Original Article

The relationships between environmental and physiological heat stress indices in Muslim women under the controlled thermal conditions

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ABSTRACT

Aims: The aim of this study was to evaluate the relationship between environmental and physiological heat stress indices based on heart rate (HR), oral temperature for the estimation of heat strain, in veiled women in hot-dry condition in the climate chamber.

Materials and Methods: The experimental study was carried out on 36 healthy Muslim women in hot-dry climatic conditions (wet bulb globe temperature (WBGT) = 22-32°C) in low workload for 2 h. The HR, oral temperature and WBGT index were measured. The obtained data were analyzed using descriptive statistics and Pearson correlation tests.

Results: The results of the Pearson test indicated that physiological strain index was a high correlation (r = 0.975) with WBGT index (P < 0.05). Also, there was a good correlation among WBGT and HR (r = 0.779) and oral temperature (r = 0.981).

Conclusion: The findings of this study illustrated that there is a good correlation between environmental and physiological heat stress indices in veiled women with Islamic clothing at the low workload over the action limit (WBGT = 31°C). So that it can be concluded that the WBGT 22-32°C is a good indicator of the heat strain in veiled women with Islamic clothing.

Key words: Heart rate, heat stress, veiled women, wet bulb globe temperature

INTRODUCTION

High air temperature is a leading cause of weather related hazard in many regions of the world and heat exhaustion is the most common response to prolonged exposure to high outdoor temperatures.[1]

A natural reaction to heat stress by a working person is to reduce physical activity, which reduces the body's internal heat production.[2] This may be called "autonomous adaptation" to climate conditions.[3] An outcome of this preventive reaction is reduced time work capacity, labor productivity, and economic output during exposure to heat stress.[3]

An increase in ambient temperature can lead to an increase in occupational accidents, dizziness, loss of concentration,

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psychological disorders and result in reducing in the safety of people and making unsafe environment for them.[4,5] A relationship between heat stress and occupational accidents has been reported several times over the last 30 year.[6-8]

Heat stress can be evaluated by environmental and physiological indices. More heat stress indices based on one or more parameters environmental, sweat rate, heart rate (HR) and core body temperature.[9,10] Among empirical indices, the wet bulb globe temperature (WBGT) is used to evaluate heat stress.[11] Today, WBGT index is one of the most indices that used in the world. This index considered the combination of the effects of humidity rate, air temperature and thermal radiation.[12] Recently, Moran *et al*. introduced a new physiological strain index (PSI) based on rectal temperature (T_{re}) and HR as representative of the combined strain. It was shown that PSI index can be applied at any time, including rest or recovery periods, whenever T_{re} and HR are measured.[13]

There are different important factors for thermoregulatory both in men and women including specific physiologic factors in women (sex hormones, body water regulation, anthropometric specifications (weight and body size), body structure (muscles and body fat content) and social-behavioral specification (level physical activity).[14]

Due to lots of differences between men and women in exposure heat stress, and also due to difference in perceptions and emotional of gender with regards to the ambient temperature, it is necessary for the effect of heat stress in employed women to be evaluated.

The difference in temperature regulation is usually appeared by greater heat stress that is quite harmful to women in very hot environments. Clothing provides a barrier against biological, chemical, and physical agents of environmentally related disease, but in turn, can barrier heat dissipation. Also, the covering body by veiled women is more than Muslim men in Islamic communities that probably affect the heat transfer between the body and the environment. The purpose of this study was the relationships between environmental and physiological heat stress indices in veiled women under the controlled thermal conditions.

MATERIALS AND METHODS

Subjects

Thirty-six healthy young veiled women volunteered to participate in the study.

Before participation, each subject underwent a medical examination that included a complete Spirometry testing. Subjects were informed as to the nature of the study and potential risks of exposure to a hot climate chamber. All subjects signed a consent form.

Protocol

The study was conducted in the climatic chamber (length 4.5 m, width 3.5 m and height 3 m) at the Isfahan University of Medical Sciences, Department of Occupational Health Engineering, Isfahan, Iran. It should be noted that environmental condition without the heat radiation and the temperature was controlled. None of the participants had a history of medical disorders for at least 6 mo before the study. 12 h before exposure, not taken any coffee or caffeine and outside of the ovulation and menstrual cycle. The subjects clothing's were selected considering the characteristics of common Islamic clothing worn by Iranian veiled women (uniform, pants and scarf). To avoid interfering factors, the participants clothing were provided by the researchers from the same model and materials. The details related to the materials used in the Iranian female clothing including the weights of individual garments and ensembles; fabric composition and body surface area coverage are presented in Table 1. Furthermore, in order to determine the intrinsic clothing insulation, I_{cl} was used in this study that is referring to, the intrinsic or basic clothing insulation and can be defined as the insulation from the skin surface to the clothing surface.

Environmental conditions

Heat exposure was performed in one trial, a hot-dry condition (22-32°C), 40% relative humidity for 120 min without physical activity (passive exposure).

Measurements

Heart rate and oral temperature were continuously monitored and recorded at 5 min intervals during the rest and heat exposure. They were rested on the bed outside the climatic chamber for 15 min, then oral temperature and HR, as a base line, were measured. HR was monitored and recorded online through polar belt electrodes (polar electro Rs.100,

Table 1: Characteristics of various Iranian female 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}	I_{cl} Clo	I_{cl} M^2°CW^{-1}	Fibre/content
Islamic clothing — summer	Pants	45	253.46	34	24	0.80	0.123	13.7% viscose, 86.3%
	Uniform	61						
	Scarf	12						
	Socks	7						

Finland). Oral temperature was measured by a medical digital thermometer (digital thermometer; Omron).[14,15]

Calculations

Oral temperatures (T_o) have been validated as a good core temperature surrogate. Both electronic and single-use disposable thermometers can be reliably used. Eating or drinking within 15 min of the oral temperature measurement has been shown to have an impact on the accuracy, as does mouth-breathing during the measurement. Since T_{rec} is difficult to obtain in any situation other than the laboratory, surrogate methods have been tested, and these are expensive, however, and are invasive by nature.[16] The PSI was calculated using T_o. As follows:

$$PSI = 5\,(T_{ret}\text{-}T_{re0})\,(39.5\text{-}T_{re0})^{-1} + 5(HR_t\text{-}HR_0) \times (180\text{-}HR_0)^{-1}$$

where T_{re0} and HR_0 are the initial T_{re} and HR, respectively, and T_{ret} and HR_t are simultaneous measurements taken at any time.

A PSI to evaluate heat stress, this simple-to-use index scales the strain to a range of 0-10 and can be used online or during data analysis, which 0 indicates the lack of heat strain and 10 represents the maximum heat strain.[13]

Statistical analysis

The data were analyzed using descriptive statistics, Pearson correlation by test SPSS 18 (SPSS Inc., Chicago). Data are presented in this study as means ± standard deviation (SD)

This study was performed after getting permission from the Ethic Committee in Medicine.

RESULTS

Subject characteristics

Thirty six subjects completed the study. The physiological characteristics and demographic including mean and SD are presented in Table 2 for HR and oral temperature at one trial.

The relationship between HR with WBGT index, dry temperature, wet temperature, and globe temperature with low workload was found as the direct and significant relationship between HR with WBGT index, dry temperature, wet temperature, and globe temperature [Figure 1].

Table 2: Demographic and physiological parameters of participants

Variable	Mean ± SD
Age	22.27 ± 2 years
Height	1.55 ± 1.26 m
Weight	55.82 ± 9.27 kg
Heart rate in resting	83.06 ± 9.41 bpm
Heart rate in low workload	87.91 ± 7.87 bpm
Oral temperature in resting	36.10°C ± 0.35°C
Oral temperature in low workload	36.89°C ± 0.22°C

SD: Standard deviation

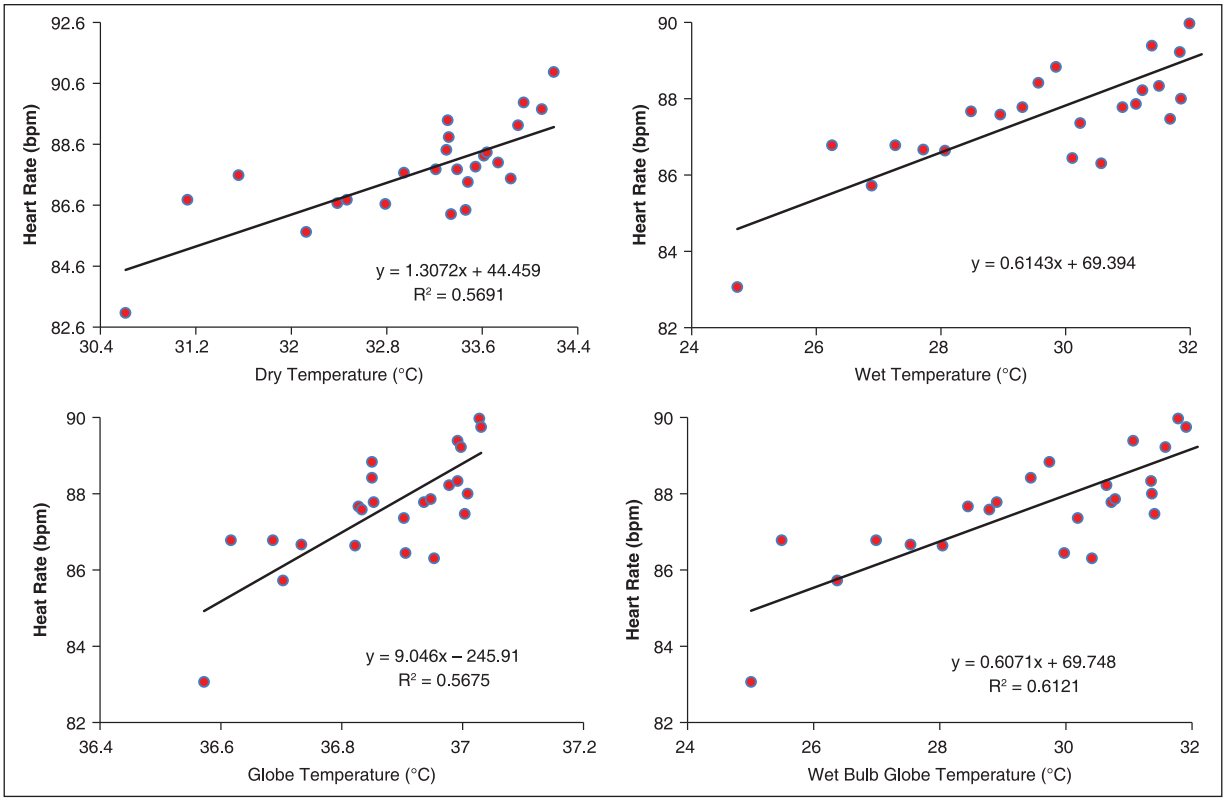

Figure 1: Relationship between heart rate with wet bulb globe temperature index, dry temperature, wet temperature, and globe temperature

The relationship between PSI index with WBGT index, dry temperature, wet temperature, and globe temperature in low workload was found as the direct and significant relationship between PSI index with WBGT index, dry temperature, wet temperature, and globe temperature [Figure 2].

The relationship between oral temperature with WBGT index, dry temperature, wet temperature, and globe temperature in low workload was the direct and significant relationship between oral temperature with WBGT index, dry temperature, wet temperature, and globe temperature [Figure 3].

DISCUSSION

The physical load, which accompanies heat stress exposure, can increase the risk of danger to the worker's safety and health. In turn, the heat stress burden could increase, and therefore so would the risk and occurrence of heat-related illness. These disorders can be reduced through providing work-rest cycles, acclimatization, fluid intake, change of clothes, and access to comfortable weather.[17] In addition, weather conditions (air temperature, radiant heat and humidity), level of physical activity, and type of clothing may also affect a person's risk for exertional heat-related illness.[18]

The assessment of heat stress can be used for evaluating the risk to workers about safety and health. The WBGT index provides a useful, first-order index of the environmental contribution to heat stress.[19] In 1998 PSI was developed to evaluate heat strain for both population of men and women in various activities at different weather conditions and PSI index based on rectal temperature (T_{re}) and HR was recently suggested to evaluate exercise-heat stress.[20]

In the present study, the PSI index was in the range of 0-2 that indicates that although the Muslim women were in Islamic cover clothing and in a not acclimatized exposure to heat under at low workload, however, Islamic cover clothing appears to have no detrimental effects on heat storage or heat strain during heat exposure.

Generally, physiological responses to heat stress include increased HR, skin temperature, sweat rate, and core body temperature. Personal factors such as an acclimation state, fitness level, and gender affect an individual's response to heat stress. Interpersonal differences in response to heat stress may be attributed to acclimation, cardiovascular fitness, and gender.[21,22]

The results showed that there is a direct and good correlation between HR with WBGT index ($r = 0.782$), dry temperature ($r = 0.757$) and wet temperature ($r = 0.796$), and also oral temperature with WBGT index ($r = 0.987$), dry temperature ($r = 0.913$), wet temperature ($r = 0.987$) and PSI index with WBGT index ($r = 0.975$), dry temperature ($r = 0.871$), and wet temperature ($r = 0.951$) ($P < 0.05$).

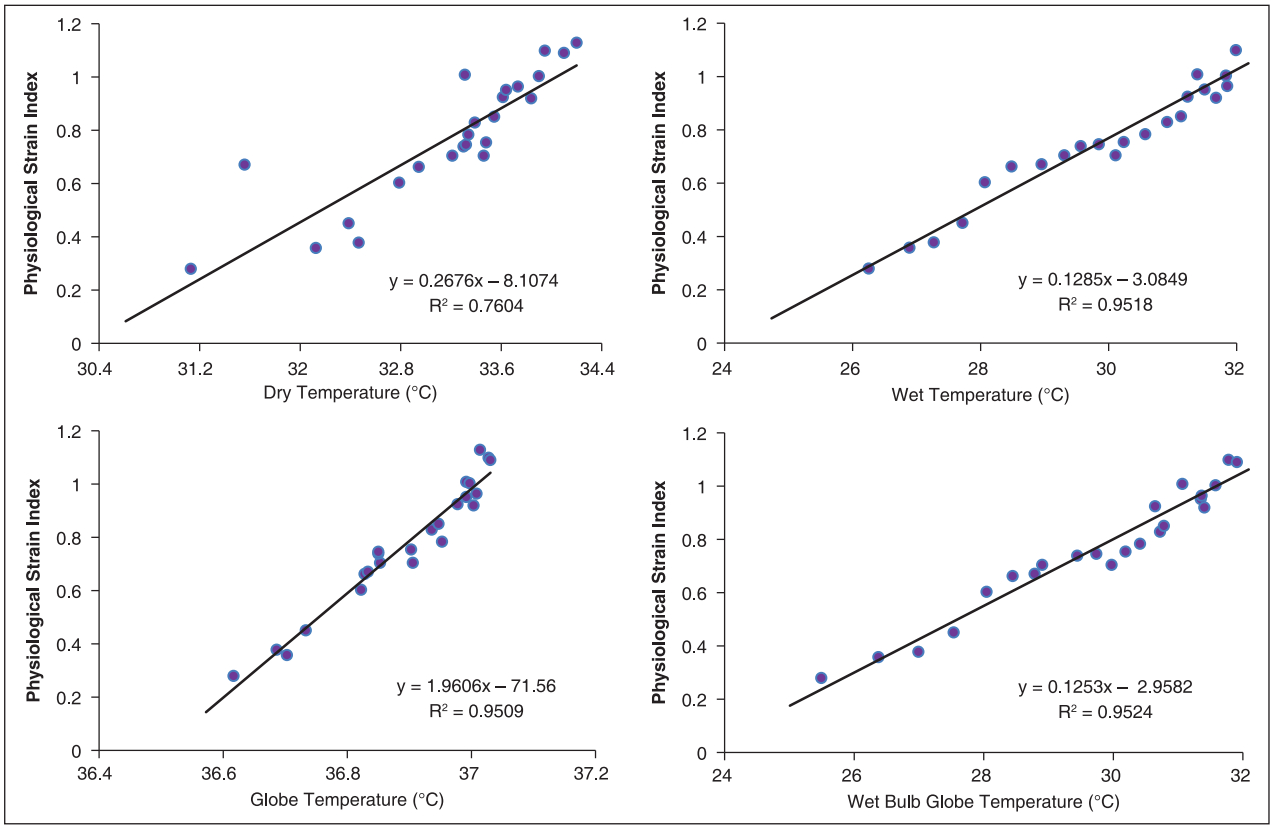

Figure 2: Relationship between physiological strain index with wet bulb globe temperature index, dry temperature, wet temperature, and globe temperature

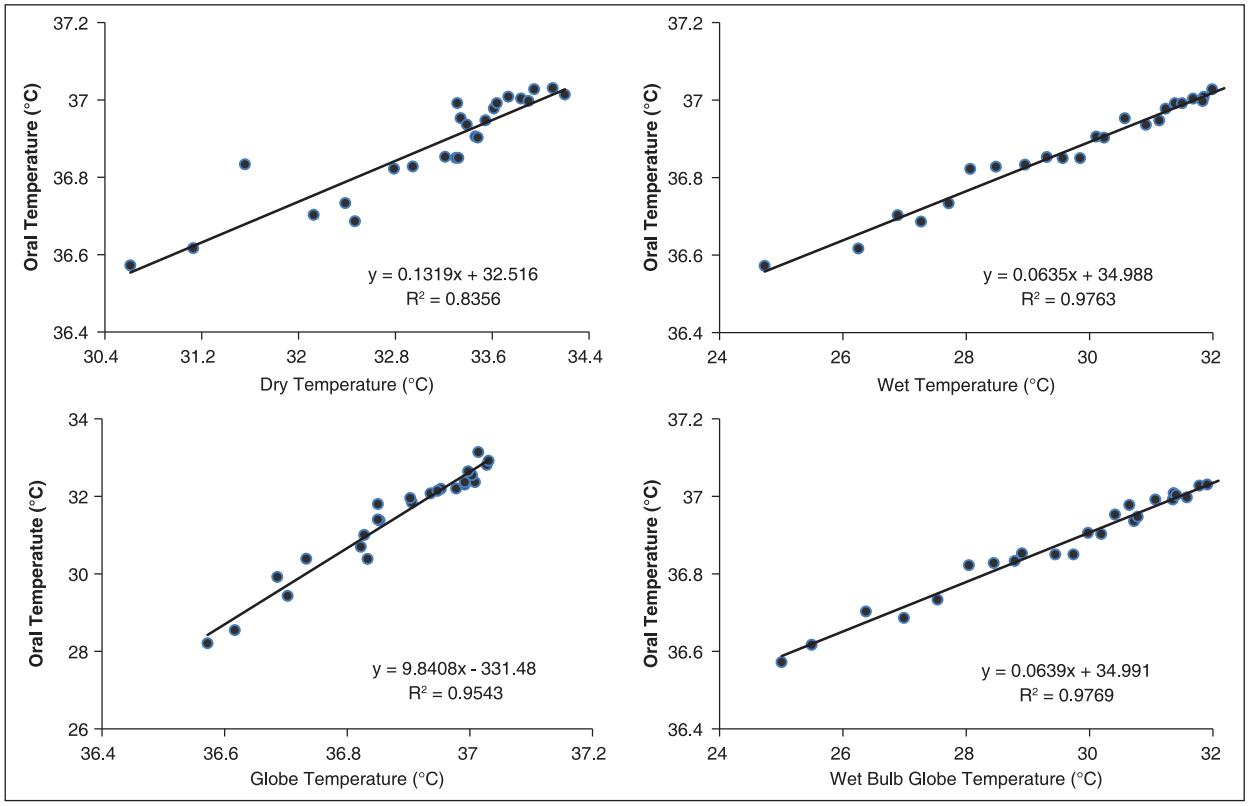

Figure 3: Relationship between oral temperature with wet bulb globe temperature index, dry temperature, wet temperature, and globe temperature

In a study conducted by Davis *et al*., on fluid balance, thermal stress, and postexercise response in women with Islamic athletic clothing was conducted; the results showed the mean HR of 154 ± 28 bpm in Muslim women with Islamic athletic clothing and 26 ± 151 bpm in traditional soccer uniform ($P < 0.05$).[23] In the present study, with an increase in heat exposure, HR increased in veiled women with Islamic clothing during low workload but, it was not exceeded the American Conference of Governmental Industrial Hygienists (ACGIH).[24] Although the results of our study showed an increase in HR and oral temperature in unacclimatization subjects in hot-dry condition during low workload through the study, it was not exceeded the threshold limit value (TLV).[4]

The ACGIH lists an indication of excessive ambient temperature as either a sustained WBGT index during low workload in unacclimatization subjects of <28°C.[24]

Although, in the present study, none of the participants had unacclimatized with the ambient temperature, and by reaching the WBGT index to the range of 32°C more than the amount recommended by ACGIH, physiological parameters were within TLV.[25] In this study although all subjects were with full Islamic clothing(uniform, pants, scarf) in exposure to hot-dry weather condition, the results showed that simultaneous with the increase in air temperature, the physiological parameters of HR and core body temperature increased too, but it was not exceeded the TLV.

CONCLUSIONS

The findings of this study illustrated that there is a good correlation between environmental and physiological heat stress indices in veiled women with Islamic clothing at the low workload over the action limit (WBGT = 31°C). So that it can be concluded that the WBGT 22-32°C is a good indicator of the heat strain in veiled women with Islamic clothing.

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