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Original

Thermal Comfort Assessment and Heat-Related Illnesses among Sellers in Periodic Local Markets: A Case Study in Hot and Dry Climate of Iran

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Abstract

Background: This study aims to evaluate the thermal conditions of periodic local markets and determine the thermal comfort and sensation of sellers, as well as the prevalence of heat-related diseases in the hot and dry climate of Iran. **Methods:** In this study, thermal comfort and sensation of 330 sellers from periodic markets in Qom city, a dry and hot climate in Iran, were evaluated. Measurements were performed for 15 days, from July 16 to August 1. To assess environmental thermal condition, wet bulb globe temperature (WBGT) index and discomfort index (DI) were determined, and participants' tympanic temperature was determined to consistency assessment with thermal indices. Finally, the effects of environmental, personal, and working conditions on the prevalence of heat-related diseases among sellers were determined. **Results:** The environmental indices, including DI and WBGT index, had the most association with heat-related illnesses and tympanic temperature ($P<0.05$). The sellers perceived the environmental conditions as warm to hot after 1:00 pm. Besides, they expressed an uncomfortable or very uncomfortable situation after 12:00 pm. The findings showed that environmental parameters play a more important role in the prevalence of heat-related diseases and heat strain than individual and occupational factors. **Conclusion:** The sellers may be at risk of heat stress in outdoor markets in nearly half of the workday in the summer months. Therefore, it is very important that these people receive the necessary training in the prevention of heat illness in order to take appropriate protective measures in accordance with local conditions.

Keywords: Thermal comfort; Thermal sensation; Periodic market; Heat stress

Introduction

In Iran, similar to the other countries, periodic markets are places for supplying agricultural and non-agricultural products and have attracted many visitors and customers over the years.[1] Local markets are places to meet the daily needs of the people and to buy and sell goods and services, which are usually held on a weekly basis.[2, 3] On the other hand, since many goods offered in these markets are provided for consumers often without intermediaries and directly from the producer to consumers, it is also

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economically important for consumers and is associated with economic benefits.[4, 5] This has led to many society segments (generally low-income or middle-income classes) also welcome these markets. In some periodic local markets such as local markets in the northern or southern provinces of Iran (Gilan, Mazandaran, Golestan, Bandar Abbas, Bushehr, etc.), where there are places for villagers with different cultures, they are important in terms of tourism and cultural aspects, too.[6-8]

Periodic local markets (such as Saturday Bazaar, Sunday Bazaar, Monday Bazaar, etc.) are examples of such markets Figure 1, which, besides offering goods produced by rural people, also increase the relationship between the cities and the villages.[7] This relationship has made them very important from various social, economic, anthropological, cultural, and tourism aspects.[7]

Despite the stated advantages and the important role of these types of markets, unfortunately, the environmental, structural, and welfare conditions of these types of markets are usually not suitable for sellers and visitors. Since they are temporarily formed in different neighborhoods, suitable facilities for both sellers and visitors are not often provided.

Wndnesday Bazar in Gorgan
(In the north of Iran)

Tuesday Bazar in Qom
(In the upper half of center of Iran)

Friday Bazar in Rasht
(In the north of Iran)

Friday Bazar in Ahvaz
(In the south of Iran)

Figure 1. Some of periodic local markets in Iran

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The three elements of human, space and human activities are the most effective factors in the formation of periodic local markets, so that they can be mentioned as a factor in the difference in the level of regional development.[7] Moreover, it seems that environmental factors can affect the prosperity and acceptance of society in these markets. So that in different climates of Iran, especially in the southern and central areas of the country,[9] in very hot conditions (e.g., at summer months and especially in the middle of the afternoon),[10] the public acceptance of these markets has decreased.

Rising local temperatures cause more people to be exposed to heat, which in hot seasons in warmer regions of the world. This can create very unhealthy and high-risk environments for people working in outdoors ,where it is not possible to cool people easily compared to indoors.[11] Therefore, people often provide the goods they need from other suitable places (shops or indoor markets). Because of the longer exposure time, sellers are more likely than visitors to be exposed to the adverse effects of thermal environmental conditions, and their health is threatened. Thermal conditions and especially ambient heat can affect the thermal comfort and thermal sensation of sellers.[12] It can reduce the work efficiency of these people and cause psychological effects (such as aggression, nervousness, and reducing resilience for these people) or physiological effects (such as increasing core and skin temperature, heart rate, sweat rate, etc.). Moreover, the increasing prevalence of heat-related complications such as heat rashes, heat fatigue, heat cramps, heat exhaustion, and even heat stroke due to long-term work in such environments will not be unexpected.[13]

Because these types of markets are generally outdoors and do not have adequate shadings to protect employees from the thermal conditions, the sellers are inevitably active and affected by environmental conditions throughout their work shift, usually from the early hours of the morning until sunset (About 12 hours).[14] Besides, lack of organizational regulations, appropriate personal protective equipment (PPE), adequate sanitary facilities such as healthy, cool and available water, suitable places to sit, as well as insufficient information about heat-related hazards can cause excessive fatigue due to heat and increase the risk of complications and illnesses induced by environmental conditions.[15] Although other researchers have considered local markets, most of the researches have focused on economic, tourism,[1, 8] and general comfort dimensions.[16] The lack or absence of studies conducted regarding thermal comfort conditions in Iran and other parts of the world, from an occupational view or the impact that environmental conditions can have on employees' health in these professions, can be clear the existing gap. Therefore, this study aims to evaluate the thermal conditions of periodic local markets and determine the prevalence of heat-related risks, the thermal comfort, and sensation of sellers in Qom, as a representative of the hot and dry climate of Iran.

Methods

Subjects

This study was a descriptive cross- sectional study conducted in July and August 2019 in Qom Province, Iran. The geographical location of Qom is in the upper half of the central regions of Iran. The average annual minimum and maximum temperatures are 16.5% and 49% C in January and July, respectively. The average annual rainfall is about 150 mm.[17] The target population was vendors working in periodic local markets in Qom. The figure 2 illustraes the geographical location of the Qom.

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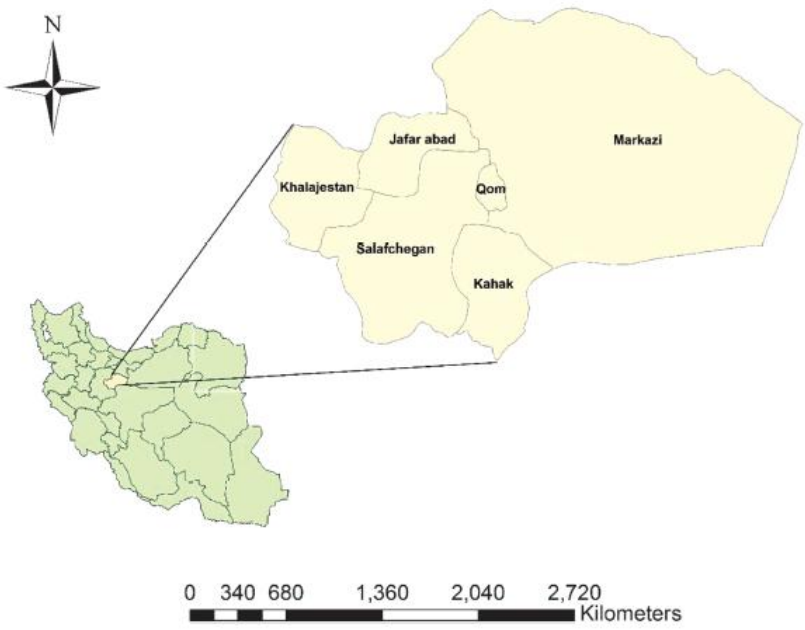

Figure 2. The geographical situation of the study area; Qom Province, central Iran

The participants were 330 males vendors randomly selected from four different local markets of Qom. The selected markets were geographically located in the north, south, east, and west of the city. Participants entered the study after informing them about the objectives of the project and obtaining their consent. At least one year of work experience was considered for the participant's entry into the study. Participants' personal information including age, metabolic rate in terms of "Watt" (estimated according to standard; ISO-8996, 2004)[18] and clothing insulation resistance in terms of "Clo" (estimated based on ISO-9920, 2009)[19] were gathered and recorded using interview and observation.

Prevalence study of the heat-related diseases

To determine the prevalence of heat-related diseases, four types of heat-related diseases, including heat rash, heat cramp, heat exhaustion, and heat stroke, were considered more common in hot environments. Because the study participants were not expected to be aware of the diseases' diagnostic signs and symptoms, heat-related symptoms were considered and asked from participants. Based on the individuals' responses to the symptoms, type (s) of heat-related illnesses experienced by the interviewees were taken into account over the past year. The symptoms of each heat-related diseases were defined as follows:

- Heat Rash (also known as prickly heat): heat rashes are usually small, itchy bumps at the entrance to the sweat glands that are usually seen as red inflammations.
- Heat cramp: weakness, nausea and vomiting, headache and dizziness with muscle aches and cramps or a feeling of chronic tiredness usually accompanied by heavy sweating.
- Heat exhaustion: heavy sweating and rapid pulse, headache, nausea or vomiting, cool and moist skin, a result of body overheating,
- Heat Stroke: having symptoms such as headache, confusion or delirium, no sweating/dry skin, hot and red skin, rapid heart rate, nausea or vomiting, unconsciousness, and body temperature above 104° F .[20-22]

Measurement parameters

Measurement parameters in this study included environmental parameters (air temperature, globe temperature, and wet temperature), which were

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measured by relevant calibrated measuring devices. In order to evaluate the thermal conditions in a complete shift of work, the measurements were recorded 8 times between 8:00 am to 5:00 pm with one-hour intervals. Measurements were performed for 15 days, from July 16 to August 1. Totally, 120 series of measurements (8 samples per day for 15 days) were recorded in this study. Due to the small size of local markets, environmental conditions in all parts of the market were assumed the same and homogeneous, and small changes in measurement values in different locations in each market were ignored. Simultaneously, the only physiological parameters related to heat in this study, tympanic temperature, were measured and recorded for all 330 participants. To measure tympanic temperature, a non-contact IR thermometer model Omron made in China with an accuracy of 0.1 ° C was used. All measurements were performed contractually in the right ear and ensured that the ear canal was empty from the earwax. Three measurements were performed in each case, and the highest value was recorded as correct tympanic temperature.

Determination of thermal indices

Indicators in this study included "Wet Bulb Globe Temperature Index (WBGT)," "Discomfort Index (DI)," "Thermal comfort" and "Thermal sensation," which a brief introduction, calculations or measurements methods of them are as follows:

WBGT index

This index, which is one of the most valid and common indicators in the assessment of heat stress, was presented by Yaglou and Minard in 1957[23] and approved by the ISO-7243.[24] This index integrates the effects of three parameters, including air temperature, natural wet temperature, and globe bulb temperature, and can be calculated for outdoor environment by the following equation:

$$WBGT = 0.7\,Tnw + 0.2\,Tg + 0.1\,Ta \qquad \text{(Eq. 1)}$$

Where:

Tnw: natural wet temperature (°C),

Tg: globe temperature (°C),

Ta: dry air temperature (°C).

In this study, the WBGT index was measured directly using an advanced calibrated WBGT meter (Microtherm Cassella, UK) at the height of 1.1 m from the ground. The time-weighted average (TWA) during one hour of WBGT was considered, and its amount was calculated and recorded by measuring at three different times per hour.

Discomfort index

We used the Discomfort Index (DI) to assess thermal discomfort. This index, which is considered the effect of two components of air temperature (Ta) and relative humidity(RH) on human thermal comfort ,[25] was first suggested by Thom[26] and then modified by Sohar et al[27]. The index can be calculated as follow:

$$DI = 0.5Tw + 0.5Ta \qquad \text{(Eq. 2)}$$

Tw: wet temperature

Ta: dry air temperature

Thermal comfort and thermal sensation

Subjective measurements including thermal sensation and thermal comfort were assessed based on the ISO 10551 standard, on a 7-point thermal sensation scale (values ranging from -3 to +3), and on a 4-point thermal comfort scale (values ranging from 0 to 3), respectively.[28]

Statistical analysis

The collected data were analyzed using SPSS 22 software. The normality of the data was tested the tests was set to be 0.05.

Results

This study was performed among 330 sellers selected from four periodic local markets in Qom city. The mean and standard deviations of the age of participants were 31.92±9.07 years. As Table 1 shows, most of the sellers had experienced a low to moderate metabolic rate (165.35±16.58 W). In addition, no correction of WBGT was needed due to Cloth

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thermal insulation (the mean and standard deviation was less than 1 Clo). Demographic data, heat-related illnesses, and applied control measures for participants are shown in Table 1. Based on the obtained results, heat rash was a very common disease among using the Kolmogorov-Smirnov test. Spearman, correlation coefficient test was used to assess the correlation among thermal indices. Moreover, the Chi-square test was used to evaluate the relationship between of personal, working, and environmental factors whit thermal indices. The significance level for all the subjects (66.7%), and heat stroke was the minimum (11.7%). Regarding control measures, the availability of water and shade, although not quite suitable, was given more attention than other measures. Most people did not have enough knowledge about heat-related risks. Besides, none of them had been trained in heat-related risks. The only protective equipment used by the people was different types of hats.

The results of Table 2 show the descriptive data of measured thermal indices, including WBGT, discomfort index (DI), Thermal sensation (TS), and core temperature (Tc), which was the tympanic temperature in this study. The one-hour interval measurements showed that all indices' mean and standard deviation followed an upward trend. Recorded values indicated that the thermal conditions were inappropriate or higher than the reference limits between 11 am and 5 pm. The reference and cut point values of each index are shown in Table 3. The cut point values were considered in the present study to assess the thermal situation in an acceptable (less than selected reference value) or unacceptable (higher than selected reference value) condition, to which each person was exposed.

The thermal comfort situation of participants was assessed based on a 4-point thermal comfort scale. The one- hour interval assessments were illustrated in Figure 3. As the results show, only until about 10:00 am to 11:00 am, the comfort conditions can exist partially. After that, the uncomfortable conditions gradually increase, and finally, in the last hours of the work shift (between 2:00 and 5:00 pm), the people's perceived thermal conditions are evaluated as very uncomfortable Figure 3.

Table 1. Demographic data, heat-related illnesses, and applied control measures for subjects (n=330)

Personal parameters	Mean	SD
Age (yr)	31.92	9.07
Metabolic rate (W)	165.35	16.85
Cloth thermal insulation (Clo)	0.62	0.09
Heat-related illnesses	**Yes (%)**	**No (%)**
Heat Rash	66.70	33.30
Heat exhaustion	30.00	70.00
Heat cramp	32.10	67.90
Heat Stroke	11.70	88.30
Control measures	**Yes (%)**	**No (%)**
Water availability	100.0	0.00
Shading	74.80	25.20
Personal protective equipment (PPE)	11.20	88.80
Training	9.10	90.90

Table 2. Descriptive data of measured thermal indices

Time period	WBGT (°C)		DI (°C)		Thermal sensation (TS)		Tc (°C)*	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
8-9	25.73	2.05	26.50	2.56	0.80	0.53	35.48	1.28
9-10	26.16	1.96	26.92	2.44	0.88	0.50	35.67	1.17
10-11	26.66	1.89	27.43	2.38	1.12	0.47	36.05	0.99
11-12	27.10	1.83	27.89	2.29	1.40	0.50	36.26	0.87
12-13	27.54	1.73	28.35	2.18	1.64	0.48	36.51	0.78
13-14	27.94	1.62	28.85	2.07	2.39	0.53	36.79	0.67
14-15	28.40	1.56	29.38	2.06	2.83	0.37	37.07	0.58
15-16	28.85	1.45	29.86	1.91	2.85	0.35	37.37	0.47
16-17	29.22	1.35	30.27	1.77	2.60	0.54	37.36	0.37

*Core temperature, which was the tympanic temperature in the present study

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Table 3. The reference values of thermal indices and interpretations of them

Index	Reference values	Interpretation	Reference
WBGT	29 °C (for low metabolic rate and not acclimatized persons)	Acceptable, if WBGT was less than 28°C Unacceptable, if WBGT was higher than 28°C	ISO-7243, 1989
Discomfort index*	22	Whitout heat stress	29
	22-24	Mild sensation of heat	
	24-28	So hot	
	>28	The heat load is severe, the risk for heat illnesses is high	
Tympanic temperature (Tc)	Acceptable, if Tc was less than 37 °C Unacceptable, if Tc was higher than 37°C		30
Thermal sensation**	Cold (-3); Cool (-2); Slightly cool (-1); Neutral (0) ; Slightly warm (+1); Warm (+2);Hot (+3)		ISO-10551,2001[28]
Thermal comfort***	Comfortable (0); Slightly uncomfortable (1); Uncomfortable (2); Very uncomfortable (3)		ISO-10551,2001[28]

* The cut point value for DI was considered 26°C in this study.

** The cut point value for thermal sensation was considered +2 in this study.

*** No cut point value allocated for thermal comfort in this study

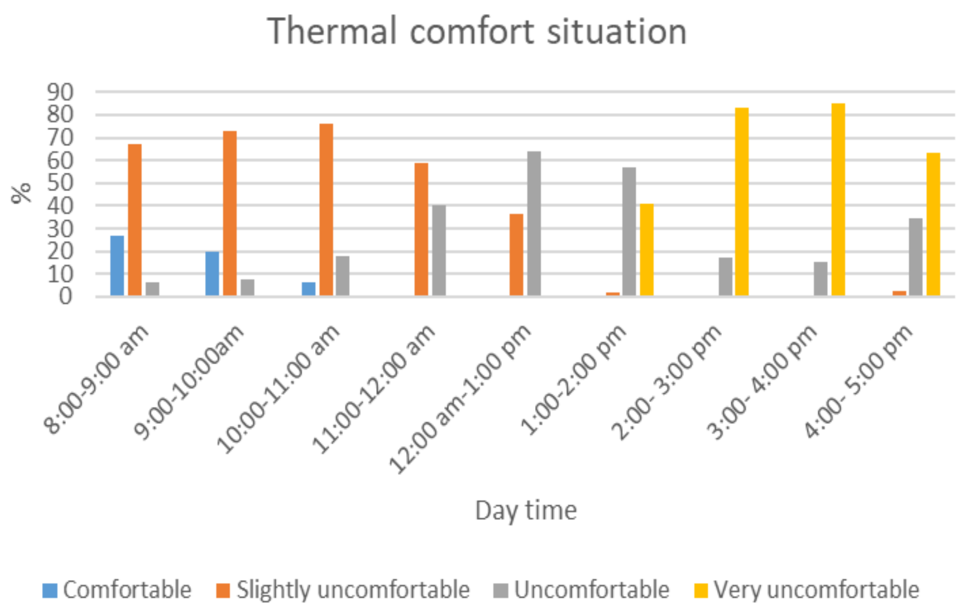

Figure 3. Thermal comfort situation from 8:00 am to 5:00 pm (n=330)

Table 4. Correlation of different indices from the same thermal condition

Indices	WBGT (°C)		DI (°C)		Thermal sensation (TS)		Tc(°C)*	
	r	*P*	r	*P*	r	*P*	r	*P*
WBGT (°C)	-	-	0.978	< 0.001	0.228	< 0.001	0.118	0.012
DI (°C)	0.978	< 0.001	-	-	0.286	< 0.001	0.112	0.042
TS	0.228	< 0.001	0.286	< 0.001	-	-	0.078	0.28
Tc (°C)	0.118	0.012	0.112	0.042	0.078	0.28	-	-

*Core temperature, which was the tympanic temperature in the present study.

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Table 5. Association of the studied factors with heat-related illnesses and tympanic temperature*

Factors	Grouped variables	Heat-related illnesses				Tympanic temperature
		Heat rash	Heat cramp	Heat exhaust	Heatstroke	
Personal factors	Age (higher than 35 years old)	×	×	×	×	×
	Without PPE	×	√	×	×	×
	Without training	√	×	×	×	×
Working factors	Without available water	×	×	×	×	×
	Without shading	×	×	×	×	×
Environmental factors	DI (>26 °C)	×	√	√	√	√
	WBGT (>28 °C)	×	√	×	√	√

*Crosstab Analysis
×: Non- significant (P>0.05)
√: Significant (P<0.05)

To compare the indicators' response in evaluating the thermal environmental conditions, their correlation coefficients were considered Table 4. The results showed that the highest correlation coefficient was between WBGT and DI (r=0.978, *P*<0.001). Thermal sensation showed the greatest correlation with DI, although it was a weak statistical correlation (r=0.228, *P*<0.001). Core temperature had weak correlations with both the DI and WBGT indices. No significant correlation was obtained between core temperature and thermal sensation (*P*=0.28).

Moreover, the association of studied factors, including personal, working, and environmental factors with heat-related illnesses and tympanic temperature, are shown in Table 5. Based on the results, working factors including water availability and shading were neither correlated with the heat-related illnesses nor with the tympanic temperature. The environmental indices, including DI and WBGT index, had the most association with heat-related illnesses and tympanic temperature (*P*<0.05).

Discussion

Based on the obtained results, heat rash was a very common disease among the subjects (66.7%), and heat stroke was the minimum (11.7%). Heat rash (miliaria rubra) is the mildest form of heat-related illness and very common when raising air temperature and relative humidity combined together. In such a condition, the pores of the sweat close in the skin and cause red and itching inflammation in that area.[22] Skin covered by clothing is most often affected.[31] Since facilities such as shading and water availability were provided for most occupants in the present study, other heat-related illnesses were lower. In a study in underground mines, the prevalence of miliaria was 38% of the prevalence of heat exhaustion at the same mine.[32] The thermal conditions of periodic markets were assessed as inappropriate or higher than the reference limits between 11 am and 5 pm. As the results show, only in primarily morning hours until about 10:00 am to 11:00 am, the comfort conditions can be partial. This is due to the combined effect of the low range of air temperature and relative humidity.[33] So that in this range of the day time, the moderate air temperature (30.58±3.0 ºC) and low relative humidity (15.16±0.21 %) caused comfort situation for occupants. After that, by increasing both the air temperature and humidity, the uncomfortable conditions gradually increase. Finally, in the last hours of the work shift (between 2:00 and 5:00 pm), the occupants' perceived thermal conditions are evaluated as very uncomfortable.

To compare the indicators' response in evaluating the environmental thermal conditions, their correlation coefficients were considered Table 4. The results showed the highest correlation coefficient between WBGT and DI (r=0.978, *P*<0.001). As an advantage, the discomfort index can easily explain the combined thermal effects of temperature and humidity on human thermal comfort.[34] Nasiri et al. (2018) obtained a similar finding between WBGT

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and Modified Discomfort Index (MDI) in open-pit mines in Tehran, Iran.[35] A WBGT higher than 28°C is considered as an extreme risk for thermal injury.[36] According to Table 2, this situation could exist around noon and afternoon of the workday. Numerous studies have shown that the mean Tc increases safely to ~38.5°C within a wide range of WBGTs (13.5–29.2°C).[37-39] Similarly, in the present study, only low correlations were seen between core temperature and other heat indices Table 4. However, Heidari et al. showed that in Iranian outdoor workers, when the tympanic temperature is used as a substitute for rectal temperature (core temperature), the maximum allowable safe limit is 37°C. This is due to some differences between the two temperatures (rectal temperature versus tympanic temperature).[30] Therefore, the sellers and visitors may be at risk of heat stress in outdoor markets in nearly half of the workday in the summer months.

Also, subjective thermal indices, including thermal sensation and thermal comfort, had no statistically significant correlation or weak correlation with core temperature or environmental indices Table 4. Based on the results of Table 2, sellers perceived the environmental conditions as warm to hot after 1:00 pm. Besides, they expressed an uncomfortable or very uncomfortable situation after 12:00 pm Figure 3. These times, environmental indices exceeded reference values gradually. Based on the results in Table 5, although working factors, including water availability and shading, are the main influencing factors to prevent heat-related risks, they neither correlate with the heat-related illnesses nor with the tympanic temperature in this study. This may be due to the same working condition regarding water availability and shading for most participants. All of the sellers (100%) used water whenever needed, and most of them (74.8%) provided shading for themselves. Therefore, despite the tendency to increase body temperature, the body temperature regulation system intervenes and keeps the body temperature constant in a narrow range (37±0.1 °C).[29] Therefore, this can be applied as a helpful and effective mechanism to prevent heat stress and strain.[30]

Personal factors, including lack or non-use of appropriate protective equipment, such as a brimmed hat, has only affected heat cramps. Besides, the lack of heat training has increased the prevalence of heat rashes ($P<0.05$). Individuals with higher ages (more than 35 years) did not experience more heat related diseases. In this regard, heat acclimatization might help older people to tolerate more heat.[40, 41] However, studies on heat tolerance show that middle-aged people (45 to 64 years old) do not tolerate working in hot condition , and when they adapt to heat, they suffer physiologically more than young people.[42, 43] Therefore, the effect of age on heat-related risks probably relies on parameters other than acclimatization. Besides, the average of individuals' ages in the present study was low (31.92±9.07). The environmental indices, including DI and WBGT index, had the most association with heat-related illnesses and tympanic temperature ($P<0.05$). So, when DI exceeded reference values (DI>26°C), a significant increase in heat cramp, heat exhaustion, heatstroke, and tympanic temperature have been reported ($P<0.05$). Similarly, consistency can be observed between raising WBGT and incidence rate of heat cramp, heatstroke, and raising of tympanic temperature ($P<0.05$). These findings indicate that environmental parameters play a more important role in the prevalence of heat-related diseases and heat strain than individual and occupational factors [44].

Conclusion

Amongst the heat-related risks, heat rash was the common disease among sellers in periodic local markets, and heat cramps and heat exhaustion were the next priorities. Most of the sellers suffer from heat conditions after 11:00 am in the summer, and thermal comfort was in unfavorable or very unfavorable condition. Both the WBGT and DI can be used for the assessment of heat stress in outdoor markets. Determining the tympanic temperature

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alone cannot be reliable for assessing the thermal condition in such working environments, and determining it along with the evaluation of environmental parameters can have better results. Environmental factors have a greater impact on heat stress, heat comfort, and heat sensation than individual and occupational factors. Therefore, to protect sellers from the adverse effects of heat exposure, protective guidelines need to be developed for the periodic markets. Also, control measures such as providing cool and healthy water, shadings, sanitary training and heat control programs for employees in periodic markets are suggested. It is essential that vendors have adequate training in heat illness prevention and take local safety measures. Behavioral adjustments such as drinking more water, making better use of breaks, and making other personal or working changes can also reduce heat stress risks.

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Conflict of interest

The authors declare that they have no competing interests.

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