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Validation of a Questionnaire for Heat Strain Evaluation in Women Workers

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Original Article

ABSTRACT

Introduction: Physiological, anthropometrical and thermal perceptual are the most important factors affecting thermoregulation of men and women in workplaces. The purpose of this study was determining the validity of a questionnaire method for assessing women's heat strain in workplaces.

Methods: This cross-sectional study was carried out on 96 healthy women. Data were continuously collected over a period of 3 months (July-September) in 2012. Mean ± (SD) of age was found to be 31.5 ± 7.48 years, of height 1.61 ± 0.05 m, of weight 61.55 ± 10.35 kg, and of body mass index 23.52 ± 3.75 kg/m^2 in different workplaces. Heart rate and oral temperature were measured by heart rate monitoring and a medical digital thermometer, respectively. Subjects completed a draft questionnaire about the effective factors in the onset of heat strain. After collecting the questionnaires, the data were analyzed by applying Cronbach's α calculation, factor analysis method, Pearson correlation and receiver operator characteristic curves using the SPSS 18 software.

Results: The value for Cronbach's α was found to be 0.68. The factor analysis method on items of draft questionnaire extracted three subscale (16 variables) which they explained 63.6% of the variance. According to the results of receiver operator characteristic curve analysis, the cut-off questionnaire score for separating people with heat strain from people with no heat strain was obtained to be 17.

Conclusions: The results of this research indicated that this quantitative questionnaire has an acceptable reliability and validity, and a cut-off point. Therefore it could be used in the preliminary screening of heat strain in women in warm workplaces, when other heat stress evaluation methods are not available.

Keywords: Heat strain, questionnaire, women

INTRODUCTION

Heat is a physical hazard that could create problems almost in all working environments, especially during the warm months.[1] Heat stress has a significant relationship with reduced performance.[2-4] Hence, in recent decades the effects of environmental factors and an individual's factors on physiologic strains due to heat (heart rate, body core temperature and the sweat rate) have been attempted to be evaluated, and an index or criterion has been tried to be presented in a numerical frame known as as heat stress index.[5] Among the empirical indices, the wet bulb globe temperature index is used as the evaluating index for heat stress caused by environment factors. To calculate wet bulb globe temperature index, it is necessary to use wet bulb temperature (T_W), black globe temperature (T_g) and dry bulb temperature (T_a) (for outdoor).[6] The physiological strain index was established and evaluated by Moran, which is an evaluating index for physiological strains, considering the input load to the cardiovascular system and body thermoregulation.[7] Sometimes, the measuring process intervenes with workplace activities by some indices and its application is practically difficult in working fields. Sometimes the measuring process requires rather long time (wet bulb globe temperature index).[7,8] Although direct indices are more applicable as compared with other indices, they only involve the environmental variables such as wet bulb, dry bulb and black globe temperatures. In this regard, Cheung suggested that not only should physiologic responses be used in occupational confrontation standards, but the thermal perceptions that are perceptual responses to heat stress should also be considered.[9]

In a study performed by Dehghan *et al.*,[10] for content reliability and validation of the structure of the heat stress score index in the climatic conditions of Iran for the male population, results showed that the heat stress score index scale is a reliable and suitable method for screening heat stress in Iran. But regarding the anatomic, physiologic and emotional differences between men and women, the results could not be generalized and considered for women, since gender could also affect the rate of heart stress that a person could tolerate.[11] The results showed that although the density of activated sweat glands is greater in women, the sweat rate in young women and also old women is less than that in men. Therefore, sweat production by the glands is considerably low in women.[12] There are different important thermoregulatory factors both in men and women, including specific physiologic factors in women (sex hormones, body water regulation, exercise capacity, anthropometric specifications (weight and body size), body structure (muscles and body fat content) and social behavioral specification (daily physical activity).[13]

The results obtained at the end of three activities in a study by Gagnon *et al.*, showed that the body core temperature in women is 38.12 ± 0.18°C as compared with 37.52 ± 0.37°C in men and the esophagus temperature in women is 38.14 ± 0.20°C as compared with 37.41 ± 0.33°C in men. Thus women get tired sooner than men when performing activities and hence production rate decreases, and they need more time to rest while performing similar working activities.[14]

In a study by Yokota *et al.*, of women soldiers, five main factors of physical structure specification (tall–fat, tall–thin, average, short–thin, short, obese) were analyzed by anthropometric multiple considerations. Results under similar heat stress showed different tolerance levels, and that body core temperature (T_c) in these women was less than that in obese–short or fat–tall women.[15]

Due to a lot of differences between men and women regarding heat exposure and also due to differences in perceptions between men and women with regard to ambient temperature, it is necessary to evaluate the effect of heat stress in employed women. The difference in regulating temperature is usually evidenced by the greater body temperature that is quite harmful for women in very hot environments. Compared with men, women require (a) a considerable amount of fat that acts as an insulator and increases heat or thermal storage; (b) a thermoregulation system for high temperatures; and (c) less aerobic capacity, which increases the relative working load of an activity.[16] Researchers have found that men have less heart rate than women for a given level of heat stress.[17] Also the area of body covered is greater in women than men in Islamic communities, which probably affects the heat transfer between the body and the environment. Therefore, the purpose of this study was to validate a questionnaire for heat strain evaluation in women.

METHODS

Subjects

This cross-sectional research was performed on 96 healthy employed women, during summer in 2012. Mean ± (SD) of age was found to be 31.5 ± 7.48 years, of height 1.61 ± 0.05 m, of weight 61.55 ± 10.35 kg, and of body mass index 23.52 ± 3.75 kg/m^2 in different workplaces. They worked in different warm workplaces, including greenhouse settings, hospital laundry, and confectionary factories. Subjects were selected by systematic random sampling. The inclusion criteria were non-cold disease during the past week, diabetes, epilepsy, convulsion, hyperthyroidism, respiratory diseases, cardiovascular diseases, and not consuming medicines. The exclusion criteria were non-participation and non-cooperation in measuring heart rate and oral temperature. This study was performed after getting permission from the Ethic Committee in Medicine.

Measurements

After selecting a subject, her height and weight were measured (weight by a digital scale with 0.1-kg accuracy). The belt-like sensor of the heart-rate monitoring device (Polar Electro RS100, Finland) was fastened to the chest and the monitor was fastened to the participant's wrists.[18] Also, oral temperature was measured by a medical digital thermometer (Digital Thermometer; Omron). Oral temperature was measured for 5 min with a closed mouth and in conditions where environment temperature (ambient temperature) was over 18°C, prohibited from eating, drinking, and smoking for at least 15 min before the measurement, to reduce the effect of environmental conditions.[19] Heart rate and oral temperature were measured in the resting and working states. After 15 min of rest out of the warm workstation (cool place), heart rate and oral temperature were measured as baseline. Then the subject started to work, and heart rate and oral temperature were measured every 5 min for 120 min. For simultaneous measurement of physiological parameters, a questionnaire, including 45 items, was asked to be filled out in the resting and working states every 30 min for 120 min (four times). This questionnaire included the most important probable factors in onset of heat [Table 1].[20-24]

The value of Cronbach's α was calculated for reliability of the questionnaire. For validity of the questionnaire's structure, calculations regarding the correlation coefficient of the questionnaire's questions, exploratory factor analysis and confirmatory factor analysis were used. The maximum likelihood method was applied for estimating the model, and to consider the fitness of the model, χ^2 indices, (goodness-of-fit indices (GFI)), comparative fit indices (CFI), root mean-squared error of approximation (RMSEA), and root mean-squared residual (RMR) were used. If GFI and CFI were greater than 90%, it would indicate very appropriate fitness and if the indices were greater than 80%, it would indicate appropriate fitness. If RMR and RMSEA were less than 0.05, it indicated very suitable fitness and if they were less than 0.08, it showed acceptable fitness.[25] Finally, after calculating regression weight, which was obtained in the three-factor model, it was multiplied by the score on each of the questions selected by individuals and the total showed the total score on the questionnaire.

RESULTS

In this study the total number of participants was 142 and the mean ± SD of age was 31.5. ±7.48 years, of height 1.61 ± 0.05 m, of weight of 61.55 ± 10.35 kg, of working history 2.55 ± 0.62 years, and of body mass index of 23.52 ± 3.78 kg/m^2. In this study, internal stability of the questions was estimated by using a Cronbach's α value of 0.68, on 45 questions. The variable intensity of thermal discomfort had the highest correlation (0.71) and the variable shift work had the lowest correlation as compared with the total correlation. Kaiser Meyer Olkin (KMO) test was used to analyze the adequacy (sufficiency) of the sample volume. The value of KMO for the present research was 0.89, which indicates suitability of the number of samples for performing the factor analysis.

For validity and significance of the model, analyses with one, five, four, and confirmatory factor analysis with two and three factors, were used. Variables that had item–total correlation less than 0.24 were eliminated from the study. Finally, the structure was accepted according to filling the indices of a three-factor model with 16 variables. Eleven variables in the first factor (perceptual), three variables in the second factor (environmental), and three variables in the third factor (individual or personal) were considered [Table 2]. Entered variables in the perceptual factor with a factor loading of 0.20-1.36 were determined. Entered variables in the environmental factor with a loading of 0.35-1.09 were considered and entered variables

Table 1: Probable effective factors onset heat strain

Perceiving the air movement	Perceiving the temperature of adjacent levels	Perceiving heat radiant	Perceiving the rate of humidity	Perceiving the ambient temperature
Water temperature	Conditions for access to drinking water	Dimensions of the working space	Sunlight	Ventilation condition
Color of clothes	Type of clothes	Physical activity	Distance to cool rest area	Water salinity
Body posture	Exposure condition (continuous or discontinuous)	Duration of exposure	Type of personal protective equipments	Clothes material
Adaptation with heat	Limitation in leaving the workstation to drink	Complexion and working concentration	No of intervals for rest	Shift work
Condition for drinking water	Education conditions	Salt consumption	BMI	Age
Intensity of fatigue	Intensity of sweating	Limitations in l sweating	History of heat stroke	Number of glass of water consumed in a working shift
Clinical symptoms	Intensity of noise	Insomnia	Thermal discomfort intensity	Intensity of thirst
Menstruation conditions	Taking anti-pregnancy pills	Breast feeding	Pregnancy conditions	Hours of sleeping

BMI=Body mass index

Table 2: Regression weight of the entered variables in the three-factor questionnaire

Variables	Coefficient*	Variables	Coefficient*
Ventilation condition	0.65	Perceiving the ambient temperature	0.79
Body posture	0.21	Perceiving heat radiant	0.66
Perceiving the rate of humidity	0.59	physical activity	0.74
Perceiving the temperature of adjacent levels	0.46	Intensity of sweating	0.80
Perceiving the air movement	0.61	Intensity of fatigue	0.66
Sunlight	0.26	Intensity of thirst	0.75
Duration of exposure	0.35	Intensity of suffering from heat	0.83
History of heat stroke	0.16	Dimensions of the working space	0.37

*P<0.001

in the personal factor with a factor loading of 0.30-0.53 were determined. The first factor of 42.4, second factor of 12.9, and third factor of 8.3 were taken from the variance and the total of three factors, with a variance 63.6 being determined.

As shown in Table 3, the RMSEA, GFI and CFI indices indicate suitable fit and confirm the estimated model.

Pearson correlation test showed that there was a significant correlation between the questionnaire scores and oral temperature ($r = 0.414$, $P < 0.001$) and heart rate ($r = 0.247$, $P = 0.015$).

Oral temperature was selected as the decision criterion for determining the cut-off point, so that we considered an oral temperature of less than 37.5°C as no or low heat strain and more than 37.5°C as heat strain. Receiver operator characteristic analysis was used to calculate sensitivity, specificity, and cut-off point Area under the receiver operator characteristic curve [Figure 1], which is a global summary statistic of diagnostic accuracy, was 0.659 ($P < 0.033$). The appropriate cut-off point of the questionnaire was obtained to be 17, which will indicate the existence of heat strain in a person [Table 4]. Sensitivity and specificity were obtained to be 0.789 and 0.584, respectively, using this cut-off point.

DISCUSSION

Gender is one of the effective factors in heat exchange between the human body and the environment Hence evaluation and assessment of

Table 3: Fitness indices in the three-factor questionnaire

RMSEA	CFI	GFI	χ^2	AIC	BIC
0.022	0.995	0.978	102.376	244.376	574.312

RMSEA=Root mean-squared error of approximation, CFI=Comparative fit indices, GFI=Goodness-of-fit indices, AIC=Akaike information criterion, BIC=Bayes information criterion

Table 4: Values of sensitivity and specificity of the questionnaire in the cut-off point domain

Specificity	Sensitivity	Cut off
0.558	0.789	16.82
0.571	0.789	17.03
0.584	0.789	17.07
0.584	0.737	17.56
0.584	0.632	18.07
0.597	0.632	18.53
0.61	0.632	19.34
0.623	0.632	19.90
0.636	0.632	20.13
0.636	0.579	20.32

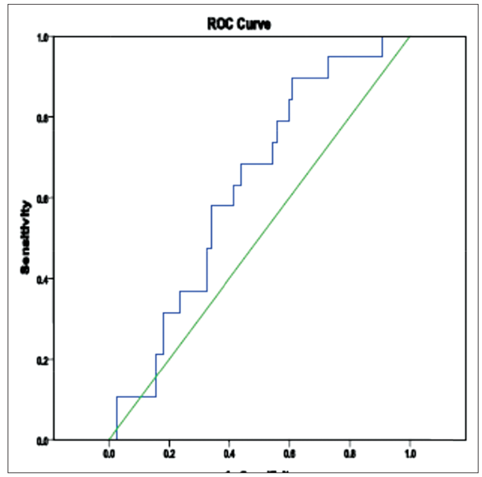

Figure 1: Area under the curve for determination of sensitivity and specificity

heat stress under different climatic conditions is essential among the male and female populations. Since men and women under heat exposure, in different studies, did not show similar results regarding heart rate and rectal temperature, under various climatic conditions and similar workplace activities,[12-14,17] therefore, the present study was performed with the aim of determining the validity of a questionnaire method to evaluate heat strain in women, in their workplaces.

In an perceptual–observational checklist, Bethea and Parsons[26] selected seven determining parameters for heat stress risk, of which five parameters, ambient temperature, humidity, radiant temperature average, air movement and rate of physical activity, had been entered into our questionnaire. Two variables type and material of the clothes had been eliminated from the questionnaire due to low item–total correlation.

The feeling of heat in human beings depends on their heat balance. Heat balance is in turn affected by physical activities, clothes, and climatic parameters such as ambient temperature, radiant temperature average, air velocity, and humidity.[27] All parameters apart from the variable clothes were accepted in our questionnaire with high factor loading. In a study performed by Maeen Zakaria, the most important parameters introduced in emergence of heat stress were physical activity, clothes, and climatic conditions, and the most important physiology responses to heat stress were heart rate, rectal temperature, and intensity of perspiration,[28] and all these parameters were considered in this investigation.

In a research done by Rodriguez[29] on the cooling responses to the heat stress, sweat rate was expressed as one of the most important mechanisms in cooling the body via skin. Also parameters ambient temperature, air velocity, and humidity were considered as the determining factors in sweat rate;[29] all the above parameters were accepted as being significant. Binkley *et al.*,[30] have recommended the use of the parameters consuming liquids and intensity of thirst during physical activities under warm climatic conditions. Mueller and Diehl[31] have stated the highest rate of heart stroke and mortality to be among athletes and people performing heavy physical activities.[31] Gaffin *et al.*, recognized sunlight intensity as the greatest source of receiving heat under warm climatic conditions and introduced direct exposure to heat sources and radiation temperature as the next factors for receiving heat, emergence of diseases, and heat exhaustion,[32] and the above items were entered into our questionnaire.

Chengalur *et al.*,[33] recognized ways of controlling heat stress in workplaces, including reducing air temperature, reducing humidity, increasing air velocity, reducing physical activity intensity, wearing suitable clothes, using a heat shield, work–rest programs, replacing fluids and electrolytes, heat adaptation, and instructing workers. All the parameters were considered in our questionnaire.

In a similar study that was performed on the male population, the variables type of clothing, color of clothing, material of clothes, type of personal protective equipments, and clinical symptoms had significant factor loading in a structured questionnaire,[10] whereas these variables had no significant factor loading in our questionnaire, therefore they were eliminated. Instead, the variables solar radiation, working dimensions, duration of heat exposure, and history of heat stroke replaced them.

The present study, which was performed among the population of women in rather warm areas, showed that the rate of heat stress was not so high in this population, the reasons for which may be: (1) due to sensitivity of women to high temperatures, most of the women were doing their heavy load work during the colder times of the day; (2) providing a cold resting area was provided at a distance near workstations; (3) had a rest time for eliminating tiredness and reducing heat stress; (4) existence of cool water sources near the workstations and in short distances, which compensation for body dehydration in the individuals; and (5) evidence show that aware workers who had been encouraged to self-pacing adjusted their work under heat stress conditions to prevent the physiological pressures imposed on them.

CONCLUSIONS

The results of this research indicated that the 16 variables in our questionnaire [Appendix 1], effective in onset of heat strain, could be measured by questions and observation including key factors in the domain of heat stress. This quantitative questionnaire also has an acceptable reliability and validity, and a cut-off point, and therefore it could be used in the preliminary screening of heat strain in women in warm workplaces, when other heat stress evaluation methods are not available The results of this study have not been under any other climate conditions, hence it is recommended that the prototype should be investigated in other climate conditions.

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APPENDIX 1

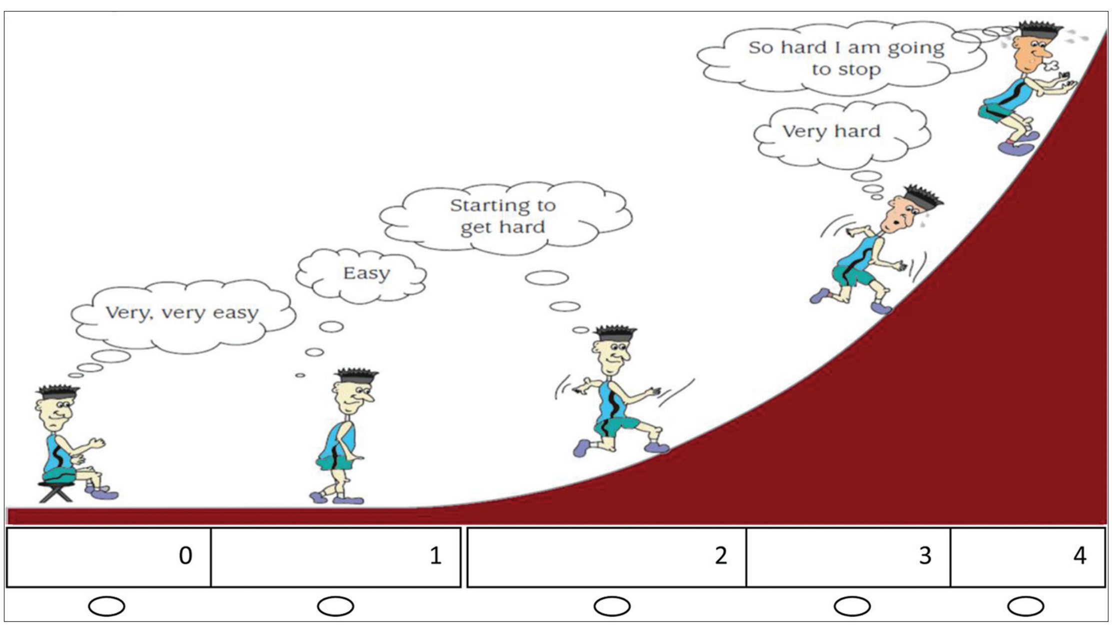
Heat Strain Score Index

Instruction for use of Heat Strain Score Index

1. Mark each question based on question of subject and your observation of the appropriate condition.
2. When completed, for each question, write your score in the" "primary score" column in the Total Score Calculation Sheet.
3. For Primary Score each question is multiplied by the effect coefficient and the final score recorded.
4. Add the final scores in the Calculation Sheet for total score result.
5. Total score, which is less than 17, indicates that the person has no thermal strain (Green Zone or safe level).
6. Total score greater than 17 indicates that onsets of heat-induced illnesses are very likely and appropriate control measures should be taken as soon as possible to reduce heat strain (Red Zone or danger level).

Questions

1. How do you feel your workplace air temperature?
   Very cold (–3)
   Cold (–2)
   Slightly cold (–1)
   Pleasing air or normal (0)
   Slightly warm (1)
   Warm (2)
   Very warm (3)
2. How do you feel the humidity level at your workplace?
   Dry (a feeling of dryness in the mouth and throat) (–2)
   Appropriate and desirable (0)
   Wet skin (1)
   Clothes sticking to skin surface (2)
   Fully wet skin (3)
   Sweat loss from skin surface (4)
3. How do you feel the temperature of adjacent surfaces due to contact with your hands?
   I feel too cold (–3)
   I feel cold (–2)
   I feel cool (–1)
   I do not feel cold or hot (0)
   I feel hot (1)
   Their heat cannot be tolerated (2)
   If my skin is in touch with them I will be burnt (3)
4. While you are working, the intensity of physical activity you do is like which of the following conditions?



5. How do you feel the flow of air in your workplace?
   Existence of cold weather circulation (–3)
   Existence of a cold weather current (–2)
   A gentle stream of pleasing air (–1)
   Sense of stability in the gentle flow of air or warm air (1)

Moderate flow of warm air (2)
An extreme current of hot air (3)

6. How much is the amount of sweating throughout your work?
   I do not feel sweat (0)
   I feel the sweat on the armpit and inguinal (1)
   I feel sweat on the chest and back (2)
   Sweating is so severe that the underwear clothing get wet (3)
   Sweating is so severe I feel it on my face (4)
   Sweating is so severe it is flowing all over my body (5)

7. How much fatigued are you at work?
   I'm not tired at all (0)
   I'm a little tired (1)
   I'm tired (2)
   I'm exhausted (3)
   I'm so exhausted I desire to have a break (4)

8. How much is the intensity of your thirst when you are at work?
   I don't get thirsty (0)
   I get a little thirsty (1)
   I get thirsty (2)
   I get very thirsty (3)
   I get so thirsty that my mouth and throat get dry and they can't be wet with saliva (4)

9. How intensively are you suffering from heat?
   I'm not annoyed (0)
   I'm a little annoyed (1)
   I'm annoyed (2)
   I'm very annoyed (3)
   I'm so annoyed I want to quit my job (4)

10. How is the ventilation system in your workplace?
   Active and high ventilation (−1)
   Appropriate ventilation, it is not needed to be ventilated (0)
   Inadequate ventilation (1)
   Despite lack of air conditioning, there is no ventilation (2)

11. If there are heat sources in your workplace, what do you feel when you are exposed to them?
   Feeling the thermal conditioning on the face (−1)
   Can be detected, feeling of heat radiation but not annoying (0)
   Feeling the heat on face (1)
   Radiant heat is intolerable on the face (2)

12. How is the sunlight in your workstation?
   Full shadow (−1)
   Sun and shadow or mild light (0)
   Full sun or intense light (1)

13. How much of your time is spent in a warm environment, in a shift?
   Less than 2 hours (−1)
   2-4 hours (0)
   4–6 hours (1)
   More than 6 hour (2)

14. Have you ever experienced heat stroke in your workplace?
    Yes (3)
    No (0)
15. What is your most frequent body posture when you are at work?
    Usually sitting (1)
    Usually standing with low mobility (2)
    Standing with high mobility (3)
    Usually I am walking (4)
16. How do you feel about the size of the workspace within the building?
    Spacious (0)
    Appropriate common space (1)
    Limited cramped space (2)

Calculation of score

Total score calculation sheet

Question number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total score
Primary score																	
Effect coefficient	0.79	0.59	0.46	0.74	0.61	0.80	0.66	0.75	0.83	0.65	0.66	0.26	0.35	0.16	0.21	0.37	
Secondary score																	

Evaluation of result

- Heat strain due to risk factors is low.
- Onsets of heat-induced illnesses are very likely and appropriate control measures should be taken as soon as possible to reduce heat strain.