Hydration Status of South African Forestry Workers Harvesting Trees in Autumn and Winter

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Objectives: To determine both the prevalence and severity of dehydration of forestry workers harvesting trees in autumn and winter.

Methods: Two cross-sectional observational studies were conducted on convenience samples of 103 and 79 workers in autumn and winter, respectively. The prevalence of dehydration pre- and post-shift was determined using urine specific gravity ($U_{SG}$), and the severity of dehydration by the percent loss of body weight across the shift.

Results: Pre-shift, 43% in autumn and 47% in winter were dehydrated ($U_{SG} > 1.020 \text{ g ml}^{-1}$) on arrival at work. There was a significant increase ($P \leq 0.001$) in the prevalence of dehydration post-shift as 64% ($P \leq 0.001$) in autumn and 63% ($P = 0.043$) in winter were dehydrated. In each area, ±22% had dehydrated by ≥2% loss of body weight. Pre-shift, 23% in autumn and 13% in winter were overhydrated ($U_{SG} < 1.013 \text{ g ml}^{-1}$). Post-shift, 4% in autumn and 2% in winter were overhydrated. An excessive consumption of hypotonic fluid (water) in combination with a reduced salt intake to prevent hypertension exposed an important minority to the risk of potentially fatal dilutional hyponatremia. Neither dehydration nor hyperhydration was related to season, gender, or job category.

Conclusions: During average shifts, the South African forestry workers, regardless of season, gender, or job category, experienced dehydration of a magnitude that compromised both their safety and productivity.

Keywords: dehydration; forestry; hot industrial environments; hyperhydration; hyponatremia

INTRODUCTION

In South Africa (SA), the forestry industry offers an important source of income for many poor people living in remote rural areas (Department of Water Affairs and Forestry, 2005). While strict safety regulations have been enforced to protect against the evident risks of harvesting trees (Director General, 1995), little attention has been placed on the more subtle threats such as dehydration. The heavy physical labour, performed in hot and often humid environments, the regulation, impermeable safety clothing, as well as the limited availability of fluids at palatable temperatures predispose this work force to dehydration (Bates et al., 2001). Workers in other hot industrial situations are usually protected by environmental monitoring strategies to identify undesirable working conditions (Miller and Bates, 2010) and have the benefit of education programs highlighting the effects of dehydration and its prevention. The SA forestry industry has no regulations in place for monitoring the environment or policies for education regarding dehydration.

Relatively mild dehydration (1–2.5% of body weight lost) results in the onset of early fatigue and an increased perception of effort (Mudambo et al., 1997; Maughan, 2003; Casa et al., 2005;
Hydration status of SA forestry workers

Methods

Two cross-sectional observational studies were carried out in rural forestry areas in the province of KwaZulu-Natal, SA; one in winter in Richmond (17°C relative humidity 39%) and the second in autumn in Nelspruit (21.1°C relative humidity 67%). In general, SA is a subtropical location with an average daily temperature in autumn of 29°C dropping to 19°C across the night. In winter, the average daily temperature is 23°C dropping to 3°C overnight.

Study sample

All the forestry workers present in these two areas on the days of the study were asked to participate in the study. In Richmond (winter), 79 out of 100 forestry workers, and in Nelspruit (autumn), 103 out of 250 forestry workers, took part in the study. Black African chainsaw operators, chainsaw operator assistants, debarkers, stackers and rough liners, both male and female, were sampled on a convenience basis in the order that they arrived at work (Table 1). Each worker was measured over one shift. Data was collected for 5 consecutive working days. There were no inclusion, exclusion, or withdrawal criteria.

The mean body mass index (BMI) was 22.3 kg m⁻² [standard deviation (SD) ±3.1, range 17.2–34.2] (n = 102) in autumn (Nelspruit) and 22.2 kg m⁻² (SD ±2.4, range 17.9–31.2) (n = 79) in winter (Richmond). In both areas, the males’ mean BMI of 21.9 kg m⁻² (SD ±1.9, range 18.1–26.5) (n = 131) was significantly lower (P < 0.001) than the females’ BMI 24.3 kg m⁻² (SD ±4.1, range 17.9–31.2) (n = 50). All the BMI measurements, however, were in the normal range.

The estimated average age in autumn (Nelspruit) was 37 years and in winter (Richmond) was 26 years. Many only knew the year in which they were born and some did not know when they were born. Those in autumn (Nelspruit) had an average of 5.1 years (SD ±2.91, range 0.1–14) of work experience versus 1.6 years (SD ±2.47, interquartile range 0.58–3) in winter (Richmond). This reflects the high turnover in forestry which is attributed to the very hard physical labour and poor pay.

Methods

The study purpose was explained to all workers on their arrival in the forest. Those who elected to participate signed an informed consent form and were

| Table 1. Description of the sample size and composition |
|-----------------------------------|-----------------------------------|
| **Autumn**                        | **Winter**                        |
| Chainsaw operators                | Chunksaw operators                |
| 11 (male, n = 11, and female, n = 0) | 8 (male, n = 8, and female, n = 0) |
| Chainsaw assistants               | Chainsaw assistants               |
| 9 (male, n = 9, and female, n = 0) | 8 (male, n = 4, and female, n = 4) |
| Stackers                          | Stackers                          |
| 42 (male, n = 42, and female, n = 0) | 63 (male, n = 56, and female, n = 7) |
| Debarkers                         | Debarkers                         |
| 41 (male, n = 2, and female, n = 39) | 79 (male, n = 68, and female, n = 11) |
| Rough liners                      | Rough liners                      |
| 103 (male, n = 64, and female, n = 39) | 63 (male, n = 56, and female, n = 7) |

(Richmond). This reflects the high turnover in forestry which is attributed to the very hard physical labour and poor pay.

Methods

The study purpose was explained to all workers on their arrival in the forest. Those who elected to participate signed an informed consent form and were
allocated an identity code to ensure anonymity. Mid-stream urine samples were then collected for \( U_{SG} \) analysis. After urinating, the forestry workers were weighed in minimal clothing (lycra shorts/bras) and their heights recorded. The fluid that they intended to drink during the shift was weighed. Demographic data were obtained through an interview using a close-ended questionnaire. On completion of the above, the workers began their shift. Approximately 2 h into the shift, just prior to their first break and before eating and drinking, the forestry workers produced a second mid-stream urine sample and were reweighed in the same outfits after being towel dried. At this time, the fluid that they returned with was weighed to establish what they had consumed up until the break. At shift end, before eating and drinking, mid-stream urine samples and body weight measurements were repeated and the remainder of their fluid was weighed.

Materials

Hydration was determined by \( U_{SG} \) and the percent loss of body weight over the shift.

Urine specific gravity was measured using a portable digital urine refractometer (Atago Uricon UG-1 D20). To control for factors that impact the \( U_{SG} \), no first morning urine samples were collected, the samples were collected prior to drinking large volumes of water and the use of diuretics and vitamin and mineral supplements were monitored. The \( U_{SG} \) was measured to the nearest 0.001. Cutoff points for categorizing \( U_{SG} \) measurements were as follows: extremely dehydrated (>1.027), very dehydrated (1.025–1.027), slightly dehydrated (1.021–1.024), euhydrated (1.018–1.020), well hydrated (1.015–1.017), slightly hyperhydrated (1.012–1.014), and extremely hyperhydrated (<1.012) (Armstrong et al., 2010).

Body weight was measured with use of Masskot scales and recorded to the nearest 100 g. Height was measured to the nearest 1 cm using a portable stadiometer approved by the International Society for the Advancement of Kinanthropometry. Both the scale and stadiometer were placed on specially constructed levelled platforms to reduce error as a consequence of the uneven forest floor.

The BMI was calculated as body weight/height\(^2\). Percent loss of body weight was calculated as ([(pre-shift weight – end-shift weight)/pre-shift weight] \times 100.

Fluid carried by the forestry workers was weighed to the nearest 0.1 g using a Phillips digital food scale. Fluid requirements could only be estimated in workers who did not consume fluid or food across the shift. Previous forestry studies reported that the workers did not eat or drink across the shifts making the calculation of fluid requirements feasible (Staal Wästerlund et al., 2004; Scott et al., 2004). However, in this study there were a number of difficulties—although the fluid the workers were taking on shift was measured, they often shared fluid while harvesting, poured the fluid over their bodies to combat heat, or were directly delivered extra fluid in the forest which they drank preferentially. The stringent safety regulations did not allow for close observation of drinking behaviour. The fluid requirement was taken as the weight lost over an average shift for those few forestry workers who did not eat or drink anything.

Data analysis

Data were analysed using SPSS version 11.5. A two-sided \( P \)-value of <0.05 was considered as statistically significant. Quantitative variables were assessed for departure from normality, using the skewness statistic and its standard error. Normally distributed quantitative variables were described using means, SDs and ranges. Groups were compared using independent sample \( t \)-tests if two matched groups, paired sample \( t \)-tests if two paired groups, and analysis of variance (ANOVA) if greater than two independent groups. Repeated-measures ANOVA was used to compare within-group changes over time, between-group factors, and interactions between time and factors. Categorical variables were described using frequency and relative frequency tables. Comparisons of categorical dependant variables between groups was achieved using the McNemar’s chi-square tests for paired groups, Bonferroni’s multiple comparison tests, and Wilk’s Lambda.

Ethics approval was granted by the Biomedical Research Ethics Committee of the Nelson Mandela School of Medicine (reference no: E045/05).

RESULTS

Dehydration (urine specific gravity)

Pre-shift dehydration. Although the mean \( U_{SG} \) readings pre-shift in autumn (1.018) indicated adequate hydration (\( U_{SG} 1.018–1.020 \), 37\% (\( n = 37 \) were already slightly to very dehydrated and 5\% (\( n = 5 \) were extremely dehydrated (Tables 2 and 3, Fig. 1). Similarly, the mean \( U_{SG} \) readings pre-shift in winter (1.019) indicated adequate hydration, but 36\% (\( n = 28 \) were already slightly to very...
Table 2. Mean urine specific gravity readings pre-shift, pre-break, and end-shift in autumn and in winter

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*The rough liners’ results were repeated under stackers and debarker as the rough liners are a combination of both stackers and debarkers.

Dehydration status of SA forestry workers

In autumn, 18% ($n = 18$) of the sample were extremely dehydrated and 2% ($n = 2$) were hyperhydrated (Table 3, Fig. 3). Those individuals who were hy-
individuals who were hyperhydrated at the beginning of the shift. Hyperhydration was not related to season, gender, or job category. Although more workers were hyperhydrated in autumn, statistical significance relating hyperhydration to season was not reached ($P = 0.330$) possibly because of the small sample number.

**Fluid requirements**

**Pre-shift to pre-break.** In winter, workers ($n = 3$) who did not consume fluid or food pre-shift to pre-break dehydrated 1.4% which was a mean of 823 g (SD $\pm 110$, range 750–950) over a 2-h period. They therefore needed to have consumed 412 ml of fluid per hour to have maintained hydration. They carried a mean of 994 ml of fluid with them into the forest.

**Pre-shift to end-shift.** In autumn, those who did not consume fluid or food during the shift ($n = 5$) lost 3% of their body weight which was a mean of 1860 g (SD $\pm 298$, range 1500–2300). They therefore needed to have consumed 465 ml h$^{-1}$ to have maintained hydration. They carried a mean of 2550 ml of fluid with them into the forest.

The mean fluid requirement for both areas ($n = 8$) was 439 ml h$^{-1}$.

**Fluid available**

Contractors supplied only water which was usually kept at the ambient air temperature. No formal
policy exists on either the amounts or types of fluid required by these workers. Neither contractor knew what or how much to provide. The water was frequently placed at sites some distance from where the actual harvesting occurred. To take fluid with them into the forest, workers brought their own containers which included used 5-l oil containers, plastic cold drink bottles, or 750-ml detergent bottles.

**DISCUSSION**

Regardless of season, gender, and job category, 44% arrived at work dehydrated ($U_{SG} > 1.021$).
NZ forestry workers were arriving at work already dehydrated and the prevalence and severity of dehydration were not significantly different between winter and autumn (Parker et al., 2002). The challenge of workers in hot industrial situations arriving on site dehydrated is not limited to forestry, as Bates et al. (2010) found that a high proportion of expatriate manual workers during summer in the Middle East arrived at work dehydrated. Before these workers even began harvesting, their physical and mental capacity to work safely and productively was compromised (Casa et al., 2005).

Our study revealed that within 2 h of harvesting, regardless of season, gender, and job category, the prevalence of dehydration had increased to half (53%) ($U_{SG} > 1.020$). The increased prevalence further amplified the potential for injury and decreased productivity (Sharma et al., 1986; Gopinathan et al., 1988; Craig and Cummings, 1996; Miller and Bates, 2010). The early onset of dehydration was important to establish, as the contractors who managed the work force believed that it was unnecessary for the workers to drink before the break as dehydration was perceived to be a risk during the hotter parts of the day only.

At shift end, regardless of season, gender, and job category, the majority (63%) were dehydrated ($U_{SG} > 1.020$). This finding was similar to Parker et al. (2001), who established that in weather conditions similar to a SA winter, 63% of NZ forestry workers were dehydrated at shift end. Forestry workers, both locally and internationally, completed their shift physically and mentally compromised and many had not recovered by the next morning perpetuating a cycle of dehydration.

Percent loss of body weight was not a precise indicator of dehydration in this study, as in contrast to most other studies in forestry, many of these workers consumed both fluid and food across the shift (Staal Wästerlund et al., 2004; Scott et al., 2004). It was impossible to determine the impact that the food and fluid consumed had on body weight at shift end. Regardless of season, gender, or job category, at least one-fifth had dehydrated a minimum of $>2-3\%$ at shift end. These figures were conservative, however, as the consumption of food/fluid would lead to an underestimation of dehydration—in addition many were already dehydrated pre shift ($U_{SG} > 1.020$) and therefore started the shift at a lower body weight than normal. All other forestry studies who used percent loss of body weight assumed that the workers were coming to work properly hydrated and did not use another method such as $U_{SG}$ to confirm this (Trites et al., 1993; Parker et al., 2001; Scott et al., 2004). These results closely compared to Scott et al. (2004), who reported that SA forestry workers dehydrated $\sim 3-4\%$ in summer (Scott et al., 2004). Forestry workers in both Vietnam and Canada lost $\sim 3\%$ over an average shift (Trites et al., 1993; Staal Wästerlund et al., 2004). This has serious implications for both the industry and the workers, as dehydration of $>2\%$ decreases maximal aerobic power and aerobic exercise ability, reducing work capacity and work output by up to 50% (Trites et al., 1993; Craig and Cummings, 1996; Parker et al., 2001, 2002; Scott et al., 2004; Staal Wästerlund et al., 2004; Sawka et al., 2007). Concurrently, the significant decrease in mental and cognitive ability results in impaired alertness and an increased risk of injury as poor decisions, particularly by chainsaw operators, could result in numerous deaths (Sharma et al., 1986; Gopinathan et al., 1988; Trites et al., 1993; Parker et al., 2001, 2002; Scott et al., 2004; Staal Wästerlund et al., 2004). Dehydration of this magnitude therefore would deleteriously impact on productivity and safety, compromising both the workers health and livelihood. Dehydration is a critical challenge facing the local and international forestry industry.

The lack of effect of season that we observed agreed with Parker et al. (2002) that the extent and severity of dehydration in NZ forestry workers were similar in both autumn and winter. It was suggested that this was because little or no effort was made to drink adequately in winter as the forestry workers did not perceive dehydration to be a threat in colder weather (Parker et al., 2002). This reflected the viewpoint of the Institute of Commercial Forestry Research, who initially were reluctant to conduct a winter study as they felt that dehydration would not be an issue in the cooler months. Emphasis
therefore needs to be placed on the prevention of dehydration across the year rather than focusing on the hotter seasons.

We observed a lack of effect of job category which was unexpected as chainsaw operators and stackers were assumed to be at a higher risk. Chainsaw operators wear regulation masks hampering drinking and have petrol contaminated hands which could taint drinking fluids (Ashby and Parker, 2003). Stackers work at higher intensities and tend to ignore regulation breaks (Ashby and Parker, 2003). In contrast to the current findings, Scott et al. (2004) reported that in summer SA stackers dehydrated more than chainsaw operators.

The highly significant increase in the prevalence and severity of dehydration across the shift signified ineffective fluid strategies during the shift. Workers arrived already dehydrated as a consequence of inappropriate strategies both pre- and post-shift. A number of factors were noticed which contributed to the risk of dehydration. For some, it was time management, as they did not want to stop to drink or urinate so as to finish as quickly as possible to avoid the hottest parts of the day and some worked a second job in the afternoon. The only fluid available to all workers was water at the ambient air temperature, which in autumn was often >30°C. At times, insufficient water was placed in the vicinity of the workers. If sufficient water was provided, the workers were expected to bring their own containers to carry the water into the forest with them. Those without containers had no access to the water during the shift because as the shift progressed, so the workers moved deeper into the forest and further away from the water source. The contractors themselves set a poor example by consciously not drinking due to the lack of toilet facilities. In many areas, there was ongoing hostility between the work force and the management resulting in workers refusing to drink the water because they feared that management has poisoned it. An in-depth investigation of the causes of dehydration in this work force is essential, as once established, an education program for the forestry workers and the industry could be implemented.

Although the risk of hyperhydration has been well established in the military (Gardner, 2002), this was the first study to identify hyperhydration as a potential threat in hot industrial situations. A study published by Staal Wästerlund and Chaseling (2005) reported that male forestry workers in Zimbabwe who were taking 1200 ml of water per hour experienced a mean body mass increase of 0.7 kg indicating an excessive fluid intake. Miller and Bates (2007) referred to a small percent of Australian miners that were ‘very well hydrated’. According to Armstrong et al. (2010) hyperhydration, in particular, severe hyperhydration is not desirable as this can lead to fluid overload and potentially fatal dilutional hyponatremia, especially if there is a pattern of drinking too much (Sawka et al., 2007; Armstrong et al., 2010). Although hyperhydration is far less probable than dehydration, the consequences are far more dangerous (Sawka et al., 2007). The majority (80%) who fluid overloaded were harvesting in autumn. Several risk factors for hyperhydration were present in this area. The workers took larger volumes of fluid with them into the forest, the fluid was hypotonic, they exercised for >4 h, and some were >40 years old and females (Casa et al., 2005; Sawka et al., 2007). In addition, working within this area were very active Community Health Workers who encouraged the consumption of as much water as possible to prevent dehydration, as the practice was thought to be safe as they assumed that any excess fluid would be urinated (Kolka et al., 2003). They also actively discouraged the use of salt during cooking and the addition of salt to cooked food in an attempt to prevent hypertension. Ironically hyperhydration and dilutional hyponatremia was a probability for those forestry workers who were attempting to protect their health. This emphasized the need for appropriate education programs for the health professionals, the industry, and the workers (Casa et al., 2005; Sawka et al., 2007) which encourage the practice of both eating and drinking during shifts and the use of salt or salty foods when sweat losses are heavy. These studies have supplied the ground work for the development and implementation of a policy to reduce the prevalence of dehydration while minimizing the risk of hyperhydration.

Provisional fluid requirements for males of 439 ml h⁻¹ (3.5 l per 8-h shift) was determined from a very small subsection (n = 8). However, this corresponded with Paterson (1997) who recommended 500 ml h⁻¹ based on the sweat rates of eight male NZ chainsaw operators. This amount was similar to the most recent recommendations of the American College of Sports Medicine (400–800 ml h⁻¹) but was substantially lower than the International Labour Organization (5 l day⁻¹), the SA Department of Minerals and Energy (1–1.5 l h⁻¹), the US revised Military Guidelines (710–946 ml h⁻¹), as well as the most recent recommendations of 600 ml to 1 l h⁻¹ for those working in hot industrial situations (Montain et al., 1999; Blombäck, 2001; Department of Minerals and Energy, 2001; Sawka et al., 2007; Miller and Bates, 2010). Forestry workers adhering
to the current industrial guidelines could be susceptible to hyperhydration. This study and that of Paterson (1997) concluded that fluid requirements, however, varied widely, and as stated by the Position Paper of the American College of Sports Medicine (2007, 2009), it is not possible to have ‘a single one size fits all recommendation’ as individual fluid requirements are impacted by a multitude of factors (Sawka et al., 2007; ACSM, ADA and Dietitians of Canada, 2009). Nonetheless, general guidelines are imperative to enable the industry to stipulate, and then enforce the amount of fluid that needs to be supplied per worker per shift to ensure that adequate fluid is available.

A point of concern is that fluid recommendations for the military and for hot industrial situations such as mining were investigated for males. The forestry industry is unique, however, as over a third of the workers are female. These recommendations would probably be excessive for females, as in general, they require less fluid and are more susceptible to hyperhydration and dilutional hyponatremia (Twerenbold et al., 2003). Further studies need to be conducted to determine gender-specific recommendations. Additional recommendations for further study would include investigation of the appropriate fluids to be supplied and the implementation and monitoring of a hydration policy and education program. Simple ways to encourage these workers to monitor their hydration status need to be found. Techniques such as urine colour which have proved useful in other hot industrial environments (Miller and Bates, 2010) are not appropriate in rural SA forestry areas as there are no toilets either at the work place or at home.

This study reflected a conservative estimate of the actual prevalence and severity of dehydration occurring in SA forestry workers. Firstly, the study was conducted at sites where the contractors implemented good work practices, and secondly, the study was conducted in the cooler months.

According to Armstrong (2007), the accepted hydration markers in controlled laboratory conditions, namely total body water and plasma osmolality, do not accurately represent hydration status in the field. He suggested that when doing field work, a minimum of two hydration assessment techniques should be used and that changes in body weight provide the most accurate index if a series of measurements are taken. Given the severe constraints of working in the field, the strength of this study was that it is the only investigation done in forestry where two acceptable methods of hydration assessment, namely $U_{SG}$ and percent loss of body weight, were used.

A potential study limitation was the use of a convenience sampling which was unavoidable given the logistics, and that the study sites were not randomly chosen but instead selected by the industry in terms of being the largest sites at which study participation was feasible.

**CONCLUSIONS**

While harvesting over an average shift in autumn and winter, SA forestry workers, regardless of season, gender, or job category, experienced dehydration of a magnitude that could compromise both safety and productivity. Rehydration strategies before, during, and after shifts were ineffective. An excessive consumption of hypotonic fluid (water) in combination with a reduction in salt intake to prevent hypertension exposed an important minority to the potentially fatal risk of dilutional hyponatremia. It is crucial that the forestry industry understands this risk, as the implementation of an inappropriate intervention program may well result in an escalation of the risk of dilutional hyponatremia and a scenario similar to that experienced by the US military. The fluid recommendations of 450 ml h$^{-1}$ were conservative when compared to other international guidelines but correlated with the most recent recommendations of the American College of Sports Medicine indicating that, if followed, they should reduce the prevalence and severity of dehydration while reducing the risk of hyperhydration.

**DEFINITION OF TERMS**

Chainsaw operators use chainsaws to fell trees as opposed to using axes or machinery—they remove the branches of the felled trees (debranching) and crosscut the debranched logs into stipulated lengths.

Chainsaw operator assistants work together with the chainsaw operators. They assist them with equipment, use poles to guide the felled trees direction of fall, and assist with debranching.

Debarkers rip the bark off the trees before they are felled. Once felled, they peel the remaining bark off the debranched logs using an axe.

Stackers stack the debarked, debranched logs into piles. These are then loaded onto tractors to be transported to the paper mills.

Rough liners do a combination of both debarking and stacking. In the Richmond area, the same forestry worker was responsible to both debark and stack the trees (rough liner) while in Nelspruit, the workers were either debarkers or stackers.
Hydration status of SA forestry workers

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