

Plasma Sodium Levels and Dietary Sodium Intake in Manual Workers in the Middle East

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Objectives: To investigate the hypothesis that workers who consume a predominately rice-based, low-sodium diet and perform long periods of manual work in the heat are at risk of chronic hyponatraemia due to inadequate replacement of sweat sodium losses.

Methods: Plasma sodium levels were assessed at the end of both the summer and winter periods in 44 male dockyard workers in the Middle East. The dietary intake of these workers was recorded and analysed by an Accredited Practising Dietitian to determine average daily sodium intake.

Results: 55% of workers were found to be clinically hyponatraemic during the summer period compared with only 8% during the winter period. Assessment of the daily diet of workers in the labour camp revealed it to be predominantly starch based with low total sodium content. The majority of the fluids provided to workers are also low in sodium content.

Conclusions: Manual labourers working in the heat and eating a low-sodium starch-based diet are at risk of chronic hyponatraemia. Increasing the sodium content of fluid and food provided to workers is warranted and may reduce the incidence of work-related illness and accidents in this population. The results of this study identify a need for sodium replacement guidelines specific for prolonged work in the heat to be developed.

Keywords: dehydration; hyponatraemia; sweat sodium

INTRODUCTION

Manual labourers working in the building and construction industry in some parts of the world perform physically demanding tasks in the heat for 12 h/day, 6 days/week. High sweat rates over the work shift can lead to progressive dehydration placing an individual at significant risk of heat-related illness and injury (Donoghue and Bates, 2000; Mirabelli *et al.*, 2010). While several studies have investigated the incidence of dehydration in susceptible populations (Bates *et al.*, 1996, 2010), there has been little focus on the need to replace electrolyte losses associated

with prolonged sweating in the occupational setting. The majority of research has focused on the electrolyte needs of endurance athletes due to their known high fluid and electrolyte losses (Maughan *et al.*, 2005; Baker *et al.*, 2009; Palmer *et al.*, 2010). The industrial population form a unique group, performing longer periods of work at a lower metabolic rate and repeating the process daily. Requirements for salt intake in this population need further consideration.

In developed countries such as the USA and Australia, an estimated 75% of salt intake comes from processed foods (Dyer *et al.*, 1997). Because of the high intake of these foods, the dietary salt intake is seldom inadequate and often excessive. In countries where the traditional diet consists primarily of rice

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and legumes with very little processed food, the salt content is comparatively low. It was therefore hypothesized that workers consuming such a diet and working in hot environments would be at risk of chronic hyponatraemia due to inadequate replacement of sweat sodium losses. Expatriate manual workers in the Middle East form such a group; many thousands of these workers in the United Arab Emirates (UAE) are housed in labour camps, where each worker is served an identical type and quantity of food at each meal. The communal nature of food preparation and consumption leads to a uniformity of dietary intake not present in other populations. The consistency in dietary intake makes this population a unique group to study while allowing for accurate dietary assessment.

Previous studies conducted in manual labourers in Australia have found average sweat rates of 1.1 l/h, equating to >10 l of fluid loss during a work shift (Brake and Bates, 2003; Miller and Bates, 2007). Average sweat sodium losses over a 10-h work shift have been estimated to be 4.8–6 g, equivalent to 10–15 g salt (NaCl) (Bates and Miller, 2008). Due to the large interindividual variation in sweat rate and sodium loss, these values may be even higher in some individuals, with reported values in excess of 10 g of sodium (25 g salt) per day (Bates and Miller, 2008). Regular consumption of food and fluid containing adequate salt content is therefore essential to replace these sweat losses to avoid the development of chronic hyponatraemia, potentially compromising the health and safety of the worker.

While chronic hyponatraemia is often thought to be asymptomatic, the consequences of a long-term decline in plasma sodium may put the health and safety of a worker at risk. The clinical symptoms of hyponatraemia depend largely on the extent of plasma sodium decline and the rapidity of onset (Freda *et al.*, 2004) and can range from nausea, headache, vomiting, confusion, coma, convulsion, and ultimately death (Kumar and Beryl, 1998). Chronic hyponatraemia can develop over several days when body mechanisms fail to maintain sodium homeostasis. This may be from profuse sweating with inadequate solute intake, resulting in a decrease in extracellular fluid volume, compromising the body's ability to thermoregulate (Hamilton *et al.*, 2006). Cases of hyponatraemia have been reported in military and civilian personnel working in extreme environmental conditions in southern Iraq (Hamilton *et al.*, 2006). While the majority of these cases were due to acute water intoxication leading to severe acute hyponatraemia, the failure of sodium homeostasis in these extreme temperatures was reported to have

been further compounded by poor dietary salt intake during the patrol period (Hamilton *et al.*, 2006).

The aim of the present study was to investigate the hypothesis that workers consuming a traditional low-salt diet and working in hot conditions are at risk of chronic hyponatraemia. First, plasma sodium levels in a group of manual labourers during both the summer and winter months were investigated for evidence of hyponatraemia. A further aim was to assess the relative adequacy of the current diet provided to workers with focus on the total salt content of the menu. The results of this study will identify whether this population consumes sufficient dietary sodium to offset the high sweat losses, particularly during the extreme summer months.

METHODS

This study was carried out at a ship-building and construction site in Dubai, UAE, during Summer (July) and winter (February).

All 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.

A total of 44 subjects were studied at the end of the summer months and 38 subjects were repeated at the end of winter. The same subjects were used in the summer and winter trials. The subjects were male dockyard workers (various trades) from India, Bangladesh, and Pakistan, aged between 18 and 50 years.

Biochemistry

Full blood tests including Liver Function Test, Full Blood Count, Urea and Electrolytes, and glucose were taken from all subjects in both the summer (July) and the winter (February) months to check general health and compare blood electrolyte profiles. Any worker with any known medical condition was excluded from the study. The venous blood sample was taken in the morning prior to eating (0800 h) by a trained phlebotomist. An approved accredited pathology laboratory completed all analysis.

Dietary assessment

An assessment of the diet of the workers was conducted in two parts by an Accredited Practising Dietitian. Part one involved recording and analysing menus and recipes to allow for an estimation of total daily salt intake. Menus and recipes from all food prepared and served in the mess hall were collected

and analysed over a 3-day period. Foodworks 2007 nutrient analysis package was then used to estimate the total daily macronutrient intake along with total daily salt intake. Estimation of serve size was conducted through observation of meals served as well as measurement of plated food. Table salt was provided on a separate table next to the bain-marie. The use of table salt at meals was observed and an estimation of the quantity added was recorded. Part two of the study involved individual interviews with the workers; 38 workers were available for this interview where questions relating to individual dietary practices were asked. Table 1 outlines the questions asked to the workers during the interview.

RESULTS

Table 2 summarizes the physical characteristics of the subject group.

Biochemistry

Results from the blood electrolyte profile in summer and winter showed that a high proportion of subjects (55%) were found to be hyponatraemic in the summer months (Fig. 1); all remaining values were in the lower part of the reference range. Only 5% of subjects had serum sodium levels <130 mM. In the winter months, only 8% of subjects were found to be hyponatraemic.

Dietary assessment

Part one: menu and recipe analysis. Table 3 summarizes the dietary assessment data collected at the site during the summer period. On average, a worker

would consume an estimated 2000–3000 mg of sodium (5–7.5 g salt) in food and fluid per day. The total sodium content of the lunch meal was particularly low averaging 600 mg (1.5 g salt). In addition to this, workers would be provided with a maximum of 1 l/day of electrolyte replacement fluid which would provide between 200 and 400 mg sodium (500–1000 mg salt). This is only provided in the summer months. Additional table salt is available at all meals; however, only 43% of workers indicated that they added salt to their meals.

Part two: interviews with workers. Ninety-three percent of the workers stated that they did not consume any other food outside of what was provided in the mess at breakfast, lunch, and dinner. This information further confirmed the consistency in dietary intake of the workers. The three subjects who did snack between meals stated that they would only consume fruit or fruit juice on occasion; these foods would not contribute significantly to overall daily salt intake.

Ninety-four percent of the workers stated that they do not change anything about their diet between the summer and the winter periods and that heat did not affect their intake.

Forty-three percent of the workers stated that they regularly add table salt to their lunch and dinner meals. One or two small pinches of salt were the typical amount added which would provide an estimated 250–500 mg of sodium (625–1250 mg salt). Observation of table salt use did support these self-reports as it was noted that few workers chose to add salt to their meals and if they did it was in small quantities.

All workers stated that they did consume an electrolyte replacement solution during working hours during the summer months. There is a limit of 1 l of electrolyte solution per worker during this period while water consumption is unrestricted. Medical staff indicated that this restriction was placed as a precaution to avoid excessive consumption of sugar and salt.

DISCUSSION

The initial hypothesis that sodium intake in this population is inadequate to replace sweat losses is supported by the results of this study. During the summer period, 55% of workers were found to be clinically hyponatraemic with plasma sodium values <135 mM, compared with only 8% during the winter period. Given that dietary intake is consistent throughout the year, these results indicate that the hyponatraemia during summer is most likely due

Table 1. Interview questions asked to workers

Question
1. Do you normally snack outside of meal times (i.e. breakfast/lunch/dinner)?
2. Do your eating habits change in summer compared with winter?
3. Do you normally add salt to your lunch and dinner meals?
4. Do you consume an electrolyte replacement drink during working hours?

Table 2. Physical characteristics of subjects

	Mean (\pm standard deviation)
Age	37 (\pm 6)
Height	168 (\pm 7)
Weight	67.5 (\pm 12.5)
Body mass index	23.8 (\pm 3.7)

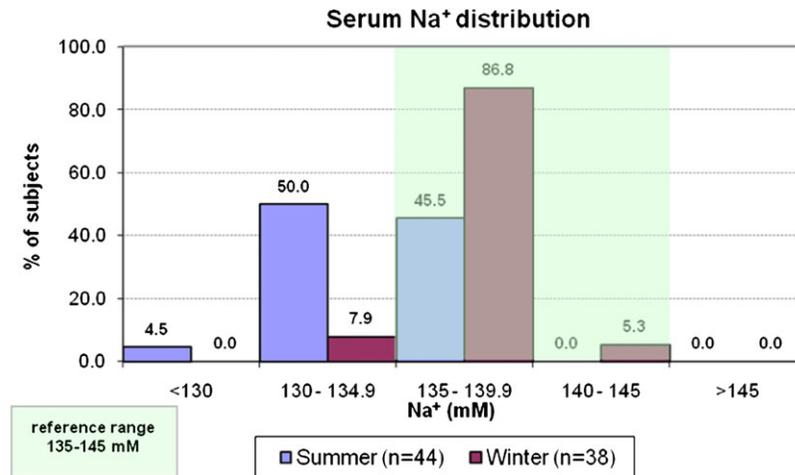


Fig. 1. Comparison of serum sodium values in summer and winter.

Table 3. Analysis of energy and sodium content in the 3-day menu

Day	Meal	Energy (kJ)	Sodium (mg)
1	Breakfast	4411	1359
	Lunch	3937	624
	Dinner	3415	773
	Total	1 1763	2757
2	Breakfast	4624	1235
	Lunch	4105	464
	Dinner	3651	1005
	Total	1 2381	2704
3	Breakfast	3903	1145
	Lunch	4263	654
	Dinner	3428	571
	Total	1 1595	2371
Average	3 Day average	1 1913	2610

to high sweat sodium losses coupled with inadequate sodium replacement. Assessment of dietary intake revealed that on average, workers consume between 2000 and 3000 mg of sodium (5–7.5 g salt) per day. This quantity is insufficient, particularly during summer when temperatures are extreme and fluid and electrolyte losses through sweat are assumed to be high due to high sweat rates.

Due to the increasing prevalence of hypertension and cardiovascular disease on a global scale, dietary salt restriction is being strongly advocated as a public health measure to reduce the incidence of chronic disease worldwide. Currently, the World Health Organization recommends that salt intake should be <5 g/day (<2 g/day sodium) (WHO, 2007). These recommendations are not appropriate for popula-

tions engaging in heavy manual labour in the heat as sweat sodium losses far exceed this level of intake.

The long-term health effects of a chronic sodium-restricted diet have not been well investigated. The results from animal studies have shown a significantly decreased plasma volume and increased haematocrit in sodium-depleted mice (Francesconi *et al.*, 1983). It is postulated that this change in haemodynamic state would seriously compromise the body's ability to tolerate further circulatory stress such as that imposed by excessive sweating. In addition to this, a higher sodium diet is known to enhance the thermoregulatory and cardiovascular adaptations that occur during heat acclimatization (Luetkemeier *et al.*, 1997). A recent study by Miyazaki *et al.* (2010) showed that stable chronic hyponatraemia resulted in impaired memory function in rats that was normalized when sodium levels were corrected to within normal range. The effect of chronic hyponatraemia on the central nervous system in humans is largely unknown and requires further investigation. A study by Renneboog *et al.* (2006) indicated that patients with mild chronic hyponatraemia had an increased incidence of falls due to a global decrease in attentional capabilities, posture, and gait mechanisms (Renneboog *et al.*, 2006). While the patients in this study were reported to be asymptomatic, the results also identified significant impairment in cognitive function. The mechanisms of these observations are thought to be a result of slowed peripheral and central nerve conduction (Renneboog *et al.*, 2006). For manual workers performing intense physical labour, any impairment in judgement or cognitive capacity will increase vulnerability to

workplace accidents and injury and is therefore a major concern.

Since conducting this research, there have been reports of a number of young labourers presenting to the intensive care unit in hospitals within the Middle East with seriously low plasma sodium levels, placing them at risk of neuromuscular dysfunction. This information and the results from this study indicate that there is a need for sodium intake guidelines specific for manual labourers working in the heat to be developed. Providing workers with specific guidelines showing estimated sweat sodium losses and practical replacement guidelines for the various working roles will acknowledge that workers in physically demanding outdoor roles will have greater fluid and salt requirements than stationary indoor workers. Interviews with the workers in this study revealed that several individuals had been actively trying to limit salt intake to prevent hypertension. Given that current health recommendations are aimed at restricting dietary salt intake, educating medical staff and workers on the importance of both fluid and sodium replacement when working in conditions of heat stress is necessary.

In order to increase sodium intake, the addition of salt to meals during cooking is indicated. In addition to this, educating workers, particularly those in more physically demanding roles on the benefit of adding table salt to meals, is also warranted. When working in severe thermal conditions, replacement of fluid losses with water alone is insufficient, as it does not replace sodium lost in sweat, thus increasing the risk of dilutional hyponatraemia and acute water intoxication (Hoorn and Zietse, 2008). The provision of an electrolyte replacement fluid that has been designed for prolonged use in an industrial setting is indicated. The benefit of providing an electrolyte replacement beverage between meals is to promote water uptake and retention and to offset fatigue by maintaining blood glucose, whilst palatability encourages fluid intake (Sawka *et al.*, 2007). However, even regular consumption of an electrolyte replacement fluid throughout the work shift would not make up for the dietary inadequacy; the addition of salt to meals is also needed.

The data from this study demonstrate that the diet of some workers in the Middle East is not adequate in salt content. High sweat sodium losses due to long periods of manual work in the heat are not being replaced leading to the chronic hyponatraemia shown. While workers are relatively asymptomatic, there may be safety implications for workers who are managing heavy machinery or working at height due to an impaired cognitive ability and increased

susceptibility to fatigue, both of which may increase the risk of workplace accidents. The information collected in this study may apply to hundreds of thousands of workers in the Middle East as well as anywhere where workers are engaged in prolonged manual labour in hot climates while consuming a diet that is predominantly starch based. Increasing the total salt content of both fluid and food consumed by workers may be effective in reducing the incidence of work-related illness and accidents in this population.

CONCLUSIONS

A significant proportion of workers at this site in the UAE were clinically hyponatraemic during the summer period. This was not shown during winter, indicating that it is primarily due to high sweat sodium losses that are not being replaced.

The salt content of the diet is insufficient to replace estimated sweat sodium losses during summer.

Workers are unable to consume food at regular intervals due to logistics of the work environment and will benefit from regular consumption of an electrolyte replacement fluid specifically designed for prolonged industrial use.

Educating workers and medical staff on the importance of adequate fluid and salt intake to prevent dehydration and electrolyte imbalances is strongly indicated.

Salt intake guidelines specific for workers engaged in prolonged work in the heat are necessary to decrease the incidence of hyponatraemia in this population.

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