Investigation of heat stress and heat strain in outdoor workers: a case study in Iran

Farideh Golbabaei[1], Mohammad Reza Monazzam[1], Mohsen Yazdani Aval[2], Teimour Allahyari[3], Ebrahim Taban[2], Maryam Rostami Aghdam Shendi[1,*]

1 Department of Occupational Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran.
2 Department of Occupational Health Engineering, School of Medicine, Tarbiat Modares University, Tehran, Iran.
3 Department of Occupational Health Engineering, School of health, Urmia University of Medical Science, Urmia, Iran.

*Corresponding Author: email address: m_rostami_68@yahoo.com (M. Rostami)

ABSTRACT

Heat stress is an important and serious threat at work and is a particular concern in outdoor occupational environments. This study aims at comparing heat stress and heat strain at different outdoor groups, examining the protective and adaptive actions which were done by workers and also provision services to them by government or employer to reduce heat load. This cross–sectional study was conducted in the hottest days of the summer 2015 in Shabestar, Iran and 53 healthy men in nine occupational groups including concrete makers, porters, construction, waste site and road making workers, stonemasons, farmers, traffic officers, and street vendors participated. A set of physiological parameters, like heart rate, blood pressure, skin temperature and etc., WBGT index details and some of the adaptive and protective parameters were measured and monitored simultaneously at different times of the day. The study finds that heat exposure in outdoor workplace is prevalent and WBGT TWA/TLV_{ave} is less than 1 in some groups like stonemasons, waste site workers, traffic officers and street vendors whereas in other studied occupations, it is more than 1.This matter is compounded by the fact that the provision of health services by employers or local government was limited, and almost all of the participants had poor or insufficient access levels to public health and welfare services. This study confirms the necessity of interventions by a range of factors, such as government plans, improvement of services in the prevention of heat stress, and planning training courses for outdoor workers to build their knowledge of heat stress**.**

Keywords: Heat stress; WBGT; Physiological parameters; Protection

INTRODUCTION

With the changing climate all over the world, millions of people in indoor and outdoor workplaces, especially during the summer months, are exposed to extreme weather conditions and it can be one of the biggest risks to the safety, health and well-being of workers.

Work in sheltered workplaces in hot weather conditions is legally regulated. Gaps exist in the case of work in open workplaces, such as building sites, agricultural work and waste site activities. Outdoor workers, in addition to the heat of the process, are exposed to heat from atmospheric conditions and solar radiation. This will also likely cause heat stress among workers. Heat stress can happen when body is overheating and body's natural cooling system is suppressed because of metabolic heat production and environmental factors like relative humidity, air temperature, etc. as they are also affected by work rate and clothing. Approximately two billion of workers in outdoor environments are vulnerable to the impacts of climate change, and it has been reported that heat-related mortality in agricultural workers is almost 20 times more than other industries and works [1]. On the other hand, the potential risks of working in hot environment depend on physiological factors. It means that when working in hot conditions, the body responds to heat by increasing the blood stream to the dermis, increasing sweating rate, elevating skin temperature, heart rate and body temperature, which all rely on the level of adaptation[2]. It should be said that risks of heat induced human illnesses are higher in children, old people, pregnant women, and those with pre-existing medical conditions such as overweighting, cardiovascular and neurological diseases[3].

Health effects from elevated air temperature, global warming, heat stress and its association with respiratory, cardiovascular, and kidney disease have been reported in other studies [4-7]. Moreover, occupational heat stress was observed to be linked with worse mental health and psychological disorders[8]. The workers in physically demanding activities are also at greater risk of heat induced illnesses[9]. Since people with low accommodation capacity and lack of mitigation measures are at increased risk of morbidity and mortality, the occupational specifications, physical habituation, working capacity and heat acclimatization are the main determinants to impress on physiological and behavioral adaptations of the population exposed to hot environment[10].

Consequently, the professional assessment of heat stress and physiological responses with regard to individual factors and the type of the work have particular importance in safety, and well-being of workers. Heat stress may be assessed by several factors while the WBGT is a more particular occupational heat-stress index [11]. WBGT index with taking into account the ambient temperature (dry, wet, radiant temperature, humidity and wind speed) and working conditions is the standard, easiest, and best way with high efficiency to evaluate ambient thermal conditions.

The present study was conducted in Shabestar, Iran (figure 1). Shabestar is one of the cities of east Azerbaijan province, located at northwest of Iran and is in proximity to Tabriz, the provincial capital. Due to proximity to Lake Urmia (and drying of this lake), summers have been rather hotter and drier during day time. Scientists have warned that alteration of local climate (increasing of regional climate) is one of the adverse effects of continued decline of the lake [12-15]. This study targeted different outdoor workers exposed to high heat and the aim of study was to analyze outdoor physiological response as regard to perception of heat related stress and strain, and the possible differences in response among different occupational groups. The study also examines the protective and adaptive steps which were taken by workers and also provision services rendered to them by government or employers to reduce heat load.

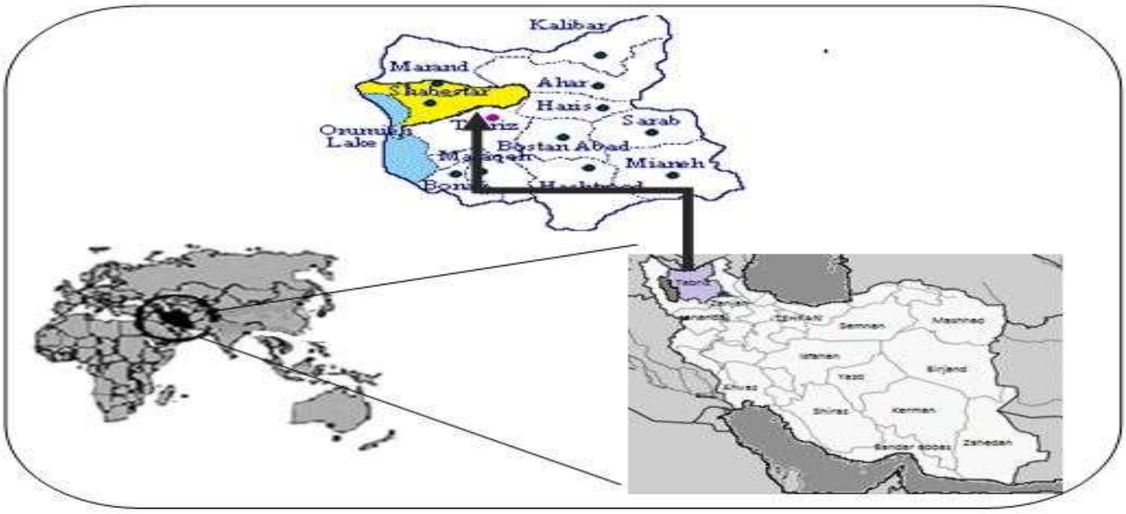

Figure1. location of study area

MATERIALS AND METHODS

This cross – sectional study was conducted in the hottest days of the summer (August) 2015 (the meteorological data of previous five years was collected from the Metrological Department and evaluated for choosing sampling days). As it has already been mentioned, our study was performed in Shabestar in two continuous weeks with the maximum temperature of 43°C. For choosing sampling sites and participants, the city map was prepared and the number of sampling site was calculated based on the equation below:

$$n = \left[\frac{z_{1-\alpha/2} + z_{1-\beta}}{\omega}\right]^2 + 3 \quad (1)$$

$$\alpha = 0.05 \quad \beta = 0.20 \quad r = 0.30 \quad (2)$$

$$\omega = \frac{1}{2} \times \ln \frac{1+r}{1-r}$$

n=84

Where, n is the sample size, Z: 95% confidence interval which corresponds to α = 0.05, 1-β is the power of the statistical test and r is the correlation coefficient.

So the city map was divided to 84 equal sites, working areas were inspected and all the workers in these sites entered the study based on inclusion criteria. The inclusion criteria was that all subjects were in good health and didn't have any disease experience and didn't take anti-diuretic drugs and medications that affect heart rate, subjects didn't have previous heatstroke, and eventually all the subjects should be native and acclimatized with the environment. Finally, 53 participants (all male) were chosen for this purpose. Number of subjects studied is more than other studies [16, 17]. Participants were in 9 occupational groups, including waste site workers (n=6), concrete makers(n=5), porters(n=4), construction(n=5) and road making workers(n=5) , stonemasons (n=5), farmers(n=8), traffic officers(n=5), and street vendors (n=5). The prevailing climatic conditions indicated that these occupational groups were potentially at risk of high heat exposures and thermal load during the peak summer months. After selecting 53 intended workers in different groups, a demographic information questionnaire were distributed to and collected from all workers and to assess the quality of provided health services to workers, peoples reaction to reduce heat stress as adaptive actions, some measures, such as access to cool water, authority of workers to leave their work for resting or drinking water, existing a room or tent for recovery, and etc. had already been taken. Environmental parameters, including dry temperature, relative humidity , air velocity wet-bulb temperature and globe temperature were measured simultaneously at work stations from 8.00 am to 16.00 pm (in three time intervals: 8-10, 10-12 and 12-16) by a calibrated WBGT meter (Ques Temp, made in Germany) and Air flow meter (LCA-6000, Air flow Co.).WBGT index, as the most applicable index for evaluating heat stress in workplaces for outdoor environment with solar radiation load was calculated as of the following equation, according to ISO 7243 standard.[12-19]

$$(3) \quad WBGT(outdoor) = 0.7\,Tnw \times 0.2Tg \times 0.1Ta$$

Where, Tnw is natural wet-bulb temperature, Tg is the black-globe temperature and Ta is the dry-bulb (air) temperature. Since all selected sites in terms of temperature (based on the pre-test) were homogeneous, measuring was carried out just around the waist (1.1 m). To calculate the average time Wet Bulb Globe Temperature index or WBGT.TWA the following equation was used.

$$(4) \quad WBGT.TWA = \frac{(WBGT \times T1) + (WBGT \times T2) + \cdots + (WBGTn \times Tn)}{T1 + T2 + T3 + \cdots + Tn}$$

Where, T shows exposure time. Metabolic rate of subjects can be estimated using standard ISO 8996.Where heat conditions in the rest area are different from those in the work area, the metabolic rate (M) should be calculated using a time-weighted average, as follows (Equation 5)[16, 20, 21].

$$(5) \quad M.TWA = \frac{(M1)\times(T1) + (M2)\times(T2) + \cdots + (Mn)\times(Tn)}{T1+T2+T3+\cdots+Tn}$$

During occupational engagement, the workers wore light clothing, trousers and short-sleeve t-shirts with insulation values ranging within 0.4 to 0.6 clo. All of them had previous experience in jobs. Physiological parameters including heart rate, systolic and diastolic blood pressure, skin temperature and oral temperature were also measured to compare groups. Each physiological parameter was measured 7-10 times on each subject during the day coinciding with environmental parameters. Heart rate and systolic and diastolic blood pressure was measured using the digital blood pressure monitor COMFORT (Model KP 6241, made in china). Skin temperature was gauged by a skin thermometer (Model TM905, Lutron Co) and the sites measured include: forehead, arm, chest, back, palm, thigh and lower leg. A digital thermometer (Model MEHECONOVA, German) was used for measuring oral temperature. All data obtained was analyzed by the use of SPSS version 18.

RESULTS

A total of 53 male workers were recruited as subjects from 9 different working groups.

Table 1 shows mean and standard deviation of subjects' demographic information. Their mean (S.D.) age was 32 (9.25) years (ranged in age from 18 to 45 years), and work experience of 7.5 (5.03) years. All subjects had more than two year of work experience. Statistical analysis indicates that there was no significant differences in demographic information such as height, weight, age and work experience between working groups (P>0.05).

Table1. Mean and SD of Subjects' Demographic Information

Job type	Number	Body mass index (BMI)	Experience (years)	Age (year)
waste site workers	6	22.53±0.5	11.1±3.48	39.33±6.7
concrete makers	5	22.32±0.61	8.8±4.92	34.2±9.3
porters	4	22.28±0.4	9±7.11	33.75±10.07
street vendors	5	22.4±0.45	5±3.39	26±10.67
farmers	8	22.92±0.52	6±4.4	28.33±8.3
road making workers	10	22.9±0.7	9.4±4.64	34.8±8.4
traffic officers	4	22.83±0.56	6.25±5.43	33.25±9.28
construction	8	21.91±1.5	5.75±3.88	32±8
stonemasons	3	22.99±0.18	4±4.35	28.66±11.1
total	**53**	22.5±0.6	7.5±5.03	32±9.25
P value	**-**	0.215	0.186	0.374

The results of WBGT TWA (time-weighted average), mean metabolic rate and WBGTTWA/ TLVave are revealed in Table 2. Since the threshold limit value of different work group is not the same, it is necessary to divide WBGT TWA to appropriate TLV. Therefore, the criterion with no units was achieved for accelerating the comparison between that unit and standard. If it is equal to or less than 1, there is no heat stress; and when more than, heat stress occurs.

Table 2. WBGT TWA, Metabolic Rate and WBGT/TLV in studied outdoor workers

Job Type	Number	Metabolic rateave (w/m2)	TLVave (0C)	WBGTTWA (0C)	WBGTTWA/TLVave	The result of estimation
waste site workers	6	130(moderate)	28	26	0.928	Safe
concrete makers	5	290(very high)	23-25	26.32	1.052	Danger
porters	4	250(high)	25-26	26.68	1.026	Danger
street vendors	5	120(low)	30	26.38	0.87	safe
farmers	8	245(high)	25-26	26.88	1.03	Danger
road making workers	10	295 (very high)	23-25	27	1.08	danger
traffic officers	4	110(low)	30	26.52	0.884	Safe
construction	8	240(high)	25-26	26.94	1.036	Danger
stonemasons	3	165(moderate)	28	26.18	0.935	safe

Table 2 shows WBGT TWA / TLVave is less than 1 in stonemasons, waste site workers, traffic officers, street vendors whereas in road making workers, concrete makers, construction workers, farmers, and porters it is more than 1; thus, they are more prone to suffer from heat stress than others. The results obtained from the physiological parameters in different work groups and the results of correlation of WBGT index and physiological parameters are summarized in table 3. Correlation analysis showed that there is a significant relationship between the WBGT index and physiological parameters ($P<0.001$). As can be seen in Table 3, the maximum correlation was between heart rate and WBGT (r=0492). The one-way ANOVA showed that the heart rate is different during the working times ($p<0.001$). In other words, by changing the rhythm of work at different times of shifts, heart rate is changed.

Table 3. Result of Mean and SD and relationship between WBGT and Physiological Parameters in studied outdoor workers

Physiological parameters based on job type		Deep Temperature (°C)	Skin temperature (°C)	Diastolic pressure (mmHg)	Systolic pressure (mmHg)	Heart rate (number per minute)
waste site workers		36.71±0.3	34.74±0.18	88.49±10.2	130.41±8.25	84.25±6.89
concrete makers		36.88±0.4	34.91±0.24	89.2±7.5	135.7±7.73	89.9±8
porters		36.85±0.3	34.95±0.13	92±12	136.62±10.75	94±8.78
street vendors		36.51±0.3	34.87±0.14	83.1±10.7	130.2±5.7	86.1±8.4
farmers		37.1±0.32	34.96±0.22	87.68±9.3	134.81±8.8	84.75±6.84
road making workers		36.95±0.45	35±0.13	89.15±8.4	134.8±7.7	86.9±7.6
traffic officers		36.28±0.1	34.89±0.05	82.375±5.5	128±2.55	78.25±2.76
construction		37.22±0.19	34.9±0.25	93.93±6.5	136.62±4.8	90.68±7.3
stonemasons		37.13±0.45	34.94±0.12	87.17±9.5	130.17±2.1	88±5.29
WBGT	Correlation Coefficient	0.368	0.421	0.31	0.435	0.492
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001

Figure 2 shows the mean WBGT and physiological parameters measured during the work. The further analysis of results also indicated that by increasing the WBGT index, the deep body temperature, blood pressure, heart rate or thermal strain increases which represents the suitability of this indicator to assessment of heat stress. Maximum amount of WBGT index is between the hours of 13 to 16 pm, so it can be said that the highest thermal stress occurs at these time intervals. The outdoor workers who were interviewed reported that they had access to some services or did some actions to reduce or protect from heat. According to interviews, the most common methods that outdoor workers used while working in hot weather were scheduled short breaks in shaded areas, drinking water frequently, using personal protective equipment like sunglasses, hats and masks (see Figures 3). When scoring the level of worker's behavior or available facilities to avoid heat, it appears that almost all of the respondents have poor or insufficient levels of them.

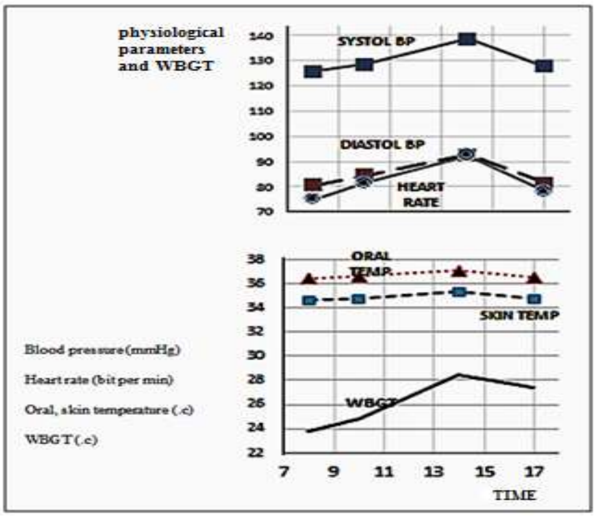

Figure 2. Change in physiological parameters and WBGT based on different time intervals of the day

As shown in this figure, only 21% of outdoor workers have access to cool water; stone masons, construction workers is reported that have maximum access and others have less access to cool water, based on the present study. In this study, 20% of workers have authority to leave their work to rest or drink water. The results showed that the number of studied occupational groups such as street vendors, farmers, stonemasons and construction workers, during their shifts took a large amount of caffeinated drinks like tea. Five percent of all workers who were interviewed reported that they buy or get given protective devices; traffic officers (100%) tend to use the protective means, while concrete makers are more likely to drink before feeling thirst. Stone masons can apply these measures more often than the other occupation groups. The level of schedule breaks in studied groups was low (12%).

DISCUSSION

Heat is an environmental and occupational hazard, Therefore the measurement, evaluation and control of heat stresses are important and essential steps in providing occupational health and safety[19]. Previous studies report that some of the working groups tend to be among those who are financially in undesirable situation, with limited access to public and welfare facilities,

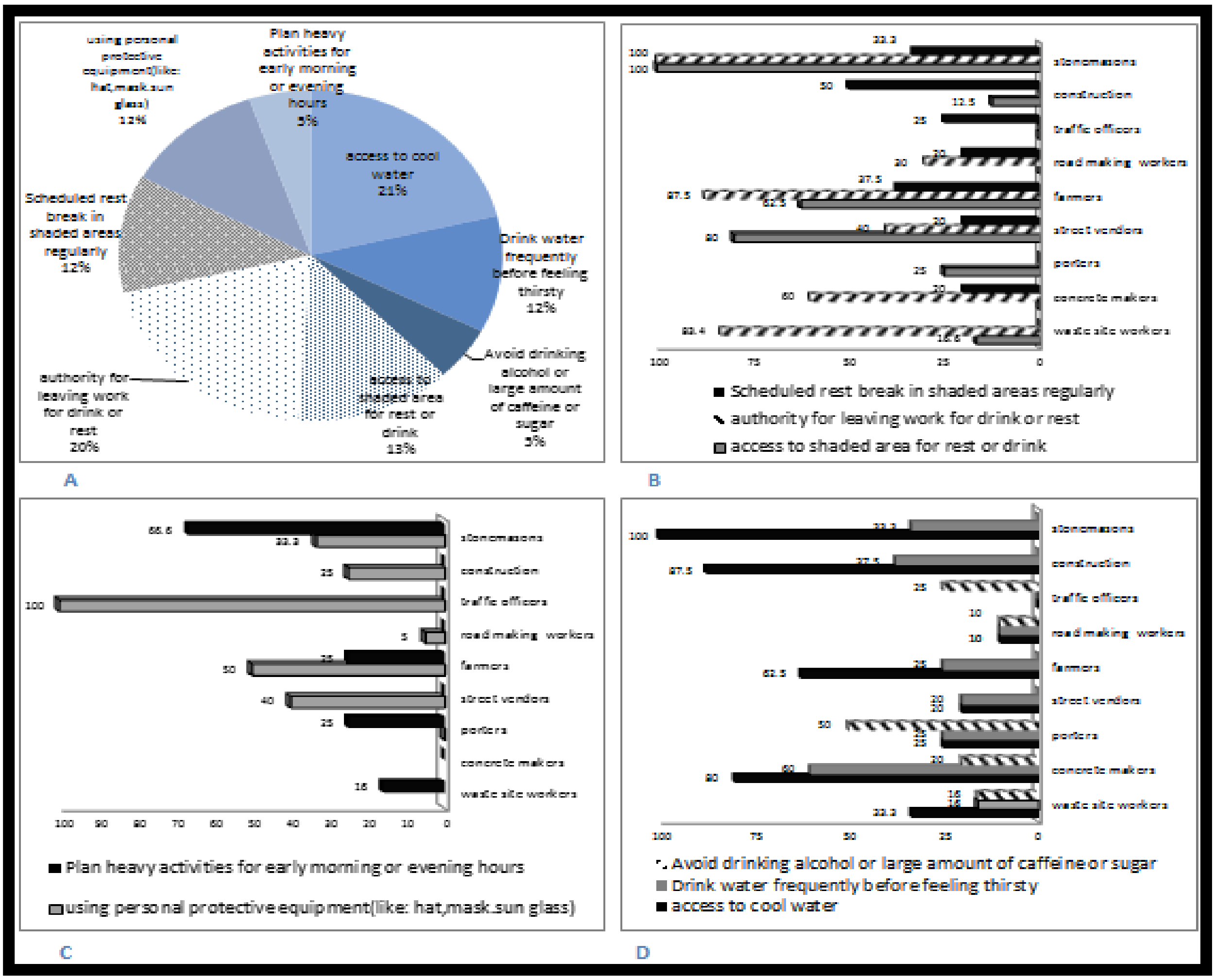

Figure 3. (A). Overall percentage of adaptive and protective strategies done to reduce heat at workplace. (B, C, D). Frequency of different adaptive and protective actions and prepared measures in the workplace by occupation

local social support programs or healthcare purvey such as women, freelance, street vendors and workers in medium and small private formations, including construction workers, stone workers and other outdoor occupations. These groups are at the risk of heat stress [22]. In most countries, outdoor workers are among neglected groups. This study population, as already has been mentioned, also consist of workers at nine outdoor occupation groups. Since heat acclimatization was also an important issue and previous studies proved that autonomic nerves reaction to prevent the elevation of the body temperature is happened rapidly 3-4 day after beginning the work in hot environments but hormonally starts after 3-4 week later [23], we took all these into consideration in our study. All of the participants in this research seemed to be acclimatized to hot environment, because they had been working there for two years or more. Table 2 shows that WBGTTWA/TLV$_{ave}$ during the working day for stonemasons, traffic officers, street vendors and waste site workers is less than 1; in other words, WBGT.TWA Index for mentioned groups is less than the limit value according to metabolic rate. Regarding the results of metabolic rate and workload, heat stress for road and concrete makers, construction workers,

farmers and porters was higher than the limit value. One of the important reasons of the increased heat load in the workplace is direct sunlight which has been focused on and demonstrated by other authors, in other fields such as in agricultures[24]. Another reason would be the location of the activity as the majority of waste site activity workers worked in urban parks and green spaces in warm hours and the impact of green space in cities is adjusting temperature, increasing the relative humidity, air freshness and absorbing the dust. On the other hand, the road makers in addition to the heat from the air temperature were also exposed to the heat of the work process (heat from the asphalt mix). Monitoring the physiological responses is beneficial to evaluate the health effect of work in hot environments. Principally heat strain or the physiological responses of body to heat stress consists of the enhancement of heart rate and systolic and diastolic blood pressure, body deep temperature, skin temperature, among which, according to the inter group study, the heart rate is more reliable than others [16, 21, 25, 26]. Correlation analysis showed that there is a significant positive correlation between WBGT index and physiological parameters and it can be said that increasing the air temperature will increase the core parameters. It matches to the findings of other researchers [27, 28]. The results of this study also showed gradual increase of air temperature during the day; the diagram represents the maximum temperature in the afternoon (13-16pm) and it also seems to be consistent with other studies [29]. Stricter work control and health care for managing the impacts of hot working environment on health of workers are essential: factors such as controlling the water intake. For indoor workers, some engineering controls can be applied to prevent heat exposure but they seem to be difficult to be taken for outdoor workers. It is better to put the cool water or liquid close to the work area with a permanent avilability to workers; on the other hand, workers should be motivated to drink small amounts every 20 minutes or more frequently, to stay hydrated. In this research, the results of health service quality also showed that traffic police and road workers don't have easy access to water. The voluntary water intake may have been impressive to prevent dehydration but porters, construction workers and traffic officers reported that they don't have enough authority to leave their posts for drinking water. Although in hot weather, breaks are often permitted for those who work in small-scale jobs, results show that workers still only take low breaks. This is because the employers or managers are always present, and don't like their workers take too many breaks, especially if they are busy with deadlines. It matches with the findings of another research [22]. A number of working groups like farmers also reported that due to the nature of their work and harvest, it is hard to change the working schedule and they should work in regular hours of day, early in the morning, and stay at work until transporting product to the emporium. Providing recovery areas can diminish the load of heat on the workers. It seems that the conditions under the temporary tent may be acceptable to reduce heat stress. An air conditioned room is more desirable, but it may be difficult to build up such rooms at all places, partially because of economic problems. In this study only 12% of outdoor workers reported that shaded area is available for them. Some of the working groups which are mentioned in this study (like road making and construction workers, farmers, porters and concrete makers) are particularly vulnerable and more susceptible to heat exposure at work. These groups also have limited access to public and health services. This lack of accessibility can be related to their unregistered status, their self-employed status, and poverty. Finally, it should be said that it is difficult to take engineering controls at the outdoor places. Therefore, administrative control can play an important role in decreasing the heat stress of workers. As one of the administrative controls, worker's health training is the key to prevent heat stress [30].
Workers themselves should take a break and drink enough water frequently, even in light work load, to prevent the heat stress.

CONCLUSION

In Iran, there is no formal guidance supporting workers' health about heat stress, and no regulations and legislative framework exists on hygiene and safety for outdoor workers. Findings of this study show that heat exposure in outdoor workplace is prevalent and significant; it also confirms the necessity of interventions by a range of factors, such as government guidance measures for employers, improvement of health, public and welfare services for the prevention of heat stress, and planning training courses for outdoor workers to build their knowledge and awareness of heat stress. It is recommended that the government provide some measures to reduce the heat stress for local workers, like planting more trees in the streets to provide shading. Provision of public toilets is also useful, to enable access to these services during their work, which would enable them to drink more frequently.

ACKNOWLEDGEMENT

We are indebted to the wonderful cooperation from the outdoor workers who generously shared with us their valuable working time, ideas and opinions while contributing to the surveys.
This article was part of an M.S. thesis supported by Tehran University of Medical Sciences.

"The authors declare no conflict of interests"

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