Original Article

Investigating relationship between perceptual strain index with indices heat strain score index, wet bulb globe temperature in experimental hot condition

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ABSTRACT

Aims: The purpose of the present study was to investigating relationship between perceptual strain index (PeSI) with indices heat strain score (HSSI), wet bulb globe temperature (WGBT) in experimental hot condition.

Materials and Methods: This study in five different temperature conditions (21°C, 24°C, 27°C, 30°C, and 35°C) was carried out on 15 male students in the climate chamber and on the treadmill with three levels of the activity. The thermal sensation and perceived exertion was recorded for calculating PeSI, and HSSI questionnaire was completed.

Results: Pearson correlation test showed a high correlation ($r = 0.84$) between the PeSI and HSSI ($P = 0.001$). Also, Pearson correlation test showed between PeSI with WBGT and air temperature, respectively, a good correlation ($r = 0.76$) and high correlation ($r = 0.81$) ($P = 0.001$).

Conclusion: The findings of the study showed that the PeSI can be used for evaluating heat strain in the absence of access to other methods of evaluating heat stress since it has an acceptable correlation with valid indices of heat stress. Also, easy application and quick and cost is much less than other evaluating heat strain indices.

Key words: Climate chamber, heat strain score index, perceptual strain index

INTRODUCTION

Thermal stress affects workers in workplace. Heat can have a negative impact on production efficiency and health of workers at work, occupational diseases and accidents of work.[1] Also in many countries, workplace exposure to heat is used as an occupational health problem and exposure to heat can cause illnesses such as heat exhaustion, heat cramps, heat shock, heat fatigue, heat stroke, and death.[2] Heat stress occurs when the body's means of controlling its internal temperature starts to fail. As well as air temperature, factors such as work rate, humidity and clothing worn while working may lead to heat stress. Therefore, it may not be obvious to someone passing through the workplace that there is a risk of heat stress. The heat stress is a serious threat in many industries including steel, petrochemicals, and glass,

and also in road construction and it can affect directly the performance and health of people.[3] A study conducted by researchers at the Indian automobile industry concluded that more than 28% of workers in the various processes of the industry are working with a risk of exposure to heat stress.[4] Many heat strain indices have been developed by researchers to evaluate heat strain. Indices developed to assess the heat strain have some disadvantages, and a single index cannot be used to evaluate the heat strain in environments with different climate conditions, or some of the indices have variables difficult and time-consuming to be measured or are expensive and costly. The physiological strain due to heat stress includes core body temperature, skin temperature, and heart rate. Physiological strain index is also a method of evaluation of heat stress in the workplace.[5] On the other hand, of the existing methods for assessing the risk of heat stress, the observational and perceptional methods have been continuously developed and used because of their simplicity and inexpensiveness, rapid answers, and feasibility to be used without interfering with the workplaces. One of the observational perceptual techniques presented recently to evaluate the thermal strain is observational technique and perceptual heat strain score index (HSSI). 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 (>18.1).[6] Another index is based on individual perception of that thermal presented perceptual strain index (PeSI). Tikuisis *et al.* have developed PeSI that measures the thermal strain in individuals through the thermal sensation and the Borg Rating of Perceived Exertion. This index is indeed a method to assess the risk of thermal strain through perception. PeSI is a simple and inexpensive method to evaluate the thermal strain and it can be used to determine the health risks to workers exposed to heat. [7] Many heat stress indices have been developed and these indices have some disadvantages.[2] The purpose of this study is to investigate the relationship between PeSI with indices HSSI and wet bulb globe temperature (WBGT) in experimental hot condition.

MATERIALS AND METHODS

This experimental study was performed on 15 male students in the climate chamber. The sampling method was the invitation of the subjects, considering inclusion criteria for the study. Inclusion criteria were a lack of cardiovascular diseases, hypertension, neurological diseases, and musculoskeletal diseases, consuming coffee and caffeine for 12 h before the test. The subjects were informed about the test procedures, and a signed participation consent form was obtained from all participants. The selection and number of samples were based on the similar empirical studies.[5,7] After selecting individuals, at the end of 10 min rest, persons

in out-of-climate chamber, variables thermal sensation and rating of perceived exertion, and also HSSI questionnaire were recorded. WBGT index and air temperature were also recorded. After resting, the individual performed a physical activity (walking) in five different thermal stages with WBGT 21°C, 24°C, 27°C, 30°C, and 35°C each for 45 min. Based on a similar study, each thermal stage was executed in a separate day, including a 45-min physical activity on a treadmill.[7] The subject engaged in physical activity on a treadmill at each of the above temperatures for the first 15 min at the rate of 2.4 kph (light physical activity), the second 15 min at the rate of 4.8 kph (medium physical activity), and the third 15 min at the rate of 6.3 kph (heavy physical activity).[1] The physical activity was performed with cotton clothes (0.6 clo). And at the end of each 15 min session and at each of above speeds and temperatures, the thermal sensation and rating of perceived exertion by the subject were recorded to calculate the PeSI and also questionnaire HSSI, in each of the velocities and temperatures completed. Finally, WBGT and air temperature at the end of each 15 min were recorded.

The PeSI is calculated as follows:[7]

$$PeSI = 5 \times ([TS - 1]/4) + 5 \times (PE/10)$$

The score for thermal sensation and perceived exertion is presented in Tables 1 and 2.

The final score for the PeSI is from 0 to 10, and is presented in Table 3.

Environmental temperature was monitored using the WBGT apparatus of Casella model, Britain, with a sensitivity of 0.1°C. The air temperature was monitored using a thermometer. The results from the study were analyzed using SPSS, version 18, IBM Company manufacture and finally, using Pearson correlation test and regression analysis. This study was performed after getting permission from the Ethics Committee in Medicine and Participant's informed about the test procedures.

RESULTS

Participant's characteristics in this study were 15 men with a mean and standard deviation (SD) of 26.43 ± 1.47 years old, 179.66 ± 9.11 cm height, 75.21 ± 3.99 kg weight, and 24.18 ± 3.86 kg/m² body mass index.

Table 1: Thermal sensation score	
Thermal sensation	**Evaluate**
1	Comfortable
2	Slightly warm
3	Warm
4	Hot
5	Very hot

The mean and SDs of the studied indices are presented in Table 4.

Pearson correlation test showed that there is a high correlation between the PeSI and the HSSI ($r = 0.84$) ($P = 0.001$).

The linear regression curve in Figure 1 shows a high correlation between the PeSI and HSSI, so that the PeSI will increase when the HSSI increases.

Pearson correlation test showed that there is a good correlation between the PeSI and WBGT ($r = 0.76$) ($P = 0.001$).

The linear regression curve in Figure 2 shows relationship between the PeSI and WBGT. There is a good correlation between these two indices that the PeSI increases with WBGT.

Pearson correlation test showed that there is a high correlation between the PeSI and air temperature ($r = 0.81$) ($P = 0.001$).

The linear regression curve [Figure 3] shows the relationship between the PeSI and air temperature. There is a high correlation between these two indices that air temperature increases with PeSI.

DISCUSSION

In most industries, and lack of protection against heat stress is a major threat to human health and productivity in the workplace. The results of this study showed that both subjective and perceptual individuals can detect heat stress under different temperature conditions. Each of the heat stress indices has limitations, for example, WBGT is expensive and time consuming. Malchaire et al. concluded that the WBGT index is not an ideal screening method.[8] Rastogi et al. in a study that examined the relationship between WBGT and heart rate of the glass workers concluded that WBGT alone is not sufficient to evaluate the thermal strain.[9] At this study, there is a significant correlation between PeSI and HSSI. Dehghan et al. examined the observational-perceptional index as 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 significant correlation with WBGT index which is consistent with the findings of the present study.[10] Gallagher et al. developed a perceptual hyperthermia index based on a laboratory pilot. They concluded that there was a direct significant correlation between the perceptual hyperthermia index and different air temperatures, and they had also a good subjective perception of the heat, which is consistent with the findings of the present study.[11] Habibi et al. concluded in a study on the relation between WBGT index and the HSSI among women that increase in WBGT will increase HSSI which is consistent with the findings of the present study.[12] Dehghan et al. studied and validated the thermal strain questionnaire focused on women in workers at the hot weather in field and concluded that participants have a correct perceptual and subjective response of the heat stress, which is consistent with the findings of the present study.[13] Haruyama et al. studied participants' subjective judgment of the thermal stress using subjective judgment scale and concluded a direct significant correlation between subjective judgment scale and WBGT, so that the scores from the subjective judgment scale is increased by increasing the WBGT. Participants had a proper perception of the heat, which is consistent with the findings of the present study.[14] Habibi et al. concluded in a study on the relation between the PSI and the HSSI among women that the increase in the PSI will increase the thermal strain index. The participants showed a proper subjective response to the heat stress, which is consistent with the findings of the present study.[15]

Table 2: Perceived exertion score

Perceived exertion	Evaluate
0-1	Extremely easy
2-3	Easy
4-5	Somewhat easy
6-7	Somewhat hard
8-9	Hard
10	Extremely hard

Table 3: The final score the perceptual strain index

Score	Evaluate
0-2	No heat strain
3-4	Low heat strain
5-6	Moderate heat strain
7-8	High heat strain
9-10	Very high heat strain

Table 4: Mean and SD of the studied indices and relevant variables

Index	Mean (SD)	Minimum-maximum range
Thermal sensation	3.78 (1.4)	1-5
Perceived exertion	7.1 (2.2)	0-9
Perceptual strain index	6.78 (2.91)	0-9.5
Heat strain score index	14.7 (4.2)	35.8-38.9
Air temperature (°C)	33 (9.1)	66-173

SD: Standard deviation

CONCLUSION

The results of this study showed that the PeSI is highly correlated with HSSI and air temperature. In this study, the correlation between PeSI with PeSI is higher than the WBGT index, indicating that PeSI compared with WBGT index has greater ability to evaluate the thermal strain. On the other hand, the application of this index is quick and easy, and the cost is much less. In fact, evaluating the thermal strain by the PeSI is a cheap and simple method and can also be used to determine the health risks of workers exposed to heat and in the risk assessment of thermal strain.
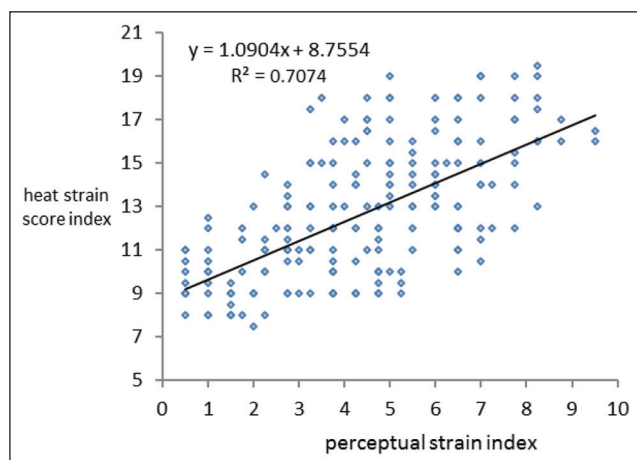
Figure 1: The linear regression analysis between the perceptual strain index and the heat strain score index
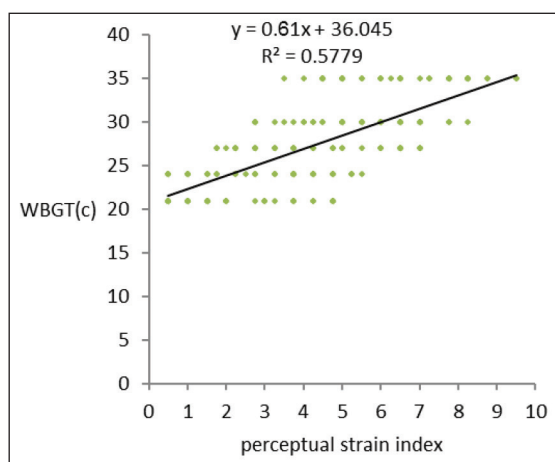

Figure 2: The linear regression analysis between the perceptual strain index and wet bulb globe temperature
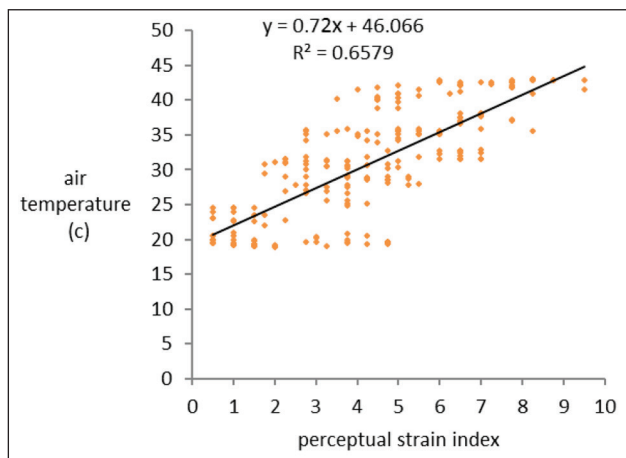

Figure 3: The linear regression analysis between the perceptual strain index and air temperature

Conflicts of interest

There are no conflicts of interest.

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