jtumed.2017.12.003
10. Krishna LV. Long term temperature trends in four different climatic zones of Saudi Arabia. Int J Appl Sci Technol. 2014; 4:233–42.
11. Alasamri H, Chrisp MT, Bowles G. A framework for enhancing and improving the safety culture on Saudi construction sites. Smith SD, ed. Proceedings of the 28th Annual ARCOM Conference. Edinburgh, UK: Association of Researchers in Construction Management; 201. p. 475–85.
12. Chinnadurai J, Venugopal V, Kumaravel P, Paramesh R. Influence of occupational heat stress on labour productivity - A case study from Chennai, India. International Journal of Productivity and Performance Management. 2016; 65(2):245–55. https://doi.org/10.1108/IJPPM-08-2014-0121
13. Dash SK, Kjellstrom T. Workplace heat stress in the context of rising temperature in India. Current Science. 2011; 101(4):496–503.

14. Dehghan H, Mortzavi SB, Jafari MJ, et al. Development and validation of a questionnaire for preliminary assessment of heat stress at workplace. J Res Health Sci. 2015; 15(3):175–81.
15. Peiffer JJ, Abbiss CR. Thermal stress in North Western Australian iron ore mining staff. Annals Occup Hygiene. 2013; 57:519–27.
16. Falahati M, Alimohammadi I, Farshad AA, et al. Evaluating the reliability of WBGT and P4SR by comparison to core body temperature. Iran Occup Health J. 2012; 9:22–31.
17. Ravandi MRG, Salimi S, Khanjani N, et al. Comparing the association between Wet Bulb Globe Temperature (WBGT) and Heat Stress Score Index (HSSI) thermal indices with physiological parameters in a melting plant. Int J Occup Hygiene. 2016; 8:9–13.
18. Habibollah MS, Jafari MJ, Meraci MR, et al. Construct validation of a heat strain score index with structural equation modeling. Health Syst Res. 2011; 6:601–12.
19. Jafari MJ, Norloei S, Omidi L, et al. Effects of heat stress on concentrations of thyroid hormones of workers in a foundry industry. Occup Med Quarter J. 2016; 7(3):69–79.
20. Tuomaala P, Holopainen R, Piira K, et al. Impact of individual characteristics such as age, gender, BMI and fitness on human thermal sensation. Build Simul J. 2013; 2305–2311.