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Investigating the Levels of Thermal Stress in Kerman City in 2016 Using Thermal Indices: WBGT, ESI, HI, HSI, and SWreq

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Abstract

Background: Thermal stress may have numerous harmful effects on human health. This study aimed at investigating thermal stress in the city of Kerman, Iran.

Methods: In this descriptive-analytical study, thermal stress was assessed from 6 AM to 9 PM in 2016 using four thermal stress indices including wet-bulb globe temperature (WBGT), environmental stress index (ESI), Humidex, heat stress index (HSI), and Required Sweat Rate (SW_{req}). Necessary data were collected from the meteorological organization of Kerman. Pearson's correlation coefficient and linear regression were used to examine the relationships among thermal stress indices and environmental parameters. All analyses were performed using SPSS version 22.

Results: Based on the results, the highest correlation coefficients were observed between ESI and WBGT ($r = 0.99$), Humidex and ESI ($r = 0.96$), Humidex and WBGT ($r = 0.97$) and SW_{req} and HSI ($r = 0.99$). On the other hand, thermal stress indices had significant relationships with environmental parameters including wind speed, air temperature, and relative humidity ($P < 0.05$).

Conclusion: All indices had strong and significant associations with one another. WBGT, HSI, and Humidex demonstrated similar thermal sensations. Furthermore, according to the obtained values of ESI, Humidex, and WBGT, people enjoy thermal comfort in all months of the year (save for January as judged by the obtained WBGT value). Thus, the climate of this city poses no threat to people's thermal comfort.

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Introduction

Thermal stress, including internal and external thermal factors, causes numerous complications for humans (1). Internal factors of thermal stress entail body temperature, the level of acclimatization, and metabolism rate. External factors, on the other hand, encompass air temperature, wind speed, radiant heat, and humidity. Thermal exchanges between human body and the external environment help us keep our body temperature around 37 °C. Thus, there should be a balance between the amount of heat produced in the body and the one entering the body from the outside environment (2). Heat stress is a physical hazard and excessive exposure to it can cause health-related problems like muscle cramp, heat exhaustion, heat stroke, etc. (3, 4). Heat stress can also result in mental fatigue and a decline in performance and efficiency, which may in turn cause distraction. It is also likely to increase the likelihood of cardiovascular diseases and work-related accidents, which may even lead to death in some cases (5-7). The results of the study conducted by Mokarami et al. show that working under conditions with thermal stress can have a negative impact on various aspects of life quality and the ability of work employees (8, 9).

Around 220 annual deaths are caused by heat stress in work environments in the US and Canada. Toronto Department of Health has estimated that the number of deaths due to heat in this state will increase from 20 cases in 2001 to 300 cases in 2020 (7). Since 1960, more than 160 heat stress indices have been introduced to assess heat in various thermal environments (10). These indices are generally categorized into three groups: analytical (rational) indices (e.g. Heat Stress Index/HSI), experimental indices (e.g. Physiological Stress Index/PSI), and comfort indices (e.g Wet Bulb Globe Temperature/WBGT) (11-13).

WBGT is an experimental index introduced by Yaglue and Minard in 1957. This index was presented as ISO 7243 standard in 1989 and can be utilized in indoor and outdoor environments (14). Moran et al. (2001) proposed another index, known as Environmental Stress Index (ESI), which is calculated based on air temperature, relative humidity, and solar radiation. Using a large bulk of data, Moran et al. demonstrated that ESI strongly correlates with WBGT (15-18). Humidex is another experimental heat stress index which was first used in Canada in 1965 to measure heat stress and was subsequently revised by Masterson and Richardson in 1979 (19, 20). This index was previously used in both indoor and outdoor environments, but based on the results of more recent studies, it is recommended to be employed in outdoor environments (21). HSI – another heat stress index – was developed by Belding and Hatch in 1955 based on the thermal balance equation of human body (22, 23). Likewise, Sw_{req}, which is a rational heat stress index, was developed as an ISO standard (ISO 7933) in 1985 and in accordance with the thermal balance equation (24, 25). Among the above mentioned indices, humidex is used for moderate environments and hot environments, and is not applicable to cold environments. Moreover, other indicators are mainly used to assess hot environments (21).

Different studies have investigated the interplay among thermal stress indices (26-30). Results have indicated that there are significant relationships between WBGT and ESI, on the one hand, and air temperature, relative humidity (27) and relative velocity on the other hand (26). Hajizadeh et al. demonstrated correlation coefficients of 0.958 (27) and 0.973 (26) between the two indices. Additionally, Moran et al. indicated that the correlation coefficient of the association between the two indices was 0.981 (15). In another study, the coefficient of the relation between the two indices in hot and dry and hot and humid environments were found to be 0.985 and 0.982 respectively (29). Likewise, Heydari et al. detected a strong correlation between Humidex and WBGT (r>0.98) (30).

Climate-related elements can affect human health and may cause various diseases. Furthermore, various heat stress indices have been developed to study the effects of thermal stress on human body. The present study was therefore designed to use different heat stress indices (including WBGT, ESI, Humidex, HSI, and SW_{req}) to:

1. Measure the environmental parameters of workplace
2. Assess the levels of thermal comfort by WBGT, ESI, Humidex, HSI, and SWreq
3. Examine the correlation between WBGT, ESI, Humidex, HSI, and SWreq and environmental parameters (air temperature, wind speed, and relative humidity)
4. Examine the correlation between WBGT, ESI, Humidex, HSI, and SW_{req} indices

Materials and Methods

Location of the study

This study was conducted in Kerman, a city located at 30.2839° N, 57.0834° E an elevation of 1753.8 meters above sea level. This city is the capital of Kerman province in the southeastern part of Iran (Figure 1) and has an arid climate (31).

Figure 1: Kerman's location in Iran (30°15′N 56°58′E)

Collecting data related to environmental parameters

Daily data from the environmental parameters including air temperature (°C), wind speed (m/s), and relative humidity (%) were obtained from the Meteorological Organization of Kerman. The organization measures these parameters every ten minutes during the day. Subsequently, the data registered between 6 AM and 9 PM and average values for every 24 hours of the first, fifteenth, and thirtieth days of each month were collected and divided into 7 groups (6 AM, 9 AM, 12 at AM, 3 PM, 6 PM, 9 PM, and the average for the entire 24 hours). The values for all indices were calculated in the light of these groups. The amounts of cloudiness and clothing insulation for various seasons and weather conditions of Kerman have been presented in Table 1. The metabolic rate was also considered to be 80 w/m^2.

Table 1. The amount of cloudiness and clothing insulation in various seasons in Kerman

Months	Metabolic rate (w/m^2)	Cloudiness (octane)	Clothing insulation (clo)
Jan-Feb-Mar	80	4	1.5
Apr-May-Jun	80	1	0.7
July-Aug-Sep	80	0	0.5
Oct-Nov-Dec	80	2	1.2

Fixed input values fed into Bioklima Software

Calculating heat stress indices (WBGT, ESI, Humidex, HSI and SWreq)

Wet-bulb globe temperature

WBGT was developed by Yaglou and Minard in 1957 and is regarded as one of the main experimental indices for measuring heat stress (32). It can be used to assess heat stress both indoors and outdoors. Depending on where a person is, different variables, including natural wet temperature, radiation temperature, and metabolic rate, are used in calculating this index (33). For indoor spaces, natural wet temperature and bulb globe temperature are utilized in calculating this index, while, for outdoor spaces, air temperature is also taken into account (34). Bioklima was used to calculate WBGT (35).

Environmental stress index

Moran et al. (2001) introduced ESI, which is calculated based on measurement of air temperature (T_a), relative humidity (RH), and solar radiation (SR) using formula (1) (15):

Formula (1): ESI = 0.63Ta -0.03 RH+0.002 SR +0.0054 (Ta× RH) –0.073 (0.1+ SR)$^{-1}$

Where

T_a is air temperature (°C)

RH is relative humidity (°C)

SR is solar radiation (w/m^2)

In the current study, the environmental parameters of air temperature (T_a), relative humidity (RH), and solar radiation (SR) were measured and ESI was calculated using the above formula (16).

Humidex index

This index was developed by Canadian meteorologists in 1965 for measuring thermal dissatisfaction perceived by individuals in various outdoor climatic conditions. Later, the index was revised by Masterson and Richardson in 1979. Health and Safety Department of Canada developed formula 2 and 3 to calculate this index (11, 36). In this study, Bioklima was used to calculate Humidex (35).

Formula (2): Humidex =T + 0.5555 (vp-10)

Formula (3):

$$vp = 6.11 \times e^{\left(5417.753 \times \left(\frac{1}{273.16}\right) \times \left(\frac{1}{273.16+td}\right)\right)}$$

Heat stress index

As the most commonly used rational indces, HSI was developed by Bleding and Hatch in 1950. It is used for controlling thermal stress engineering by revising thermal equations of individual and environment.

HSI value may be negative or positive. The negative value indicates cold stress, while zero signifies that workers do not have any particular problem in terms of thermal stress. In addition, values over 30 are indicative of excessive heat stress (37). In the current study, the tool developed by Bioklima was used to calculate HIS (35).

Required Sweat Rate

This index was presented by the International Organization of Standardization in 1985 based on the thermal balance equation of human body (Code number: ISO 7933) (38). In the present study, Bioklima methodology was exploited to calculate Required Sweat Rate (35).

Comparing thermal perceptions of WBGT, Humidex and HSI according to standard values for each index. Table 2 presents a comparison of thermal perceptions based on the above mentioned indices (11, 22).

Table 2. Thermal stress indices normalised to the thermal sensation and heat stress category

Heat stress categories	WBGT (^{0}C)	Humidex	HSI (%)	Color code
extreme danger[1]	> 30	> 55	-	
Very strong[2] (danger[1])	28-30	45-55	>80	
Strong[2] (extreme caution[1])	23-28	40-45	40-80	
Moderate[2] (caution[1])	18-23	30-40	20-40	
No heat stress[2] (No danger[1])	< 18	<30	0-20	

[1] For WBGT and Humidex index
[2] For HSI

Statistical analysis

Collected data were analyzed by SPSS 22. We applied statistical tests such as Pearson correlation coefficient and linear regression. In addition, Excel 2016 was used to draw diagrams. The statistical significance level was set at P < 0.05.

Results

Mean and standard deviation of environmental parameters

Table 3 shows the mean and standard deviation of environmental parameters including air temperature, relative humidity, and wind speed for the twelve months of 2016. It should be noted that a huge table was required for presenting the mean values for every measurement hour (6 AM, 9 AM, 12 AM, 3 PM, 6 PM, and 9 PM). Due to lack of enough space, we did not present this table in the current paper and were only confined to demonstrating the monthly mean scores and standard deviations. The highest and lowest wind speed (m/s) during the 12 months respectively were from July (3.97 ± 1.20) and November (2.04 ± 0.88). Also, the maximum and minimum relative humidity were registered in November (42.91 ± 8.01) and July (7.42 ± 1.31) in that order. Finally, the highest air temperature (°C) mean score was recorded in June (31.36 ± 1.13), whereas the lowest value was registered in December (8.18 ± 2.36).

Table 3. Mean and standard deviation of environmental parameters for the twelve months of 2016

Hour	Parameters		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
24-hour mean	Wind Speed (m/s)	Mean	2.24	2.74	2.07	3.07	3.41	3.48	3.97	3.66	2.48	2.24	2.04	1.96
		SD*	1.81	1.42	0.67	1.25	1.39	0.87	1.20	1.08	1.04	0.70	0.88	1.03
	Humidity (%)	Mean	20.18	39.58	38.28	22.41	11.38	7.83	7.42	11.04	17.73	19.03	42.91	29.11
		SD	7.35	10.55	14.11	9.22	3.82	1.93	1.31	2.56	7.47	4.37	8.01	10.17
	Air Temperature (^{0}C)	Mean	9.99	9.54	13.72	20.92	28.09	31.3	29.8	27.83	25.40	23.17	12.61	8.18
		SD	3.91	4.76	5.22	3.50	2.50	1.13	1.38	1.09	2.83	1.47	2.93	2.36

*SD: Standard deviation

The values of WBGT, ESI, Humidex, HSI and SWreq

Table 4 displays mean and standard deviation of calculated indices (WBGT, ESI, Humidex, HSI and SW_{req}) for the twelve months of 2016. It should be noted that a huge table was required for presenting the mean values for every measurement hour (6 AM, 9 AM, 12 AM, 3 PM, 6 PM, and 9 PM). Again, due to lack of space, we did not present this table in the current paper. Therefore, the monthly mean scores and standard deviations were demonstrated. The highest mean scores for WBGT (18.69 ± 1.40), Humidex (26.71 ± 2.38), HSI (13.79 ± 7.39) and SW_{req} (40.14 ± 12.51) were recorded in June and maximum mean score for ESI (14.15 ± 2.53) was observed in July.

The highest values of WBGT (18.69 ± 1.40), Humidex (26.71 ± 2.38), HSI (13.79 ± 7.39), and SW_{req} (40.14 ± 12.51) were recorded in June. On the other hand, the greatest value of ESI (14.15 ± 2.53) was observed in July.

Table 4. Mean and standard deviation of the WBGT, ESI, Humidex, HSI and SWreq indices in a 24-hour period in 12 months of 2016

24-hour mean of Indices			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
24-hour mean	WBGT (ºC)	Mean	-0.53	4.24	1.33	9.72	9.54	18.69	13.50	11.33	9.29	7.71	6.77	-3.18	7.37
		SD	4.00	3.83	4.04	1.46	0.67	1.40	2.58	2.34	1.72	0.96	4.81	2.62	2.54
	ESI (ºC)	Mean	0.36	3.48	-0.86	10.06	10.10	11.98	14.15	12.02	9.88	7.89	3.45	-4.44	6.51
		SD	3.75	4.27	4.78	1.23	0.55	0.73	2.53	2.19	1.84	0.69	4.83	1.73	2.43
	Humidex (ºC)	Mean	-1.66	2.56	-0.03	12.06	12.02	26.71	18.23	14.89	11.74	9.08	4.06	-5.52	8.68
		SD	5.17	1.88	5.34	1.96	0.89	2.38	4.02	3.37	2.64	1.18	7.02	2.91	3.23
	heat stress index (%)	Mean	-3.61	6.54	2.55	3.22	5.99	13.79	10.01	3.12	-4.56	7.59	-1.37	-13.32	2.50
		SD	6.01	5.98	6.88	2.25	3.83	7.39	6.75	5.70	5.67	2.10	8.85	3.70	5.43
	Swreq (W/m²)	Mean	-13.80	23.26	6.97	7.17	19.17	40.14	36.55	10.99	-16.41	26.70	-6.54	-46.06	7.35
		SD	22.80	21.08	23.83	2.18	11.59	12.51	24.76	20.71	20.50	6.66	28.86	18.22	17.81

The correlation between WBGT, ESI, Humidex, HSI and SWreq indices and environmental parameters (wind speed, relative humidity and air temperature)

Results indicated that WBGT, ESI, Humidex, HSI, and SW_{req} were significantly associated with environmental parameters including wind speed, relative humidity, and air temperature ($P < 0.05$) (Table 5). The correlation coefficients of the above mentioned heat stress indices and wind speed ranged from 0.38 to 0.45, while the coefficients between heat stress indices and air temperature varied from 0.85 to 0.99. Also, the correlations between heat stress indices and relative humidity were negative with coefficients ranging from 0.62 to 0.76 (Table 5). Moreover, the highest slope value belonged to the relationship between SW_{req} and air temperature (Slope = 4.98).

Table 5. The correlations between heat stress indices (WBGT, ESI, Humidex, HSI, and SWreq) and environmental parameters (wind speed, relative humidity, and air temperature)

Environmental parameters		ESI	WBGT	Humidex	SWreq	HIS
Wind Speed	Pearson Correlation (r)	.45	.45	.38	.43	.42
	P	.001	.001	.001	.001	.001
	Slope	1.89	1.68	2.20	14.18	3.69
Relative humidity	Pearson Correlation (r)	-.76	-.69	-.70	-.63	-.62
	P	.001	.001	.001	.001	.001
	Slope	-0.29	-0.23	-0.36	-1.86	-0.49
Air Temperature	Pearson Correlation (r)	.99	.99	.97	.86	.85
	P	.001	.001	.001	.001	.001
	Slope	.74	.65	.98	4.98	1.33

The presented diagrams in Figure 2 demonstrate the correlations and regression lines for the associations between heat stress indices (WBGT, ESI, Humidex, HSI, and SW_{req}) and air temperature.

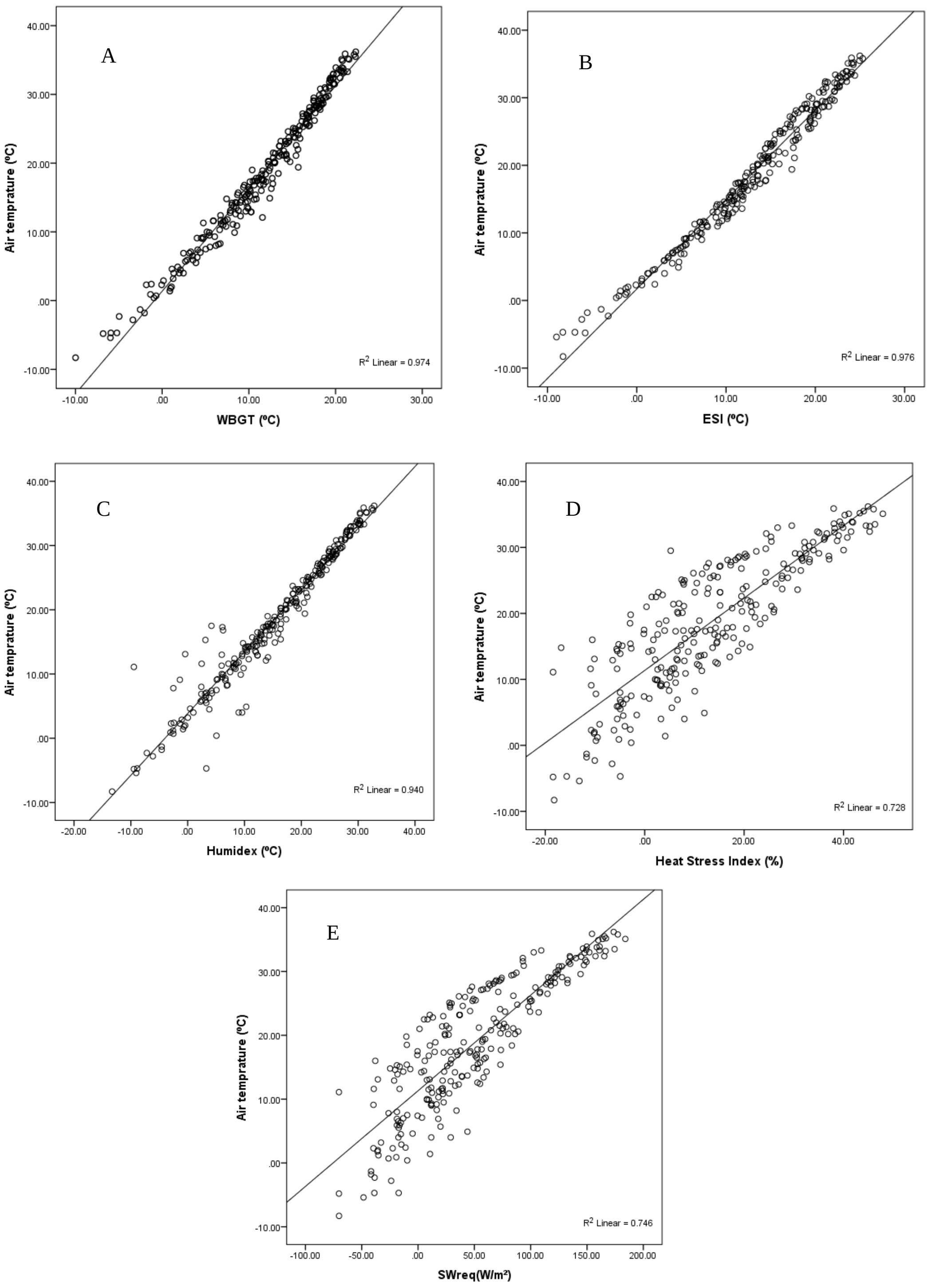

Figure 2. The correlations and regression lines indicating the relationship

(A) the correlation and regression line showing the relationship between WBGT and air temperature; (B) the correlation and regression line showing the relationship between ESI and air temperature; (C) the correlation and regression line showing the relationship between Humidex and air temperature; (D) the correlation and regression line showing the relationship between HSI and air temperature; (E) the correlation and regression line showing the relationship between SW_{req} and air temperature.

The correlations among WBGT, ESI, Humidex, HSI, and SW_{req}

The correlations among WBGT, ESI, Humidex, HSI, and SW_{req} are illustrated in Table 6. As can be observed, all correlations were statistically significant ($P < 0.05$) with high correlation coefficients that indicate strong correlations among heat stress indices.

Table 6. The correlations among WBGT, ESI, Humidex, HSI, and SWreq

Indices		ESI	WBGT	Humidex	SWreq	HSI
ESI	Pearson Correlation (R)	1	.99	.96	.86	.86
	P		.001	.001	.001	.001
	Slope		.88	1.3	6.66	1.79
WBGT	Pearson Correlation (R)	.99	1	.97	.84	.84
	P	.001		.001	.001	.001
	Slope	1.11		1.45	7.33	1.97
Humidex	Pearson Correlation (R)	.96	.97	1	.88	.87
	P	.001	.001		.001	.001
	Slope	.71	.63		5.02	1.35
SW_{req}	Pearson Correlation (R)	.86	.84	.88	1	.99
	P	.001	.001	.001		.001
	Slope	.11	0.09	0.15		0.27
HSI	Pearson Correlation (R)	.86	.84	.87	.99	1
	P	.001	.001	.001	.001	
	Slope	.41	.35	.57	3.67	

The diagrams presented in Figure 3 illustrate the correlations and regression lines for the indices with strong correlations.

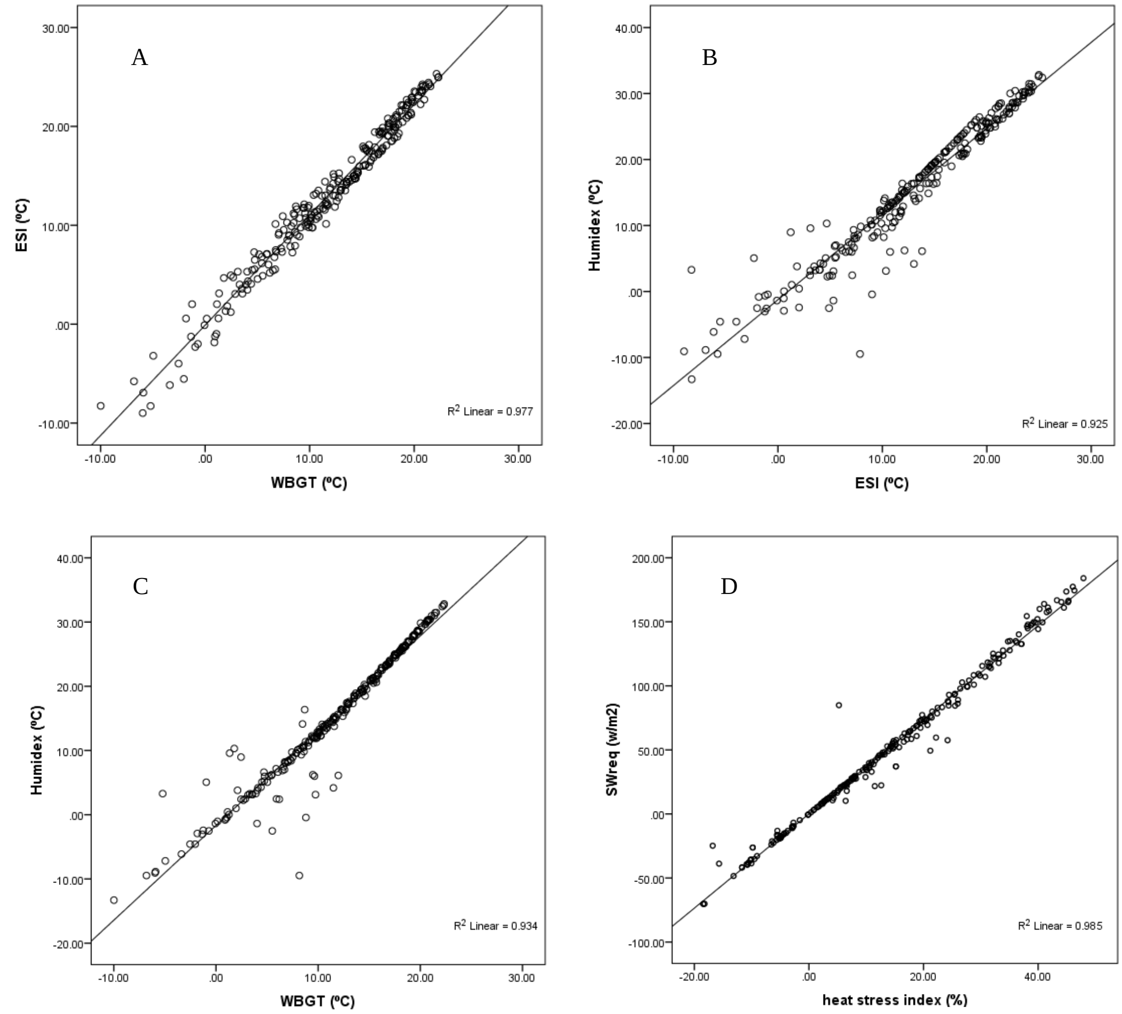

Figure 3. The correlations and regression lines indicating the relationship (A) WBGT and ESI; (B) ESI and Humidex; (C) WBGT and Humidex (D) HSI and SWreq.

Comparing 24-hour mean values of heat indices (WBGT, ESI, Humidex, HSI, and SW_{req})

Figure 4 provides a comparison for 24-hour mean values of heat indices (WBGT, ESI, Humidex, HSI, and SW_{req}) for the 12 months of 2016.

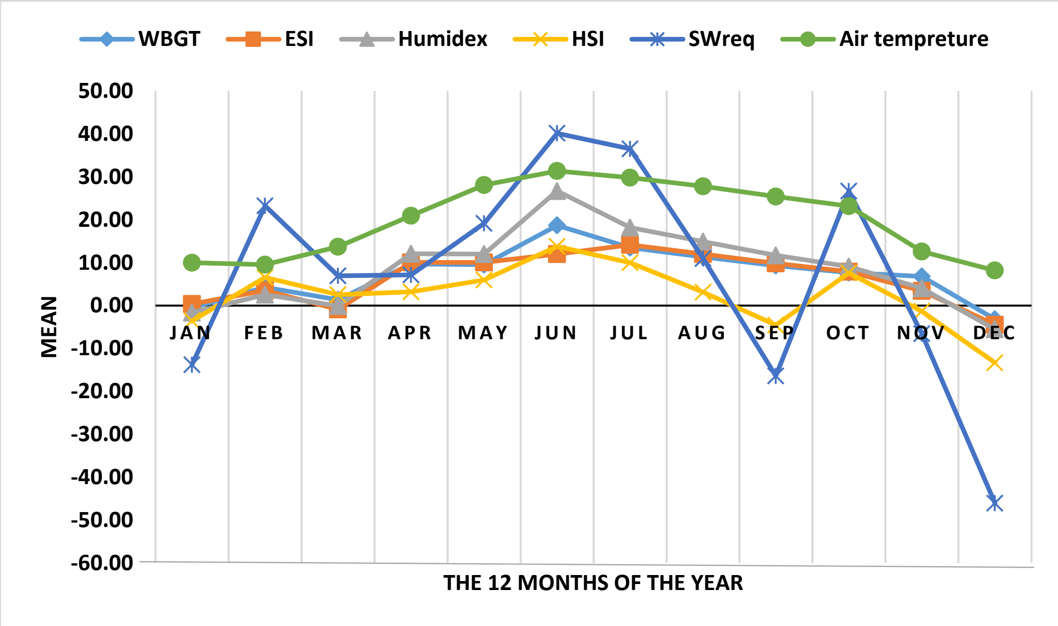

Figure 4. Comparison of 24-hour mean values of WBGT, ESI, Humidex, HSI, and SWreq, and air temperature during various months of 2016

Table 7 presents 24-hour mean values of WBGT, Humidex, and HSI and makes a monthly comparison among them (also see Table 2).

Table 7. Comparing thermal stress based on WBGT, HSI, and Humidex

24-hour mean of Indices		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
24-hour mean	WBGT	-0.53	4.24	1.33	9.72	9.54	18.69	13.50	11.33	9.29	7.71	6.77	-3.18	7.37
	Humidex	-1.66	2.56	-0.03	12.06	12.02	26.71	18.23	14.89	11.74	9.08	4.06	-5.52	8.68
	HSI	-3.61	6.54	2.55	3.22	5.99	13.79	10.01	3.12	-4.56	7.59	-1.37	-13.32	2.50

Discussion

The present study investigated thermal stress in Kerman using WBGT, ESI, Humidex, HSI, and SW_{req}. Thermal stress indices were measured in various times during the 12 months of 2016. The results indicated that thermal stress parameters (WBGT, ESI, Humidex, HSI, and SW_{req}) were closely connected with environmental parameters (wind speed, relative humidity, and air temperature) ($P < 0.05$). Thermal stress indices had direct and strong relationship only with air temperature. Moreover, the highest slope value was recorded between ESI and WBGT with air temperature (Slope = 0.99). On the other hand, thermal stress indices had insignificant relationships with wind speed ranging from 0.38 to 0.45. Also, slope value between thermal stress indices and relative humidity was not remarkable. On the other hand, thermal stress indices had moderate relationships with relative humidity varying from -0.62 to -0.76 (Table 5).

Hajizadeh et al. demonstrated significant associations between WBGT/ ESI and environmental parameters including air temperature and relative humidity (27). In another study, the same researchers showed that WBGT and ESI were also significantly connected to wind speed. Their results are similar to our findings. Furthermore, in both studies, weak correlations were observed between WBGT/ ESI and air temperature/relative humidity. Additionally, in one of these studies, a poor relationship was also detected between WBGT/ ESI and wind speed. By the same token, the correlation coefficients obtained between WBGT/ ESI and air temperature were both equal to 0.99. On the other hand, WBGT had a coefficient of 0.69 with relative humidity, while ESI registered a coefficient of 0.76 with the same environmental parameter. In the study conducted by Hajizadeh et al, the obtained coefficients for the relationships between WBGT/ ESI and environmental parameters were close to each other and were very much similar to our findings (27).

In this study, all indices were significantly and strongly correlated with one another ($P < 0.05$). The highest correlation coefficients were observed between ESI and WBGT ($r = 0.90$, Slope = 1.11), Humidex and ESI ($r = 0.96$, Slope = 1.3), Humidex and WBGT ($r = 0.97$, Slope = 1.45), and SW_{req} and HSI ($r = 0.99$, Slope = 3.67) (Table 6).

Moran et al., who aimed at replacing ESI with WBGT, showed that the correlation coefficient between these two indices was 0.981 (15). In another study, Moran et al. evaluated the use of ESI in hot and dry environments versus hot and humid environments. They reported correlation coefficients of 0.985 and 0.982 between WBGT and ESI for each of the above mentioned environments in that order (16). Additionally, Hajizadeh et al. studied the possibility of using ESI to assess heat stress in outdoor occupations. They detected a strong correlation coefficient ($r = 0.958$) between ESI and WBGT (ISO 7243) (27). Hajizadeh et al. also examined heat stress among outdoor workers in hot and arid areas based on meteorological data in Qom province. They reported a correlation coefficient of 0.973 between WBGT and ESI, a strong relationship which is also confirmed by the results of our study ($r = 0.99$) (26). Heydari et al. aimed at validating Humidex in assessing heat stress of outdoor occupations in arid and semi arid areas. They reported a strong correlation coefficient ($r > 0.98$) between Humidex and WBGT (30). In the current study, a considerable correlation coefficient ($r = 0.97$) was detected between these two variables as well.

Figure 3 shows that monthly mean values of WBGT, ESI, and Humidex are close to one another forming a particular pattern. These values are smaller than the mean scores of air temperature and are a function of variations in air temperature in various months. They reach the peak in hot months, and drop to the minimum in cold months of the year. Also, the correlation coefficients between the above mentioned thermal indices range from 0.96 to 0.99 (Table 6). On the other hand, the monthly mean values of HSI and SW_{req} are similar to each other; however, they follow a pattern that is more inclusive than that of other indices. A correlation coefficient of 0.99 was observed between these two indices (Figure 3) as well. It was also discovered that, based on the WBGT value, June had moderate thermal stress, whereas other months did not experience any thermal stress. Similarly, Humidex and HSI values indicated that there was no thermal stress in any months of 2016.

Zare by examining human comfort with respect to the climate indicators in hot and dry areas of Iran through collecting meteorological data of five years ranging from 2001-2006, concluded that SET of Kerman was lower than the thermal stress range (39). The results of the current study also showed that, according to the obtained values for ESI and Humidex, individuals experience a sence of thermal comfort duiring all months of the year. Moreover, the value obtained for WBGT reveals that individuals feel thermally comfortable all year long (save for January). Hence, thermal stress poses no threat to the residents of this city. Observing Kerman meteorological data in 2016, Zare et al. also concluded that thermal perception of WBGT is more identical to that of UTCI. They also demonstrated that, according to UTCI in Kerman, thermal stress is mild during January, February, March, Novermber, and December, and there is no thermal stress during the rest of the year except for June (40).

In general, it is concluded that, in this study, all indices had strong, significant correlations with one another ($P<0.05$). Furthermore, thermal indices had significant relationships with environmental parameters (wind speed, air temperature, and relative humidity) ($P < 0.05$). The highest correlation coefficients were registered between thermal indices and air temperature (0.85-0.99). Also, WBGT, HSI, and Humidex demonstrated similar thermal sensations.

There were some limitations in this study. We did not have access to metrological data prior to 2016. Additionally, the data were obtained from the already arranged meteorological stations, which cannot accurately reflect the condition of indoor spaces.

Ethical considerations

Ethical approval was obtained from the Ethics Committee of Kerman University of Medical Sciences (ID: IR.KMU.REC.1395.637).

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Conflicts of interest

The authors declare no conflicts of interest.

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