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The relationship between observational – perceptual heat strain evaluation method and environmental / physiological indices in warm workplace

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ABSTRACT

Objective: Heat stress is a hazard common in the industries. Several indices are used to evaluate heat stress. But most of the indices need expensive instruments especially in developing countries. The purpose of this research was to determine validation of an observational – perceptual method as heat strain Score Index (HSSI) in warm conditions.

Methodology: This research was performed on 145 healthy subjects. Oral temperature and heart rate were measured by a heart rate monitoring (POLAR RS100 model) and oral thermometer (TB100 model) at rest and field. Wet Bulb Globe Temperature (WBGT) were also recorded and HSSI questionnaire was completed simultaneously. Data was analyzed by Pearson correlation test and regression analysis.

Results: Pearson correlation test showed a significant correlation between the HSSI values and PSI values ($r = 0.397$, $p < 0.001$). Pearson correlation Between WBGT values and Physiological Strain Index (PSI) values observed a significant association ($r = 0.57$, $p < 0.001$) A moderate correlation between the HSSI values and oral temperature was also observed($r = 0.556$).

Conclusion: This research showed that heat strain Score Index, in comparison with WBGT index, had a higher correlation with PSI. According to HSSI moderate correlate with others valid indices is economical and also easier to use. Hence, HSSI can be used as the heat strain screening tool in the warm workplace when other heat stress evaluation methods are not available.

KEY WORDS: Wet Bulb Globe Temperature, Physiological Strain Index, Heat Strain Score Index, Heat strain.

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INTRODUCTION

Heat stress exposure is a hazard common and constant problem in some industries. Heat stress is more associated with high temperature and humidity environments. These conditions can be seen in industries such as foundry, ceramic, power plants, construction and agricultural settings[1] Heat stress causes disorders such as heat syncope, heat exhaustion, heat stroke, confusion, reduced concentration and fatigue. It also increases costs such as reduced production, loss of income to workers and increased cost.[2-6] There are different ways for controlling heat stress in the workplace, for example reduced temperature and humidity, increase air movement, reduce workload, suitable clothing for work, protection shields against radiant

heat, the rest- work cycle, training, replaced fluids and compliance.[2]

In general, assessment of heat stress is determined by climatic parameters that can estimate impact of various factors on the physiological ability.[7] Since the environmental parameters such as air temperature, radiant temperature, humidity and air velocity along with physical activity and type of clothes are effective in onset of heat strain, therefore many indices has been developed heat stress evaluation in heat exposed individuals.[8,9] These indices in general fall into two categories: analytical indices and empirical indices. Analytical indices are based on the heat exchange between human body and environment while the empirical indices have been established based on human response to different environmental factors. Among empirical indices, Wet Bulb Globe Temperature (WBGT) is mostly used in the assessment of hot environments.[10] This index is measured based on three parameters which include natural wet bulb(N_{WB}),air temperature(t_a) and globe temperature(g_t). Despite the widespread use, this index has some limitations. Its main limitation is that when rate of sweat evaporation due to increase of humidity or decrease in air flow, is limited, WBGT can not reflect the heat strain added accurately. On the other hand, interpretation of WBGT data needs precise evaluation of the physical activity intensity and clothing as each of these can lead to large errors in interpretation of the data results.[6] Also response time to the radiant heat measurement in WBGT set is too long, therefore Grahame states that the WBGT index, to assess the environment heat stress, cannot be a good index.[6]

The body response to heat stress is known as the strain by which physiological and psychological parameters are measuring. That largeness of these responses depends on amount of the body exposure to heat stress.[11] Physiological strains related with heat load include deep body temperature, skin temperature, heart rate, evaporation and loss weight.[12] At present one of the indices used to assess the heat strain is physiological strain index (PSI). This index was based on the heart rate and core temperature measurements and also has a scale of zero to 10. Zero value signs the absence of strain and 10 value the highest amount of strain.[13] The main disadvantage of PSI is invasive measurement of deep body temperature (such as rectal temperature, esophageal temperature and ingestible pill). As such the use of these techniques is difficult and even impossible in actual workplace.

In recent years, in addition to the above mentioned indices (WBGT and PSI) the other methods are used for assessment of risk factors such as observational and perceptual techniques. This techniques has been widely used due to good performance, save time and costs, desirability among users, simple and cheap, fast response and applicable without interfering with the workforce. One of these indices that is based on observational- perceptual techniques as heat strain score index(HSSI) has been recently developed.[14,15] This index was measured in the form of a questionnaire(where several factors related to heat stress and strain are included in)that the number of questions are measured based on the observation and also the number are measured based on individual perceptions and judgments and the final value obtained from is entitled as HSSI. This index is a 17-item questionnaire including 12-item observational questions and 5-item perceptual questions. This index has three levels of heat strain risk including low strain, possibility of heat strain and definitive heat strain. This index has been validated in very hot conditions in the south of Iran where WBGT index was above 30 ° C (mean 33.1° C). The question raised, is the HSSI index validated for heat strain evaluation in warm conditions? So this study was attempted to determine HSSI index correlation with physiological strain index (PSI), oral temperature and Wet bulb globe temperature.

METHODOLOGY

This cross-sectional study was performed on 145 healthy subjects who were working in warm workplaces in 2011. Subjects were selected using systematic random sampling. The participants were medically screened for cardiovascular disease, respiratory disease, infectious disease, diabetes, *hyperthyroidism and* no medicine use; all subjects were presence at least two weeks continuous in the workplace. Procedures of the study were approved according to the Declaration of Helsinki by the Medical Ethics Committee of Isfahan University of Medical Sciences. The aim and conditions of the study were introduced to the subjects and the necessary instructions about the different procedures and experiments of the study such as adequate rest during night, no coffee and alcohol consumption in the night before the measurement were clearly explained. The written informed consent were obtained from all subjects.

On testing day, after measuring height and weight, heart rate monitoring ((Polar RS100, Finland) was closed on chest and wrist, like a watch.[16,17] After rest for five minutes out of workplace (cool

area), heart rate and oral temperature (Digital Thermometer, Rossmax TB100) were measured and recorded as baseline. Then, without separating heart rate monitoring device, the subject was asked to go to work and begin his daily work activity. After starting the work in warm workplace, environmental factors (Microtherm Casella CEL, UK), heart rate, oral temperature and heat strain score index (HSSI) questionnaire measured for 1.5 hours. In total during 1.5 hours monitoring values of heart rate, oral temperature, WBGT and HSSI for 9 times, were recorded.PSI index was calculated based on equation1.

$$PSI= 5(T_{ret} - T_{re0}).(39.5 - T_{re0})^{-1} + 5(HR_t - HR_0).(180 - HR_0)^{-1}$$ Equation1

Where T_{ret} and HR_t are oral temperature and heart rate at working and HR_0 and T_{re0} are oral temperature and heart rate at rest values respectively.[13]

HSSI index questionnaire, of which reliability and validity has been investigated[14], contained 18 questions. Where its variables including; air temperature, air humidity, air movement, sweating severity, thirst severity, fatigue severity, discomfort severity, clinical symptoms, surface temperature, air conditioning, type of work clothing, color of work clothes, work clothes material, type of protective equipment, physical activity intensity, posture, dimension of work space and location of tasks. This index has three levels of risk as follows: low heat strain; if the index value is less than 13.5. Probably of the heat strain; if the index value is between 13.6 and 18 the individual has, that in order to determine presence or absence of heat strain, further analysis is required. If the HSSI index value higher than 18.1 certainly strain.

In order to determine relationship among PSI, HSSI and WBGT indices, Pearson correlation and regression analysis tests was used., One way ANOVA test was used for comparing the PSI, WBGT and oral temperature at HSSI different levels.

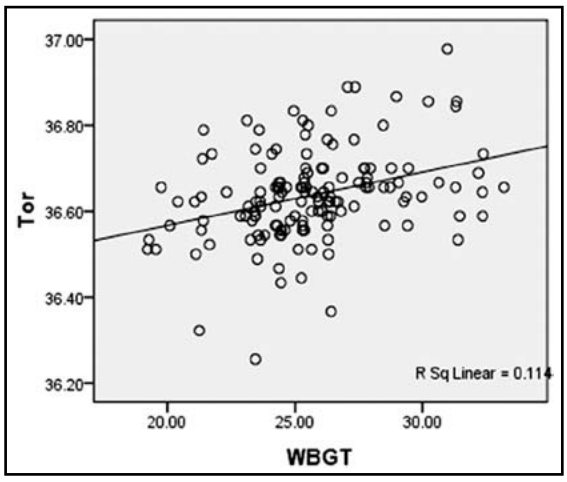

Fig.1: scatter plot & regression line Tor based on the WBGT.

Table-I: The mean (SD) values of PSI and WBGT indices and oral temperature based on HSSI different levels.

HSSI different levels	*PSI index*	*WBGT index(°c)*	*Oral temperature(°c)*
Level 1: without strain	0.96(0.39)	24.8(2.5)	36.60(0.09)
Level 2: probably strain	1.09(0.39)	26.7(2.9)	36.67(0.08)
Level 3: definite strain	1.6(0.5)	27.7(3.4)	36.72(0.12)

RESULTS

In this study, 145 subjects with Mean (SD) age 34.9(8.5) year, weight 69.6(8.3) kg, height 172.6(6.2) cm, BMI 23.3(2.3) were included. The mean (SD) of WBGT index was 25.6(2.9) °C (range 19 and 33°C), the average of heart rate and oral temperature were 75.8(6.3) bpm and 36.6(0.14) °C at rest respectively.

The mean (SD) of heart rate was 95.4(11.6) with range of 95 – 136 bpm, oral temperature 36.6(0.1) with range of changes 36.2- 37 °C, physiological heat strain 1.06(0.45) with range of changes 0.12 – 2.5, heat strain score index 12.6(4.5) with range of changes 4.8 – 28,

According to level of risk defined for HSSI, 66.2% of subjects were without strain (one level), 22.1% of the subjects had the strain (two level) and 11.7% of the subjects were certainly in the strain (three level). Also according to defined risk level for the physiological strain index[13], 48.3% of subjects were without physiological strain and 51.7% of subjects had low physiological strain. Mean (SD) values of PSI & WBGT indices and oral temperature (T_{or}) for every three risk levels of HSSI is shown in Table-I.

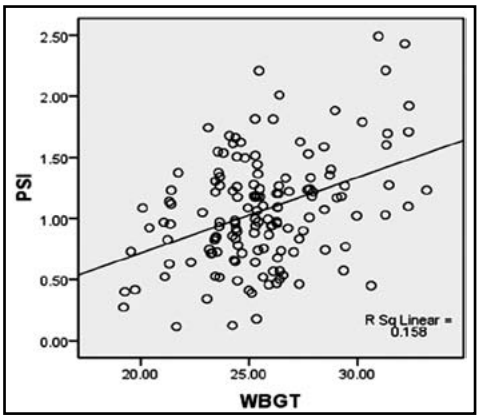

Fig.2: scatter plot & regression line PSI based on the WBGT.

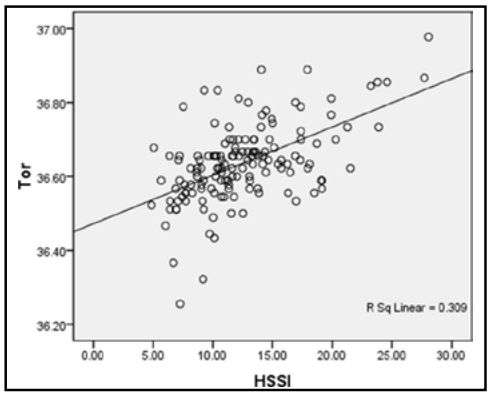

Fig.3: Scatter plot & regression line Tor based on the HSSI.

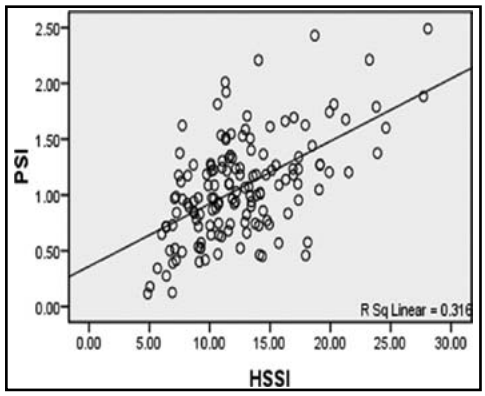

Fig.4: Scatter plot & regression line PSI based on the HSSI.

That one-way ANOVA test showed mean PSI and WBGT, and oral temperature in the levels of risk of HSSI had a significant difference ($p< 0.001$).

Pearson correlation test showed that there was a significant and direct correlation relationship ($r = 0.397$) between WBGT and PSI index ($P <0.001$).And prediction PSI index based on the WBGT index was obtained as following: PSI = - 0.522 + 0.062WBGT

Pearson correlation test showed that between WBGT index with oral temperature ($r= 0.377$) and heart rate ($r= 0.439$) had a significant relationship ($P < 0.001$). Scatter plot (Fig. 1 and 2) shows regression line of PSI index and Tor based on the WBGT index.

Pearson correlation test showed a significant and positive correlation($r = 0.57$) relationship between HSSI and PSI index ($P<0.001$). Estimation of PSI index based on the HSSI index was obtained as following: PSI = 0.359 + 0.056 HSSI.

Pearson correlation test also showed that between HSSI index with oral temperature ($r=0.556$) and heart rate ($r=0.428$) had a significant relationship ($P < 0.001$). Fig. 3 & 4 shows scatter plot and regression line of PSI index and Tor based on the HSSI index.

DISCUSSION

In this study, WBGT index with PSI index, oral temperature and heart rate was observed to have a significant relationship ($P<0.001$) however, because the value of Correlation was obtained less than 0.5, therefore this index was not a high correlation with physiological strain index ($r = 0.397$), and did not achieve an acceptable prediction equation. This finding indicates WBGT index is not a good screening method, and this result is conforming to study by Malchaire.[15]

HSSI index that has been introduced as a primary screening tool as well, showed a significant relationship with PSI, core temperature and heart rate ($p<0.001$). Table-I shows mean value of PSI and oral temperature expressed in three risk levels of HSSI. It also shows that changes process values of PSI and oral temperature are increasing and this is also a significant increase. For example, subjects who in HSSI index evaluation are in risk level of three, have the highest values of PSI and oral temperature. And subjects, who are in risk level of low heat strain, have lowest values of PSI and oral temperature. This confirms that HSSI index in the categories of individuals at different levels of strain has also been successful. On the other hand, as the regression line in Fig.4 shows, relationship between both PSI and HSSI index are directed linear. Based on value of correlation between these two indices is more than 0.5 ($r= 0.57$) therefore HSSI index compared with WBGT index showed a better and higher correlation with physiological heat strain. Correlation of oral temperature with HSSI index is better and higher compared with WBGT index($r= 0.556$).

Baker and colleagues in a study to survey of relationship perceptual effort with physiological heat strain concluded that in a short term moderate activity (12 minutes), value of PSI is greater than the perceptual effort. But this index in a long term activity (60 min) showed highly correlation with perceptual effort.[18] This study conforms with results of Baker. In a similar study Wong and colleagues examined the relationship between physiological and perceptual effort responses related to heat concluded that both perceptual and physiological responses were significantly affected by heat. Between measured humidity of the skin and feel of humidity was observed highly correlation ($r^2=0.96$). Comparison of perceptual and physiological patterns showed that perceptual pattern provides clearer picture of mental heat and humidity understanding.[19] Tikusis and colleagues used two physiological strain index

and perceptual strain index for assessment of heat stress in untrained and trained groups. During the first hours of exposure physiological strain index (PSI) in both groups were same and perceptual strain index were low in the untrained group. At the end of exposure both groups showed the same perceptual strain index.[20] Study by Tikusis showed that both physiological and perceptual strain indices to evaluate heat strain have obtained similar results between untrained and trained groups. In other words, when the physiological strain index is shown the same strain exists between two groups, perceptual strain index has also shown that same strain exists between two groups and this reflect the fact that, there are correlation between physiological and perceptual strain index that was consistent with this study.

Hostler et al examined effects of hyper hydration on physiological and perceptual strain index and found both physiological and perceptual strain index between hydrated and non-hydrated conditions showed similar results. This indicates that there are correlation between perceptual and physiological strain index. Relationship between perceptual strain index and core temperature was observed to have high correlation.[21] In this study correlation more than 0.5 was obtained between HSSI index and oral temperature, compared with WBGT index, it had better and higher correlation.

CONCLUSION

Observational – perceptual method, as heat strain Score Index, in comparison with WBGT index, showed a higher correlation with PSI. The values of WBGT, PSI and oral temperature for different levels of HSSI trend to increase. According to HSSI moderate correlate with others valid indices are economical and also easier to use. Hence, HSSI can be used as the heat strain screening tool in the warm workplace when other heat stress evaluation methods are not available. The correlation of HSSI index with physiological strain index and core temperature is higher to compared with the WBGT index.

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