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Relationship of Environmental, Physiological, and Perceptual Heat Stress Indices in Iranian Men

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ABSTRACT

Background: Heat stress is a known occupational hazard, which cause reduced exercise capacity. The purpose of this study was to evaluate the relationship among environmental, physiological, and perceptual heat stress indices in Iranian men.

Methods: This analytical study was carried out on 24 healthy men (age 23.34 ± 1.64 years) with normal body weight (body mass indices 21–25 kg/m^2) in low workload for 120 min under hot climates (22–32°C, 40% relative humidity). Physiological strain index (PSI), wet-bulb globe temperature (WBGT), oral temperature, heart rate (HR), and heat strain score index (HSSI) questionnaires were simultaneous measurements taken at any 5 min during the exposure and resting state the initial measurements.

Results: The results showed that the range of WBGT index was 20.47–31.40°C. Significant correlation were found among WBGT and HSSI (r = 0.995), PSI (r = 0.990), oral temperature (r = 0.991), and HR (r = 0.972) indices. Also, significant correlation were found among HSSI and oral temperature (r = 0.983), HR (r = 0.978), and PSI (r = 0.987).

Conclusions: The results have shown that simultaneous with the increase in valid indices of heat stress such as WBGT and PSI indices, the amount of HSSI has also increased with high power. Therefore, when there is no access to a reliable heat stress method such as WBGT, or PSI indices, HSSI, an observative and subjective heat strain method, can be used as a simple, fast in least 5 min, and inexpensive for evaluating the heat strain in Iranian men.

Keywords: Heat strain score index, physiological strain index, wet-bulb globe temperature

INTRODUCTION

The people response differentially to heat stress exposure and some of them are more susceptible to it than others.[1] When the human body is exposed to heat stress, either environmental external stress, the body attempts to maintain the above heat balance using a number of thermoregulatory mechanisms such as body core temperature, skin temperature, and heart rate (HR).[2] Prolonged exposure to high temperature and humidity can cause health dangers such as heat cramps, heat syncope, heat exhaustion, and heat stroke.[3] Symptom of heat exposure includes increasing the risk of accidents and decrease in productivity in work places.[4] The necessity of evaluating in order to control the heat stress by using the indices, measuring the amount of exposure

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with a worker without interfering the activity and its reflection.[5] Among empirical indices, wet-bulb globe temperature (WBGT) is by far the most widely used heat stress index throughout the world.[5] Physiological strain index (PSI) was developed to evaluate heat and physiological strain by measurement HR and body core temperature.[6] Heat strain score index (HSSI) was developed to evaluate perceptual responses in Iranian women and men in hot workplaces.[7] The HSSI scale includes variable, observative and subjective questions, relating to heat stress such as thermal and humidity sensation,[8] intensity of sweating,[9] intensity of suffering from heat, dimensions of the working space, intensity of fatigue,[10] intensity of thirst, and other probable effective factors onset heat strain. The main purpose of this study was to relationship among environmental, physiological, and perceptual heat stress indices in Iranian men.

METHODS

Twenty-four healthy adult men ([mean ± standard deviation (SD)]: Age 23.34 ± 1.64 years; height 188 ± 1. 74 cm; weight 79.60 ± 8.34 kg) of normal body weight (body mass indices 21–25 kg/m^2).[11] The sampling method was the invitation of the subjects, considering inclusion criteria for the study. The subjects were informed about the test procedures and signed participation consent. Before participation, each subject underwent a medical examination that included a complete spirometry testing. Voluntary participation forms that contain the administrative procedure were analyzed prior to heat exposure. The test was stopped when 85% of predicted maximal HR (220 – age) was reached or when the subject asked to stop or showed signs of over station and body temperature was reached 39°C. In addition to explaining the motivation for participate in a scientific research study was also charged a paid for the study.

Subjects were informed as to the nature of the study and potential risks of exposure to exercise in a hot climate chamber. None of the participants had a history of medical disorders for at least 6 months, nonsmokers, and avoided caffeine for 12 h before the experimental session. Selection and number of samples were based on the similar empirical studies.[6] The study was conducted in a climatic chamber (length 4.5 m, width 3.5 m, and height 3 m) at the Isfahan University of Medical Science, Department of Occupational Health Engineering, Isfahan, Iran. The subjects wore same clothing (shirts, pants, and socks), which the details related to the materials used in the Iranian men clothing including the weights of individual garments and ensembles, fabric composition, and body surface area coverage are presented in Table 1.

The subjects performed exercise in a hot-dry climatic condition of (22–32°C), 40% relative humidity for 120 min. After 15 min of the rest outside the climate chamber, the subjects in the chamber began light activity (low workload). Termination at any time was according to the attending physician's decision. During the rests and exposures, HR, and oral temperature (T_o) were continuously monitored and recorded at 5-min intervals. HR was measured using a Polar heart rate monitor (Polar Electro RS100, Finland)[12] and the oral temperature was measured by a medical digital thermometer (Digital Thermometer; Omron). The WBGT index was measured by heat stress monitor (Casella Microtherm Heat Stress Monitor, Casella, USA).[13]

For simultaneous measurement of physiological parameters, ratings of HSSI[7] were measured using a questionnaire validated scales witch asked to be filled out in the rests and exposures at 5-min intervals.[14] The PSI is a combination of core temperature and HR to show the overall system heat strain.[2] In this study, the oral temperature was calculated for core temperature because rectal temperature measurement was not possible.[7] The data were analyzed using correlation and regression Data are presented in this study as means ± SD. This study was performed after getting permission from the Ethic Committee in medicine and participant's informed about the test procedures and signed participation consent.

RESULTS

Twenty-four healthy normal men subjects completed the study. The physiological characteristics including mean and SD are presented in Table 2, for HR and oral temperature at low workload.

Table 1: Characteristics of various Iranian men clothing materials used

Ensemble type	Clothing ensembles	Body surface area covered (%)	Weight (g/m^2)	The density of warp yarns (cm^{-1})	The density of weft yarns (cm^{-1})	Icl		Fiber/content
						Clothing	m2°CW^{-1}	
Islamic clothing-summer	Pants	45	223.15	31	24	0.80	0.123	13.7% viscose, 86.3%
	shirts	61						
	Socks	7						

Oral temperatures reliably range from 0.3°C to 0.7°C lower than the core body temperature, averaging around 0.5°C lower than core body temperature. Core body temperature is recommended to remain below 38°C by National Institute of Occupational Safety and Health, and by the World Health Organization.[2]

The relationship among WBGT index, HSSI, HR, PSI, and oral temperature during low workload for 120 min. Significant relationships ($P < 0.001$) were observed among WBGT index and HSSI, HR, PSI, and oral temperature [Figure 1 and Table 3].

The relationship between HSSI and oral temperature in low workload for 120 min significant relationships ($P < 0.001$) were observed between HSSI and oral temperature [Figure 2].

Table 2: Physiological characteristics of subjects

Variable	Mean±SD
HR (resting)	73.38±9.74 bpm*
HR (low workload)	79.21±5.93 bpm
Oral temperature (resting)	36.92±0.35°C
Oral temperature (low workload)	36.70±0.45°C

*Beats per minute. HR=Heart rate, SD=Standard deviation

DISCUSSION

Physiological responses to heat stress such as increased HR, skin temperatures, sweat rate, and body core temperature. Personal factors such as acclimation state, habit individual, and fitness level affect an individual's response to heat stress.[15] When environmental temperatures are higher, the body gains heat stress. Heat transfer is dependent on the four factors of conduction, convection, radiation, and evaporation.[16] Although physical activity, environmental conditions (humidity, dry temperature, and wet temperature), and clothing define the level of heat stress, heat strain defines the physiological response of the stress.[17] So, having no protects against heat exposure can be considered a high hazard to the health, comfort, performance, and productivity at workplaces.[18] Several indices are applied for the heat stress on individuals.[5,13] Among analytical indices, PSI and of empirical indices, WBGT index are considerable.[13] HSSI was established and evaluated by Dehghan *et al*., which is an evaluating index of emotional – perceptual variables by a questionnaire method for assessing heat strain in Iranian women and men in hot workplaces.[7,19] In a study conducted by Tikuisis *et al*., perceptual versus

Table 3: Correlation coefficient between variables

Variables	HSSI index	HR	PSI index	Oral temperature	Dry temperature
WBGT index	r=0.995**	r=0.972**	r=0.990**	r=0.991**	-
HSSI index	-	r=0.978**	r=0.987**	r=0.983**	r=0.923**

**P<0.001. HSSI=Heat strain score index, WBGT=Wet bulb globe temperature, HR=Heart rate, PSI=Physiological strain index

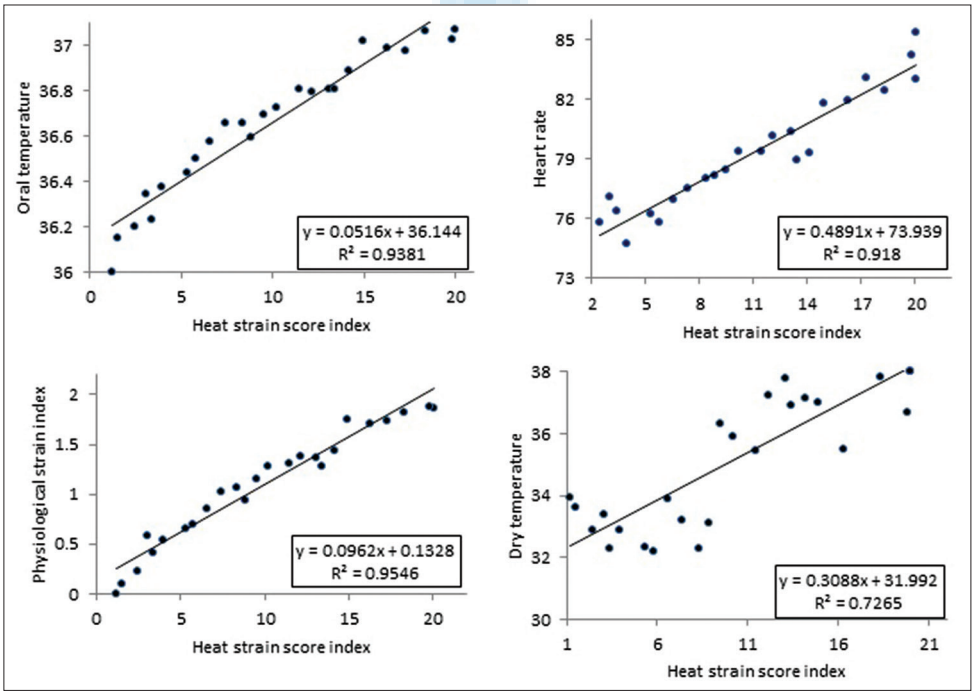

Figure 1: The scatter plot among wet-bulb globe temperature index, heat strain score index, heart rate, physiological strain index, and oral temperature

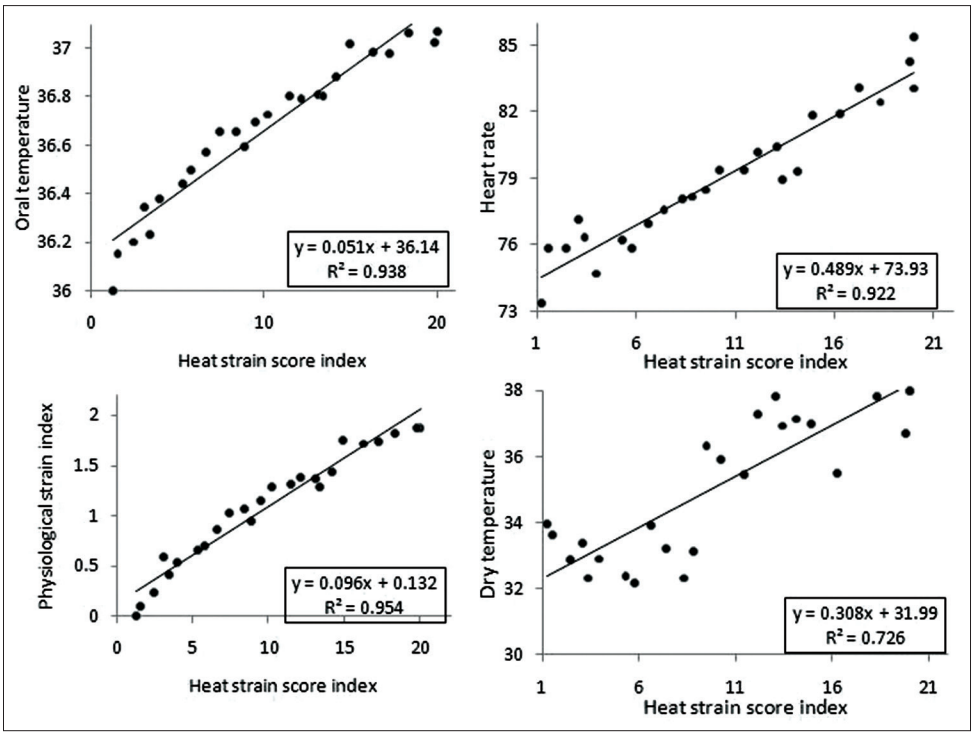

Figure 2: The scatter plot among heat strain score index and oral temperature, heart rate, physiological strain index, dry temperature

physiological heat strain during exercise-heat stress, based on normalized increases in body core temperature and HR, is matched by its perceptual analog. This research showed that the endurance trained underestimated and untrained consistently perceived their physiological strain, by PhSI, in accordance with the measured increases in body core temperature and HR throughout an exposure to uncompensable exercise-heat stress.[17] The results of our study showed that emotional – perceptual variables of HSSI which included main parameters (thermal sensation and rating of physical exertion) in accessed of heat strain in accordance with the measured increases in body core temperature and HR throughout an exposure to heat stress in sitting workload.

In a study conducted by Gallagher Jr *et al.*, development of a perceptual hyperthermia index to evaluate heat strain during treadmill exercise on firefighters and nonfirefighting volunteers participated while wearing thermal protective clothing. Moderate-to-strong correlations were found between body core temperature and perceived exertion and thermal sensation.[20] The results of our study showed that strong correlations ($P < 0.001$) were found between oral temperature and HSSI, which included all variables emotional – perceptual such as thermal sensation and perceived exertion. Furthermore, Gallagher Jr *et al.*, showed that strong correlations were found between perceived exertion and thermal sensation and HR, respectively ($r = 0.822–0.936$, $r = 0.862–0.916$).[20] Strong correlations ($P < 0.001$) were observed between HSSI and HR in this study.

Results of this study showed that the HSSI could be in high correlation with PSI and environmental variables ($r = 0.976$, $r = 0.992$), respectively.

CONCLUSIONS

The results showed that there was a direct and significant relationship between HSSI and physiological variables of HR, oral temperature, PSI, and WBGT index. So simultaneous with the increase in valid indices of heat stress evaluation such as WBGT and PSI indices, the amount of HSSI has also increased with high power. Therefore, it is concluded that when there is no access to reliable heat stress methods such as WBGT or PSI indices, HSSI, an observative and subjective heat strain method, can be used as a simple, fast in least 5 min, and inexpensive for evaluating the heat strain in men.

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