

Evaluation of Heat Stress among Farmers Using Environmental and Biological Monitoring: A study in North of Iran

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ABSTRACT

In this cross-sectional study carried out in spring and summer, 79 farmers working in different job positions including agriculture, husbandry and horticulture in north of Iran were participated. Evaluation of the heat stress was conducted using Wet Bulb Glob Temperature (WBGT) index according ISO7243 and heat strain evaluation using measuring the individual physiological responses including aural, oral and mean skin temperatures according ISO 9886. The demographic characteristics of the subjects such as age, job experience, BMI and body area were also gathered through a questionnaire. In general, the subjects were in middle ages (38.44 ± 8.86 yr) and mean and standard deviation of years of experience were almost high (17.49 ± 9.41 yr), too. The statistical analysis was performed by SPSS 18 software. The results showed that the WBGT index values had ranging from 24 to 32.6°C in summer regardless of clothing insulation, metabolic rate and work rest regimens. Of course, by correction of these parameters the WBGT will accompany with an incensement. Conversely, the heat strain monitoring revealed that in no case the aural and oral temperatures are higher than the limit allowed. The best correlation coefficient was obtained for aural temperature and WBGT index ($r = 0.84$, $P < 0.001$). It seems that evaluation of hot and humid environment using WBGT index can be associated with an overestimation and encountered our judgment about the environmental condition with a significant error.

KEYWORDS: Heat stress, Biological monitoring, Farmer, WBGT index

INTRODUCTION

Hot and humid conditions exist either indoor or outdoor environments. There are a lot of people who work outdoors. Unlike indoor situations which there are commonly engineering controls such as cooling systems, air conditioning and displacement ventilation, in outdoors, the self- pacing can be one of the most effective means to protect the workers exposed to hot conditions from an excessive physiological strain and keep them within

acceptable limit of heat exposure [1-2]. Outdoor environment means an environment where work activities are performed outside. Therefore, outdoor workers include any workers who spend a main portion of the shift outdoors. Examples include construction workers, agricultural workers, farmers, road construction workers, and so on [3].

The North of Iran has hot and very humid weather especially from late May to September months. Since the dominant occupation of people in these areas is working on the farm (including agriculture, animal

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husbandry and horticulture), they spend a lot of times outside and so they exposed to hot and humid condition in these months. On the other hand, working on the farm was often done along with the heavy activities, and this can impose heavy workload and increase individual metabolic rate thereby make the human body more heat. Other factors such as working under direct sunlight, performing prolonged or strenuous work and wear heavy protective clothing or impermeable suits along with above-mentioned parameters can put the farmers in heat stress situation.

The human body functions best within a narrow range of internal temperature. This "core" temperature varies from 36°C to 38°C. When the core temperature exceeded above 38°C, the body uses two cooling mechanisms for keeping the equilibrium situation and drop core temperature. These include: 1) The heart rate increases to move blood and heat from internal body parts (vital organs) to the external ones (the skin) and 2) Sweating increases to loss heat to the environment by evaporation. However, when too much sweat is lost through heavy activities or working under hot and humid conditions, which is the case of farmers in the North of Iran, the body cannot have enough water loss to cool itself [4]. In addition, in such conditions, generally the vapor saturated air does not allow enough evaporation to keep thermal equilibrium. Therefore, the results can be dehydration, rising core temperature above 38°C and a series of heat-related illnesses such as heat cramp, heat syncope, heat exhaustion and heat stroke [5].

People at risk in the farms are in different age and sex groups including ranging from young or lower age to elderly and both men and women. The adverse health effects can be seen more in the elderly, those living alone, and people without access to air conditioning and adequate water supply. People with pre-existing medical conditions (e.g., cardiovascular disease, renal diseases, obesity, neurologic or psychiatric disease), and other disorders that interfere with salt and water balance (e.g., some medications such as diuretics, anti-cholergic agents, and tranquilizers that impair sweating), are at greater risk for heat-related illness and death. Having prolonged outdoor physical activities (such activities to be included in the farm) in hot and humid environment also are risk

behaviors associated with heat-related illnesses [6].

On the other hand, people employed on the farm due to the low level of awareness and lack of knowledge about heat exposure associated risks, often do not pay enough attention to the hazards and take preventive and protective measures.

Considering climate change and global warming can exacerbate the environmental situation and directly or indirectly can increase weather related illness. According to IPCC (Intergovernmental Panel on Climate Change), the effects will increase progressively all over the world [7]. In Iran rising temperature trends in different parts could be also seen [8-10].

To prevent heat-related illnesses, International Standard Organization (ISO) states that workers should not be allowed to work when their deep body temperature exceeds 38°C (100.4°F) [11]. In order to keep working condition in which people can work cautiously without any harmful effects due to heat exposure, and keep the deep body temperature below 38°C, ISO has recommended the reference values for work according to Wet Bulb Globe Temperature (WBGT) [12]. These values also depend on metabolic rate, thermal insulation of cloth and work- rest regimens. WBGT index recommended by Yaglou and Minard, 1957[13], which is well-known and most common index to heat stress assessment. It was accepted by ISO-7243 (1989), and can be used for evaluation of both indoors and outdoors. For outdoor environments in which solar radiation exist, WBGT can be calculated as follows [11]: (Equation1)

$$\text{WBGT} = 0.7 \text{ NWB} + 0.2 \text{ GT} + 0.1 \text{ DB}$$

Where is:

NWB= Natural wet bulb temperature (°C)

GT= Glob bulb temperature (°C)

DB= Dry bulb temperature (°C)

In spite of a lot of risk factors mentioned above related to heat exposure, unfortunately there has been lack of enough research focusing on issues of thermal comfort and heat stress in outdoor settings, particularly field studies [14]. A quick look at work activities and different production processes in farms demonstrates that, one of the most important and common occupational health problems in such environments is inappropriate climate, meaning hot and humid working conditions.

Due to the importance of the subject

and also the number of jobs in the outdoor environments, particularly working on the farm, this study was defined to evaluate heat stress exposure through environmental and biological monitoring of exposed farmers.

The main objects of this field investigation were 1) prevalence of heat stress condition in north areas of Iran at hot months and 2) evaluation of physiological responses of exposed workers, which result in encountering to hot and humid conditions. It is also expected that the results can produce comparable data for test agreement and correlation of the heat stress and strain indices to judge about whether a person who finds to be stress condition based upon WBGT reference value, has really abnormal condition based upon heat strain indices or not?

MATERIALS AND METHODS

In this cross sectional study done in spring and summer 2013, heat stress was evaluated using WBGT index and heat strain evaluation by biological monitoring of aural temperature, oral temperature and skin surface temperature was performed.

Seventy-nine outdoor workers worked at the farm including agriculture jobs (30 persons), animal husbandry jobs (24 persons) and horticulture jobs (25 persons) were randomly selected. All workers had the same pattern of work and rest regimen (on average 75% work and 25% rest per hour). The mean of subject workload (metabolic rate) (according ISO-9920) and thermal insulation of cloths (according ISO-8996) were estimated 300 to 415 W and 0.78 clo, respectively.

The WBGT index values recorded directly using a calibrated advanced thermal monitor (Casella, UK) and repeated at 9:00 am, 12:00 pm and 15:00 in accordance to early, middle and end of work shift, respectively.

Environmental parameters including dry air temperature (T_a), globe bulb temperature (T_g), and natural wet temperature (T_{nw}) also recorded from WBGT monitor, simultaneously and air velocity (V_a) and relative humidity (RH) of the work stations measured by thermal anemometer and a digital hygrometer, respectively. All measurements were performed in accordance to ISO- 7243 in 1.1 meters height from ground surface, since workers had standing or semi- standing posture throughout the work shift and there

were no significant differences between the air temperature in different heights from ground surface (The homogenous environment).

Physiological responses including aural temperature, oral temperature and skin surface temperature were measured according ISO- 9886 using a non- contact infrared thermometer (for cases of aural and skin temperature) with ± 0.1 °C accuracy (Omron model, china), and a simple digital thermometer (for case of oral temperature) with ± 0.1 °C accuracy (beurer model, Germany). Skin temperature was measured in four points of the body surface (ISO 4 points method) during the work and then means skin temperature was calculated in term of degree of centigrade as follows [11]:

(Equation 2):

$$\text{Mean skin temperature} = (\text{Right scapula } 2.8) + (\text{Neck } 2.8) + (2.8 \text{ Right shin}) + (\text{Left hand } 0.16)$$

Constant values here represent the ratio of selected skin surface area to the size of the entire skin surface of the body.

In order to compare the environmental and physiological parameters and their effects on each other, physiological parameters simultaneously with environmental parameters were measured. All measurements were also repeated in the spring and summer. Therefore, for 79 subjects in this field study, totally we recorded 474 measurements (79 subjects multiply 3 times in a shift work multiply 2 seasons in a year). All demographic data such as age, job experience, body mass index (BMI) and body area were collected through a researcher made questionnaire for the subjects.

To answer this question that whether the heat stress index values and related heat strain responses have agreement with together or not, both the heat stress and strain indices were categorized to two groups (normal and abnormal or permissible or impermissible range) according to reference values presented by international organizations. So, for WBGT index, the cut point was determined 27.6 based on heavy work load and 75% work + 25% rest; each hour (From ACGIH (American Conference of Governmental Industrial Hygienists, 2006)). Therefore, each measurement, which obtained lower this value, considered permissible and upper values considered impermissible. A similar classification for heat strain indices including aural temperature, oral temperature and mean

skin temperature was done; so that the values of 38, 37.5 and 35 degree of centigrade were selected as reference values for aural, oral and mean skin temperature, respectively (ISO 9886). Agreement of the indices and percentage of real positive and negative responses and false positive and negative responses in each case analyzed using Cross tab, Chi2 and Fisher exact statistical tests. Correlation between the heat stress indices was evaluated based on Spearman coefficient.

RESULTS

Demographic characteristics of the subjects

The demographic data recorded in this study showed that in general the subjects were in middle ages (38.44± 8.86 years) and mean and standard deviation of years of experience were almost high (17.49 ± 9.41years), too. These amounts, which presented for different work environments separately demonstrated in Table 1. BMI (dimensionless) and body area (in terms of square meter) also calculated for the subjects.

Table1. Demographic information of the subjects

Work environments	Demographic information								n*
	Age (year)		Job experience (year)		BMI		Body Area (m2)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Agriculture	42.30	10.96	19.60	9.95	26.36	4.35	1.82	0.20	30
Animal husbandry	33.17	5.92	15.42	7.60	26.60	3.47	1.95	0.16	24
Horticulture	39.87	9.71	17.47	10.68	24.92	4.22	1.88	0.18	25
Total	38.44	8.86	17.49	9.41	25.96	4.01	1.88	0.18	79

* Number of subjects

Environmental and biological monitoring: Mean and standard deviation of environmental and biological parameters have shown in Table 2 and 3, respectively. Environmental parameters including air temperature (Ta), natural wet temperature (Tnw), glob temperature (Tg), relative humidity (RH) and air velocity (Va) which measured for agriculture, animal husbandry and horticulture separately in different stations and time intervals of work shift (9:00 am, 12: 00 pm and 15: 00) have demonstrated in Table 2. In addition, the simultaneous measurements of WBGT index in each station have presented in this table (Also, see the Fig. 1 for range of WBGT Index value measured in spring and summer). According to Fig. 1, the WBGT index values can be reached to 32°C in summer. Obtained results showed that the

mean value of Ta, Tnw and Tg have increased by spending the time from morning to evening. The relative humidity had converse manner during the work shift, so that it has been the highest amount in the morning and decreased by increasing air temperature during the day. It was not seen any considerable trend during the day in case of air velocity, and the only considerable thing was the highest air velocities at the noon (12: 00 pm) in all work environments. By considering mean and standard deviation of WBGT index value and taking account the garments thermal insulation and metabolic rate for doing the duty in each job, the index values exceeded from reference value (27.6 degree of centigrade for heavy work load and nearly continues work), especially for middle to end of work shift or between 12: 00 pm to 15 (Table 2 and Fig. 2).

Table 2. Mean and standard deviation of environmental parameters of studied occupational outdoor environments

Work environments	ti me	Environmental parameters										n*		
		Ta (°C)		Tnw (°C)		Tg (°C)		RH (%)		Va (m.s ⁻¹)			WBGT(°C)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		Mean	SD
Agriculture	9	25.55	2.07	23.12	1.95	26.97	2.35	81.58	1.83	.68	.56	24.17	2.05	60
	12	29.02	2.31	24.78	1.86	32.05	3.03	71.30	5.74	.79	.55	26.64	2.00	60
	15	29.72	3.21	24.52	2.11	32.39	4.45	66.05	6.05	.75	.43	26.67	2.59	60
Animal husbandry	9	23.07	4.34	20.10	3.85	25.08	4.92	76.98	8.57	.74	.50	21.42	4.05	48
	12	25.83	7.05	21.21	4.95	21.21	4.95	68.71	11.52	1.41	1.16	23.35	5.81	48

	15	27.23	7.39	21.96	5.21	29.47	8.53	65.38	10.22	.79	.77	23.97	6.11	48
Horticulture	9	27.73	2.88	23.28	2.89	31.14	2.15	69.21	6.06	.86	.55	25.35	2.68	50
	12	31.46	3.70	24.45	4.31	35.87	2.83	56.69	9.66	1.50	1.14	27.31	3.76	50
	15	32.40	3.92	24.30	3.98	36.05	5.13	51.54	4.92	.60	.45	27.45	4.27	50
Total		28.00	4.09	23.08	3.45	30.02	4.26	67.49	7.17	.90	.67	25.14	3.70	47.4

*Number of exposed subjects in measured stations

As can be seen in Table 3, mean and standard deviation of aural temperature are higher than oral temperature and ones for oral temperature are higher than skin temperature. According to the

reference values exist for each parameter (refer to the method section), just skin temperature exceeded permissible limit and aural and oral temperatures are in normal range almost in all measurements.

Table 3. Mean and standard deviation of biological parameters of studied occupational outdoor environments

Work environments	time	Biological parameters						n*
		Aural temperature (°C)		Oral temperature (°C)		Mean skin temperature (°C)		
		Mean	SD	Mean	SD	Mean	SD	
Agriculture	9	36.37	0.44	36.35	0.43	35.74	0.89	60
	12	36.91	0.26	36.51	0.34	35.76	0.78	60
	15	36.88	0.25	36.59	0.28	35.84	0.69	60
Animal husbandry	9	36.69	0.38	36.39	0.42	35.03	1.15	48
	12	36.81	0.41	36.41	0.40	35.08	1.17	48
	15	36.81	0.42	36.37	0.66	35.45	1.17	48
Horticulture	9	36.84	0.42	36.45	0.40	35.47	1.23	50
	12	37.02	0.41	36.52	0.46	35.66	1.10	50
	15	37.01	0.43	36.43	0.64	35.91	1.03	50
Total		36.81	0.38	36.44	0.44	35.54	1.02	474

*Number of exposed subjects in measured stations

Crosstabs statistical analysis was done for comparison of heat stress and strain results which obtained in the same environmental conditions. So agreement degree of responses in each case was examined. As the results show in Table 4 in cases of aural and oral temperatures, the percentage of abnormal range are more less than for the normal range (i.e. aural and oral temperatures were in normal range almost in all environmental conditions, whereas the WBGT index values have been higher than permissible limit). In other words,

the sensitivity and specificity of the index and compatibility to strain parameters was low. Therefore, for example in case of aural temperature we have 335 false positive responses. The reverse results obtained for the mean skin temperature. On the other hand, correlation coefficient of physiological parameters and heat stress index showed that the best correlation obtained between aural temperature and WBGT value ($r = 0.84, P < 0.001$) (Table 5).

Table 4. Consistency percentage of heat stress and heat strain responses base on accepted reference values *

WBGT index (°C)		n= 474		Physiological responses								
				Aural temperature (°C)			Oral temperature (°C)			Mean skin temperature (°C)		
				(+)**	(-)***	Total	(+)	(-)	Total	(+)	(-)	Total
Impermissible limit (+)	N	0	335	335	0	335	335	214	121	335		
	%	0	100	100	0	100	100	63.9	36.1	100		
Permissible limit (-)	N	0	139	139	3	136	139	138	1	139		
	%	0	100	100	2.2	97.8	100	99.3	0.7	100		
Total	N	0	474	474	3	471	474	352	122	474		
	%	0	100	100	0.6	99.4	100	74.3	25.7	100		

P-Value	****	0.025	< 0.001
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* The accepted reference values for WBGT, aural temperature, oral temperature and mean skin temperature were supposed 27.6, 38, 37.5 and 35 degree of centigrade, respectively (refer to method for more information).

** (+) Positive response or abnormal range

*** (-) Negative response or normal range

**** No statistics are computed because abnormal aural temperature is a constant.

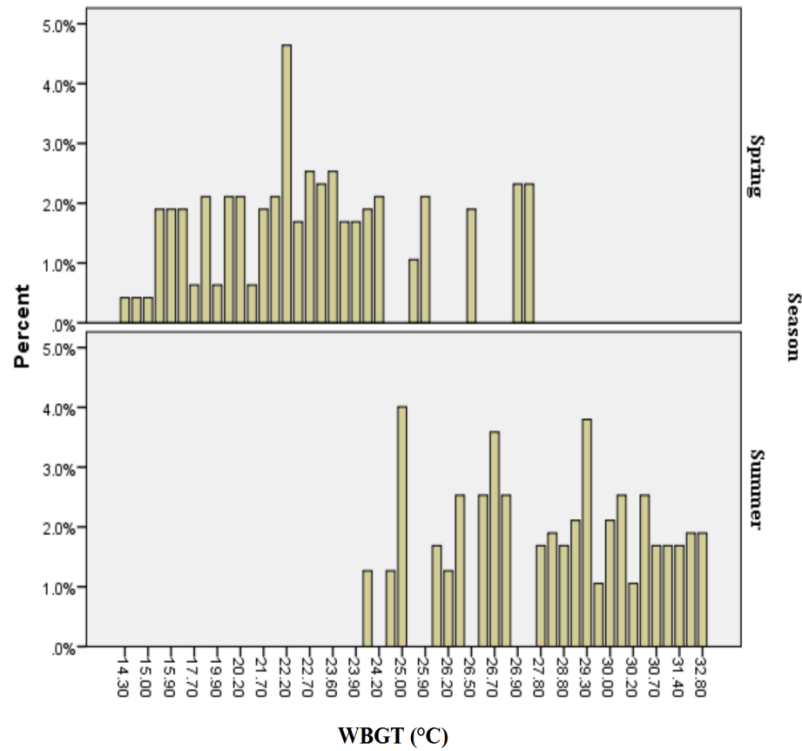


Fig 1. Range of WBGT Index value measured in Spring and Summer

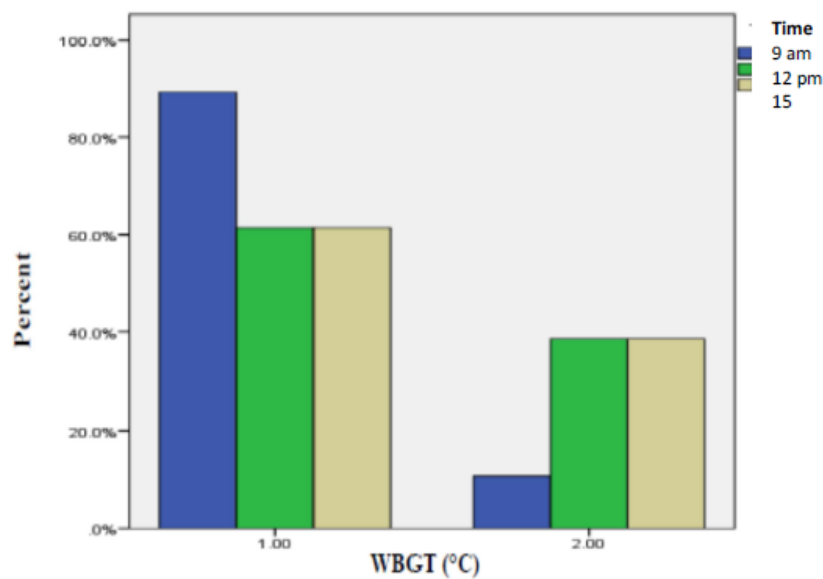


Fig 2. Percentage of WBGT Index value in terms of under threshold limit value (Group 1) and above threshold

limit value (Group 2)

Table 5. Relationship between biological parameters and heat stress index in outdoor environments

(N= 474)	WBGT (°C)		Aural temperature (°C)		Oral temperature (°C)		Mean skin temperature(°C)	
	r	P-value	r	P-value	r	P-value	r	P-value
WBGT (°C)	--	--	0.84	< 0.001	0.35	< 0.001	0.62	< 0.001
Aural temperature (°C)	0.84	< 0.001	--	--	0.31	< 0.001	0.52	< 0.001
Oral temperature (°C)	0.35	< 0.001	0.35	< 0.001	--	--	0.31	< 0.001
Mean skin temperature(°C)	0.62	< 0.001	0.52	< 0.001	0.31	< 0.001	--	--

DISCUSSION

According to the obtained demographic information (Table 1), the mean and standard deviation of the subjects age and experience were relatively high (38.44±8.86 years and 17.49± 9.41 years, respectively). Mean and standard deviation of the BMI was also above normal range (25.94± 4.01; the normal range of the BMI is ranging from 18.5 to 24.9). These parameters can exacerbate the situation for the subjects exposed to heat and may be increase heat related illnesses.

The effect of BMI on heat exhaustion has studied and revealed that heat exhaustion cases had a significantly higher BMI than control group ($P=0.006$). The odds ratios increased with BMI. For a BMI of 32.00-36.99, compared to a BMI of less than 27.00 the odds ratio was 3.63 (95% confidence interval, 1.42-9.36) [15]. The similar results obtained by Bedno et al. [16]. Ageing is often accompanied by other conditions (e.g. hypertension, diabetes, cardiovascular insufficiencies, long-term therapeutic drug modalities) which further affect heat tolerance and thermoregulation [17]. Older workers—over the age of 45—had higher physiological cost of work and lower work ability in a hot environment than younger workers [18]. Therefore, especial control measures may be need for the exposed individuals in hot environments to reduce risk of heat stress.

In this investigation, the measured WBGT index values exceeded threshold limit value (27.6 °C, considering workload, work- rest regimen and cloths properties) almost in all studied work environments including agriculture, animal husbandry and horticulture, especially between 12: 00 pm to 15: 00 and in summer. The condition was worst for the horticulture work environments. So that, the WBGT index had reached maximum value of it- self (27.45 ± 4.27°C). These values obtained in conditions in which, dry air temperatures and globe bulb temperatures more than 30°C experienced by the subjects (Table2). In hot and

humid environments (such as selected areas in this study), we can see that the WBGT index exceeded the recommended reference value at not necessarily very high dry or globe temperature, instead in these conditions due to high amounts of relative humidity (mean and SD were equal to 67.49±7.17 percent in this study) and thereby rising natural wet temperature, resultant WBGT can reach above threshold limit value even though the air or globe temperatures had been not very high. According to the fractional portions of each environmental parameter, which demonstrated in equation 1, the relative humidity has the main role in heat stress of the environment in such situations. In a study has done by Dehghan et al. at hot and humid environments in Persian Gulf, the similar results were obtained [4].

Evaluation results based on the WBGT index have been higher than the allowable limit, while the obtained results based upon physiological responses, especially in cases of aural and oral temperatures, have been lower than standard references values (38 and 37.5°C for the aural and oral temperature, respectively). For the mean skin temperature however, in all measurements, the amounts were higher than recommended reference value (35°C). It seems that environmental assessments in hot and humid conditions using WBGT index can accompanied with an overestimation.

In these environments as mentioned above the dry air temperature due to of existence high humidity can not to be very high (rarely more than 37°C). In addition, there is not a significant difference between air temperature and globe bulb temperature. Therefore, the most important parameters, which can be change WBGT index values is relative humidity and resultant natural wet bulb temperature. In an epidemiological research which done in Japan revealed that death from heat stroke in the occupational field occurred at 34°C and more °C at dry bulb temperature when the

relative humidity was less than 40%. It occurred at around 28–30°C at dry bulb temperature when the relative humidity was more than 65% [19].

In spite of global validity and usability of the WBGT index, the most serious limitation of it is that environments at a given level of the index are more stressful when the evaporation of sweat is restricted (by high humidity or low air movement) than when evaporation is free [20]. This situation can be seen in North of Iran. Motamedzade and Azari evaluated heat stress and strain in one of the southern seaports of Iran, which has nearly similar weather conditions, and concluded that heat exposure evaluation using biological monitoring such as deep body temperature can result in better and more accurate results than using the heat stress assessment using WBGT index only [21].

The physiological responses in our study have similar rising trend during the day and as mentioned just mean skin temperatures exceeded standard reference value. On the other hand, as you see in Table 4, according to physiological responses (as gold standards) comparing WBGT index, the evaluation of the environment using WBGT has accompanied with large false positive responses (WBGT index is impermissible whereas physiological responses, are in normal range). This situation can be seen for the aural and oral temperatures, and for the mean skin temperature, conversely the false negative responses increased. This means that heat stress assessment using WBGT compare to aural, oral temperatures (heat strain assessment) are associated with an overestimation, and it is almost underestimation for the mean skin temperature. Heat exposure evaluation using both wet bulb globe temperature (WBGT) and heart rate in hot climatic conditions can produce better estimation rather than WBGT index assessment only [2].

According to Table 5, the correlation coefficient between the aural temperature and WBGT was obtained maximum value ($r=0.84$, $P<0.001$). Therefore, it can be concluded that if correctly measured, aural temperature can be used along with WBGT index as a good combination method for evaluation of heat stress in hot and humid environments. In some studies were done in worldwide, tympanic temperature has been suggested as a core temperature for the evaluation of heat strain [22-23].

CONCLUSION

Farmers worked in conditions in which serious health risk related to heat exposure, especially in the summer can be exist. Similarly, the evaluation of heat stress using WBGT in such environments (hot and humid condition), may face us with inaccurate judgment about the real environment. On the other hand, the workers who

work under heat condition at outside environment have often heavy jobs and without any awareness and knowledge on heat stress. Therefore, evaluation of heat exposures and exposed workers using both the heat stress and heat strain indices strongly suggested. Beside this, raising workers awareness on heat stress, health care provision and providing heat preventive measurements at workplace are necessary for reduction of health risk in hot and humid environments.

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