Heat Stress in the Workplace: A Case Study of a Cement Manufacturing Facility in Trinidad

Winston G. Lewis and Ricardo Rodriguez

Abstract Heat stress is a well-known occupational health disorder and since Trinidad is a tropical island in the Caribbean, there is a serious risk to heat stress illness occurring when workers operate in adverse thermal working environments. This paper aims at illustrating the prevalence of work-related heat stress within a cement manufacturing facility in Trinidad. Using the Threshold Limit Value (TLV) Standard, it was found that 10 out of 11 work stations exceeded the recommended time to perform the given task. The study of heat stress experienced by workers was linked to the subjective heat related symptoms as identified using a questionnaire. On average, kiln workers experienced a greater number of symptoms than mill workers with the most common symptoms to both groups being dehydration, fatigue and headaches. The study showed that symptoms increased with the age and body mass index (BMI) of the participants.

Keywords Work related heat–stress disorders · Heat stress · Heat strain

1 Introduction

Many indoor and outdoor occupations require employees to work in high temperature environments and in tropical countries such as Trinidad the problem of heat stress illness is thus increased. It is important to ensure that the Core Body Temperature (CBT) of workers in those conditions remain constant in order for the body to function efficiently (Parsons 2005). When the body gains heat, this heat

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must be continually dispersed to the surrounding. Factors that influences the rate of heat dissipation are; environmental parameters, metabolic rate and the clothing worn. These factors determine the overall heat load to which workers are exposed to (Bernard 2012). In extreme thermal conditions the body cannot dissipate enough heat causing the CBT to increase, this leads to heat strain on the body developing. Heat stress illnesses occur due to heat strain on the body, it is the body's way of responding to the intense thermal environment. Some heat illnesses are heat exhaustion, heat stroke and heat cramp (Adelakun et al. 1999). High levels of heat strain may lead to a complex range of heat related illnesses.

Heat stress illnesses can lead to the impairment of a person's physiology causing them to experience symptoms such as fatigue, headaches, nausea and dehydration. This affects the worker's performance causing a decrease in productivity, reduced physical performance, and an impairment of mental function leading to near misses, injuries or accidents.

Trinidad does not have specific laws or regulations governing heat exposure and resulting heat stress. In the absence of clearly prescribed standards, Threshold Limit Values (TLVs) for heat stress as outlined by the American Conference of Governmental Industrial Hygienists (ACGIH) should be followed (OSHA 1999). These TLVs can be used as a guideline for enforcing the legislation's general duty clause, which requires employers to take every precaution reasonable to protect workers' health and safety.

2 Literature Review

This study seeks to evaluate the levels of heat exposure and symptoms of heat-related disorders encountered by workers at a cement manufacturing facility in Trinidad. Although employees in many industrial manufacturing processes are at risk of suffering heat strain and heat-related illness, workers in a typical cement manufacturing plant may be particularly at risk due to the specific challenges of their work-environment. With the many demanding tasks combined with high working temperatures in a tropical country, the body may begin to accumulate heat from both the work-environment and metabolic load thereby increasing chances of heat related illness. At present there is a lack of studies seeking to evaluate heat stress in cement manufacturing facilities and no formal data focusing on heat related disorder in facilities in Trinidad.

Heat stress may pose significant problems for workers especially in a manufacturing facility. Workers may become disoriented, with impaired judgment, as heat stress increases. This increases the risk of injury as the ability to take protective measures is reduced due to impaired decision making (Glazer 2005). The body's inability to thermo-regulate and cool itself may result in heat related illnesses such as heat exhaustion or heat stroke. Such outcomes however are preventable by properly monitoring environmental and work conditions, applying the appropriate preventative measures, as well as training employees and supervisors on heat exposure safety (Environmental Protection Agency 1993). However, with a lack of regulation and directed policy, it is difficult to implement these steps.

Occupational studies highlight the significant relationship between the environment, work rate metabolic load, and core body temperature. During work and activity, core body temperature remains relatively constant for a given metabolic rate even with an increase in environmental temperatures. This occurs until a threshold temperature is reached. At threshold temperature, core body temperature increases steeply in a highly non-linear fashion with increased ambient heat. As work rate increases, the amount of environmental heat a worker can tolerate decreases. Inversely, as environmental heat increases, work rate should be decreased for an exposed employee (Bernard et al. 1994).

Thermoregulation in humans is the ability to regulate a constant core body temperature of approximately 38 °C under varying environmental conditions. In the event that the core body temperature rises above 41 °C, severe disorders may occur, with a core body temperature over 43 °C resulting in death. The specific transfer mechanisms of heat include radiation, convection, conduction and evaporation. The effectiveness of heat transfer as well as the direction in which heat transfer occurs depend on environmental factors including temperature, humidity and radiant temperature as well as the metabolic rate of the subject. Other factors may also affect the heat gain and heat loss transfer such as the type of clothing worn.

Whenever activity is performed there is an accompanied increase in internal heat production and an increase in the core body temperature. The rate of increase of core body temperature is higher in hot environments. If due to environmental or other factors, the ability of heat to be transferred from the body is diminished, even low levels of activity may result in a rapid rise in the core body temperature. Initial response may include sweating and increased skin blood flow for increase heat loss. The increased skin perfusion associated with this blood flow causes an increase in skin temperature facilitating greater heat loss by evaporation. An equilibrium is thus reached with the increased lost to new heat gained, so that the core temperature stabilizes at a higher level (Hunt 2011).

3 Heat Illnesses

Cement manufacturing poses a great risk to workers contracting heat related illnesses such as heat stroke which carries with it accompanying symptoms that include: headaches, speech disability, dizziness, cramps, confusion and in extreme cases, coma. The high temperatures in the factory environment which may occur due to high heat exposure as well as physiological strain induced by increased metabolic loads and work duration, could lead to core hyperthermia which is an abnormally high CBT above 41 °C. This is a serious medical condition that requires urgent attention when it occurs since it could lead to death through organ failure if the body temperature passes the threshold temperature for normal functioning. Other heat-related conditions that can occur include heat fatigue, heat cramps, heat syncope, heat rash, and heat exhaustion, all of which play a pivotal role in the health and well-being of the worker and whether he is capable of executing his duties efficiently which could lead to downtime and loss of earnings and profits to the organization (EPA 1993).

4 Heat Strain

Upon exposure to heat stress, the body is focused on maintaining the CBT within an acceptable range. The body's resultant response from heat stress is known as heat strain (DiCorleto et al. 2002). Factors and conditions including hydration status, fitness, age, acclimatization and gender can influence the levels of heat strain. Individuals react differently to heat (Hancock and Vasmatazidis 2003) hence it is important to distinguish the risk factors that can substantially raise the potential of a worker experiencing heat stress (Bernard 2012).

5 Methodology

The use of empirical methods to determine situations where excessive heat may cause harm due to heat stress is critical in ensuring the protection of workers in hot environments. Thermal stress or heat stress indices attempt to predict the effect of hot environments, by preventing core body temperature from exceeding 38 °C. Many indices have been developed in the 20th century that seek to evaluate heat stress in the workplace for specific industries.

Indices can be categorized into either rational or empirical subgroups, where rational indices are based on the principles of heat exchange and heat balance in assessing human physiological responses. Unlike rational indices, empirical indices are based on processed data from field experiments that were performed under different thermal environmental conditions. These indices describe heat stress limits in relation to environmental conditions, work rate and clothing parameters without relying on physiological conditions and measurements.

Common empirical indices include Oxford index, Effective temperature, Corrected effective temperature, Wet bulb temperature and Wet bulb globe temperature index. The accuracy of empirical and rational indices have been well studies and document all over the world with the WBGT being deemed as the most appropriate index for use in studies and evaluations in workplaces (Hartley and Waterhouse 2003).

Parsons (2005) have noted that the WGBT Index is the most common method for the assessment of occupational heat stress, due to its reliability, simplicity and robustness as well as the fact that it is appropriate for both outdoor and indoor analyses of exposure to extreme or moderate heat. Comparison between WBGT and other heat stress indices for many occupational settings have been investigated.

Bernard (2012) concluded that the WBGT is correlated with CBT rather than heart rate or sweat loss.

The WBGT provides a combined measure aimed at estimating the effect of temperature, humidity, and solar radiation on humans. The WBGT data collection instrument collects all three parameters simultaneously and calculates values that are used to estimate if a problem exists by determining whether measured values exceed reference values. WBGT values are used most commonly in conjunction with work rest schedules based on metabolic rates and clothing adjustment factors.

6 Data Collection and Analysis

Data for the thermal environmental exposures of workplaces in Trinidad is lacking. Information is needed to evaluate the symptoms experienced upon heat exposure that exceeds the threshold values. The prevalence of worker heat related disorder symptoms will also be investigated and assessed through a questionnaire.

7 Environmental Monitoring

To assess the heat stress in the thermal environment the Wet Bulb Globe Temperature (WBGT) was found. This was used to evaluate the heat stress that workers are exposed to along the kilns and mills in accordance to the standards set out by ACGIH (2012). The types of jobs monitored at the kilns were; creep measurements along piers, greasing, hot kiln alignment and maintenance under the kiln. The types of jobs monitored at the mills were; inspection inside the mill, cleaning inside the mill and maintenance at the mill.

For each task, interviews were done with workers and observational assessment for existing work practices were recorded to assess the type of work load category the work performed is categorized as light, moderate, heavy or very heavy. It was determined that the tasks monitored for this study at the kilns varied from light to moderate whereas, the workload at the mills varied between light to heavy.

Analyzing the results seen with the increasing values of dry bulb, wet bulb and black globe temperature from pier 2 to pier 5, this directly relates the expected trends of the WBGT values to increase as well. The WBGT readings obtained can be seen in Fig. 1. These WBGT values were analyzed using the ACGIH Standards (ACGIH 2012). Using the work rest regimes for light work load determined from the ACGIH Standards, it can be seen that these valves have exceeded the TVL value of 32.5 °C. Thus the work rest regime derived is 0/100 %, this means work 0 % and rest 100 %.

The TVL Standards take into account a recommended hourly rate, therefore workers are required to rest for the 60 min and work for 0 min. This value means that for light workloads, workers cannot tolerate the heat exposure and no work

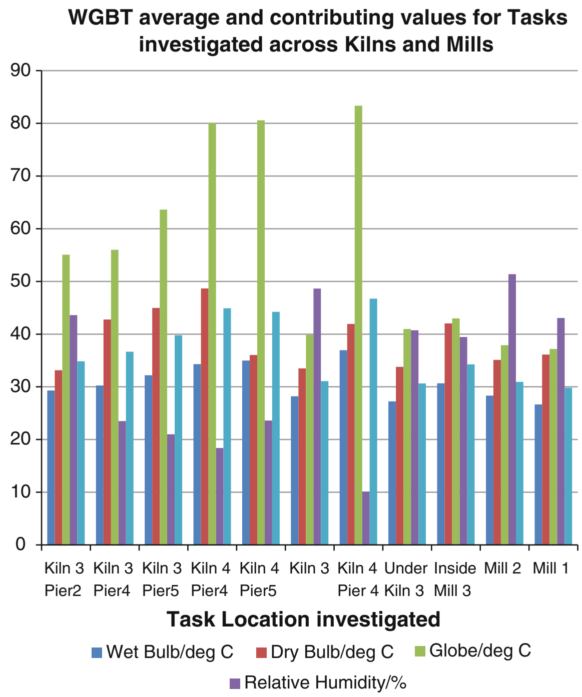

Fig. 1 Shows the WBGT average and contributing values for tasks investigated across kilns and mills

should be performed. Since work is performed exceeding the recommended TLV Standard workers are exposed to heat stress, this would give rise to individuals experiencing heat related symptoms. All workers working or performing tasks should take precaution and control measures.

Even though work at these temperatures is not permitted according to the Standards set out by ACGIH, work must be performed. All workers performing tasks should take precautions and recommended control measures must be taken.

8 Characteristics of Participants

The data collected using a questionnaire was analyzed to obtain statistical trends regarding the prevalence of symptoms in relation to heat strain as well as underlying contributing factors and predispositions of the subjects. The administration of the questionnaires was conducted at all stations where the environmental heat stress survey was conducted.

The participants of the survey were characterized by age, BMI, activity levels conducted per week and years of employment. This is because the literature points to these characteristics as having an influence on the degree of heat strain experienced by the individual. From the results it was found that the majority of workers both at the kilns and mills were in the 30–40 year age group (75 % of the mill workers were in this category, while 58.4 % of kiln worker were in this category). The second largest age group for both kiln and mill workers was the 20–30 year age group, with the 25 % remaining mill workers and 33.3 % of kiln workers falling in this group. The final 8.3 % of kiln workers fell in the 40–50 year age group. No mill worker age 40–50 participated in the survey. These results clearly indicate that most of the survey participants were middle aged. A total of 66.7 % of the kiln worker participants and 75 % of mill worker participants were employed for more than 5 years.

The participants were separated into categories of overweight and not overweight using BMI. Equal percentages of kiln worker participants were categorized into overweight and not overweight. The majority (75 %) of mill worker participants were found to be overweight. Participants were grouped into those that engaged in no physical activity per week and those engaging at least one activity per week. The majority of the participants of the survey engaged in no physical activity whatsoever (75 % of all kiln workers and 62.5 % of all mill workers). Since the majority of the participants are middle aged (30–40 yrs.) and engaged in no physical activity it was expected that many of the participant in the survey would have experienced some degree of heat strain and associated symptoms obtained. This is because the level of heat strain increases with age and lack of physical activity (Havenith et al. 1988).

From the data collected on kiln workers, the most affected participants experienced 29 % of possible symptoms and no worker experiences less than 5 % of total symptoms. By contrast, the most affected participants in the mill experience a total of 15 % less symptoms than the most affected individual working in the kiln. In addition, there is more than one mill worker exhibiting no sign or symptoms of heat strain. The data shows that the average percentage of total symptoms experienced in the kiln workers was 15 %, while the average percentage of total symptoms experienced by mill workers was 8 %. These trends suggest that kiln workers are more affected by heat stress and are at a greater risk for heat strain than workers in the mill. This is supported by the data obtained from the environmental monitoring, with WBGT values being all higher in the kilns than those recorded at the mills.

9 Discussion

The distribution of each heat strain symptom occurring in kiln and mill workers were examined for each symptom mentioned in the questionnaire and the frequency of participants reporting this symptom was noted. It was found that the three most common symptoms reported by participants both in the kiln and mills are; dehydration, fatigue and headaches. These symptoms occur in the same order. Studies done by Mei-Lien et al. (2003) found that the most prevalent symptom among steel workers were dehydration and fatigue.

In general, kiln workers experience a greater number of symptoms than mill workers. Specifically five symptoms: muscle cramps, weakness, low coordination, hot and dry skin and high body temperature are experienced by kiln workers but not by mill workers. Also, it was found that symptoms common to both groups are experienced to a greater degree by workers in the kiln. This again confirms the general trend outline previously that kiln workers are much more affected by heat stress and are at a greater risk for heat strain than workers in the mill.

A total of 11 symptoms included in the survey were not experienced by any of the participants either in Kiln or Mill. These symptoms were occurrence of red rash, fainting, nausea, dizziness, confusion, irrational behavior, loss of consciousness, seizures, unable to concentrate, difficulty in breathing and nervousness. This suggests that the heat stress experienced by workers at the mill are not as adverse as those experienced by the kiln workers.

10 Conclusions

Based on a comparison with the recommended ACGIH (2012) TLVs the workers at the cement manufacturing facility were monitored at the kilns and mills. It was found that using the TLV Standards that 7 out of 9 kiln studies and 1 out of 3 mill studies had a recommended work rest regime of 0/100 %. To ensure worker safety against environmental heat stress it is recommended that no work should be performed. It can also be noted that the WBGT obtained at the kiln exceeded those at the mills. The physiological response the body has towards heat stress in the work environment is termed heat strain. Individuals at the kilns and mills are exposed to a high likelihood of heat strain and an increased risk of heat illness. When investigating subjective heat related disorder symptoms via a questionnaire given to kiln and mill worker it was found that in general kiln workers experienced an average of 8 % more symptoms than those of mill workers and a total of 5 symptoms that were reported by kiln workers were not experienced by mill workers. The most common symptoms to both groups were dehydration, fatigue and headaches. The extent of symptoms varied among different participants depending on age, BMI and activity levels. It was found that the amount of symptoms increased with the age of the participants; BMI (≥25 for an overweight person) and person who perform no weekly activity. Workers that were above the TLV Standards indicate that a recommended Work Rest Regime should be implemented and general controls at the facility such as self-pacing, training programs, health surveillance, shielding of radiant heat sources, ventilation, PPE, acclimation programs must be implemented and maintained.

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