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Original Article

Heat Stress Level among Construction Workers

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Abstract

Background: The purpose of this study was to determine the level of heat stress to construction workers using Thermal Work Limit (TWL) and Wet Bulb Globe Temperature (WBGT) indices and by measuring Urine Specific Gravity (USG) among construction workers in Iran and comparing the appropriateness of these indices for measuring heat stress in Iran climate.

Methods: This comparative and experimental study was conducted during September 2012 in Baghe Ketabe Tehran, one of the large size construction sites in Tehran City, Iran. Sixty participants were randomly selected in two groups (exposed to sun and non-exposed) among the construction workers in a construction campus with similar work type, climate and diet. TWL and WBGT and USG were measured in two consequent days and at the beginning, mid and end of the work shift, for both groups.

Results: The mean WBGT index was 22.6 ± 0.9 ºC for control group and 27.5 ± 1.2 ºC for exposure group, the mean TWL index measure was 215.8 ± 5.2 W/ m^2 for control group and 144 ± 9.8 W/ m^2 for exposure group and the mean USG was 1.0213 ± 0.0054 in control group and 1.026 ± 0.005 in exposure group. There was a significant difference in TWL, WBGT and USG between exposed and non-exposed group ($P<0.01$).

Conclusion: workers were at an allowed level of heat stress. TWL, WBGT and USG measures were significantly correlated; however as TWL level enabled classification based on required intervention, it had some merit over WBGT index.

Keywords: Heat stress, Thermal work limit, Wet bulb globe temperature, Urine specific gravity, Construction workers

Introduction

Large number of workers in the construction, agriculture and other externally paced work are under thermally stressful situation, which is going to be exacerbated by predicted warming, globally(1).
Heat stress is a well-recognized health hazard to the workers, that in addition to a well-known adverse impact on health including a wide range of physical, mental, and psychological function deterioration (2-4) like skin problems (e.g. prickly heat), heat strain, heat illness, heat exhaustion, heat stroke and chronic heat disorders, (5) affects the productivity and safety of workers (6).
In Iran 9-12% of workers are construction workers (7). Construction workers are among the most vulnerable health group workers, which usually work in unorganized sectors and are uninsured. There is no or minimal control over their occupational health by the public health system, in Iran.

Large number of occupational injuries and fatalities among them is an evident of their unsafe and uncontrolled work environment (7).

In high temperature work condition, a reliable and easy to apply tool to monitor the heat stress condition, in order to avoid any harm to the workers' health and efficiency is necessary. Many indices have been developed to measure heat stress, and some of them are designed specifically for the industrial work environments (8) which may not be appropriate in small and unorganized sectors like construction workers.

Wet Bulb Globe Temperature (WBGT) is a simple heat stress index which is used across the globe and has application in controlling heat stress for military, industrial, domestic, sporting and commercial workers. The WBGT is determined by two single readings, the wet bulb temperature and the globe temperature (9). However, WBGT is relatively insensitive to the cooling effect of air movement, against the most cost effective intervention of increasing the ventilation. Also estimating the workers' metabolic rates is difficult due to variation of metabolic rate during shift work and voluntarily alteration by self-pacing workers (6).

Thermal Work Limit (TWL), a newly developed indices, incorporates all needed inputs, and generates a single figure specifying a maximum work limit and is claimed to be "simple to use, less prone to interpretive error, reliable and far superior to currently recommended indices as an indicator of thermal stress"(6). All the five main parameters that define the thermal environment, dry bulb temperature (DB), wet bulb temperature (WB), radiant temperature (Trad), air velocity or wind speed (WS) and atmospheric pressure (Patm) has been utilized by TWL to predict a safe maximum metabolic rate for the conditions. Also, TWL accommodates the clothing factor, which is a reflection of behavioral and physiological factors that affect thermal stress (6).

There are different physiological parameters for evaluating heat strain including body core temperature, heart rate, sweat loss and urine specific gravity (USG). (10) Testing urine specific gravity has been shown to be a good and an important indicator of the absolute hydration status of the body (11) that can be used as a single measure, non-invasive, easy and quick to conduct in the field work (10). USG could be used as an educational tool for workers about the required fluid intake before and after heat exposure (12). However, urinary specific gravity does not show a perfect linear relationship with body water loss, where there is diuresis as a result of alcohol or caffeine intake, or vitamin supplements or some drugs. The maximum concentrating capacity of the renal system is about 1.050 (11).

The purpose of this study was to determine the level of heat stress to construction workers using TWL and WBGT indices and by measuring USG in Tehran, Iran and comparing the appropriateness of these indices for measuring heat stress in Iran climate.

Material and Methods

This comparative and experimental study was conducted during September 2012 in Baghe Ketabe Tehran, one of the large size construction sites in Tehran City, Iran. Sixty participants were randomly selected among the construction workers in a construction campus in a hot climatic area that were working on similar work type and environment and had a similar diet. The participants were divided to two groups, 30 workers in each group. One group was exposed to sun heat and one group was not exposed to sun heat (control group) and worked in shadow. Both groups worked under similar condition and were matched considering the work metabolism rate (65-130 W/m^2), work duration, meal and beverage consumption, work hours, place and duration of rest and type of clothing.

Medical records of participants were assessed for the genetic or other related diseases like renal diseases, diabetes and skin diseases, also other information like being under any medication especially diuretic medication, were collected by the help of health care center in the construction campus. Information related to age, weight and height of the participants were collected. To control the water consumption, all the participants received water bottle of the same size and similar brand (300 CC/hour). The process of distribution and consumption of water bottle was controlled by the HSE officers in the site, and if any worker did not follow the water consumption assignment, were excluded from the study. To control the diuretic effect of tea, the mid-day tea break was set after the urine sample collection.

The urine samples of both groups were collected in three times (beginning, middle and end of the work hours) in two consequent days. The urine samples were kept in a box under ice bags and were sent to Noor laboratory, Tehran, Iran. All the samples of the first day were checked for creatinine to identify any hidden renal failure and those with abnormal level of creatinine (more than 150 mg/dl) were excluded from the study (one worker was excluded from the control group).

The atmospheric parameters required for calculating the WBGT and TWL indicators (DB, WB, Trad, WS, Patm) was measured three times a day in the beginning, mid and end of the work hours in the working place of both groups. To ensure accuracy of measurements, all the measures were taken twice in two consequent days. The clothing of the workers was a uniform with the thermal resistance Clo equal to 0.71 I_{cl} (13). by calculating the metabolic rate, the WBGT and TWL indicators was calculated each day for the beginning, middle and end of the work hours in two consequent days. The WBGT indicator was measured based on ISO 7243 standard and measurements were done in three parts of the body (at the head, abdomen and legs height). The working metabolism rate was 135-65 W/m^2 for both exposure and control group and the mentioned WBGT in the beginning, middle and end of shiftwork was the final WBGT score with considering the metabolism rate. For measuring the atmospheric parameter, the WBGT measuring instrument MTH-1 made in UK was used. The wind speed was measured by thermal digital anemometer VT50 made in France. In order to facilitate in calculation, the calculation equations were programed in Excel software (Microsoft Office 2007) that provide a software package for calculation of WBGT based on ISO 7234(9) and TWL based on the method designed by Brake and Bates 2002 (8).

The five main atmospheric parameters (DB, WB, Trad, WS and Patm) and the clothing parameter (I_{cl}) were used as input and TWL, the central body temperature and the sweating level were the three calculated output. There were five zone with different advised intervention based on TWL level, in TWL < 115 or DB> 44 ºC or WB > 32 ºC there was withdrawal zone showing that the continuation of ordinary work is not allowed in absence of any intervention to reduce the thermal stress, in TWL between 115 to 140, there was buffer zone showing the required special intervention like not working alone or increasing wind speed by 0.5 m/s at each workers upper torso , etc. the TWL between 140 to 220 was acclimatization zone and TWL > 220 was unrestricted zone.

Statistical Analysis

All analyses were performed using statistical package for social sciences (SPSS) version 19.0 for windows (IBM Corporation, New York, United States), Repeated measures ANOVA test, related samples Friedman test, *t* test , Mann-Whitney test and Pearson Chi square test was used to measure the association and compare the groups.

Ethical observation

Review Board of the Department of Occupational Health, Tehran University of Medical Sciences approved the study. Ethical approval was obtained from the Ethical Committee of Occupational Health Research Center, Tehran University of Medical Sciences. The trial was conducted in line with the latest revision of the Declaration of Helsinki. All participants gave written consent to participate in the study.

Results

The mean age of participants was 30.5 ± 5.9 yr in control group and 31.1 ± 7.3 in exposure group. The mean weight and height was 75.6 ± 6.2 kg and 1.75 ± 0.06 m in control group, respectively and 73.4 ± 7.6 kg and 1.76 ± 0.06 m in exposure group, respectively. There was no significant difference in age (P=0.728), weight (P=0.254) and height (P=0.463) between the two groups.

Table 1 shows the WBGT, TWL and USG measures in both groups. The mean WBGT index was 22.6 ± 0.9 ºC for control group and 27.5 ± 1.2 ºC for exposure group. Maximum measured level of WBGT was 24 ºC and minimum measured level was 21.7 ºC for control group, while these measures were 29.6 ºC and 26.4 ºC in exposure group, respectively. All the measures of WBGT index, showed allowed level of thermal stress (< 30 ºC). The independent t test showed that the WBGT level was significantly different in two groups (P=0.004). The trend of WBGT during the working hours showed that maximum WBGT was in mid shift work in both groups, however the results of Friedman test showed that the difference among the three measurements was not significant (Table 2).

The mean TWL index measure was 215.8 ± 5.2 W/ m^2 for control group and 144 ± 9.8 W/ m^2 for exposure group, which shows that control group were in unrestricted group and exposure group were in acclimatization group (both in allowed range) (Table 1). The trend of TWL level during the working hours showed that maximum TWL level was in middle of shift work, however the results of Friedman test showed that the difference among the three measurements was not significant. The independent t test showed that the TWL level was significantly different in two groups (P=0.003) (Table 2).

USG test, as indicator of heat strain, showed that mean USG was 1.0213 ± 0.0054 in control group and 1.026 ± 0.005 in exposure group, which does not show a clinically dehydration status. The USG level was significantly different in two groups (P=0.001) (Table 1). The trend of USG during the working hours showed that maximum USG level was in middle of work hours, however the repeated measures ANOVA test showed that this difference was significant for exposure group (P=0.024), but not significant for control group (P>0.05) (Table 2).

The Pearson correlation measure showed a significant correlation (P= 0.001) of 0.89 between the USG and WBGT and a significant correlation (P= 0.001) of -0.93 between the USG and TWL, and a significant correlation (P= 0.007) of -0.89 between the WBGT and TWL.

Table 1: Comparing Thermal Work Limit (TWL) and Wet Bulb Globe Temperature (WBGT) indices and Urine Specific Gravity (USG) measures in exposed (to sun) and non-exposed group

	Number of samples	Range	Mean	Standard deviation	*P* value
WBGT					
Exposure group	6	26.4-29.6	27.5	0.48	0.004#
Control group	6	21.7-24.0	22.6	0.36	
TWL					
Exposure group	6	-	144	17.0	0.003#
Control group	6	-	215.8	9.0	
USG					
Number of samples from exposure group (n=30 workers)	173	-	1.0259	0.0050	0.001*
Number of samples from Exposure group (n=30 workers)	171	-	1.0213	0.0054	

Mann-Whitney test, * *t* test

Table 2: Comparing Thermal Work Limit (TWL) and Wet Bulb Globe Temperature (WBGT) indices and Urine Specific Gravity (USG) measures in the beginning of the work, middle of the work and end of the work

Mean of measures	Exposure group: Beginning of the work	Exposure group: Middle of the work	Exposure group: End of the work	Control group: Beginning of the work	Control group: Middle of the work	Control group: End of the work
WBGT	26.5	28.7	27.2	21.7	23.5	22.5
TWL	161.5	127.5	143.0	224.5	206.5	216.5
USG*	1.0263	1.0273	1.0252	1.0217	1.0211	1.0212

* The difference of three measurement in the beginning of the work, middle of the work and end of the work was significant for exposure group (*P*<0.05)

Discussion

Construction workers are among the most vulnerable health groups in Iran with high level of occupational morbidity and mortality. According to the knowledge of authors, this is the first study that assesses the thermal stress among construction workers in Iran by using different measurement and indices of TWL, WBGT and measuring USG.

In this study, the TWL and WGBT were measured thrice a day (beginning, mid and end of shift work) in two consequence days. This kind of measurements that minimize the errors was used in other similar studies, specially study of Miller and Bates as a complementary study to the study that TWL indicators was introduced for the first time (14).

The result of this study showed that the WBGT level was higher in exposure group, as expected. The ISO 7243 in the metabolism range of 65-130 W/m^2 defined the allowed WBGT equal to 30 ºC, while in this study maximum WBGT was in exposure group and equal to 29.6 ºC which is in the allowed range. The TWL indicator showed that the control group with a TWL level of 215.8 W/m^2 were in the unrestricted group and exposure group with a TWL level of 144 W/m^2 were in acclimatization group. The USG measure showed that USG level was less than 1.030, which is a clinically dehydrated state in both groups. USG showed a significantly high correlation with both WBGT and TWL indices (the correlation with TWL was negative as a lower TWL represents a higher level of thermal stress and therefore higher level of WBGT and USG), also there was a significantly high correlation between WBGT and TWL indices (the correlation with TWL was negative as a lower TWL represents a higher level of thermal stress and therefore higher level of WBGT and USG), which show a high level of efficiency of WBGT and TWL in assessing heat stress, but TWL has some more advantage over WBGT including possibility of measuring work load, evaluating the ventilation and air conditioner systems, measuring the work and rest cycle, no need for calculating the metabolism rate and possibility of providing an index for work prohibition limit of workers.

A study by Srivastava et al. (15) on measuring heat exposure in the workplace in a glass manufacturing unit in India, showed that American Conference of Industrial Hygienists (ACGIH) advices for work and rest regulation, based on WBGT index cannot be used in hot climate. The review of Parson on heat stress standard ISO4243 and its global application (8) also showed a high correlation between GBWT and TWL and concluded that both indices are efficient but TWL results are more accurate and realistic. A prospective longitudinal observational study by Bates and Schneider (6) on hydration status and physiological workload of UAE construction workers showed that in hot and harsh environment like UAE, people can work, without adverse physiological effects if they are provided with the appropriate fluids and are allowed to self-pace. Their results also, demonstrated that the use of WBGT as a thermal index was inappropriate for use in Gulf conditions, however TWL was found to be a valuable tool in assessing thermal stress, and WBGT was too conservative and inappropriate for practical use in industry as there was no physiological change in the body of workers. Study of Ramanathan and Belding (16) on physiological evaluation of the WBGT index for occupational heat stress showed that in high ambient humid condition higher heart rate, body core temperature, forehead temperature, and sweat loss was observed, but under dry conditions, the strain of exposure at WBGT 85 and 89 could not be differentiated. Under these conditions computed HSI values and observed Botsford wet globe readings were better indicators of relative strain resulting from the exposures than WBGT.

However this study showed that WBGT is an appropriate index as well as TWL for measuring heat stress in Iran climate condition (with caution about the limited study clamatical condition in this study, September). Some other studies also showed the superiority of TWL index in measuring heat stress in outside works (17).

Conclusion

Construction workers were facing allowed level of heat stress, which was measured by GBWT, TWL indices and USG measures. The level of USG and other measures were highest in mid-day and among exposure group. Also this study showed that both GBWT and TWL were good indicators of heat stress in Iran climate but TWL has some merit due to its based-on-required-intervention classifications. However it should be noted that this study was conducted in the month of September (end of summer) and these results can only be considered for a very limited climatic condition, and the result may differ in other seasons and months of a year.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely observed by the authors.

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