



## Investigation of stress and heat strain in asphalt workers

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### Abstract

Heat stress is one of the harmful factors in workplaces. Asphalt workers are exposed to thermal stress due to the open environment and process. The aim of this study was to assess the heat stress and strain in asphalt workers. This study was conducted on 29 employees of asphalt workstation. The heat stress was measured based on Wet-Bulb Globe Temperature (WBGT). Also, physiological parameters such as blood pressure and heart rate of asphalt workers were measured. The mean of WBGT index for drivers of asphalt machinery, trowels, shovels people and burner servicemen were 27.77, 27.77 and 29.61°C respectively whereas this value was 29.81, 29.85 and 3.23°C for workers of asphalt workstations respectively. The process of asphaltting has significant effect on heat stress and physiological parameters of individuals. The Pearson correlation between WBGT and heart rate, systolic blood pressure and diastolic blood pressure was significant. Asphalt workers are exposed to heat stress caused by different sources which may generate a host of heat strains in these people so special attention should be paid to control heat stress.

**Keywords:** Heat, Strain, Worker

### Introduction

Heat stresses has been one of harmful physical factors in the workplace which has recognized as one of the factors harmful to health of workers especially in the developing countries and may be people exposed to health problems and work process [1]. Outdoor workers are exposed to heat stress caused by Earth's climate. Such changes and their subsequent environmental and health-related effects have been acknowledged in various studies [2]. The consequences of occupational exposures initially emerge in form of heat strain which is indicated by increased heart rate and body

temperature stimulated by the heat exposure [3]. Failure to control heat strain in long term may give rise to wide range of symptoms and disorders ranging from muscle cramp, heat exhaustion, skin rashes, heat syncope, heatstroke, reduced physical and mental performance, mental and nervous symptoms, lower consciousness and perception which subsequently lead to hampered productivity, increased incidence of accidents and reduced level of safety in work place [4-6]. Heat regulating mechanism of the body is untouched in mild and moderate disorders

including muscle and thermal exhaustion, but this mechanism may be damaged in the heat shock thereby jeopardizing the individual's life [7]. Heatstroke is caused when the body's internal temperature reaches 103 degrees Fahrenheit. It can simultaneously disrupt the functions of in different organs which may lead to death within hours [1,8,9] even the survivors of heatstroke may increase risk of premature death in the future [10]. In addition, heat deaths are usually observed in maladjusted individuals with underlying diseases such as cardiovascular disorders. Heat also is considered as a risk factor for cardiovascular disease [11-13]. In a study to evaluate the effects of warming on the work of the workers who were working intermittently, it was shown that an increase of one degree Celsius in the ambient temperature was associated with an extra beat in heart rate of workers per minute [14]

Currently, number of deaths by heat stress in the workplace in America and Canada is 220 cases annually. Canada's health department has estimated that deaths caused by the heat in the workplace will rise from 20 cases in 2001 to about 300 cases in 2020 [8]. Today, more attention has been paid to identifying and controlling the factors contributing to heat stress in academic circles due to the severe effects of heat stress on workers in different workplaces. Also, serious control measures should be adopted to protect the workforce against the harmful effect of heat stress, [15]. Moreover, the first and foremost step is to recognize the status of related factors to make effective control interventions. Most workers employed in outdoor workplaces not only are exposed to the heat caused by atmospheric conditions but also to the heat resulting from the work process. Kjellstrom et al. (2009) showed that in countries with hot seasons, the increased internal temperature of the body as a result workers' exposure to heat is more than the tolerance of physiological mechanism of the body. According to the results of this study, the work capacity is significantly reduced when Wet-Bulb Globe Temperature (WBGT) is increased from 26 to 30 C [16]. Another

study released that by the year 2080, in the absence of any particular adjustment; there will be a drop of 10 to 27% in the productivity of most Southeast Asia, Central America and the Caribbean countries [4]. The study of Amengual et al., about the effect of heat waves with high impact on human health in Europe showed that the heat waves frequency in the years 2075-2094 which may increase by as much as 40 times within 20 days. Further, a major increase in the extreme heat waves, such as wave frequency, duration and amplitude is expected. [17]. A study on the share of work process in heat stress can be pivotal to adopting control measures because controlling the heat generated by the process is much easier than controlling the environmental heat. Workers in outdoor workplaces especially in hot seasons and dry areas are exposed to heat energy of solar radiation which in some cases is compounded by the heat produced in the work process. Asphalt workers are especially at risk of heat stresses.

Since asphalt making is a heating process especially in hot seasons and asphalt workers in the outdoor workplace are exposed to solar radiations, in addition to the environmental conditions of workstations, the aim of this study is to evaluate heat stress and strain in workers of asphalt work stations.

### **Method**

This is a cross-sectional study which carried out in the summer of 2012 in asphalt workstations of Qom city, Iran. In this study, the heat stress and physiological parameters of all workers employed in the asphalt stations in Qom city (29 participants), who worked under the supervision of the Qom municipality were studied by using census method. With respect to the type of work, 22 participants working as burner machine servicemen, drivers of asphalt machinery, trowels, and shovels participants were in direct contact with the asphalt, which exposed them both to the environmental heat and the heat caused by the work process. Furthermore, seven

asphalt workers exposed to heat stress caused by environmental conditions, who were not directly in contact with asphalt work, including supervisors, crushers and loader drivers, were also studied. To determine the effect of asphalt work process on heat stress, in addition to measurement of heat stress in work stations, the value of WBGT was also computed based on atmospheric parameter in the region.

The aim of this study was to first evaluate the heat stress and strain in asphalt workers and then determine the effect of asphalt work process, irrespective of environmental conditions, on heat stress (i.e. WBGT increase caused by the asphalt). To remove the effect of the environmental conditions, the value of WBGT

arising from the environmental conditions of the study area was also calculated. For this purpose, the data were collected from a distance where asphalt process did not have any environmental effect. Moreover, WBGT was measured in the radius of asphalt work (WBGT resulting from environmental conditions + WBGT caused by the process of asphalt work). The WBGT difference inside and outside the area of asphalt work indicates the extent of WBGT increase caused by asphalt process. For estimation of heat stress, WBGT index was used. In Figure 1, the asphalt process and the relevant equipment has been shown. WBGT was measured at three different time intervals at three heights.



**Figure 1** Process of asphalt work: a) finisher machine; b) rubber and steel rollers and c) shovelers

WBGT-meter device Model MK427JY built by Casella Company was used to measure the environmental parameters such as dry temperature, wet temperature and radiant temperature, the. Physiological parameters of blood pressure and the heart rate of the workers were also measured by TRULY manometer device Model MDW-701, which has ISO, Food and Drug Administration (FDA) and Conformance Europeenne (CE) standards, along with the environmental parameters. All measurements were conducted in accordance with guidelines of ISO7243 [18], at three abdomen, chest and head heights at three different times (7:30-10, 10-12 and 12-14:30), and then the average time period was calculated during the work shifts. Then, using Eq. 1, the equivalent WBGT for workers in the workplace was determined. All measurements were repeated three times and their

average was assumed as the final value to reduce the measurement errors. Correction factor of 0.6 was included in WBGT calculation [18] as given that workers' ordinary work uniform consisted of a long sleeve shirt and pants.

$$WBGT = \frac{WBGT_{head} + (2 \times WBGT_{Abdomen}) + WBGT_{feet}}{4} \quad \text{Eq. 1}$$

The relationship between physiological parameters and WBGT as well as the WBGT caused by atmospheric conditions and asphalt work process was determined by using t-test and Pearson correlation at the significant level of 0.05. In addition to SPSS-19, EXCEL 2010 was also used for data analysis.

## Results

The mean value of WBGT for asphalt groups working in direct contact with the

asphalt process was measured in three different time periods are shown in Table 1. Further, these results of WBGT measurement based on

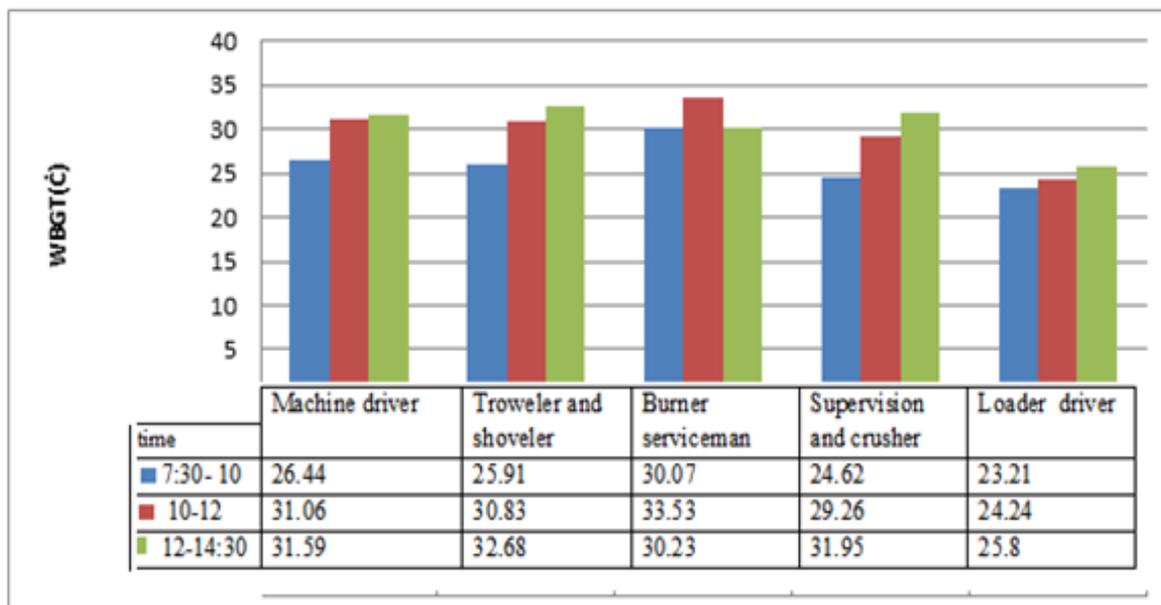
environmental conditions regardless of the asphalt work process have also been displayed in Table 1.

**Table 1** The results of heat stress measurement (WBGT) at asphalt workstations (inside the asphalt work area) and WBGT caused by regional atmospheric conditions (outside the asphalt work area)

Job		WBGT caused by regional atmospheric conditions				WBGT in asphalt workstation			
		7:30-10	12-10	12-14:30	8-hour mean	7:30-10	12-10	12-14:30	8-hour mean
Asphalt machine driver	Mean	22.70	29.32	31.20	27.77	26.44	31.06	31.59	29.81
	SD	1.38	1.42	2.09	1.49	1.79	1.00	3.40	1.12
	Range of variation	3.06	3.08	4.52	3.59	6.22	3.05	10.75	3.59
Troweler and shoveler	Mean	22.82	29.44	31.38	27.77	25.91	30.83	32.68	29.85
	SD	1.25	1.30	1.92	1.49	1.04	1.49	1.31	1.07
	Range of variation	3.06	3.08	4.52	3.59	3.04	3.81	3.45	2.73
Burner serviceman	Mean	27.46	29.19	33.07	29.61	29.01	30.07	33.53	30.23
	SD	0	0	0	0.48	2.19	1.25	0	0.39
	Range of variation	0	0	0	0.68	3.1	1.77	0	0.56

The mean value of WBGT at different time intervals inside the workstation (WBGT of asphalt work stations) and outside

the workstation (WBGT caused by the environmental conditions of the region) is shown in Figure 2.



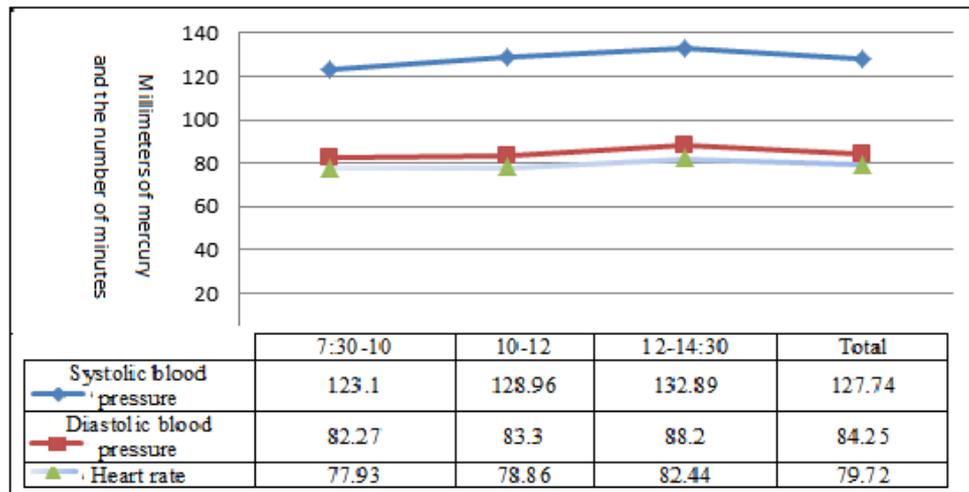
**Figure 2** Mean WBGT at different time intervals in the workstation

Table 2 shows the results of heat stress measurements (WBGT) in workstations of workers indirectly exposed to asphaltting (i.e. their work environment was detached from asphaltting process) along with the WBGT measurement caused by the atmospheric

conditions of the region. The results of systolic and diastolic blood pressure as well as heart rate measurements at three different intervals have been shown in Table 3 and Figure 3.

**Table 2** Results of heat stress measurements (WBGT) inside and outside workstations for asphalts workers indirectly exposed to asphaltting process

Job		WBGT caused by regional atmospheric conditions (without work process)				WBGT in asphalt workstation (with work process)			
		7:30-10	12-10	12-14:30	8-hour mean	7:30-10	12-10	12-14:30	8-hour mean
Supervisor and crusher	Mean	24.62	29.26	31.95	28.55	24.62	29.26	31.95	28.55
	SD	2.82	1.60	1.99	1.84	2.82	1.16	1.99	1.84
	Range of variation	6.52	3.08	4.63	4.48	6.52	3.08	4.63	4.48
Loader driver	Mean	27.46	29.19	33.07	29.27	23.21	24.24	25.8	24.25
	SD	0	0	0	0	3.13	4.46	6.78	4.47
	Range of variation	0	0	0	0	4.43	6.31	9.6	6.33



**Figure 3** Changes in physiological parameters of asphalt workers in three different time intervals

**Table 3** Mean value of physiological parameters of asphalt workers in three measured time intervals

Job	Systolic pressure mmHg				Diastolic pressure mmHg				Heart rate Beat.min			
	Time		Time		Time		Time		Time		Time	
	7:30-10	10-12	12-14:30	Daily mean	7:30-10	10-12	12-14:30	Daily mean	7:30-10	10-12	12-14:30	Daily mean
Driver of asphalt machine	116.88	122.44	128	122.4	80.22	76.88	84	80.32	76.11	74.44	82.33	77.65
Trowels and shoveled	121.54	125.09	128.27	124.84	81.09	84.72	89.72	85.23	78.27	79.36	82	79.89
Berners serviceman	130.50	146	147	141	84.50	86.50	81	83.50	79.50	79	81	79.85
Supervisor	134	137.70	143	138.33	92.66	94	97.66	95	77.66	82.66	83.66	81.33
Crusher	128.50	133.50	137	133	80.50	72.50	79.50	77.50	72	75.50	74	73.83
Loader driver	130.50	145	147	133.35	83	96	100.50	88	89	92	93.50	91.50

The results of t-test show that there is a significant difference between the value of WBGT inside and outside the work place of

asphalt workstation. There is a significant difference between WBGT values at foot and abdomen height and the head height in

workers who are exposed to both heat caused by the solar radiation and the heat produced in the asphaltting process, ( $p < 0.05$ ) but the mean WBGT is significantly different between abdomen and foot heights in trowels, shovels people, ( $p < 0.05$ ). Also, the mean WBGT value in

asphalt machine drivers was not significantly different for all heights ( $p < 0.05$ ).

The results of correlation test between WBGT in asphalt workstation and heart rate, systolic blood pressure and diastolic blood pressure are shown in Table 4.

**Table 4** Correlation between WBGT and heart rate, systolic pressure and diastolic pressure

		Heart rate	Systolic pressure	Diastolic pressure
WBGT	Correlation coefficient	-0.077	-0.194	-0.044
	p-value	0.691	0.314	0.822

## Discussion

According to the results, WBGT has its lowest value early in the morning whereas in the middle of the day (12-14: 30) it reaches its maximum value, increasing the exposure of workers to heat stress. As shown in Figure 2, in all measured workstations, WBGT value within asphalt work area was greater than the outside area. According to Table 3, around the midday and with an increase in WBGT, the mean diastolic blood pressure, systolic blood and the heart rate rises, though this increase is greater in systolic blood pressure. In the study of Golbabaee et al in a petrochemical industry, the correlation coefficient between WBGT index and physiological parameters of systolic and diastolic blood pressure, heart rate and skin temperature was 0.731, 0.451, 0.357 and 0.695 respectively [19].

The study of Falahati et al. [20] also suggested a significant relationship between WBGT index and oral and eardrum temperature [20]. The findings of this study are consistent with the literature, demonstrate a significant relationship between WBGT index and physiological parameters. Accordingly, the results suggest that all asphalt workers are exposed to heat stress, which is mainly caused by direct exposure to the sunlight. Moreover, the process of asphalt work also intensifies the heat stress in asphalt workers. Unfortunately, there is a paucity of studies in this field. The heat produced inside the human body during the work leads to an increase in the internal temperature of the body, thus influencing the

health and performance of people [21]. The study of Ro-Ting Lin et al in Taiwan showed that the average maximum temperature in 4 to 6 months of the year was over 30 C, constituting one of the most important causes of heat stress in these workers [22]

The average exposure to heat stress in trowels, shovels people was higher than other groups of asphalt workers which could be attributed to the closeness of these workers to the asphalt process. A study by Haji Azimi et al [23] showed that the workers in the melting platform were more exposed to the heat stress due to their closeness to the asphalt tank. Therefore, by controlling the heat-generating sources, the heat stress can be largely prevented.

Asphalt workers are not homogeneous in terms of their exposure to the heat in different organs of body (the head, abdomen and feet) with workers directly exposed to asphalt showing highest WBGT in their feet. The results of the present study suggest that asphalt workers are exposed to severe heat in their feet. That is, given the proximity of their feet to the asphalt and its resulting heat, asphalt workers receive the greatest amount of heat in this part of their body.

According to Figure 2, heat exposure of 12 hours up to 14:30 is more than others.. The study of Hajizadeh et al on evaluating heat stress in small jobs in Qom province suggested that WBGT reached its maximum value in this time interval, a finding which is

consistent with our study [24].

According to the results of this study, there was not any significant relationship between WBGT and systolic blood pressure, diastolic blood pressures and heart rate. However, the results of Table 2 suggest that WBGT and mean blood pressure at the midday are greater than that of the morning. This is not consistent with study of Golbabaee et al., but is consistent with the study of Christian et al., [25] on 18770 people, which revealed a reverse relationship between WBGT and blood pressure. As suggested by the results of this study, a 10-C drop in the temperature causes an increase of 1.5 and 2.4 mm Hg in blood pressure of men and women respectively.

According to the heat stress management process and indicators, there are three ways to reduce the risk of heat stress: 1) controlling heat stress exposure by using action threshold triggering system; 2) controlling continuous working time (maximum allowable exposure time) by determining the work–rest cycle, and 3) encouraging self-paced through the empowerment of workers [26]. Since this was an uncontrolled field study, life style, nutrition and other factors that may influence the blood pressure or heart rate were excluded. Therefore, definite conclusions about the impact of environmental conditions on blood pressure or heart rate cannot be drawn. Also, given the fact that in addition to the study variables, factors such as the type of asphalt can also affect the emergence of heart stress in asphalt workers, further studies are needed to identify the sources of heat stress and present effective strategies for controlling and reducing the exposure of asphalt workers to heat stress.

### Conclusion

According to the results, the mean of WBGT in all sectors except the truck driver is more than the permitted level [27]. Asphalt workers are exposed to heat stress resources such as regional atmospheric conditions, work process and the heat resulted from the body metabolism, which may lead to heat-related diseases and complications. As a result, managers and

engineers should take necessary controlling measures to reduce the extent of exposure to heat stress and strain.

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### Contribution

Study design: RH

Data collection and analysis: RH, MMH

Manuscript preparation: MMH

### Conflict of Interest

"The authors declare that they have no competing interests"

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