ORIGINAL ARTICLE

The Assessment of Thermal Conditions Using Humidex in Different Weather Conditions: A Case in Different Climates of Iran

Farideh Golbabaei[1], PhD;
Hamidreza Heidari[2], PhD;
Aliakbar Shamsipour[3], PhD

[1]Department of Occupational Health, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran
[2]Department of Occupational Health, School of Public Health, Qom University of Medical Sciences, Qom, Iran
[3]Department of Physical Geography, School of Geography, University of Tehran, Tehran, Iran

Correspondence:
Hamidreza Heidari, PhD;
Department of Occupational health, School of Public Health, Qom University of Medical Sciences, Qom, Iran
Tel: +98 25 37833361
Email: Hr.heidari.tums@gmail.com
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Abstract

Background: This study aimed to illustrate the applicability of the Humidex index for assessment of outdoor thermal environments in a wide range of weather conditions in different climates in Iran.
Methods: This is a cross-sectional study. Both field measurements (1452 measurements) and the long-term meterological data (between 1965 and 2009) were used in this research. After determining the appropriateness of correlation coefficients between these two types of data, only meteorological stations data were used to generalize the results to climatic regions. For this purpose, Arc/GIS 10.2 software was used.
Results: The results showed three levels of comfort including safe, caution and stress regions by graphical maps. The results showed that the center and south of the country, especially at the middle and the end of the shift hours, experienced more thermal stress in summer months (ranging from 39.60±1.07 to 49.29±2.13ºC for central areas and ranging from 47.76±2.59to 57.71±1.65ºC for southern areas. In the northern regions, most of the measurements in different stations and time periods at spring were in caution condition and less than 1% of them experienced stress conditions.
Conclusion: The dependence of this index on the minimum metrological parameters (temperature and humidity), which are easily measured and reported daily in meteorological stations, and its non-dependence on the globe temperature, which is an unusual parameter in the measured metrological parameters, can be used as advantages of the Humidex for assessment of the heat stress conditions in outdoor environments in different climates.

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Introduction

Heat is one of the most harmful factors in the workplace, which puts many people at risk, especially outdoor workers in the hot seasons and threatens their health. Many jobs, such as road and asphalt workers, farmers, construction workers, etc. are often done outdoors and the workers in these jobs are, therefore, more exposed to heat hazards than others.

Activity in such environments causes the human body to deviate from the state of thermal equilibrium, which is called heat stress, and in such conditions, the human body enters physiological responses to overcome the temperature pressure, which is called heat strain. Consequences of long-term exposure to heat lead to heat exhaustion disorders, heat syncope, heat cramp, heatstroke,[1] decreased physical and mental function, decreased productivity,[2,3] increased incidence of accidents, and decreased level of safety in the workplace.[4]

On the other hand, raising temperature induced by climate change and global warming can cause increased rates of mortality and morbidity associated with exposure to high ambient temperatures.[5] Many countries experience heat-related mortality during heatwaves throughout the summer.[6] Additionally, increase in ageing populations in high-income countries and rapid urbanization in many low-income countries can exacerbate the health effects of hot weather for exposed people.[7, 8] Some studies performed on climate changes in Iran showed that this country would also be accompanied by an increase in temperature, particularly in the south and central regions in the decades to come.[9] Climate changes and raising temperature can affect the outdoor workers more. Outdoor workers are exposed to many types of hazards that depend on their type of work, geographic region, season, and duration of time they work.

For assessing the heat stress condition, a lot of indices have been introduced in the last few decades,[10] the use of which requires special equipment to measure one or more environmental factors (dry temperature, wet temperature, radiant temperature, air velocity), occupational factors (estimation of thermal insulation of work clothes and work metabolism) and/or physiological responses of the body to heat (core body temperature, skin temperature, heart rate, weight loss due to sweating).[5] In addition, the calculation of some of these indicators, such as the predicted heat strain index (PHS) is long and complex and requires the use of a computer.[6] In some of them, such as the physiological strain index (PSI), the measurement process interferes with worker's activities and is practically difficult to use in the workplace.[7, 8] On the other hand, the wet bulb globe temperature (WBGT) index, which is adopted as a standard and common index, has a relatively long measurement process and its calculation depends on the globe temperature, which is not one of the common meteorological parameters that are measured and recorded daily.[11, 12]

On the other hand, various studies showed that being aware of the risks and having the necessary training play an effective role in reducing exposure to heat and preventing diseases and complications caused by heat.[13, 14] Heat health warning systems that trigger community alerts and emergency actions in response to forecasts of adverse weather conditions can help the community to take protective measures and avoid adverse health effects of excessive heat exposures. Undoubtedly, one of the systems that can play an important role in informing the public and reducing heat hazards when heat waves occur is the Meteorological Organization. It can measure atmospheric parameters affecting heat stress on a daily basis and then predicts and reports the state of heat stress using appropriate indicators.

One of the most widely used experimental indices is Humidex, which is a temperature and humidity index, and was initially recommended for both outdoor and indoor environments. This index was originally developed in Canada and was one of the thermal indicators used by the Meteorological Agency to determine the state of thermal stress and the presence or absence of thermal comfort in an area to be used for public awareness.[13]

Due to the conditions in Iran, which is mainly located in the desert and semi-desert regions and experience hot summers in most parts of the country, as well as the population of outdoor workers in this country, which according to non-official reports is estimated to be about three fold the number of employees in indoor environments, this study aimed to demonstrate a comprehensive view of the heat stress in Iran using the Humidex.

Methods

Climate Categorization

According to the main aim of the study, which was demonstrating a comprehensive view of heat stress situation in outdoor setting in Iran, different climates including hot and dry, hot and humid and temperate regions with different intensity were selected. Climate categorization was done based on DeMartonne climate classification after a few modifications for Iran.[15] Therefore, nine different climates, as shown in Table 1, were considered for heat stress evaluation. The climatic categorization was based on the prevailing weather in the hot seasons of the year and cold regions were not included due to the nature of the research, which involved the heat stresses. This categorization was carried out aiming to generalize the results to all provinces of the country with the same weather.

Study Environments

In this stage of the study, nine synoptic stations from nine provinces of the country were selected according to the climatic classification, so that each province represented a climate in the country. Then, one or more outdoor working environments at the closest distance to the selected meteorological stations were chosen for the study. The selected provinces and outdoor workplaces are shown in Table 1.

Heat Stress Assessment Based on Humidex

To assess heat stress assessment, we used one of the most widely used empirical indices, Humidex or HD index. This index is a temperature and humidity index, which was initially recommended for both

Table 1: Description of the studied environments

Climate category	Nominal category*	Synoptic stations	Studied outdoor environments	Number of working stations
1	Arid, cool and warm to very warm region	Qom	Open mine	25
2	Semi arid, moderate and very warm region	Ahvaz	Petrochemical products distribution	27
3	Semi arid, cool and warm region	Mashhad	Cement factory	30
4	Arid, cool and warm region	Kerman	Asphalt workplace	30
5	Arid, cool and very warm region	Yazd	Railway maintenance	24
6	Arid, moderate and very warm region	Bandarabbas	Shipbuilding workplace	27
7	Humid, cool and warm region	Sari	Agricultural fields	24
8	Semi Humid, cool and warm region	Gorgan	Construction workplace	25
9	Post Humid, cool and warm region	Rasht	Municipal services	30

*Cool in the nominal category is one of the properties of winter weather conditions, not necessarily spring and summer weather conditions which is emphasized on in this study.

outdoor and indoor environments. This index was definitively introduced in 1979 by Masterton and Richardson for correlating outdoor thermal discomfort of mild Canada's areas.[16]

The value specified by this index indicates the average human sensation of heat from its environment based on the combination of two parameters of temperature and humidity. HD calculation is based on a Thom's index modification[17] and it is expressed through the merely empirical equations:

$$HD = ta + \frac{5}{9} \times (Pas - 10) \quad \text{(Eq. 1)}$$

$$Pas = 6.112 \times [10^{\frac{7.5 \times ta}{237.7+ta}}] \times \frac{RH}{100} \quad \text{(Eq. 2)}$$

where *ta* is the air temperature in Celsius, *P* is the saturated vapor pressure of water in hPa, and *RH* is the relative humidity in percent.[13]

242 outdoor working stations from nine climatic regions including railway workers, farmers, shipbuilding, steel, cement and asphalt industry, etc. were evaluated in this investigation and heat exposure of outdoor workers was assessed. Environmental parameters including air temperature, wet temperature and relative humidity were measured simultaneously in three interval periods of the shift work at 9: 00 a.m., 12: 00 a.m. and 15: 00 relating to early, middle and end of the shift work, respectively. All measurements were done in the workplaces at approximately 1.5-2 meters' height, which corresponds to the average height of the vital organs of the human body in standing work position. Measurements were performed twice in the year (in spring and summer). According to the number of selected outdoor working stations (242 stations), the repetition of the measurements in a year (twice a year) and in a work-day (three times with a three hours' intervals), total measurements of environmental parameters were 1452. The measured environmental parameters were compared with the corresponding data measured at the nearest meteorological stations to the research site. For this purpose, first, the correlation coefficients between the measurement data in this study and the data measured simultaneously in meteorological stations were calculated. After determining the appropriateness of correlation coefficients (r>0.87 for air temperature and r>0.84 for relative humidity in different stations), only meteorological stations data were used to generalize the results to climatic regions with similar temperature and humidity characteristics. For this purpose, Arc/GIS 10.2 software was used.

To generalize the studied stations to similar climatic regions in the country, we used the long-term data of each weather station (between 1965 and 2009). Then, the calculated values of HD for each station were linked to similar climatic stations. The values of the indicator were categorized into the statistical software media according to the proposed limits of the index and then link to the climatic zoning of the data in the GIS information layers.

Based on the proposed limits of the index, three areas including safe or little discomfort (20°C≤HD≤29°C), caution or some to great discomfort (29.1°C≤HD≤45°C) and stress or dangerous limits (HD<45°C) were defined for the Humidex index.[13] Finally, the results of the heat stress situations in spring and summer, as well as the interval periods of a shift work were presented graphically on the several maps of Iran country using Arc/GIS 10.2.

Results

The range of environmental parameters measured in this study, regardless of the type of station selected and the season of year (Spring or summer), confirmed a wide range of environmental parameters including air temperature (from 14.6 to 46 ºC; Mean±SD= 31.63±6.18) and relative humidity (from 20.9 to 93.8%; Mean±SD=51.78±16.86%). The mean and standard deviations of these parameters are shown for each synoptic station in spring and summer in Table 2.

Based on the results shown in Table 2, in some stations located for example in Ahvaz (in the south-west of Iran) and Bandarabbas (in the south of Iran),

Table 2: Mean and standard deviations (Mean±SD) of the measured environmental parameters in each synoptic station

Synoptic stations	n*	Spring		Summer	
		t_a (°C)	RH (%)	t_a (°C)	RH (%)
Qom	150	25.60±4.89	50.99±14.45	36.18±3.83	30.65±6.33
Ahvaz	162	31.14±3.80	51.34±10.23	39.56±5.13	35.90±10.44
Mashhad	180	30.95±3.81	40.94±5.98	33.39±3.76	46.00±8.10
Kerman	180	24.42±2.60	45.85±6.23	32.55±2.99	35.07±7.67
Yazd	144	37.45±2.50	34.78±4.78	37.19±4.29	32.39±6.16
Bandarabbas	162	35.45±2.81	60.66±7.71	38.40±2.42	61.73±9.93
Sari	144	19.52±2.75	75.71±9.73	31.23±3.26	65.01±10.05
Gorgan	150	27.42±2.06	54.32±9.88	33.64±3.02	63.97±8.29
Rasht	180	26.60±2.82	72.17±8.10	29.60±2.72	73.77±8.09

*Number of working stations

Table 3: Mean and standard deviations (Mean±SD) of the Humidex in different times and synoptic stations

Synoptic stations	Humidex (°C)		
	Time of day	Spring	Summer
		Mean±SD	Mean±SD
Qom	9	24.42±5.13	34.19±0.62
	12	29.50±4.07	39.60±1.07
	15	30.98±2.17	43.18±1.10
Ahvaz	9	34.54±1.80	40.39±2.45
	12	38.46±4.35	47.76±2.59
	15	40.24±4.93	52.06±4.16
Mashhad	9	29.51±4.11	35.92±0.91
	12	36.91±2.22	39.54±4.11
	15	36.42±2.02	43.57±1.97
Kerman	9	23.67±2.92	32.12±3.73
	12	26.17±2.62	35.17±0.60
	15	26.27±1.90	36.22±1.39
Yazd	9	39.64±1.21	34.03±1.29
	12	43.79±1.69	40.75±1.56
	15	44.26±3.45	49.29±2.13
Bandarabbas	9	45.38±1.39	53.27±0.55
	12	48.16±0.44	56.68±1.97
	15	53.11±3.05	57.71±1.65
Sari	9	22.77±1.63	36.68±1.90
	12	22.95±3.65	42.99±0.83
	15	24.24±3.82	44.95±0.48
Gorgan	9	31.34±1.61	41.66±2.89
	12	32.58±0.63	48.04±3.68
	15	34.48±0.44	48.60±0.80
Rasht	9	31.32±0.83	38.53±1.98
	12	36.92±2.25	41.53±4.14
	15	36.07±3.87	42.49±3.45
Test result	**df**	**F**	**P**
One-way ANOVA between synoptic stations in spring	8	383.86	<0.001
One-way ANOVA between synoptic stations in summer	8	169.77	<0.001
Mean equality test in two seasons regardless of synoptic station type (t-test)	1414.70	t=-20.64	<0.001

the combination of air temperature and relative humidity is very high for both spring and summer. These can introduce high thermal stress for outdoor workers in these areas. On the other hand, some stations such as Rasht (in the north of Iran) have high relative humidity, which can create high thermal situations when combined with high air temperature.

In Table 3, the calculated values for Humidex (Mean±SD) in different times and synoptic stations were shown. In addition, the mean of differences between synoptic stations in summer and spring and mean equality test in two seasons, regardless of synoptic station type, were shown using One-way ANOVA and t- test (P<0.001). In other words, the heat stress situations based on humidex indicated significant differences between different synoptic stations as well as between different seasons (Spring and Summer). As shown in Table 3, over time, from the beginning of the shift to the middle and end of the shift, the humidex index increases. This means that the number of stations experiencing thermal discomfort increases over time, from the beginning to the middle and end of the shift. This situation was worst in summer rather than the spring. Figure 1. illustrates the graphic maps of thermal stress situation in the country based on Humidex in spring and summer at different intervals of work shift. Thermal stress zoning was done based on the reference limits for safe, caution and stress regions. Due to the nature of research that involves the heat stresses, cold regions, which is showed by yellow color in maps, were not included in this study.

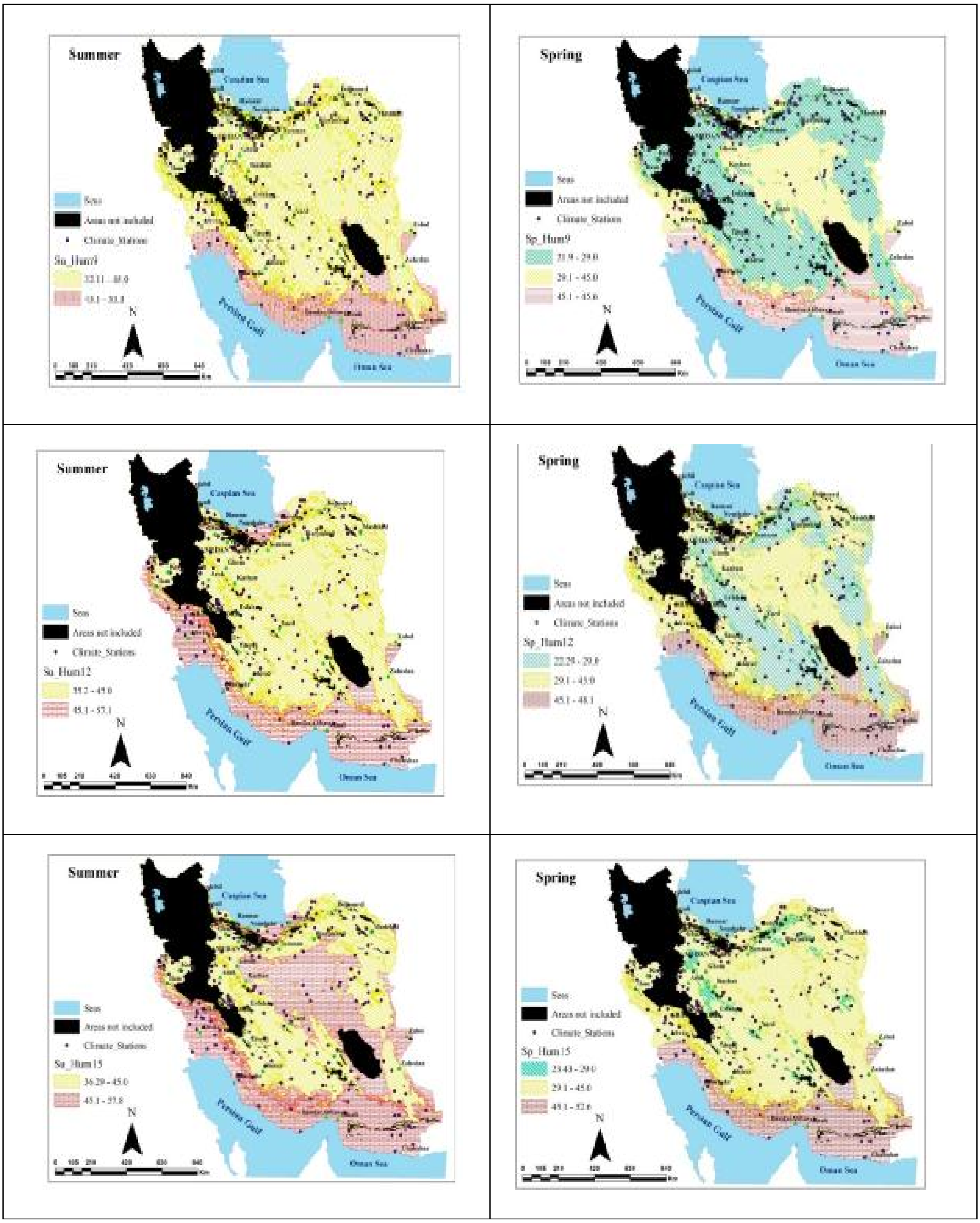

Figure 1: Graphic maps of thermal stress situation in the country based on Humidex in spring (three maps on the right) and summer (three maps on the left) at 9, 12 and 15 o'clock.

Discussion

This study aimed to present a general view of thermal stress situations in warm seasons in different climates of Iran. This assessment was performed based on the very common temperature- humidity index, Humidex, indicating thermal stress situation in three levels of safe, caution and stress areas. Many studies used metrological-based indices to offer a comprehensive view of thermal conditions worldwide.[14, 18-20] For example, thermo-hygrometric index, THI, was used to assess heat stress by estimation from the daily weather data. It has been observed that 72.99% days of summer months have discomfort scores ranging from 3 to 5. The number of stress events was high in the month of May (59.37%).[18] Thermal indices such as humidex, which is calculated only using recorded daily metrological parameters, have the advantage that they can be reported daily along with other atmospheric parameters. This can warn the exposed people (occupational or public populations) to take protective measures and keep themselves healthy. Heidari et al. showed that humidex could be used as a substitute for WBGT in evaluating of outdoor environments and had a good consistency with tympanic temperature of the exposed persons to heat.[21]

Based on the results presented in maps of Figure 1, the center and south of the country experience the maximum thermal stress in summer months, so that in no part of the country there are safe conditions; in contrast, most of them have experienced cautious or stressful conditions, especially in the middle to the end of the work shift. This condition was worst in Ahvaz, Yazd and Bandarabbas stations (Table 1). In one comprehensive investigation performed in Iran, the whole country was assessed to create climatic classification based on Tourism Climate Index (TCI). The results show that with the exception of the Northwest Territories (the areas which are not included in our research because it was assumed these areas were never involved with heat stress and probability of their placement in heat stress region was almost negligible) and in parts of the Northeast, which has favorable status in the summer, almost in the entire country inappropriate conditions can be seen.[19] Therefore, in non-occupational outdoor environments such as pleasure places, sports fields and so on, the heat stress is also the issue which should be paid more attention regarding the rising temperature in the future to take control measures. These findings are in tandem with the results of the present study. More intense heat stress can be seen in the South (the cities of Bandarabbas and Ahvaz) and Centre (the cities of Yazd and Qom) of the country. In Southern regions such as Bandarabbas and Ahvaz, the humidex values during middle and end of work shift were determined ranging from 38.46±4.35°C to 53.11±3.05°C, and 47.76±2.59°C to 57.71±1.65°C for the spring and summer, respectively. Based on the mean values of the index, only 25% of all measurements in different stations and time periods at spring were in safe condition. In addition, none of the measurements was in safe condition at summer.

In a study using the UTCI index, the state of heat stress in the south and north of Iran was compared. The findings showed that the southern coast of the country had moderate to very severe heat stress for at least 6 months of the year, so that in August the UTCI was recorded at 48, which indicates very severe heat stress.[22] However, in the north of the country, especially in the northwest and northeast, not only is there no heat stress, but also about 8 months of the year cold stress is seen in these areas. These findings confirmed the results presented in our research. The safe conditions at spring were observed in Sari station (the humid, cool and warm region in north of Iran), Kerman (the arid, cool and warm region in lower half of central Iran) and the early hours of work day in Qom (the arid, cool and warm to very warm region in the center of Iran). On the other hand, 74% of all measurements in different stations and time periods at spring were in caution condition and less than 1% of them experienced stress conditions at spring. These values were about 70% and 30 % at summer for caution and stress situations, respectively. The results of a similar study using Wet Bulb Globe Temperature (WBGT) index in different areas of Iran yielded similar results.[15] In another study, which investigated the trend of temperature changes in the coming decades with emphasis on heat stress in outdoor environments of Iran, it was found that the lowest WBGT index equal to 17.50±0.99°C was related to the early morning hours (at spring and in the northern regions of the country) and the maximum values was equal to 35.10±0.55°C related to noon and evening hours (at summer and in the southern regions of the country). In addition, it was found that most of the areas affected by climate change were the central and southern regions of the country, and in 2075 the highest temperature increase was expected in most parts of the country.[23]

Therefore, considering rising temperature in the future over the entire of the country, especially Southern and Central regions, which is reported in many studies,[23-26] and humidex values obtained in this study, it can be concluded that heat stress situation will be worse in future decades.

There are desert and very hot areas with long hours of radiation of the sun in the center of Iran[15]. Moisture is low in these areas and in some parts it is so low that, as shown in Table 2, the moisture level is as low as 30 to 40% at summer for nearly 44% of the studied stations. The southern areas of the country which have a desert climate and are very hot, due to the vicinity of the Oman sea and the Persian Gulf, not only experience very high air temperature (38.40±2.42°C), but also have high relative humidity (61.73±9.93%). The combined effect of these two environmental factors plays a vital role in heat stress incidence and discomfort in these areas. As the geographical maps show, throughout these areas heat stress exposure exists throughout shift hours in hot months, so that the minimum and maximum average of humidex was obtained to be 34.54±1.80°C (in the case of Ahvaz, 9:00 am, at spring) and 57.71±1.65°C (in the case of Bandarabbas, 3:00 pm, at summer), respectively. It means that the minimum and maximum values of the index at summer (32.12±3.73°C for Kerman station at 9.00 am and 57.71±1.65°C for Bandarabbas station at 3.00 pm, respectively are nearly 3°C higher than the maximum limits of the Index defined for the safe conditions and nearly 12°C higher than the ones for the caution conditions.

Since the air temperature in these regions is usually higher than the normal skin temperature (33°C-35°C), the body usually absorbs heat through convection and radiation. Since the body cannot lose adequate heat through convection and radiation, the only way to dispose of the body heat is evaporation of sweat from the skin surface.[27] On the other hand, because of high humidity, in such conditions, the efficiency of heat loss through evaporation is reduced. Thus, neglecting the optimization of working conditions, work-rest cycles and provision of cool and healthy water can introduce major problems to workers which may lead to unbearable working conditions. Considering thermal insulation and moisture permeability of the clothes required for proper heat exchange, heat stress will be aggravated if inappropriate characteristics of clothes such as material, thickness, color and so on relating to weather conditions are to be used.

Moreover, in the northern regions of the country (e.g. Sari and Rasht) due to the vicinity to the Caspian Sea on the one hand, and the existence of the Alborz Mountains with a little distance from the sea on the other hand, there are highly humid conditions (more than 70% in spring and summer). However, fortunately, in the spring due to the relatively low average air temperature (19.52±2.75 for Sari and 26.60±2.82 for Rasht station), heat stress usually cannot be seen even in the middle and final hours of work shift. The situation will change in the summer when warming air is combined with high humidity. Therefore, as shown in Table 3, in the middle and final hours of work shift, the humidex values are put in caution or some to great discomfort area. This is the case which has been well illustrated in maps of Figure 1. This is compatible with the results of heat stress assessment based on WBGT index throughout the country[15] and study of heat stress among farmers in the north of Iran.[28]

It should be noted that the values provided for thermal indicators are usually provided for healthy, young, and heat-acclimatized individuals, while many exposures in the workplace may involve people with different age groups, history of illness and non-acclimatized. In addition, working in hot environments when accompanied with raising work load, for example in the heavy works, or raising the amount of thermal insulation, as well as having protective devices, can impose extra heat load on the human body.

Conclusion

The dependence of this index to the minimum metrological parameters (temperature and humidity), which are all easily measured and reported daily in meteorological stations, and its non-dependence on the globe temperature, which is an unusual parameter in the measured metrological parameters have led to the expansion of the use of this index. The center and south of the country areas experience more thermal stress in summer months than other parts of the country. Most of the measurements in different stations and time periods at spring are in caution condition and less than 1% of them experience stress conditions at spring. Therefore, with regard to these findings and the fact that outdoor works in Iran are less organized and health supervision such as provision of plenty of cool and healthy water, regular work and rest cycles, and proper shelter to rest may not be sufficient for them; thermal stress status can be more troublesome and will require special attention.

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References

1 Dehghan H, Mortazavi SB, Jafari MJ, Maracy MR. Cardiac strain between normal weight and overweight workers in hot/humid weather in the Persian Gulf. International journal of preventive medicine. 2013;4(10):1147.

2 Azmoon H, Dehghan H, Akbari J, Souri S. The relationship between thermal comfort and light intensity with sleep quality and eye tiredness in shift work nurses. Journal of environmental and public health. 2013;2013.

3 Kjellstrom T, Gabrysch S, Lemke B, Dear K. The 'Hothaps' programme for assessing climate change impacts on occupational health and productivity: an invitation to carry out field studies. Global health action. 2009;2(1):2082.

4 Morabito M, Cecchi L, Crisci A, Modesti PA, Orlandini S. Relationship between work-related accidents and hot weather conditions in Tuscany (central Italy). Industrial health. 2006;44(3):458-64.

5 Dehghan H, Mortazavi SB, Jafari MJ, Maracy MR, Jahangiri M. The evaluation of heat stress through monitoring environmental factors and physiological responses in melting and casting industries workers. International Journal of Environmental Health Engineering. 2012;1(1):21.

6 Parsons K, Bethea D. The development of a practical heat stress assessment methodology for use in UK industry. Res Rep. 2002;8:20-5.

7 Budd GM. Wet-bulb globe temperature (WBGT)—its history and its limitations. Journal of Science and Medicine in Sport. 2008;11(1):20-32.

8 Gunga H-C, Sandsund M, Reinertsen RE, Sattler F, Koch J. A non-invasive device to continuously determine heat strain in humans. Journal of Thermal Biology. 2008;33(5):297-307.

9 Masuodian S. Investigation of Iran temperature at past half-century. Geogr Res. 2005;54:29-45.

10 Epstein Y, Moran DS. Thermal comfort and the heat stress indices. Industrial health. 2006;44(3):388-98.

11 Heidari H, Golbabaei F, Shamsipour A, Rahimi Forushani A, Gaeini A. The cut-off point for tympanic temperature as a heat strain index for evaluation of outdoor workers: a field study. International journal of occupational safety and ergonomics. 2018;24(2):224-32.

12 Parsons K. Heat stress standard ISO 7243 and its global application. Industrial health. 2006;44(3):368-79.

13 Alfano FRdA, Palella BI, Riccio G. Thermal Environment Assessment Reliability Using Temperature—Humidity Indices. Industrial health. 2010:1008190028-.

14 Heidari H, Golbabaei F, Shamsipour A. Determination of air enthalpy based on meteorological data as an indicator for heat stress assessment in occupational outdoor environments, a field study in Iran. Journal of research in health sciences. 2016;16(3):133.

15 Heidari H, Golbabaei F, Shamsipour A, Forushani AR, Gaeini A. Outdoor occupational environments and heat stress in IRAN. Journal of Environmental Health Science and Engineering. 2015;13(1):48.

16 Masterton JM, Richardson F. Humidex: a method of quantifying human discomfort due to excessive heat and humidity: Environment Canada, Atmospheric Environment; 1979.

17 Thom EC. The discomfort index. Weatherwise. 1959;12(2):57-61.

18 Bhattacharya R, Pal S, Biswas G, Karmakar S, Banik R. An estimation of heat stress in tropics. Int J Eng Sci Tech. 2012;4(10):4302-7.

19 Farajzadeh M, Ahmad AA. Assessment and zoning of tourism climate of Iran using tourism climate index (TCI). 2010; 42 (71):4.

20 Thorsson S, Lindberg F, Björklund J, Holmer B, Rayner D. Potential changes in outdoor thermal comfort conditions in Gothenburg, Sweden due to climate change: the influence of urban geometry. International Journal of Climatology. 2011;31(2):324-35.

21 Heidari H, Golbabaei F , Arsang Jang S , Shamsipour A. Validations of humidex in evaluating heat stress in outdoor jobs in arid and semi- arid climates of Iran. Journal of health and safety at work. 2016;6(3):29-42.

22 Baaghideh M, Shakeri F, Mayvaneh F. Comparative Study of Thermal Stress on North and South Coasts of Iran. J Health Res Commun. 2017; 3 (3) :1-11.

23 Heidari H, Golbabaei F, Shamsipour A, Rahimi-Forushani A. Occupational Heat Stress in Outdoor Settings Considering the Regional Climate Change in the Future Decades in Iran. Iran Occupational Health. 2019;16(2):33-47.

24 Rahimi J, Malekian A, Khalili A. Climate change impacts in Iran: assessing our current knowledge. Theoretical and Applied Climatology. 2019;135(1-2):545-64.

25 Sharafi S, Karim NM. Investigating trend changes of annual mean temperature and precipitation in Iran. Arabian Journal of Geosciences. 2020;13(16):1-11.

26 Abbasi F, Asmari M. Forecasting and assessment of climate change over Iran during future decades by using MAGICC-SCENGEN model. 2011.25 (1): 70-83

27 Heidari H, Golbabaei F, Shamsipour A, Forushani AR, Gaeini A. Consistency between sweat rate and wet bulb globe temperature for the assessment of heat stress of people working outdoor in arid and semi-arid regions. The International Journal of Occupational and Environmental Medicine. 2018;9(1):1.

28 Heidari H, Golbabaei F, Shamsipour A, Rahimi-Forushani A, Gaeini A. Evaluation of heat stress among farmers using Environmenta l and biological monitoring: a study in north of Iran. International Journal of Occupational Hygiene. 2015;7(1):1-9.