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Heat Stress Evaluation Using Environmental and Biological Monitoring

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Abstract: Scientific and technological advances in ergonomics/human factors have greatly contributed to the health promotion and comfort of workers in different working environments around the world. Nevertheless, the heat stress is one of the damaging factors to be treated in various industries and jobs. This study was conducted to compare environmental and biological markers of effect of heat stress among the workers engaged in one of the southern seaports of Iran. According to designed methodology, in the hottest hours of the day during the hottest month of the year, the Wet Bulb Globe Temperature (WBGT) was evaluated. Also, biological markers of effect including heart rate and body temperature were studied. To determine worker's energy demands, the procedure of ISO 8996 was applied. The results showed that during summer, according to environmental monitoring, all of the workers experienced heat stress higher than recommended ACGIH limits. Although, comparison of obtained results from environmental monitoring versus biological monitoring of effect, showed that only 16.25% of exposed population experienced heat stress according to biological markers measurements. According to questionnaire data, acute heat-induced disorders were reported among 23.5% of exposed workers during the study period. Present finding showed that biological monitoring could be regarded as a low cost and more reliable procedure in evaluation and control of heat stress among exposed population for providing comfortable working environment and promoting quality of working life. It may be concluded that in this study, estimation of heat stress using biological monitoring is closer to reality of heat stress in exposed workers, in comparison with WBGT index in which, all of the exposed workers, are experiencing heat stress.

Key words: Heat stress, environmental monitoring, biological monitoring, WBGT

INTRODUCTION

Scientific and technological advances in ergonomics/human factors have greatly contributed to the health promotion and comfort of workers in different working environments around the world. Nevertheless, the heat stress is one of the damaging factors to be treated in various industries and jobs.

Human beings live their entire lives within a very small range of internal temperatures. The maximal tolerance limits for living cells range from about 0°C to about 45°C, however, humans can tolerate internal temperatures below 35°C or above 41°C for only very brief periods. To maintain internal temperature within these limits, people have developed very effective and in some instances specialized physiological responses to acute thermal stresses. These responses-designed to facilitate the conservation, production or elimination of body heat-involve the finely controlled coordination of several body systems (Karasek and Stellmann, 1998).

The cardiovascular system is under considerable strain when a person is working in hot environment. In such a situation peripheral vasodilatation requires an increase in blood flow to the skin and working muscles demands increased blood supply. In long run, worker becomes dehydrated, sweat production decreases and core body temperature increases.

In extreme situations, the thermoregulatory system may be unable to cope. If core body temperature rises above 42°C, blood pressure may drop and insufficient blood is pumped to the vital organs including the heart, kidney and brain. Under such a condition, a worker will collapse with heat stroke (Bridger, 1995).

The NRC Biomarkers Committee divided biomarkers into three types: exposure, effect and susceptibility (NRC, 1989). Clearly, a continuum exists between biologic markers of exposure and effect that can be extended to a continuum between source and disease (Lioy, 1990).

This study was conducted to compare environmental and biological markers of effect of heat stress among the workers engaged in one of the southern seaports of Iran.

MATERIALS AND METHODS

Heat stress occurs when air temperature, radiant temperature, humidity, air velocity, clothing and activity

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interact to produce a tendency for body temperature to rise. In such a situation, the thermoregulatory system responds to increase heat loss. This response can be powerful and effective, but it can also produce a strain on the body that leads to discomfort and eventually to heat-induced disorders and even death. It is important therefore to assess heat stress to ensure the health of workers.

In this study, evaluation of heat stress was done using environmental and biological monitoring. Wet Bulb Globe Temperature (WBGT) is the simplest and most suitable technique to measure the environmental factors. WBGT index is by far the most widely used throughout the world. It was developed in a US Navy investigation into heat casualties during training as an approximation to the more cumbersome Corrected Effective Temperature (CET), modified to account for the solar absorptivity of green military clothing (Karasek and Stellmann, 1998). The determination of WBGT requires the use of a black globe thermometer, a natural wet-bulb thermometer and a dry bulb thermometer (ACGIH, 2004).

WBGT values are calculated by the following equations:

Outdoors with solar load: WBGT = 0.7 NWB + 0.2 GT + 0.1 DB

Indoors or Outdoors with no solar load: WBGT = 0.7 NWB + 0.3 GT

Where:

WBGT = Wet Bulb Globe Temperature
NWB = Natural Wet Bulb Temperature
DB = Dry Bulb Temperature
GT = Globe Temperature

According to ACGIH, the measurements were done in cold and hot seasons in the hottest hours of the day during the hottest month of the year.

In order to calculate workers' energy consumption, the procedure of ISO 8996 (1990) was applied. The biological monitoring of effect, using measuring of oral temperature and heart rate was done according to ISO, NIOSH and OSHA recommendations (ISO 8996, 1990; NIOSH, 1986; OSHA, 1999). Checking the recovery heart rate and oral temperature did personal monitoring. According to OSHA, the recovery heart rate checked by comparing the pulse rate taken at 30 sec (P_1) with the pulse rate taken at 2.5 min (P_3) after the rest break starts. The two pulse rates can be interpreted using Table 1.

Similarly, a method of work and recovery heart rate is described by NIOSH (1986). Body temperature and pulse rates are measured during recovery following a work cycle or at specific times during the working day. At the end of a work cycle the worker sits on a stool, oral temperature is taken and the following three pulse rates are recorded:

P_1: Pulse rate counted from 30 sec to 1 min
P_2: Pulse rate counted from 1.5 to 2 min
P_3: Pulse rate counted from 2.5 to 3 min

The ultimate criterion in terms of heat strain is an oral temperature of 37.5°C.

If P_3 >90 and P_1-P_3 = 10, this indicates work level is high but there is little increase in body temperature. If P_3>90 and P_1-P_3<10, the stress (heat + work) is too high and action is needed to redesign work.

Heart rate was measured with a Polar Heart Rate Monitor (Polar Electro Oy, 1993). Oral temperature was measured with a clinical thermometer before work and during WBGT measurements according to ISO 9886 procedure (ISO 9886, 1992). Oral temperature readings exceeding 37.5°C, considered as stressful conditions.

RESULTS AND DISCUSSION

The results showed that during summer, according to environmental monitoring, all of the workers experienced heat stress higher than recommended ACGIH limits. Although, comparison of obtained results from environmental monitoring versus biological monitoring showed that only 16.25% of exposed population experienced heat stress according to biological markers of effect including heart rate and oral temperature. According to heart rate recovery criteria (Table 1), 12.5% of exposed population was under stress. In this group with P_3 >90, 40% of them had a (P_1-P_3)> 10 and 60% of them had a (P_1-P_3)<10. According to oral temperature criteria, 16.25% of exposed population had readings over 37.5°C and were under stress. In majority of workers who classified as under stress according to heart rate and oral temperature criteria, the oral temperature was over 37.5°C and the recovery heart rate was P_3>90.

There was a significant correlation between WBGT readings and workers' recovery heart rate (P_3) and also oral temperature readings during cold and hot seasons.

According to questionnaire data (self-report), acute heat-induced disorders including heat exhaustion (17 cases), heat stroke (2 cases) and heat cramp (13 cases) were reported among exposed workers (totally 23.5% of exposed workers) during the study period.

Table 1: Heart rate recovery criteria

Heart rate recovery pattern	P_3	Difference between P_1 and P_3
Satisfactory recovery	<90	--
High recovery (Conditions may require further study)	90	10
No recovery (May indicate too much stress)	90	<10

It may be concluded that in this study, estimation of heat stress using biological monitoring is closer to reality of heat stress in exposed workers, in comparison with WBGT index in which, all of the exposed workers, are experiencing heat stress.

According to questionnaire data, heat-induced disorders were observed among 23.5% of exposed workers. Meanwhile, biological monitoring of effect using heart rate and oral temperature as the markers of heat effects revealed that 16.25% of exposed population is at risk. This figure shows that estimation of biological monitoring of effect is closer to reality of the workers' stress, according to questionnaire data.

This study was conducted to compare environmental and biological markers of effect of heat stress among the workers engaged in one of the southern seaports of Iran. The estimation of heat stress using biological monitoring was closer to reality of heat stress in exposed workers. The study revealed that biological monitoring of effect of heat stress could be regarded as a low cost and more reliable procedure in evaluation and control of heat stress among exposed population in order to providing comfortable working environment and promoting quality of working life.

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