Chapter

Occupational Heat Stress: A Technical Scan

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Abstract

The trouble for every person is to competently interact with his/her environmental variables. India being a tropical country will have a huge impact on individuals' health as a result of this global warming. Workers who are working in a hot environment pose an extra risk as they are exposed to additional heat in the workplace. The diversity in Indian climatic systems necessitates scientific study in different regions of the country. Methods to quantify the heat strain vary in different countries & different professional groups. Most of the previous studies on assessing the health effects have been conducted on simulation settings rather than actual field settings. Research in occupational heat stress is much needed to find out the health impacts and suitable intervention to protect workers health which subsequently reduces the morbidity.

Keywords: climate change, occupational heat stress, heat strain, prevention, adaptive measures

1. Introduction

The current prediction on climate change says that there will be an increase in the ambient temperature of about 0.5 to 1 degree C by 2030 which may pose a significant risk to the people [1, 2]. India being a tropical country will have a huge impact on individuals' health as a result of this global warming [2]. Workers who are working in a hot environment pose an extra risk as they are exposed to additional heat in the workplace [3]. Occupational heat stress is the net heat load experienced by the worker which includes the combined contributions of metabolic heat produced during the time of work, environmental factors, and clothing [4]. Continuous exposure to excessive heat may result in heat-related illness which ranges from heat rash to heat stroke which life is threatening. Apart from this the workers are at increased risk of accidents at workplaces, decreased productivity which all can cause an increase in morbidity and decrease in community economy. Various factors play a major role in determining the heat stress which includes ambient temperature, humidity, air movement, source of heat, duration of exposure, fluid loss/intake, etc. [5]. Indoor and outdoor workers are at risk of heat stress. Occupational heat stress will cause potential negative health with wellbeing outcome. In this chapter, the basics of occupational heat stress and heat strain, physiology thermoregulation, vulnerable population group, health impacts, Current status of research in occupational heat stress, prevention, control and adaptive measures will be discussed. To achieve this, a technical scan of various research papers pertaining to heat stress that were published in the last ten years were considered and the key points are included in this chapter.

2. What is occupational heat stress?

Heat stress includes many physical reactions that result from a body's capacity to regulate its temperature in response to the environment [6, 7]. Failure in the body regulatory mechanism will lead to heat stress which may cause increase in core body temperature and heat rate. This may further cause accumulation of excess heat in the body which cause the worker to lose concentration in working environment and may become irritable or sick [8]. High air temperatures, radiant heat sources, high humidity, direct physical contact with hot objects, and strenuous physical activities may cause increase risk of developing heat related illness.

Occupational heat stress is that the net load to which a worker is exposed from the combined contributions of metabolic heat, environmental factors, and clothing worn which leads to rise in heat storage within the body [1]. Workers who are working in hot environment are at increased risk of developing heat related illness. Heat stress results in heat related illness and also it may account for an increase in workplace accidents, and a decrease in worker productivity [7, 9]. Heat stress related health impacts ranges from less severe heat rash to more severe heat stroke. Sweaty palms, fogged-up safety glasses and dizziness are the main causes for workplace injury. Burns may also occur as a result of accidental contact with hot surfaces or steam [6, 10]. In India occupational heat stress is becoming more significant as the average temperatures increase but remains overlooked [3, 11, 12]. Both indoor and outdoor workers are at risk of developing heat related illness. Outdoor work sector includes agriculture, construction, brick industry where as indoor work includes firefighters, bakery workers, farmers, miners, boiler room workers, factory workers [12, 13].

3. Physiology of thermoregulation

The internal temperature (Core) of healthy human body should be maintained around 37°C for the various metabolic processes to function at optimum range inside the human body [14]. Variations, usually of less than 1°C occur with the time of the day, level of physical activity or emotional state [15]. As the environment warms-up, the body tends to warm-up as well. In this way, the body increases the rate of heat loss to balance the heat burden created by the environment. In a very hot environment, the rate of heat gain exceeds the rate of heat loss and the body temperature begins to rise. There are number of physiological heat control mechanisms playing a vital role in maintaining the core body temperature even when the external air temperature is greater than 37° C [16]. The pre-optic area in the anterior hypothalamus of the brain along with posterior hypothalamus, medulla, pons and spinal cord maintain core body temperature within normal range. The thermal sensors maintain a constant core body temperature by increasing blood flow to the skin (Vasodilatation) and by increasing sweat production [15]. To balance the heat burden created by the environment, the body increases the rate of heat loss. A rise in the body temperature results in heat related illnesses [17].

The main source of heat gain in a human body is production of its own internal heat called metabolic heat. It is generated within the body by the biochemical processes that keep us alive and by the energy we use during physical activity. The body exchanges heat with its surroundings mainly through radiation, convection, and evaporation of sweat [6]. Radiation is the process by which the body gains heat from surrounding hot objects, such as hot metal, furnaces or steam pipes and lose heat to objects such as chilled metallic surfaces without contact with them [14]. Convection is the process by which the body exchanges heat with the surrounding air. The body gains heat from hot air and loses heat to cold air which comes in

contact with the skin. Convective heat exchange increases with increasing air speed and increased differences between air and skin temperature [14]. The body cools as the evaporation of sweat from the skin occurs. Evaporation sets in very quickly and effect is more enhanced with high wind speeds and low relative humidity. In hot and dry workplaces, the cooling due to sweat evaporation is limited by the amount of sweat produced by the body [6].

The body also exchanges small amounts of heat by conduction and breathing. By conduction the body gain or lose heat when it comes into direct contact with hot or cold objects. Breathing exchanges heat because the respiratory system warms the inhaled air. The body's excess heat is pushed away as the exhalation sets in. However, the amount of heat exchanged through conduction and breathing is normally small enough to be ignored in assessing the heat load on the body [18].

4. Heat stress and heat strain indicators

There are many indices that are used to assess heat stress such asWet bulb Globe Thermometer (WBGT), Universal Thermal Climate Index, Humidex, etc. WBGT is the gold standard internationally accepted indices for measuring heat stress and it was used to measure the heat stress in most of the previous research work conducted in different occupational sectors [19] (**Figure 1**).

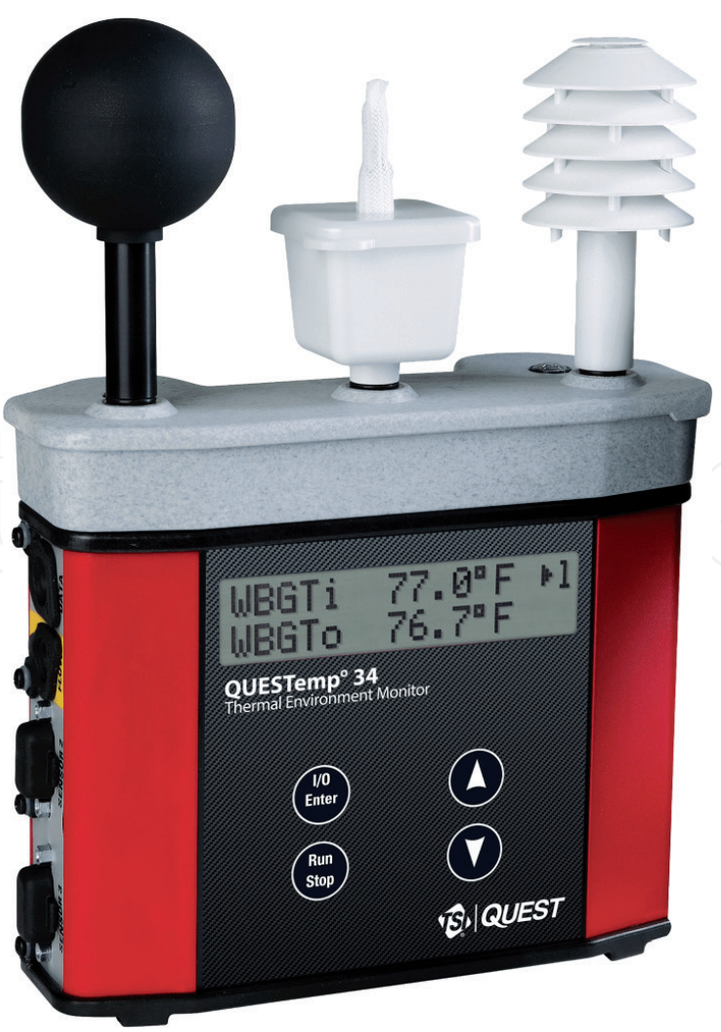

Figure 1.
WBGT.

A wide range of clinical observations and measurement have been used to indicate heat strain, ranging from perception of workers, observational parameter like skin rash to hospitalization due to heat stroke. Most of the previous studies on assessing the health effects have been conducted on simulation settings rather than actual field settings. Such studies although provides us with important information on the relationship, it might not be possible to use the same methodology at work place. The heat strain parameters that were measured in the previous studies include core body temperature [20], Skin temperature [14], Sweat rate [21], Resting/working heart rate [22], Urinary specific gravity [23], Serum creatinine, Serum electrolytes, VO2 Max [14]. The most commonly used heat strain indicators in previous studies are core body temperature, resting heart rate, working heart rate, recovery heart rate and sweat rate. These are done in non invasive manner, so it is easy to perform in field based study. Other parameters such as urine specific gravity, serum electrolytes, creatinine, Vo2 max though reliable but could not be used in the field based study due to the constraints faced in working environment. In fact, these parameters were used in experimental set up study rather than actual field based study. Methods to measure these parameters vary in different study. The most commonly used instrument to measure the core body temperature is through tympanic thermometer as tympanic temperature is the reliable, convenient and most easily accessible site to measure core body temperature (**Figure 2**). Polar heart rate monitor was used to measure the different heart rate in working environment as it is capable of recording continuous heart rate (**Figure 3**). Sweat rate was measured by using the body weight and fluid intake and output of the worker during the working period. The most commonly preferred method to measure the heat strain indicators is to check the pre exposure and post exposure values of these parameters as it can be compared with the standard values given by ACGIH, OSHA etc.

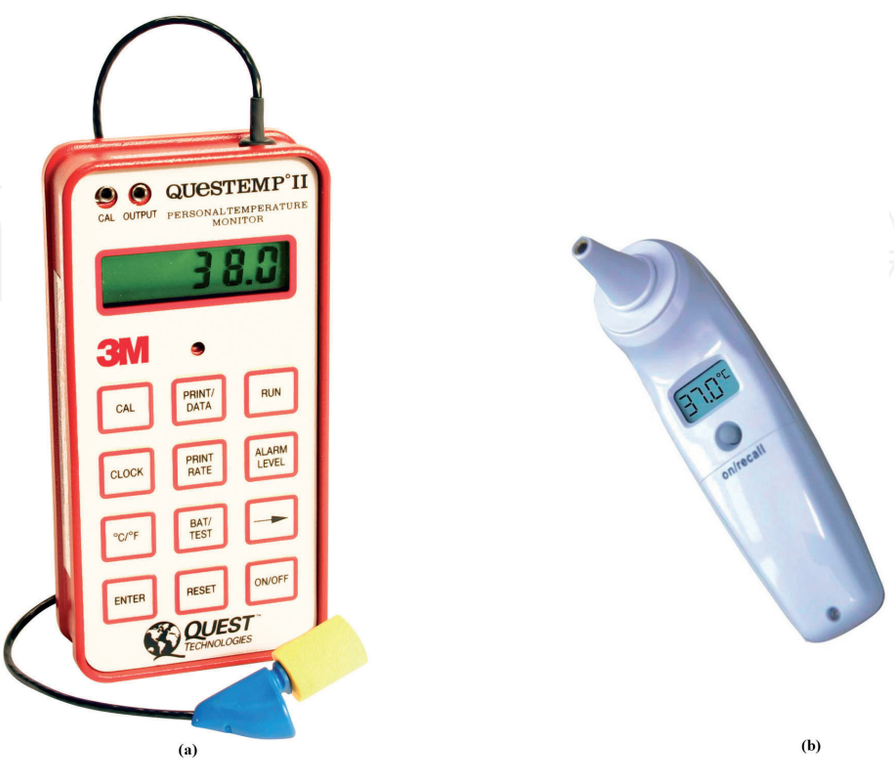

Figure 2.
Tympanic thermometer: (a) quest temp personal monitor, (b) Infrared tympanic thermometer.

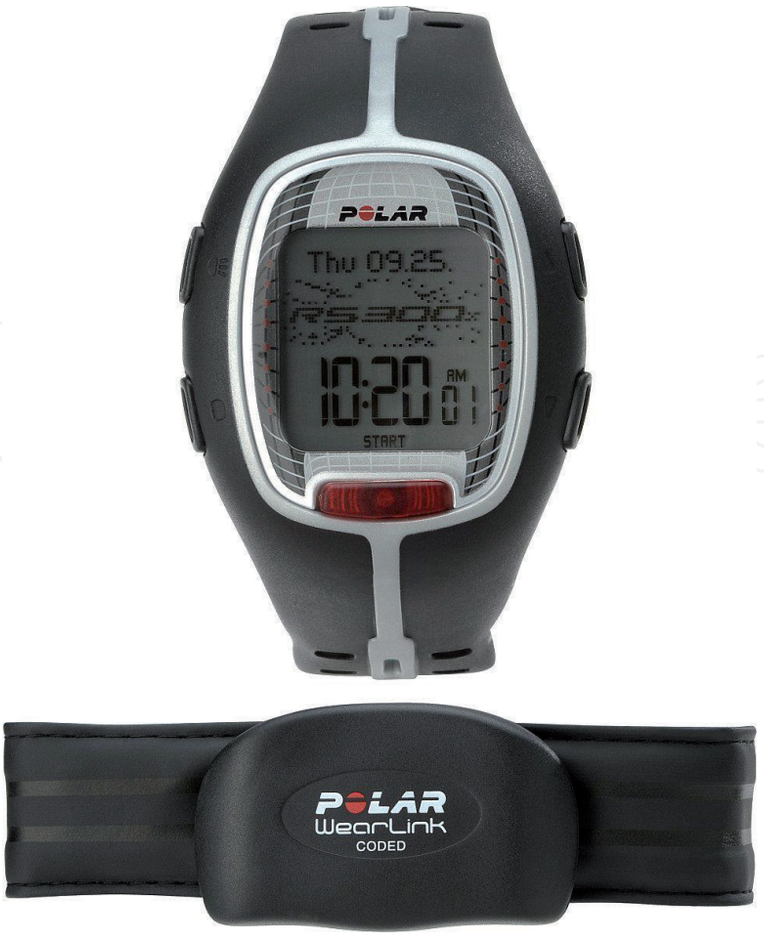

Figure 3.
Polar heart rate monitor.

5. Who is at risk?

Elderly people above 50 years, pregnant women, workers with other co morbid conditions are at increased risk of developing heat related illness. Most of the functions of the human organs are dependent on the temperature and pH. So if there is alteration in any of these two, then it will definitely have impact on other functions of human body. Workers with history of diabetes mellitus, hypertension, and thyroid disorder are at increased risk as it will cause extra burden to the various organs while working in hot environment. Workers at risk of heat stress include outdoor workers such as agriculture, brick industry, construction and indoor occupation such as firefighters, bakery workers, miners, boiler room workers, factory workers. The major reason that working people belongs to vulnerable group is because of internal heat produced when muscles are used during work [14]. Some people tend to keep working beyond the safe limit for heat exposure because of their need to complete work tasks during a particular period or their need to maintain work output to get paid [24]. During prolonged work periods in the heat, the high sweat rates leads to progressive dehydration. It has been well documented that losses of fluids through sweating can lead to dehydration which has a detrimental effect on productivity.

6. Health hazards due to heat stress exposure

When the air temperature or humidity rises above the optimal ranges for comfort, can leads to health impacts [14]. The initial effects are subjective in

nature, they often relate to how you feel. Exposure to more heat stress for a longer duration can cause health problems which impair workers' ability to execute the task and may cause adverse health effects [10]. The body temperature increases because of internal heat production during muscular activity in work place. If the ambient temperature is more than the body temperature, then the heat loss from the body will be minimized by conduction, convection, radiation. As a result the core body temperature will keep increasing and may result in heat related illness such as heat rash, heat syncope, heat exhaustion, heat stroke. The heart rate also increases to pump more blood through skin so that excess heat can be lost to the environment through sweating [14]. These changes will cause additional load on the body. Changes in blood flow and excessive sweating will lead to decrease in person's ability to do physical and mental work [8]. When the environmental temperature rises above 30°C, it may interfere with the performance of mental tasks [14]. The occupational heat stress can affect the workers health either directly or indirectly. The direct health impacts include the heat related illness such as heat rash, heat syncope, heat edema, heat exhaustion and heat stroke [6, 14]. The indirect health impacts include physical and mental stress, hypertension, diabetes mellitus and chronic kidney disease.

Heat rashes are the red spots on the skin which cause a prickling sensation during heat exposure. Heat edema is swelling which generally occurs among people who are not acclimatized to working in hot conditions. Heat cramps are sharp pains in the muscles that may occur as a result of salt imbalance resulting from the failure to replace salt lost due to sweating. Heat exhaustion is caused by excessive loss of body water and salt through excessive sweating. Heat syncope is heat-induced giddiness and fainting because of insufficient flow of blood to the brain while a person is standing which is caused by the loss of body fluids through sweating. Heat stroke is the most serious types of heat illnesses. The body temperature often increases more than 41°C.

7. Status of research in occupational heat stress

The environmental temperature increases day by day to due to the ongoing climate change that is occurring in various part of the world. Deforestation, urban heat island effect, Modernization process, increase in number of industries cause a rise in ambient temperature level, which also has impacts on workers health. Studies pertaining to heat stress across the globe are carried by researchers and they have found that exposure to excessive heat in work place has impacts on workers health and productivity.

Studies in occupational heat stress in India are limited because of the following challenges and constraints [25].

a. Permission from Industries to collect data and to publish it

b. Organized vs. Unorganized sector

c. Improper record/documentation of heat/any occupational disease by the employer or worker

d. Study Design

e. Assessment of health parameters

Specific heat wave events in the Northern hemisphere have been associated with marked short term increases in mortality, with reported excess mortality ranging from 4–142% [4]. It is estimated that in 2003, up to 70,000 additional deaths occurred over the summer months in Western Europe as a consequence of severe heat waves [26]. An estimated 560 extra deaths were observed during the three heat waves of 2002 in Russia. Lag times of just a few days have been observed between the onset of a heat wave and the rise in mortality, suggesting that people succumb quickly to the effects of extreme heat. Some of the deaths occurring in heat waves are due to exacerbation of preexisting illnesses particularly cardiovascular and respiratory diseases, and diseases of the nervous system [27]. Mortality associated with heat waves has been reported to be greatest in city areas, in conjunction with observed high night-time minimum temperatures, high levels of air pollution, and poor housing conditions. Few studies have investigated the effects of extreme hot weather on population morbidity. Hospital admissions have been observed to increase during heat waves. However studies have revealed discrepancies between the impact of heat waves on morbidity and mortality, in terms of magnitude, cause, and age group [28]. Reports of a lesser impact of heat waves on hospital admissions than on mortality may indicate that people die quickly during heat waves before they are able to reach hospital or be noticed by others. Studies of patients admitted to hospitals during heat waves for treatment of heatstroke have shown this illness to be associated with an outcome. The risk of heat stroke among working people is well known and explained by the limits of human physiological adaptability [14]. Significant number of working people dies due to heat stroke even in high income countries as described in a study of agricultural workers in the USA. A substantial amount of body water may be lost as sweat, including loss of fluid through respiration, gastrointestinal tract as well as kidney. Increased dehydration disturbs the homeostasis of the body, leading to decreased skin blood flow, elevated core body temperature, decreased sweat rate leading to impaired to tolerance to work resulting in increased risks of heat injuries. Continuous exposure to excessive heat may cause profound increase in heart rate which may lead to sympatho - vagal imbalance if not treated appropriately [20]. Heart rate is useful in evaluating the exertion required by physical labour in working conditions [22]. Trainings including acclimatization may be useful in maintaining the core body temperature and heart rate within normal range among workers exposed to excessive heat [17]. A wide range of clinical observations & measurements have been used to indicate heat strain, ranging from perception of workers to hospitalization due to heat stroke. > 20% of people are being estimated to have health impacts of heat stress, ranging from skin rash to heat stroke. About 28% of workers were at risk of health impairment due to high heat exposure at work place [29]. There was a noticeable disconnect between worker's perceptions and their ability to perform task [30]. Most of these studies were done in experimental set up which cannot be considered as a standard protocol for studies in field/industry. Some of the examples include rectal temperature, capsule method for core body temperature, nude body weight measurement, etc. Apart from heat, many confounding factors also play a role in health impacts. With all this issues, it is important to identify globally acceptable heat strain parameters and methods. Such methods can be used as relevant indicators locally by the health professionals to develop health surveillance and prevention programs for workers to protect the workers health. There are only few studies done in India about Occupational heat stress and its health impacts and no studies conducted on assessment of heat stress and its physiological responses in this geographical location. So it is very essential to do more studies in India to document the health impacts of heat stress.

8. Prevention and control

Prevention is better than cure. It will be ideal for each worker to follow certain preventive measures to reduce the health impacts due to heat stress. The prevention methods may vary with different occupational sectors. The occupational sectors can broadly be classified in to outdoor (Unorganized) and indoor sector (organized). Adequate rest, following work rest cycle, providing adequate fluid during work time can be followed as a preventive measure in outdoor sector. Along with these measures, engineering intervention such as providing fan, coolers, PPE can also be followed in indoor sectors as prevention and control measures. Health education about the heat stress and its health impacts will greatly help to reduce the burden of the disease [6].

- Educating the management and administrative members to provide training to the workers regarding heat strain at the time of employment
- Health education is very important for the workers.
- Advised workers to consult doctor if any health problem is noticed by the worker
- Periodic health assessment of the workers (health surveillance)
- Suggestions for engineering intervention such as proper ventilation, exhaust, work rest cycle can be given to the management

9. Adaptive measures

Heat exposure levels can be lowered by use of certain control measures such as engineering intervention (Proving fan, coolers), personal protective equipments, proper ventilation, adequate rest, following work rest cycle as per ACGIH guidelines, providing adequate fluid to prevent dehydration, periodic medical checkup, etc. Special attention should be provided to aged workers and also to workers with significant medical illness. Health education to workers regarding heat related illness and ways to prevent it can help in reducing the morbidity. Studies of this kind using mapping can help in detecting the vulnerable areas inside the industry and also can protect the workers health. All workers should be made aware of the heat levels in all the areas inside the industry and should be instructed to take all precautionary measures while working in high heat generating areas. Engineering controls like by providing fan, adequate ventilation in working environment and by following work rest cycle as per ACGIH guidelines can protect the workers health. These recommendations could help the workers to protect their health from heat related illness.

10. Conclusion

Occupational heat stress will cause potential negative health with wellbeing outcome. The industries (Management) and the workers should be educated about the health impacts of occupational heat stress. Proper measures should be laid down to prevent the heat related illness which can be helpful to reduce the morbidity and mortality that may indirectly improve the community economy.

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