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Hydration Status of Expatriate Manual Workers During Summer in the Middle East

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Background: Implicit in all indices used for risk assessment in the prevention of heat stress is the assumption that workers are healthy and well hydrated; studies in Australian mine workers have shown that this is not the case. Where workers are poorly hydrated, the level of protection offered by management strategies based primarily on environmental monitoring is compromised. Objectives: To investigate the hydration status of expatriate workers during summer in a range of work environments in the Middle East as large numbers of expatriate workers are employed as manual labourers in construction and other industries under extreme heat stress conditions where heat illness is a significant concern. The aim was to ascertain whether the generally inadequate hydration status, previously documented in Australian workers, is also an issue in these workers and make practical recommendations for control.

Methods: Studies were carried out at four sites to document the hydration status of exposed workers in different workplaces using urine specific gravity at three time points over two different work shifts.

Results: Although the workers were found in general to be better hydrated than their Australian counterparts, a high proportion were still found to be inadequately hydrated both on presentation for work and throughout the shift. Hydration status did not alter greatly over the course of the day at individual or group level.

Conclusions: Interventions are required to ensure that workers in extreme heat stress conditions maintain adequate levels of hydration. Failure to do so reduces the protection afforded by heat stress indices based on environmental monitoring.

Keywords: environmental monitoring; heat-related illness; heat stress; hydration; manual work

INTRODUCTION

Construction and other industries in the Arabian Gulf emirates of Abu Dhabi and Dubai rely on large numbers of expatriate workers, mainly from south Asia. In 2008, 17 million migrants were working in the Gulf, forming more than a third of the population of the region (Walt, 2008). In the United Arab Emirates (UAE), only 15–20% of the residents in 2007 were citizens; of a workforce (aged 15–64 years) of ~3 million, 93% were foreign (US Department of State, 2007).

Daytime summer temperatures in the gulf regularly exceed 40°C for prolonged periods of time often with high humidity, particularly in the morning and evening (GoDubai). There is little relief at night as humidity remains high and there is little air movement. These extreme environmental conditions make heat-related illness the most important health issue facing outdoor workers in the region.

Similar environmental conditions occur for much of the year in tropical Australia, exposing workers

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in the mining and resources industries to similar risks. Studies in northwest Australia (Miller and Bates, 2007) found that the majority of outdoor workers investigated were consistently inadequately hydrated for the conditions, despite efforts on the part of employers to improve their hydration status. Earlier Australian studies had yielded similar findings (Gunry *et al.*, 1996; Brake, 2001; Brake and Bates, 2003). Whether the reasons for this are physiological, behavioural, or cultural is not clear, and factors such as the consumption of alcohol during leisure hours and caffeinated beverages at work may also play a part.

Strategies for management of work in heat have focused on measurement of environmental parameters and the development of indices to quantify heat stress. Implicit in the use of all such indices is the assumption that workers are not compromised in their ability to respond physiologically to the conditions, in other words that they are healthy, moderately fit, acclimatized, and above all adequately hydrated. If this is generally not the [illegible] reliance on heat stress indices [illegible] questionable. The expatriate workers in the UAE constitute a group, which differs from Australian workers [illegible] ically, and [illegible] behavior. The studies reported in this paper were carried [illegible] in the UAE are also at risk due to inadequate hydration and to assess the extent of the problem and the need for intervention measures.

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The importance of hydration

Hydration status is a crucial determinant of the ability to tolerate heat stress. The water content of the body determines its heat storage capacity while failure to maintain an adequate plasma volume compromises heat loss mechanisms. For workers performing manual labour in a thermally stressful environment, the maintenance of an adequate level of hydration is essential to minimize the risk of heat illness and avoid excessive fatigue.

Numerous studies (Sawka and Pandolf, 1990; Cheung and McLellan, 1998; Yoshida *et al.*, 2002; Marino *et al.*, 2004; Cheuvront *et al.*, 2005; Oturi *et al.*, 2006) have shown reduced physical work capacity and accelerated fatigue with fluid losses of as little as 1–2% of body weight, while others (Gopinathan *et al.*, 1988) have found cognitive impairment at similar levels of dehydration, probably resulting from the combination of cellular dehydration and increased deep body temperature (McMorris *et al.*, 2006). More recently, a Chinese study (Lu and Zhu, 2007) found impairment of thermoregulation with as little as 1% dehydration. Fatigue and impaired judgement probably account for the increased incidence of unsafe work behavior in thermally stressful conditions (Ramsey *et al.*, 1983). In addition, chronic dehydration has been shown to be a risk factor for the development of urinary calculi and bladder cancer (Michaud *et al.*, 1999).

The risk of all forms of heat illness is greatly exacerbated by poor hydration. Manual labour in conditions of high ambient and/or radiant temperature, particularly in combination with high humidity, leads to fluid losses in sweat that may exceed 1 l h^{-1} (Brake and Bates, 2003; Miller and Bates, 2007); failure to replace this fluid loss adequately and appropriately results in progressive dehydration during prolonged work in the heat predisposing to symptoms such as headaches and lethargy and impairing judgement increasing risk of injury.

Previous work in underground (Brake, 2001; Brake and Bates, 2003) and outdoor mine workers (Miller and Bates, 2007) in Australia showed that few workers were adequately hydrated [illegible] in heat, with many reporting for work in a state of moderate or even severe dehydration. As hydration status often improved over the course of the shift, [illegible] compromised, reducing their productivity and increasing their [illegible] heat-related illness. Environmental conditions in the gulf region are similar to those in northern and interior parts of Australia and the dangers of working in a poorly hydrated state are comparable. Thirst alone may not be an adequate stimulus to maintain euhydration, as some studies have found that drinking may not be triggered until fluid equal to 1–2% of body weight has been lost (Nadel *et al.*, 1990), a level at which performance and thermoregulation are measurably impaired. The majority of individuals in fact appear to operate at a level of poor to marginal hydration, drinking only sufficient fluids to maintain this level. Studies in Australia (Brake and Bates, 2003) have shown that improving the hydration of workers in hot environments requires the creation of a culture of 'hydration awareness' involving education of workers and their supervisors and the introduction of practical measures to monitor hydration status and enhance the availability and consumption of appropriate fluid.

The importance of hydration was reinforced by a study conducted at Al Ain in the UAE (Bates and Schneider, 2008) which indicated that with interventions to encourage fluid intake, self-paced construction workers were able to work in extreme temperatures, often in excess of 45°C, with no evidence of physiological strain as assessed from working heart rates and aural temperatures. The danger is that when hydration status is inadequate or conditions are severe, a worker who is unable to reduce his workload, or who does not recognize signs of heat strain, will continue to work at a pace which leads to heat accumulation and consequent heat illness.

The studies reported in this paper were carried out at construction sites and industrial facilities in Abu Dhabi and Dubai without intervention, in order to assess the hydration status of representative groups of expatriate workers in a range of environments in the UAE. The aim was to ascertain whether the generally inadequate hydration status, previously documented in Australian workers, is also an issue in these workers. If the problem is found to be widespread, it casts doubt on the common practice of managing heat stress by protocols linked to heat stress indices derived from environmental monitoring alone, as all commonly used heat stress indices assume that workers are in good health and well hydrated. Poorly hydrated workers will be at greater risk of thermal strain than predicted by the index, leading to a reduction in the level of protection provided.

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Methods

Protocols [illegible] of the workplace, the organisation of the work shift, and the arrangements with the management. The two studies on construction sites (Sites 1 and 2) were conducted in the July–August period when regulations stipulate an extended break for all construction workers between 12:30 and 3 pm; the workers then returned to work for a further 3 h until 6 pm. The studies at Sites 3 and 4 were conducted in September and December, respectively.

Participants, recruited from the migrant workforce, were monitored at three time points: at the beginning of the shift (between 6 and 6.30 am), at the end of the morning work period (between 11.30 am and 12 pm), and at the end of the shift (2.30–3.30 pm at Site 4 and 6 pm at the other sites). The majority of subjects participated over a period of 2 consecutive working days. Other than presenting at these times, the subjects were not asked to modify their work behaviour in any way.

All the participants were volunteers who gave their written and informed consent to participate in the study. The study was supported and authorized by management and ethical approval was obtained from the Al Ain Medical District Human Research Ethics Committee.

Field sites

Site 1: offshore island development (60 subjects, 120 subject-days). The workers were unskilled and semi-skilled labourers engaged in installing plumbing infrastructure. Most were working in full sun throughout the shift. Much of the work was manual although some were machinery operators.

Site 2: downtown redevelopment project (45 subjects, 90 subject-days). The subjects were skilled and semi-skilled workers, including riggers, carpenters, and masons. Work environments ranged from below ground level to several floors above and varied in terms of exposure to sun and air movement.

Site 3: dockyard (45 subjects, 90 subject-days). Participants were skilled tradesmen. In addition to the environmental conditions, many were exposed to increased thermal stress as a result of the heat generated by the work, protective clothing, or other personal protective equipment (PPE), or the location of the work [illegible] in some cases all three applied, e.g. welders.

Site 4: aluminium smelter (36 subjects, 72 subject-days). This study was carried out in winter [illegible] heat stress from heat generating industrial processes independent of environmental conditions. All aspects of the process [illegible] tion line ranged up to 50°C or more, and workers in this area were required to wear heavy fire-retardant clothing to protect against molten aluminium splashes; however, they were not required to remain in these conditions for long periods at a time. Face masks are required PPE in all processing areas. Away from sources of heat, the environmental conditions were mild and pleasant. The requirement for protective clothing and other PPE which significantly increase the thermal stress on the wearer would be a much more significant issue over the summer.

Assessment of hydration status

A urine sample was collected at each time point for measurement of specific gravity using a digital refractometer (Atago). Specific gravity (U_{sg}) is widely accepted as a convenient and reliable indicator of hydration status in most circumstances and correlates well with the colour of the urine (Armstrong *et al.*, 1994, 1998) enabling informed workers to monitor their own hydration status. The interpretation adopted by the authors for work in hot environments (Table 1) is based on the classification used by Donoghue *et al.* (2000). According to these authors, a U_{sg} of <1.015 indicates that a subject is optimally hydrated; values above this indicate varying degrees of hypohydration, with a value >1.030 representing a clinical state of severe dehydration.

RESULTS

Table 2 summarizes all data collected at all four sites (means and standard deviation for data that followed a normal distribution). As shown by the 'all samples' average urine specific gravity (U_{sg}), hydration status varied considerably between subject groups. The average U_{sg} at both construction sites (Sites 1 and 2) indicates at best a marginally adequate level of hydration in most subjects (U_{sg} = 1.016–1.020, Table 1). The U_{sg} distribution of all urine samples collected at each site is presented graphically in Fig. 1 which shows a markedly lower proportion of adequately hydrated samples at the construction sites than at the two industrial plants (Sites 3 and 4). Approximately 31% of samples at [illegible] and 29% at Site 2 indicated a level of hydration [illegible] (Table 1). At Sites 3 and 4, only about half as many samples (15 and 16%, respectively) fell into this category. [illegible] greatly during the course of the day and this was seen at an individual as well as a group level. Figure 2, which illustrates the breakdown for each site by time of day, shows some reduction in the number of adequately hydrated subjects at the midday collection at Sites 1 and 2; however, at the end of the day, the distribution at these sites was similar to the morning pattern.

Table 1. Guidelines for interpretation of urine specific gravity readings

U_{sg}	Hydration status
≤1.015	Optimal level of hydration (euhydrated)
1.016–1.020	Marginally adequate hydration
1.021–1.025	Hypohydrated
1.026–1.030	Severely hypohydrated
	At increased risk of heat illness and impaired performance
	Should not work in hot conditions
>1.030	A clinically dehydrated state based on the criteria used by the Australian Pathology Association

DISCUSSION

The UAE workers were better hydrated in general than those in the Australian studies, where in one data collection period 51% of the urine samples collected (n = 383) had U_{sg} ≥1.026 and in another period (n = 182 samples) the figure was slightly better at 39% (Miller and Bates, 2007). Nevertheless, the findings particularly at the construction sites indicate that poor hydration is not exclusively an Australian problem.

The observation that U_{sg} and therefore hydration status tended not to change greatly over the course of a shift parallels the findings of Australian studies, which [illegible] that unless there is an active [illegible] will [illegible] tain the level of hydration to which they are habituated and that in many cases this level is inadequate [illegible].

Any improvement in hydration status requires a fluid intake in excess of sweat losses, which may [illegible] upper level of fluid absorption from the gut (1.2–1.5 l h^{-1}). Individuals starting the day well hydrated appear to protect this status with U_{sg} remaining low throughout the shift. As hypohydration places individuals at increased risk of developing heat-related illnesses, particularly if work rate increases (increasing heat production) or environmental conditions become more severe (increasing heat load or impairing heat loss), education needs to be directed not only towards replacing fluid lost during the shift but also to improving hydration level at the start of the shift.

Differences in average hydration status between the sites could reflect a variety of factors. Urine specific gravities at the two construction sites (Sites 1

Table 2. Specific gravity of urine samples collected from workplaces in the UAE

Average U_{sg}	Site 1 (n = 120)	Site (n = 90)	Site 3 (n = 90)	Site 4 (n = 72)
am	1.019 ± 0.008	1.019 ± 0.009	1.014 ± 0.009	1.017 ± 0.008
Midday	1.022 ± 0.007	1.022 ± 0.008	1.015 ± 0.008	1.016 ± 0.008
pm	1.021 ± 0.009	1.019 ± 0.008	1.018 ± 0.008	1.018 ± 0.007
All samples	1.020 ± 0.008	1.020 ± 0.008	1.016 ± 0.009	1.017 ± 0.008

Data are means of all samples from the site ± standard deviation; n is the number of subject-days for which samples were collected.

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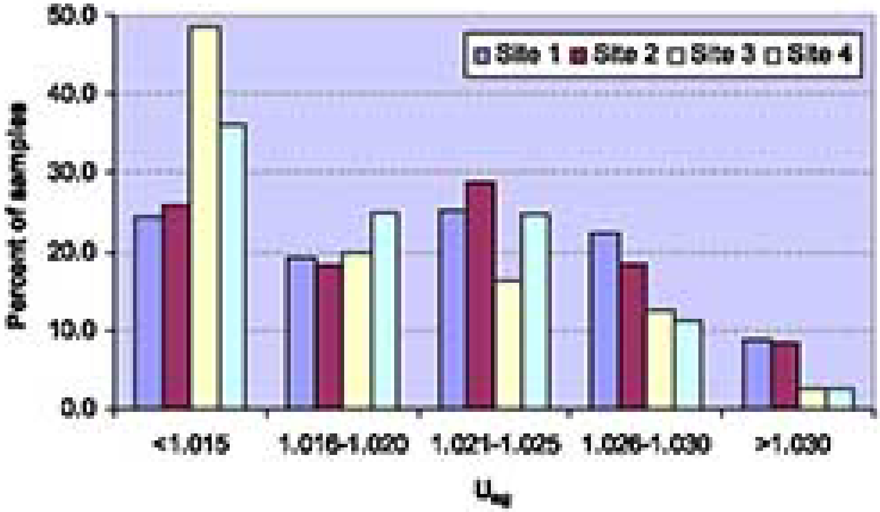

Fig. 1. Specific gravity of all urine samples gathered at each site. The samples are distributed according to hydration categories as defined in Table 1. The columns show the percentage of samples collected at each site falling into each category. Number of samples at each site = n, where n is the number of subject-days (Table 2).

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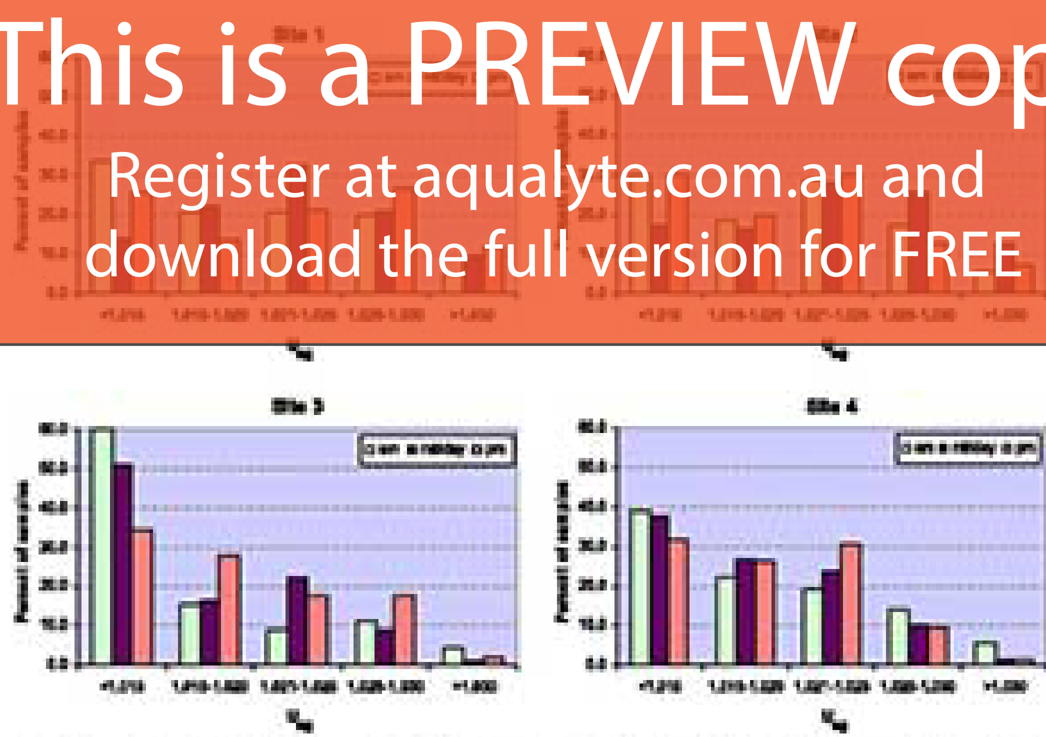

Fig. 2. Change in hydration status throughout the day at each site. Specific gravity (U_{sg}) of urine samples collected at the beginning (am) and end (pm) of the shift and at the midday break for workers at each site. The samples are distributed according to hydration categories as defined in Table 1. The columns show the percentage of the samples collected at each time falling into each category. Number of samples at each site for each time point = n, where n is the number of subject-days (Table 2).

and 2) were generally higher than at the industrial plants (Sites 3 and 4); however, an interventional study at a construction site Al Ain in the UAE (Bates and Schneider, 2008) demonstrated that it is possible for construction workers to maintain hydration in extremely hot conditions. The differences are more likely to relate to logistical considerations and to the amount of emphasis placed on hydration awareness.

Both industrial plants (Sites 3 and 4) have well-equipped medical centres and a strong health and safety team. The workforce is stable and is accommodated close to the plant. The permanent nature of the workplace allows installation of water dispensers, air-conditioned recovery rooms, meals areas, etc. Construction sites on the other hand are serviced by temporary facilities. The workforce is housed at labour camps often at some distance from the site and transported to and from by bus, a journey that may take as much as an hour. The fact that workers at Site 1 and 2 were less well hydrated at the start of the day than those at Sites 3 and 4 may be simply because they limit their morning fluid intake in anticipation of the bus ride. During the day, construction workers may be deployed some distance from a source of water, those working on high-rise buildings may have to climb down several ladders in order to get a drink and then back up again to their place of work. [illegible] fluid every 15 min, this must be readily accessible. The [illegible] Schneider [illegible] the provision of personal drink containers, were effective [illegible] 1.5% of all samples [illegible].

In conditions where sweat losses are high, replacement with water alone may be insufficient to maintain hydration; electrolytes lost in sweat need also be replaced.

Based on the data from previous studies, sweat rates of manual labourers in hot conditions often exceed 1 l h^{-1} (Brake and Bates, 2003; Miller and Bates, 2007). Sodium content in the sweat of acclimatized subjects averaged 45 mmol l^{-1} (Bates and Miller, 2008), equivalent to 2.6 g of salt per litre of sweat. Salt losses over a shift can therefore be considerable and if these are not replaced adequately in the long term chronic hyponatraemia may result, endangering health. Diets based largely on rice such as offered in the work camps in the UAE may be deficient in this respect. In the short term, where salt losses have been heavy, rehydrating with plain water is less effective for fluid retention and if large volumes are consumed can lead to dilutional hyponatraemia and acute water intoxication.

Regular consumption of food over the shift is essential to maintain both electrolyte and glucose levels. Where workers are required to work >2 h without a meal break, consideration should be given to providing an electrolyte replacement beverage to promote fluid absorption and retention. This needs to be formulated for industrial rather than sporting use and be suitable for consumption in quantity over prolonged periods.

The workers in this study were better hydrated in general than their Australian counterparts; this may reflect cultural differences in terms of choice of beverage consumed, particularly in leisure hours, major differences in lifestyles, or a wide variety of other differences. Nevertheless, although all were working in the heat and were advised of the importance of maintaining a high fluid intake, a high proportion of workers in both countries were poorly hydrated at the start of the shift and failed to improve this over the course of the shift. These findings in two widely divergent groups of workers in two countries suggest that this may be a fundamental issue for all manual workers in hot environments. It appears that the level of hydration that is spontaneously maintained by most people is not adequate for working in heat and that a conscious effort is required to change this. [illegible] not only to educate and maintain [illegible] awareness of the importance of hydration but also to address the logistics of supplying adequate quantities [illegible] workers on site. Without this, management based solely on environ[illegible] of offering the level of protection required.

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CONCLUSIONS

Implementation of strategies to maintain adequate hydration is the single most important intervention in the management of work in heat. Hydrated workers are much more likely to be able to maintain an acceptable work rate without danger under a wide range of environmental conditions.

- Although better hydrated in general than Australian workers, a significant proportion of subjects at all sites were inadequately hydrated for working in the heat, suggesting that this is a fundamental issue for all manual workers in hot environments.
- Hydration status was better at the industrial sites than at construction sites, this may be related as much to logistical factors as to awareness of the importance of hydration.
- Pre-work fluid intake is of particular importance as most workers who are well hydrated at the start of work maintain a better hydration status

throughout the shift than those who start the day dehydrated.

- Programmes to improve hydration status need to incorporate practical strategies to address logistical issues and promote good hydration behaviour.
- Heat management based on environmental monitoring without at the same time addressing the hydration issue falls short in terms of protecting workers from the effects of heat stress.

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