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Abstract

Background: High process temperatures associated with industrial operations augment risk of heat stress and illness, particularly during summer months in the Gulf Region. Lack of hydration and nutrition during day time, during Ramadan can subject workers to even greater risk of heat stress and illness.

Aims: To examine the physiological effects of prolonged fasting in thermally challenging conditions.

Methods: Longitudinal measurements were carried out on employees during fasting in Ramadan 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 increased in the first 4 hours of shift work, while tympanic temperature did not rise significantly. Moreover, in the second 4 hours of shift work, urine specific gravity stabilized compared to the first 4 hours.

Conclusions: Robust workplace 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 illness during Ramadan.

Keywords: Heat stress, heat illness, Ramadan, aluminium smelting, work place, Gulf

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Introduction

Stressors of various kinds affect manual labourers including physiological as well as sociocultural factors (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°C 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 workforces (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, resulting in hypohydration (5). While this behaviour is erratic and differs between individuals, there are few studies examining the effect of food and fluid deprivation 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 professionals in a challenging environment in the context of ensuring worker health and safety (8).

Lifestyle prior to industrialization in the Gulf Region was 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 of Ramadan (10). However, the discovery of oil and subsequent industrialization brought about new occupational challenges. Industries that require operation 24 hours a day for 7 days a week generally employ 3 shifts of 8 hours or 2 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 several years, and eventually the cycle repeats every 33 years (13). When Ramadan occurs during the summer months, daytime duration is 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.

Methods

Study procedure

Longitudinal observations were conducted by selecting 201operational (field) male employees (average age 27.33 years) involved in physically strenuous and demanding work in an aluminium smelter in Oman. All participants took part in consecutive fasting for > 14 days during Ramadan from 2009 to 2010. The periods of observation were the summer months of August and September covering the beginning, middle and end of Ramadan. One third of the subjects was hypo-hydrated at the start of the shifts and was excluded from the analysis. Fasting during Ramadan can be considered as intermittent fasting for 29–30 days (14). Three departments at the smelter were identified as prone to excessive heat, namely: (1) casting house (due to high temperatures from metal melting and casting furnaces; 73 participants); (2) carbon anode plant (due to radiation from anode baking furnaces; 76 participants); and (3) electrolytic reduction (due to a temperature of ~950°C in the pot cells; 52 participants). Sets of employees working in the same shift for 2 successive days were chosen each day. Two employees from each work area mentioned above were the focus of observations for 2 consecutive days. Informed consent (both English and Arabic versions made available) of participating employees was obtained before enrolment in the study.

Heat strain measurement

Heat strain was measured using a chest strap that monitored heart rate continuously, and was a surrogate for physical strain resulting from activity and heat. Heart rate data were transmitted to a remote recorder (FT 80; Polar Electro, Kempele, Finland) worn by the worker. Hydration status was assessed from urine specific gravity measured at the start, middle and end of the shift. Hypohydration was defined as specific gravity > 1025. Tympanic temperature and blood pressure were also measured at these times or as demanded in between. The heart rate data were downloaded from the Polar Electro watch and transferred to the Case Record Form as mean and maximum heart rates over 4-hour periods. An Excel spreadsheet was used to collect

and analyse the data separately for the 3 departments.

Statistical analysis

Continuous data such as heart rate, tympanic temperature, blood pressure and urine specific gravity were summarized as means and standard deviations (SDs). The observations at the end of 4 and 8 hours were analysed in this fashion. Hypohydration data were presented as percentages and departmental data were compared by χ^2 test. One-way analysis of variance (ANOVA) was used to compare the parameters at baseline and 4 and 8 hours into the shift period. Repeated-measures ANOVA was undertaken to determine the overall effect of heat stress between the various time points across departments. All statistical analyses were done using SPSS version 20. P

Results

The departments were similar in terms of the baseline parameters, except systolic and diastolic blood pressures, which were significantly lower in the casting house (Table 1). The mean values of other baseline parameters were not significantly different, especially urine specific gravity.

After the first 4 hours of work, average heart rate increased from resting heart rate by > 13 beats per minute; tympanic temperature increased slightly; and urine specific gravity increased substantially (Table 2). None of these differences were significant. Average heart rate during the second 4-hour shift increased beyond what was recorded during the first 4 hours. The tympanic temperature increased in the electrolytic reduction department and casting house, whereas the average heart rate registered an increase in all three areas (Table 3). Urine specific gravity stabilized compared to the first 4 hours of the shift.

Estimated marginal means of the 3 main physiological parameters adjusted by department using repeated-measures ANOVA are graphically represented in Figure 1 . The data show steady increases up to 4 hours for urine specific gravity and average heart rate, followed by later stabilization. There was only a marginal increase in tympanic temperature during the corresponding periods.

The effect of Ramadan fasting in statistical terms is shown in Table 4 . The above-mentioned changes were all statistically significant in employees normally arriving hydrated at the start of the shift. However, there was no significant increase beyond the clinically accepted values of tympanic temperature. The interdepartmental differences were not statistically significant.

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 to 34%, 51.2% and 24.6% in carbon anode plant, electrolytic reduction department and casting house, respectively, in the first 4 hours. At the end of the second shift, the casting house showed that 32.9% of employees were dehydrated, whereas the electrolyte reduction department (48%) and carbon anode plant (32.9%) corrected the situation to some extent.

Discussion

Average heart rate during the first 4 hours of shift increased from resting heart rate by > 13 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 increased risk of developing heat stress in fasting individuals exposed to high occupational heat. Average heart rate during the second 4 hours of shift increased without a corresponding increase in tympanic temperature. Urine specific gravity more or less stabilized in the second compared to the first 4 hours. This most likely reflects the physiological slowdown 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 lowers productivity. Safety of workers could be significantly jeopardized in the absence of self-pacing and other supportive workplace measures (16).

Classically, heat stress is characterized by elevation of average heart rate above 110 beats per minute for a period, as per 1969 World Health Organization recommendations (17). If the heart rate is above the maximum sustainable rate, performance deteriorates, putting the worker and the process at risk (18). The increase in heart rate is consistent with loss of hydration to the extent of 10 beats for every 1% loss in body weight. Hypohydration also increases the core temperature at proportionate levels of 0.22°C for every 1% loss of mass. Core body temperature above 38°C puts workers at risk of exhaustion (19). Religiously mandated fasting can subject people to higher stresses than caused by lack of fluid intake, which curtails production of sweat for body cooling.

This study had some 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 clinical setting, it is the most convenient means available in a factory setting. The other limitations were that heart rate and urine specific gravity were also affected by personal factors, including use of certain medications. Even though observations were made throughout 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.

Conclusions

Physiological observations during fasting showed a steady increase in the 4-hour period with regard to urine specific gravity and average heart rate. These changes were all significant in employees arriving normally hydrated at the start of the shift. Our observations indicate that workplaces with high environmental temperatures and physically demanding tasks require better administrative workplace controls, including temperature reduction, generous work–rest regimens, and optimization of shift duration and number of workers during hotter parts of the day, to ensure that variations in physiological parameters do not jeopardize the health and safety of workers. We also recommend investigating development or use of a thermal index more suitable to local conditions and culture in the Gulf Region than currently available heat indices, to improve the health and safety of workers while sustaining productivity levels and targets.

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Effets du jeûne pratiqué pendant le Ramadan sur les paramètres du stress thermique

Résumé

Contexte : Les températures de process élevées, associées à des opérations industrielles, augmentent le risque de stress thermique et de maladie, en particulier pendant les mois d'été dans la Région du Golfe. L'absence d'hydratation et de nutrition pendant la journée sur la période du Ramadan peut exposer les travailleurs à des risques encore plus élevés de stress thermique et de maladie.

Objectifs : Étudier les effets physiologiques du jeûne prolongé dans des conditions thermiques difficiles.

Méthodes : Des mesures longitudinales ont été effectuées sur les employés de trois départements d’une fonderie d’aluminium pendant le jeûne du Ramadan. Après obtention de leur consentement éclairé, leurs paramètres physiologiques ont été mesurés toutes les quatre heures.

Résultats : La fréquence cardiaque et la gravité spécifique de l'urine moyennes augmentaient au cours des quatre premières heures de travail posté, tandis que la température tympanique ne connaissait pas d’augmentation significative. En outre, au cours des quatre heures suivantes de travail posté, la gravité spécifique de l'urine se stabilisait en comparaison des quatre heures précédentes.

Conclusions : Il est nécessaire que les industries où les ouvriers sont confrontés à des températures de process élevées dans la Région du Golfe prennent des mesures énergiques sur le lieu de travail, afin de minimiser le risque accru de stress thermique et de maladie pendant Ramadan.

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