2008-5435/14/63-143-148
INTERNATIONAL JOURNAL OF OCCUPATIONAL HYGIENE

IJOH 6: 143-148, 2014

CASE STUDY

Productivity Loss from Occupational Exposure to Heat Stress: A Case Study in Brick Workshops/Qom-Iran

ROOHALAH HAJIZADEH[1], FARIDEH GOLBABAEI[2*], MOHAMMAD REZA MONAZZAM[3], SOMAYEH FARHANG DEHGHAN[4], and ESMAIL EZADI NAVAN[5]

[1]*Department of Occupational Health Engineering, Faculty of Health, Tehran University of Medical Sciences, Tehran, Iran;* [2]*Department of Occupational Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran ;* [3]*Associate Professor, Department of Occupational Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran;* [4]*Department of Occupational Health Engineering, , School of Public Health, Tehran University of Medical Sciences, Tehran, Iran;* [5]*Department of Occupational Health Engineering, Faculty of Health, Shahid Beheshti University of Medical Sciences, Tehran, Iran.*

Received March 17, 2014; Revised May 25, 2014; Accepted June14 30, 2014

This paper is available on-line at *http://ijoh.tums.ac.ir*

ABSTRACT

Heat stress particularly at outdoor workplaces in hot-dry climates can disrupt the physical or mental functions and effect negatively on human performance. We aimed to study the effect of heat stress on productivity loss among workers of brick workshops in Qom Province – central Iran. This cross-sectional descriptive and analytic study was performed on 184 workers in 40 brick workshops. Environmental parameters including dry temperature, natural wet-bulb temperature, globe temperature, relative humidity and air velocity were measured at three times during work shift. WBGT (Wet Bulb Globe Temperature) heat stress index was calculated based on equation provided by Australian Bureau of Meteorology. Potential labor productivity losses due to heat stress were determined using a graph presented already. The total average of WBGT was 31.84±3.46°C. WBGT index according to different jobs was 39.48±8.2°C, 29.86±2.79°C, 29.31±0.97°C and 28.69±1.89°C for working in kiln, material handling, working on conveyor and making adobe, respectively. The average loss productivity in mentioned tasks was 93.57±16.54, 66.58±20.58, 65.53±15.26 and 48.27±13.04 respectively, with total average of productivity loss 68.48±16.35%. The statistically significant relationships were found between WBGT values and percentage of loss productivity in total and for all understudy jobs ($p<0.001$). Heat stress can lead to decrease in labor productivity at outdoor workplaces like brick industries. According to climate change in the future and gradual global warming, paying more attention to the occupational health issues in outdoor workplaces at dry and warm environment seems to be more important than before.

Keywords: *Loss of Productivity, Heat Stress, WBGT, Brick Workshops*

INTRODUCTION

Heat stress as a physical agent is a common hazard at hot outdoor and indoor workplaces. Assessment of occupational exposure to heat stress was done using some internationally recognized indices. WBGT-index (Wet Bulb Globe Temperature) approved by International Standard Organization is one of the most well-known and most frequently used indices for estimating the heat stress on workers in hot

*** Corresponding author:** Farideh Golbabaei, Email: fgolba-baei@sina.tums.ac.ir

Fig 1. Image of Tempering (a) and Firing (b) steps in one of the brick workshops of Qom

environments which it considers the effects of the basic parameters in any human thermal environment [1-2] .

Exposure to heat stress can lead to some physical and psychological health problems. Heat can effect on human health ranging from a mild annoyance, such as heat rash, to death from heat stroke [3-5]. Working in hot-dry environment can lead to severe performance degradation and consequently to a sharp drop in labor productivity [2, 6]. Under heat stress conditions, the gradual accumulation of heat in the body over time disrupts thermal equilibrium and imposes some changes on human body, which cannot be compensated for; therefor, heat exposure can negatively influence cognitive and psychomotor abilities of the workers [7-8].

Outdoor workers are at greater heat stress risk than indoor ones because of both environmental and occupational exposure to heat [9-10]. In addition, global average air temperature has been increasing, the forecast for a rise of 1.8 to 4 degree Celsius by 2100 [11], which can exacerbate the heat stress conditions for outdoor labor such as construction workers, farmers, ranchers, and workers in brick industries.

The outdoor WBGT (Wet Bulb Globe Temperature) of some industrial sites in Thailand is in extreme caution region according to heat index chart [6]. Climate change and global warming could potentially threaten human health and decrease the industrial production rate. The amount of productivity loss is from 10% to 66.7% among different jobs [6]. Working capacity of people is beginning to decline in the WBGT above 25°C, and it will be difficult to do any work in the WBGT above 40°C [4].

For outdoor workers, sun radiations and climatic conditions (e.g. low air movement, high humidity levels and high air temperature) can contribute to heat stress besides heat induced from the hot process streams. Qom Province of Iran located within the latitude and longitude of 34.64 N, 50.88 E has a desert and semi-desert climate with low humidity and scanty rainfall (average and maximum temperature in 2013 were, respectively, 22°C and 37°C) [12]. It contains 563 brick workshops with considerable numbers of outdoor workers who are at risk of heat stress, especially in hot seasons, though little research has been done to assess the heat stress and its adverse effects on physical and mental health among workers, with emphasis on productivity loss which can be due to reduced performance at work caused by heat stress. Moreover, during climate change and global warming, workplace heat stress and productivity is becoming an increasing challenge for low and middle-income countries [11].

Therefore, the present study aimed to investigate heat stress effects on productivity loss of workers employed at the brick workshops at province of Qom, Iran.

METHODS

This cross-sectional, descriptive and analytical study was conducted among 40 brick workshops located in the south-west corner of Qom Province-central Iran in the summer season, in 2013. A short description of the brickmaking process includes tempering (adding water to the clay soil), Molding (putting the clay mix into a mold), Drying (allowing the molds to dry in the sun), Firing (Laying out and heating the bricks in kiln) (Fig 1).

Sample size was calculated based on the below equation:

$$n = \frac{Z^2_{1-\alpha/2} \times p \times (1-p)}{d^2} = \frac{1.96^2 \times 0.5 \times (1-0.5)}{0.15^2} = 43 \quad (1)$$

Where, n is the sample size, Z: 95% confidence interval which corresponds to $\alpha = 0.05$, d: margin of error (%) and p: the best estimate of the true percent of population that meet or not meet our criteria. total number of brick workshops in Qom was 563, so the finite population correction was used (according to Eq. 2) to determine the required the sample size.

$$n = \frac{n_0}{1+\frac{n_0}{N}} = \frac{43}{1+\frac{43}{563}} = 40 \qquad (2)$$

After selecting 40 intended workshops by simple random sampling, a demographic information questionnaire and a questionnaire of workplace preliminary assessment, which involved feeling the heat experienced by workers, were distributed and collected to all workers. Metabolic rate of subjects was calculated using body position and movement, activity level and type of work regarding American Conference of Industrial Hygienists (ACGIH) recommendation [13] and the Clo (the thermal insulation of typical suit) was estimated based on ISO 9920 [14] .

Environmental parameters, including dry temperature, wet-bulb temperature, globe temperature, relative humidity and air velocity were measured at workstations from 8.00 am to 19.00 pm (in three times: 8-10, 10-13 and 16-19) by WBGT meter (Quest model. 3070-003) and Air flow meter (Gmbh-5308, Lutron Co.).

WBGT index, as the most applicable index for evaluating heat stress in workplaces, for indoor and outdoor environment was calculated as follow equations, according to ISO 7243 standard (3):

$$WBGT_{(Indoor)} = 0.7T_{nw} \times 0.3T_g \qquad (3)$$

$$WBGT_{(outdoor)} = 0.7T_{nw} \times 0.2T_g \times 0.1T_a \qquad (4)$$

Where, T_{nw} is natural wet-bulb temperature, T_g is the black-globe temperature and T_a is the dry-bulb (air) temperature.

ISO 7243 method for calculating WBGT is simple equation developed more than 50 yr. ago and is still in use. Despite all of its capabilities, there are some limitations for using it for heat stress assessment, and it is claimed that it can provide only a general guide to the likelihood of adverse effects of heat. At the present study, WBGT was calculated based on the suggested method by Australian Bureau of Meteorology (Equation 5 and 6). It uses an approximation based on standard measurements of temperature and humidity for typical outdoor work exposure situations with calm air movements [15-16].

$$WBGT = 0.567 \times T_a + 3.94 + 0.393 \times p \qquad (5)$$

$$p = RH/100 \times 6.105 \times \exp(17.27 \times T_a/(237.7 + Ta)) \qquad (6)$$

Where T_a is air temperature, p is water vapor pressure (hPa) and RH is relative humidity (%).

Potential labor productivity losses due to heat stress were determined using a graph presented by Kjellstrom et al. [11] (Fig 2). They presented the percent of work capacity for people as function of WBGT based on recommendations Australian Bureau of Meteorology. The four curves shown in Fig 2 indicate work intensity levels.

RESULTS

Overall, 184 male workers were recruited as subjects from the kiln (66 workers or 35.86%), material handling (41 workers or 22.28%), working on conveyor (55 workers or 29.89%) and making adobe (22 workers or 11.95%) parts. Their mean (S.D.) age was 27.51 (4.08) years (ranged in age from 9 to 70 years), and work experience 9.81 (0.7) years. All subjects had more than one year of work experience, and therefore they were considered acclimated workers.

More than half (66.3%) of workers described their workplace as “too hot” and 32.6% reported their work environment as “warm”. 43.5% stated that they have a strong tendency to taking the rest, because of the feeling of extreme tiredness. 52.7% reported that they get very tired during working. 5.2 percent of the workstations were more than 100 meters away from their rest area and 36.4% were between 50 to 100 meters away from. Metabolic rate class (work intensity) of all workers of understudy brick workshops was obtained 500 watt. Results of environmental parameters measurement and calculation of WBGT according to recommendation of Australian Bureau of Meteorology are presented in Table 1. Workers of kiln part have experienced the highest dry-bulb temperature, wet-bulb temperature, globe temperature and relative humidity in their workplace environment in comparison to other jobs in brick workshops. WBGT values were obtained 29.86°C, 39.48°C, 29.31°C, and 28.69°C for material handling, kiln, working on conveyor and making adobe tasks, respectively. All of them were higher than threshold limit value recommended by the ACGIH based on their working conditions (i.e. 25.9°C).

Table 2 presents mean loss productivity (%) in understudy tasks. Correlation between WBGT and productivity loss is also shown in Table 2. Analysis of the Pearson R coefficients indicated that there was statistically significant relationships between loss productivity and WBGT at all intended tasks (for mean total score: r=0.81, *p*-value <0.001).

DISCUSSION

Heat stress has the serious effects on physical and mental health and cognitive and psychomotor abilities of the workers which can lead to performance degradation at work and so the reduced labor productivity [6]. Workers employed in brick workshops as outdoor workers are exposed to both environmental and occupational heat stress. They are also at a much high risk due to doing vigorous physical activities, and

Table1. Measurement results of environmental parameters

Environmental parameters \ Type of Work		Material handling	Kiln	Working on conveyor	Making adobe	Total
Dry-bulb temperature (^oC)	Mean	37.56	42.74	37.27	34.9	38.12
	SD	2.27	4.38	1.14	3.62	2.85
	Range	11.64	16.04	3.39	11.44	10.63
Relative humidity (%)	Mean	17.87	31.63	17.08	19.14	21.43
	SD	4.9	1.37	3.68	2.99	3.24
	Range	29.25	44.25	10.5	8.25	23.06
Globe temperature (^oC)	Mean	45.27	50.63	45.01	43.97	46.22
	SD	1.99	5.7	1.32	2.98	3.00
	Range	9.24	23.76	4.69	13.6	12.82
Natural wet-bulb temperature (^oC)	Mean	20.75	24.21	20.6	19.29	21.21
	SD	1.69	2.85	0.86	1.4	1.70
	Range	8.96	11.11	2.8	3.91	6.70
Air velocity (m/s)	Mean	0.22	0.09	0.16	0.44	0.23
	SD	0.16	0.17	0.03	0.22	0.15
	Range	0.68	0.73	0.13	0.65	0.55
WBGT (^oC)	Mean	29.86	39.48	29.31	28.69	31.84
	SD	2.79	8.2	0.97	1.89	3.46
	Range	18.58	30.53	2.98	3.87	13.99

working in hot processes that all cause major production losses for Brick manufacturers. In Qom Province, outdoor workers experience a desert and semi-desert climate with hot summers and low precipitation. Hear stress conditions can be aggravated for them by global warming phenomena.

In the present study, furnace workers are exposed to more heat stress than other ones (WBGT 30. 8) which is consist with the study of Haji Azimi et al. [17]. They concluded that weather conditions are unfavorable for work in foundry platform and its workers are exposed to higher thermal stress than threshold limit value. They introduced the distance between worker and the heat source as one of the main factors in heat stress exposure.

According to our findings, workers of kiln experience the highest dry-bulb temperature, wet-bulb temperature, and relative humidity in their workplace environment in comparison to other jobs in brick workshops. In brick kiln, the wet bricks are stacked, so moisture contents begins to evaporate during drying of bricks which causes the production of more heat and higher relative humidity. The highest globe temperature was observed in measurement stations related to kiln, which the results are in agreement with Gomes et al. [18] who indicate the furnace flame contribute to higher radiance.

As can be seen in Table 2, percent of loss productivity ranged from 48 to 94. Regarding the strong positive correlation existed between WBGT and loss of productivity (r=0.705), this wide range of percent of loss productivity can be due to different heat exposure

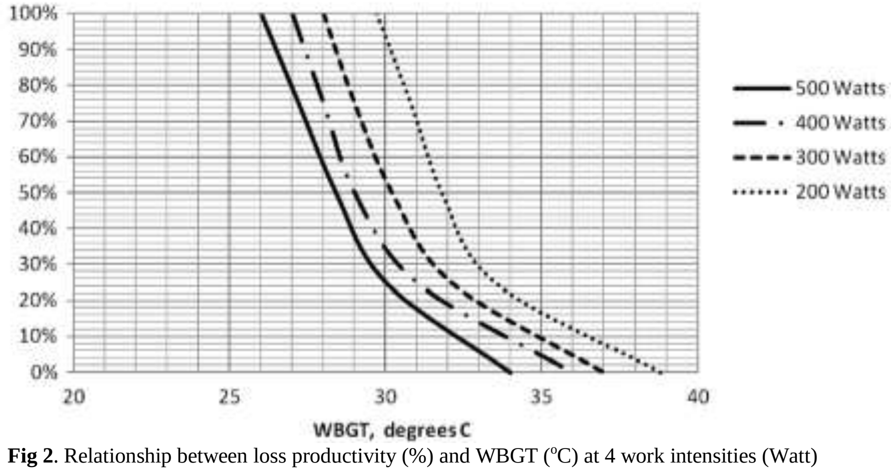

Fig 2. Relationship between loss productivity (%) and WBGT (^oC) at 4 work intensities (Watt)

Table 2. Calculation results of loss of productivity and relationship between loss productivity and WBGT

parameters \ Type of Work		Material handling	Kiln	Working on conveyor	Making adobe	Total
Productivity loss (%)	Mean	66.58	93.57	65.53	48.27	68.48
	SD	20.58	16.54	15.26	13.04	16.35
	Range	84	54	38	67	60.75
Productivity loss (%) vs. WBGT (°C)	Correlation coefficient	0.67	0.67	0.913	0.985	0.81
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001

levels. In a study conducted by Langkulsen et al. [6], health impact of climate change on occupational health and productivity in Thailand was assessed. They found the range of production loss from 10% to 66.7% that this difference could be corresponding to different level of heat exposure, socio-economic differences, different nutritional status and cultures.

Tatterson et al. [19] studied the effects of heat stress on physiological responses and exercise performance in elite cyclists. They demonstrated the performance of participants during a 30 min time-trial is reduced by high ambient temperatures. Wyon et al. [20] investigated the effects of moderate heat stress on mental performance and found that performance begins to decrease at temperatures above 26 degrees. They prove hypothesis of reduced arousal in moderate heat stress in the absence of conscious effort. These findings indicate indirectly the psychological performance responses to heat stress and their adverse consequences in work capacity and productivity. In dry temperatures above 40°C, workers report the heat-related effects like irritability and exhaustion resulting in difficulty in maintaining the constant level of work output. For people working in sun-exposed conditions in hot process, heat can reduce work performance, leading to an output loss [21], which is consistent with our observations.

The data from the Hübler et al. study suggested that heat exposure causes a productivity loss resulting in total economic loss, so an output loss of between 0.1% and 0.5% of GDP, the gross domestic product on German federal state level, is forecasted. Kjellstrom et al. predicted in 2080 the working capacity will reduce about 11% to 27% due to global climate change [11]. In occupational health, there has been considerable attention drawn to evaluation of heat stress exposure among outdoor workers because of its potential effects on productivity loss of workers employed at outdoor workplace including the brick manufactures, especially in warm climate like Qom, Iran and also climate change and global warming phenomena.

CONCLUSION

Totally, in order to control the adverse effects of heat stress in understudy workshops, it is recommended to take the appropriate administrative and engineering measures (hygiene plan) like installation of the radiant barriers in kiln units, the provision of well-ventilated rest area and implementation of the suitable work-rest and fluid intake schedule. Moreover, in understudy brick workshops long distance between employee's workstations and their rest area causes longer exposure to heat, shorter rest period and therefore the adverse impact on working capacity of workers and increase in productivity loss.

ACKNOWLEDGMENTS

This study was funded by Tehran University of Medical Sciences (TUMS); Grant no. 92-03-27-22887. We would like to thank the participants for their patience and contribution to this study. The authors declare that there is no conflict of interests.

REFERENCES

1. Monazzam MR, Golbabaei F, Hematjo R, Hosseini M, Nassiri P, Dehghan SF. Evaluation of DI, WBGT and Swreq/PHS Heat Stress Indices for Estimating the Heat Load on the Employees of a Petrochemical Industry. *IJOH* 2014; 6 (1): 6-10.
2. Parvari RA, Aghaei HA, Dehghan H, Habibi E, Maracy MR, Dehghan SF. The effect of fabric type of common Iranian working cloth on the induced cardiac and physiological strain under heat stress. *Arch Environ Occup Health* 2014;. doi: 10.1080/19338244.2014.891965.
3. Golbabaei F, Monazzam MR, Hematjo R, Hosseini M, Dehghan SF. The assessment of heat stress and heat strain in

pardis petrochemical complex, Tehran, Iran. *IJOH* 2013;5(1):6-11.

4. Lin R-T, Chan C-C. Effects of heat on workers' health and productivity in Taiwan. *Glob Health Action* 2009. 2: 10.3402/gha.v2i0.2024.
5. The Office of Radiation, Chemical and Biological Safety, Michigan State University .MSU Employee Guidelines for Working in hot Environments. 1999[cited 2014 10, 1]; Available from: http://www.ehs.msu.edu/occupational/programs_guidelines/heat_stress/heatstressmanual.pdf.
6. Langkulsen U, Vichit-Vadakan N, Taptagaporn S. Health impact of climate change on occupational health and productivity in Thailand. *Glob Health Action* 2010; 3: 10.3402/gha.v3i0.5607.
7. Enander AE. Effects of thermal stress on human performance. *Scand J Work Environ Health* 1989; 15(1) 27-33.
8. Hancock P, Vasmatzidis I. Effects of heat stress on cognitive performance: the current state of knowledge. *Int J Hyperthermia* 2003; 19(3):355-72.
9. Jay O, Kenny GP. Heat exposure in the Canadian workplace. *Am J Ind Med* 2010; 53(8):842-53.
10. Miller V, Bates G. Hydration of outdoor workers in north-west Australia. *J Occup Health Saf Aust NZ* 2007; 23(1):79-87.
11. Kjellstrom T, Holmer I, Lemke B. Workplace heat stress, health and productivity–an increasing challenge for low and middle-income countries during climate change. *Glob Health Action* 2009; 2: 10.3402/gha.v2i0.2047.
12. Climatevo. Qom weather, Iran, Islamic Republic of - climate information 2014 [cited 2014 10, 1]. Available from: http://climatevo.com/qom,ir.
13. ACGIH. TLVs and BEIs. Thermal Stress: American Conference of Industrial Hygienists; 2014.
14. ISO. ISO 9920, Ergonomics of the thermal environment -- Estimation of thermal insulation and water vapour resistance of a clothing ensemble. International Organization for Standardization; 2007.
15. Kjellstrom T, Lemke B, Holmér I. *Climate change and occupational heat stress*. Proceedings of the International Congress on Biometeorology, 22-26 September 2008; Tokyo, Japan.
16. Lemke B, Kjellstrom T. Calculating workplace WBGT from meteorological data: a tool for climate change assessment. *Ind Health* 2012; 50(4):267-78.
17. Haji Azimi E, Khavanin A, Aghajani M, Soleymanian A. Thermal stress measurement according to WBGT index in smelting industry. *IJMS* 2011; 13(2):59-64.
18. Gomes J, Lloyd O, Norman N. The health of the workers in a rapidly developing country: effects of occupational exposure to noise and heat.*Occup Med* 2002; 52(3):121-8.
19. Tatterson AJ, Hahn AG, Martini DT, Febbraio MA. Effects of heat stress on physiological responses and exercise performance in elite cyclists. *J Sci Med Sport* 2000; 3(2):186-93.
20. Wyon DP, Andersen I, Lundqvist GR. The effects of moderate heat stress on mental performance. *Scand J Work Environ Health* 1979; 5:352-361.
21. Mathee A, Oba J, Rose A. Climate change impacts on working people (the HOTHAPS initiative): findings of the South African pilot study. *Glob Health Action*. 2010; 3: 10.3402/gha.v3i0.5612.