Abstract

Background: High process temperatures associated with industrial operations augment risk of heat stress and Heat Illnesses, particularly during summer months in the Gulf region located in the northern hemisphere in the latitude of 26.7o N. Lack of hydration and nutrition during day time, during Ramadan can subject workers to even greater risk of heat stress and heat illness.

Aim: This study aims to examine the physiological effects of prolonged fasting in thermally challenging conditions.

Methods: Longitudinal measurements were carried out on employees during Ramadan fasting period, in three departments of an aluminium smelter. After informed consent, physiological parameters were measured at 4 hour intervals.

Results: Average heart rate and urine specific gravity showed an increase in the first four hours of shift work, while Tympanic temperature did not rise significantly. Moreover, in the second four hours of the shift work, urine specific gravity stabilized compared to the first four hours.

Conclusions: Robust administrative work place measures are needed for industries with high process temperatures, located in the Gulf region, in order to minimize the enhanced risk of heat stress and heat illness during Ramadan.
Introduction

Stressors of various kinds affect manual labourers including not only physiological factors but socio-cultural as well (1,2). High heat exposure is one of the primary reasons for work stress in the Middle East. In parts of the Region, ambient temperatures rise above 45 degrees Celsius in the summer and the accompanying relative humidity can reach 90%, putting immense pressure on the bodily systems of outdoor workers (3). Manual labourers often consist of national and expatriate workforce (4), and many local workers are known to be reticent in terms of intake of fluids and food in the morning when reporting to work during Ramadan and resulting in hypo-hydration (5). While this behaviour is erratic and differs between individuals, it appears there are few studies examining the effect of deprivation of food and fluids during the fasting months of Ramadan in the Middle East (6). This fasting period of Ramadan occurs during the summer months in successive years in accordance with the Islamic calendar and creates a unique situation for health and safety professionals (7). While consumption of water ad libitum does not completely eliminate dehydration of workers during other times, the mandatory withholding of fluids and food during daylights hours in Ramadan places health and safety professional in a challenging environment in the context of ensuring worker health and safety (8).

Lifestyle prior to industrialization in the Gulf region had been predominantly based on agriculture and fishing, which permitted periods of rest during the heat of the day (9) as well as the requirements and practices during Ramadan (10). However, the discovery of oil and subsequent industrialization brought about new occupational challenges. Industries requiring 24/7 operation generally employ three shifts of 8 hours or two shifts of 12 hours. Changes in lifestyle after the onset of industrialization include longer working hours, consumption of diets high in processed foods, higher calorie count, carbonated drinks, and lower physical activity levels (11).
Maintaining the health and safety of fasting individuals (workers) during Ramadan is a challenge in the modern industrial context (12). Ramadan follows the lunar calendar and thus moves back 10 days each year, meaning that the month of Ramadan takes place at different times over a number of years, and eventually the cycle repeats every 33 years (13). When Ramadan happens to occur during the summer months, daytime duration is much longer and predisposes the fasting individual to greater risks of heat fatigue due to lack of fluids and nutrition, especially in workers engaged in physically strenuous tasks outdoors. This study aimed to examine the physiological effects of prolonged fasting in thermal stress conditions mandated for religious reasons.

Methodology

Longitudinal observations were conducted by selecting operational (field) employees involved in physically strenuous and demanding work in an aluminium smelter during Ramadan from 2009 to 2010. Fasting during Ramadan can be considered as intermittent fasting for 29 to 30 days. Three departments at the smelter were identified as prone to excessive heat, namely: 1) cast house (due to high temperatures from metal melting and casting furnaces); 2) carbon anode plant (due to radiation from anode baking furnaces); and 3) electrolytic reduction (due to temperature in the pot cells, approximately 950 degrees Celsius). Informed consent (both English and Arabic versions made available) of participating employees was obtained before enrollment in the study. Sets of employees working in the same shift for two successive days were chosen each day. Two employees from each work area mentioned above were the focus of observations for two consecutive days.

All workers who participated were males on consecutive fasting for more than 14 days. The periods of observation were the summer months of August and September covering the beginning, middle and end of Ramadan. A third of the subjects was hypo-hydrated at the start of the shifts and was excluded from the analysis.

Heat illness was measured using a heart rate monitoring chest strap that recorded heart rate continuously, and was a surrogate for physical strain resulting from activity and heat. Heart rate data were transmitted to a remote recorder (Polar watch®) worn by the worker. Hydration status was assessed from urine specific gravity measured at the start, mid and end of shift. State of hypo-hydration was defined as a specific gravity more than 1025. Tympanic temperature and blood pressure were also measured at these times or as demanded in between. The heart rate data was downloaded from the Polar watch® and transferred to the Case Record Form (CRF) as mean and maximum heart rates over four-hour periods. Calories expended were estimated automatically by the instrument based on the continuous heart rate assessment. An excel spreadsheet was used to collect the data and used for analysis. Analysis was done separately.
Continuous data such as heart rates, tympanic temperature, urine specific gravity and calorie counts were summarized as means and standard deviations (SD). The observations at the end of 4 and 8 hours were analyzed in this fashion. Hypo-hydration data were presented as percentages and department wise comparison was made using chi-square test. Results of these analyses were presented as tables. One way ANOVA was used to compare the parameters at baseline, 4 hours and 8 hours into the shift period. Repeated measures ANOVA was undertaken to see the overall effect of heat stress between the various time points across departments. All statistical analyses were done using SPSS version 20 (14). A P-value of less than 0.05 was taken as statistically significant.

**Results**

The analysis included 76 individuals of the carbon department, 52 of the reduction department and 73 of the cast house department employees during the period of Ramadan. The divisions were similar in terms of the baseline parameters except the age and blood pressure values, which were low in the cast house department (Table 1). The mean values of other significant parameters were not different, to start with, especially urine specific gravity (Table 1).

Average heart rate during the first 4 hours increased from resting heart rate by more than 10 beats per minute as well as slight increases in the tympanic temperature. Urine specific gravity, however, increased substantially from baseline (Table 2). Average heart rate during the second 4 hours of shift increased beyond that recorded during the first four hours, but the tympanic temperature did not increase correspondingly. Urine specific gravity stabilized compared to the first four hours of the shift (Table 3).

The analysis of the three main physiological parameters adjusted by the three departments among the subjects is graphically represented in Figure 1. The data shows the steady increase in the four hours of variables of urine specific gravity and average heart rate, and later stabilizing. There is only marginal increase in the tympanic temperature during the
corresponding periods. The effect of Ramadan fasting in statistical terms is laid out in Table 4. The above-mentioned changes are all statistically significant in employees normally arriving hydrated at the start of the shift. However, the increases did not produce a critical increase beyond the accepted values of tympanic temperature. The interdepartmental differences were only nearly significant statistically.

Intervention by means of hydration of workers that is usually followed during normal times could not be enforced in the fasting period. Hence, the percentage of employees becoming hypo-hydrated during shift progressed in the manner shown in Table 5.

Discussion

As observed in the results, average heart rate during the first 4 hours of shift increased from resting heart rate by more than 10 beats per minute and there was a corresponding increase in the tympanic temperature and urine specific gravity. Variations in these parameters are clear indicators of increase in the risk of developing heat stress in fasting individuals exposed to high occupational heat. Average heart rate during the second hours of shift increased without a corresponding increase in tympanic temperature. Urine specific gravity more or less stabilized in second 4 hours, compared to the first 4 hours of the shift. This most likely reflects the physiological slowdown in the individual brought on by fatigue and consequent self-pacing. Cognitive and physical capabilities of workers may be significantly lowered due to inadequate nutrition and fluid intake (15). Clearly this sequence of events significantly brings down the levels of productivity. Safety of workers could be significantly jeopardized in the event of absence of self-pacing and other supportive workplace measures (16).

Classically, heat stress would be characterized by elevation of average heart rate above 110 beats per minute for a period, as per WHO recommendation (1969) (17). As a corollary, if the heart rate would reach above the maximum sustainable rate, the performance deteriorates, putting the worker and the process at risk (18). The increase in heart rate is consistent with the hydration loss of an individual to the extent of 10 beats for every 1% loss in body weight. The hypo-hydration also increases the core temperature at proportionate levels. Core body temperatures above 38 degrees Celsius put workers at risk of exhaustion (19). Religiously mandated fasting would subject a person to higher stresses than warranted due to lack of intake of fluids, which will curtail production of sweat for body cooling.

Conclusions

Physiological observations during fasting show a steady increase in the 4 hour period with
regard to the variables of urine specific gravity and average heart rate. These changes are all statistically significant in employees arriving normally hydrated at the start of the shift.

These observations indicate that work places with high environmental temperatures and physically demanding tasks would require better administrative work place controls including work place temperature reduction, generous or liberal work–rest regimen, optimization of shift duration, and optimization of number of workers during hotter parts of day, in order to ensure that variations in physiological parameters do not jeopardize the health and safety of workers. It is also necessary to look at possibilities of developing or using a thermal index more suitable to local conditions and culture in the Gulf region than currently available heat indices, in order to improve the health and safety of workers while sustaining the productivity levels and targets.

**Limitations**

Physiological observations were made in a factory setting and could not be conducted in a manner similar to those in a controlled laboratory environment. Although tympanic temperature may not be the best way to measure body temperature in an ideal laboratory or clinic setting, that is the most convenient means available in a factory setting. The other limitations are that heart rate and urine specific gravity could also be affected by personal factors including usage of certain medications in some instances. Even though observations were done throughout the period of Ramadan, analyses were not done separately for different phases of Ramadan (early, middle and end). Although the context of physiological adaptations during different phases was essential for the purpose of this article, the difficulty in the availability of volunteers for real-time observations limited our sample size.

**Acknowledgements**

Authors would like to thank the management and staff of Sohar Aluminium for their support. Authors would also like to thank the entire medical team of Sohar Aluminium Health Center, particularly occupational nurses Sara Jacob and Edwin Bagto.

Funding: None.

Competing interests: None declared.

**References**


