HSE IJ Iranian Journal of Health, Safety & Environment, Vol.3, No.2, pp.535-539

Validation of Physiological Strain Index Based on Heart Rate in Experimental Hot Conditions

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Received: 05 Oct. 2015, Revised: 12 Dec. 2015, Accepted: 07 Jan. 2016

ABSTRACT
Heat stress is a common problem in industrial workplaces. Thermal stress is a caused reduces concentration of and fatigue increases individuals and thermal condition can be one of accident risk factors .The purpose of this study was validation of Physiological Strain Index Based on Heart Rate in experimental condition.
This Semi experimental study was conducted to 16 male in five different temperature conditions (21, 24,27,30,35^{oC}) in the climate chamber and on the treadmill with two levels of activity 2.4 kph (light physical activity) and 4.8 kph (medium physical activity).Heart rate was measured to for calculating Physiological Strain Index Based on Heart Rate, rate perceived exertion and questionnaire Heat Strain Score index was measured. The correlations between the indices were evaluated using Pearson correlation test and regression analysis.
Pearson correlation test showed a significant correlation between Physiological Strain Index Based on Heart Rate and rate perceived exertion ($p \leq 0.001, r=0.96$).also a high correlation was observed between Physiological Strain Index Based on Heart Rate and wet bulb globe temperature ($p \leq 0.001, r=0.90$). A very high correlation was observed between Physiological Strain Index Based on Heart Rate and Heat Strain Score Index ($p \leq 0.001$, $r=0.93$).
The results of this study showed Physiological Strain Index Based on Heart Rate a suitable method for strain heart evaluation is caused by thermal stress because there was an acceptable correlation with heat stress valid indices.
Keyword: Physiological Strain Based on Heart Rate, Heart Rate, Heat Strain, Perceived Exertion, Climate Chamber

INTRODUCTION
Heat stress is a common occupational health hazard at indoor workplaces especially in a hot-humid climate. Overheating of the body can cause a number of problems, including heat rash, heat cramps, dizziness, heat exhaustion, and heat stroke [1] Heat stress is one of the main and the most common problems in the work environments. Extreme heat exposure can cause different clinical symptoms, including headache, nausea, vomiting [2] In some workplaces, employees are exposed to heat, which may deteriorate work efficiency, safety and productivity [3] Another accredited index for evaluating thermal strain is the Physiological Strain Index (PSI), which was developed by Moran *et al.* (1998). This index compares changes in oral temperature (T re) and heart rate (HR) at two rest and work states [4] Usually measured heart rate or a heart rate monitor (Sport tester) or by counting the pulse simple, inexpensive and is operational but deep temperature measurement (esophageal temperature, oral temperature, the temperature tympanic) is difficult. Heat stress can also increase heart rate and risk of stroke and coronary artery disease could also lead to a heart attack. Heat stress also causes the atrial and ventricular arrhythmias. The most common cause arrhythmia, is atrial fibrillation [5] Dehghan and *et al.* in a study to assess the physiological responses induced by heat melting the metals industry have concluded that the correlation between the temperature of the ear canal and WBGT index physiological strain, respectively, 0.67and 0.69 and moderate correlation there was between these indicators. One of the problems of heat stress on the cardiovascular system is the heart of the industry is suffering from fatigue, because it is necessary to regulate the body temperature normal and high performance of the heart muscle to work harder and harder, the risk of sudden heart failure and often death. One of the criteria for the validation of physiological strain index is based on heart rate in this study used observational perception index HSSI, which is developed by Dehghan *et al.* this index has a questionnaire that questions is the basis of observation and perception. The HSSI scale includes 17 items, observation and subjective questions, relating to heat stress such as thermal and humidity sensation and heat strain assessment included three

levels of risk, without heat strain (score less than 13.5), the medium of heat strain (13.6 to 18) and high heat strain (greater than 18.1) [6] RPE scale, strain caused heavy physical work, which was introduced in 1960 by Borg. Borg 10 point scale that measures the amount of effort in a range of 0 to 10 [7] (Fig. 1). Physiological Strain Index is based on heart rate determines the amount of strain placed on the cardiovascular system and using the results obtained by this indicator could be that people prone to heat strain and strain the heart screening. This study aimed to validate an index of physiological strain on the heart rate in hot conditions laboratory.

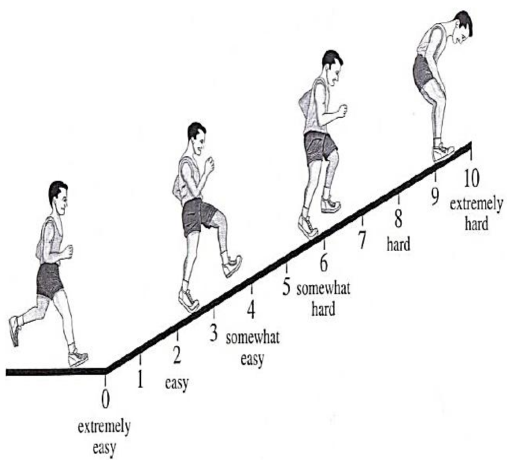

Fig 1. Perceived Exertion score

MATERIALS AND METHODS

This cross-sectional study was performed on 16 male students in the laboratory of thermal stress. Sampling method was the invitation of the subjects, considering inclusion criteria for the study. Inclusion criteria were lack of cardiovascular diseases, pulmonary diseases, hypertension, diabetes, neurological diseases, musculoskeletal diseases, consuming coffee, caffeine and alcohol for 12 hours before the test. The subjects were informed about the test procedures, and signed participation consent. Selection and number of samples were based on the similar empirical studies [4, 8] after resting 10 min, heart rate with use a cardiograph apparatus RS 100 POLAR model and oral temperature recorded. Also Borg Rating of Perceived Exertion and Heat Strain Score Index (HSSI) questionnaire recorded. After resting, the subject performed a physical activity (walking) in 5 different thermal indexes of 21, 24, 27, 30 and 35^{oC} based on WBGT for 40 min. Each thermal stage was executed in a separate day, including a 40 min physical activity on a treadmill. The subject engaged in physical activity on a treadmill at each of above temperatures for the first 15 min at the rate of 2.4 kph (light physical activity) and 4.8 kph (medium physical activity). Each temperature stage was 20 minutes of physical activity light on a treadmill and 20 minutes of physical activity medium on a treadmill [9] and at the end of 20 minutes of physical activity on treadmill heart rate for the calculation index of physiological strain on the heart rate, the Borg RPE scale to calculate HSSI questionnaire in each of temperatures recorded.

How to measure the physiological strain based on the heart rate is given below:

$$\mathbf{PSI\ hr\ = \{5*(HR\ w\text{-}HRs)\}/(180\text{-}HRr)}$$

That HRw is heart rate during exercise and HR r is heart rate at rest. [4]. The final score for physiological strain based on the heart index from zero to five is presented in Table 1.

Table 1. Final score physiological strain based on the heart index

Evaluate	Score
No heat strain	0
Low heat strain	1
Moderate heat strain	2
High heat strain	3
Very High heat strain	4
Extreme heat strain	5

Environmental temperature was monitored using the WBGT apparatus of Cassella model, Britain that sensitivity 0.1^{oC}. Finally, **results** of the present study were analyzed using SPSS, version 20 IBM.

RESULTS

Participant's characteristics in this study were 16 men with a mean and standard deviation of 24.10±2.72 years ages and 23.33±3.81 kg/m2 BMI.

The mean and standard deviations of the studied indices are presented in Table 3.

Table 3. Mean and standard deviations of the studied indices and relevant variables

Index	Mean(standard deviations)	Minimum-Maximum range
Rate Perceived Exertion	6.2(1.6)	0-8
Heart rate	122(17.8)	69-137
physiological strain based on the heart rate	3.1(1.09)	0.4-4.1
HSSI questionnaire	14.5(3.09)	4-19

The Pearson correlation test showed that there is a very high correlation between the physiological strain based on the heart rate and Rate Perceived Exertion (r=0.96) (p≤0.001).

The linear regression curve in Fig. 2 is shown a high correlation between the physiological strain based on the heart rate and Rate Perceived Exertion, so that the physiological strain based on the heart rate will increase when the Rate Perceived Exertion increases.

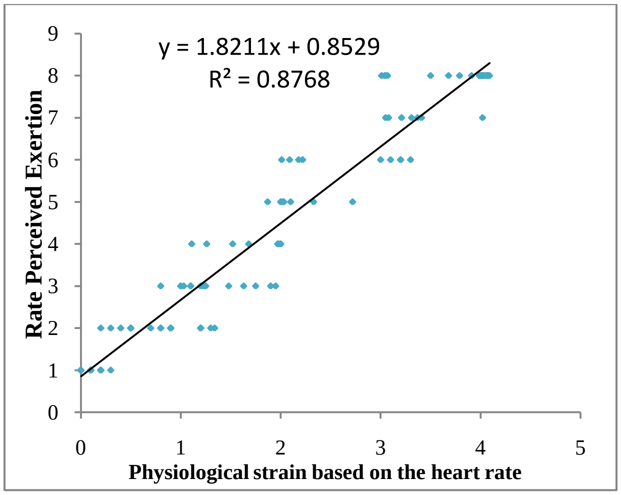

Fig.2. The linear regression curve between the physiological strain based on the heart rate and Rate Perceived Exertion

Pearson correlation test showed that there is a very high correlation between the physiological strain based on the heart rate and WBGT (r=0.90) (p≤0.001). The linear regression curve in Fig. 3) is show a high correlation between the physiological strain based on the heart rate and WBGT, so that the physiological strain based on the heart rate will increase when the WBGT increases.

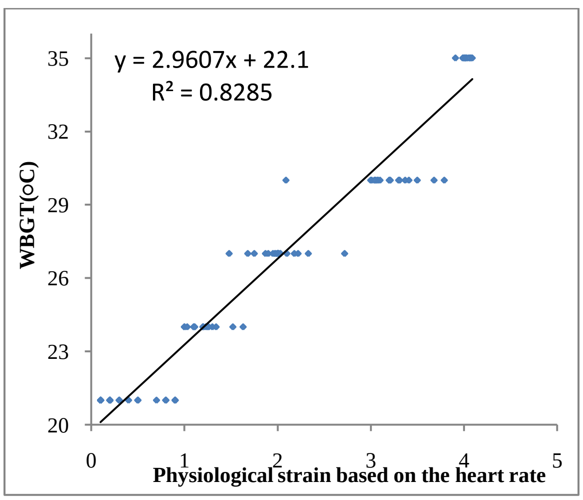

Fig.3. The linear regression curve between the physiological strain based on the heart rate and WBGT

The Pearson correlation test showed that there is a very high correlation between the physiological strain based on the heart rate and HSSI questionnaire (r=0.93) (p≤0.001).

The linear regression curve in Fig. 4 is shown a high correlation between the physiological strain based on the heart rate and HSSI questionnaire, so that the physiological strain based on the heart rate will increase when the HSSI questionnaire score increases.

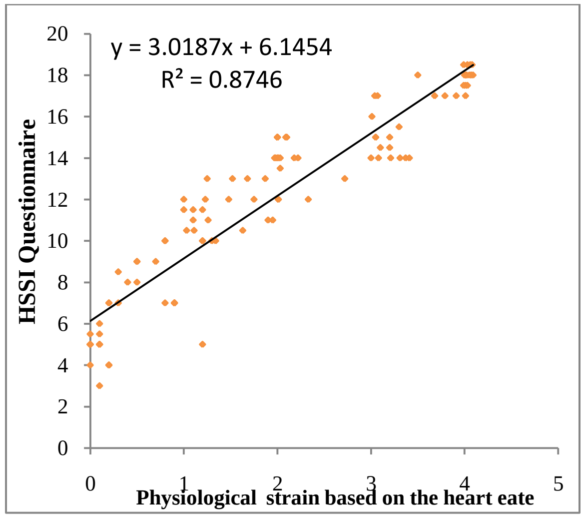

Fig. 4. The linear regression curve between the physiological strain based on the heart rate and HSSI questionnaire.

DISCUSSION

Heat stress is a common problem in most industries and lack of protection against heat stress is a major threat to human health and productivity in the work place. This study showed highly correlated between the physiological strain based heart rate and Wet Bulb Globe Temperature, which shows the index physiological strain based heart rate can be used as a suitable tool for the assessment of heat strain. In the study of Dehghan *et.al.* on application of the combined of physiological strain on the heart with Wet Bulb Globe Temperature index for the assessment of heat strain in the metal melting industry studied concluded that there is a high correlation between the physiological strain on the heart with WBGT can be used to evaluate the thermal strain. [10] Malchaire *et.al.* in their study to evaluate the WBGT index conducted as WBGT a not suitable tool for screening heat strain, that with the findings of our study is consistent [11] Rastogi *et.al.* in a study that examined the relationship between Wet Bulb Globe Temperature and heart rate glassmakers workers has come to the conclusion that the WBGT index is not suitable index for thermal strain assessment, which is consistent with the findings of the present study [12] Dehghan *et.al.* in a study that examined the relationship between physiological strain index and WBGT index concluded that by increasing the WBGT index of physiological strain index increases, which is consistent with the findings of the present study [13] Habibi and *et.al.* in a study that examined the relationship between physiological strain index, heart rate and WBGT index in climate chamber concluded that significant relationship there is between physiological strain index, heart rate with WBGT index, which is consistent with the findings of the present study [14] Latzka in a study that examined impact Rate Perceived Exertion on heart rate intensity during exercise in warm conditions in the laboratory has concluded that by increasing Rate Perceived Exertion, heart rate increases that are consistent with the findings of this study [15] Between Physiological strain based on heart rate of RPE and HSSI was showed a significant relationship. Hostler *et al.* studying the effect of the increased perspiration on the physiological strain index, reached to this conclusion that with Rate Perceived Exertion increases, heart rate increased [16] Habibi *et.al.* examined the observational-perceptional index as Heat Strain Score Index (HSSI) in the form of a questionnaire, and concluded that participants have a good subjective perception of the heat stress in workplaces, and the obtained score of this index has a direct and significant correlation with the resulted physiological strain index, heart rate, which is consistent with the findings of the present study [17] Schaeffer *et al.* in a study on the impact of heat stress on heart rate and oxygen consumption have concluded that with increasing rate perceived exertion, heart rate, oxygen consumption increases, which are consistent with the findings of the present study 18].

CONCLUSION

The results of this study showed Physiological Strain Index Based on Heart Rate a suitable method for strain heart evaluation is caused by thermal stress because there was an acceptable correlation with heat stress valid indices. However, this index is a simple, easy to use and can be used to determine the risk assessment of workers exposed to heat and heat strain.

ETHICAL ISSUES

Ethical issues such as plagiarism have been observed by the authors.

CONFLICT OF INTERESTS

Authors declare that there is not any competing interest.

AUTHORS' CONTRIBUTIONS

Ghanbary Sartang was designer and conducted the study. Dehghan was Corresponding author and advisor the study.

FUNDING/ SUPPORTING

This research was supported by Isfahan University of Medical Science

ACKNOWLEDGMENT

This study was conducted in School of Health, Isfahan University of Medical Sciences, in climate chamber. The authors would like to thank Miss. Peymaneh Habibi, the engineer and the director in the laboratory chamber of thermal stresses for her sincere cooperation during the study.

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