Fluid Intake and Hydration Status of Forest Workers -- A Preliminary Investigation

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ABSTRACT

Dehydration and its milder form hypohydration have both short term and long term health effects. In the short term poor, body hydration impairs cognitive performance, physical strength and aerobic power, rendering the worker prone to injury and heat illness. In the long term the potential consequences of hypohydration are kidney stones and bladder cancer. The aim of this study was to evaluate hydration status of forest workers in New Zealand and their preferred fluid replacement. The specific gravity (sg) of urine was used as an indicator of body fluid status. In addition daily fluid loss was compared with a tested algorithm of sweat rate to better understand if workers are hydrating at the desired rate. The results of this preliminary study clearly demonstrate that loggers are working at sub-optimal hydration levels and are consuming inappropriate fluids to replace sweat losses. The hypohydrated state of these workers may pose both an immediate and long term health and safety risk.

Keywords: *dehydration, fluid intake, urine specific gravity, forest worker, New Zealand.*

INTRODUCTION

The temperature of the deep tissues of the body (the core) remains almost constant, within ± 0.5°C, day in and day out. The range of normal body temperature is between 36.0°C and 37.5°C. Even when exposed to temperatures as low as 10°C and as high as 40°C in dry air, the body can maintain an almost constant internal body temperature. The skin surface temperature, in contrast to the core temperature, rises and falls with the temperature of the surroundings. It is the surface temperature of the body that is important when the ability of the body to lose or gain heat to the surroundings is considered.

Body heat is gained directly from the reactions of energy metabolism (physical work). When muscles become active their heat contribution can be tremendous. For example, at rest the rate of body heat production is relatively low; the resting oxygen consumption is approximately 250 ml/min corresponding to a rate of heat production of 70 watts. During work, the rate of oxygen consumption can increase eightfold, and the rate of heat production is correspondingly increased. This metabolic heat gain will, in a short space of time, increase the core temperature of the body to dangerous levels if it is not lost to the environment. The heat is lost by the physical mechanisms of radiation, conduction and convection, and the evaporation of water from the skin and respiratory passages.

The six factors that influence a person's state of heat balance are:

1) *Air temperature* (dry bulb temperature). When the air temperature is above 35°C the body can increase heat gain by convection.

2) *Humidity* (relative humidity, wet bulb temperature). The importance of humidity in human heat exchange lies in its effect on evaporation of sweat.

3) *Radiant heat* (globe temperature). Radiant heat is not affected by air temperature or humidity. The direction of heat exchange depends on the absolute temperature difference between the body and surrounding surfaces. This can be considerable in some circumstances, for example working on the logging landing or skid site where heat is radiated from the sun and ground surface.

4) *Air movement* Depending on the air temperature, this can have a marked effect on heat exchange by convection.

5) *Clothing* The type and amount of clothing can have a major effect on the amount of heat lost or gained by the body. Protective clothing generally reduces heat loss.

6) *Muscular activity* This is particularly important, as discussed above, as more than 90% of metabolic energy is given off as heat. Some logging tasks are particularly physically demanding.

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As ambient temperature increases, the effectiveness of heat loss by radiation, conduction and convection decreases. When ambient temperature exceeds body temperature, heat is actually gained by these mechanisms of thermal transfer. In such environments (or when conduction, convection and radiation are inadequate to dissipate large metabolic heat loads) the only means for heat dissipation is by sweat evaporation. The rate of sweating increases directly with the ambient temperature.

The total amount of sweat evaporated from the skin depends on three factors:

1) Surface area of skin exposed to the environment
2) Temperature and humidity of the ambient air
3) Convective air currents around the body.

The maximum sweat rate is believed to be approximately 2 L/hr although 1.5 L/hr is regularly reported [5]. The maximum absorption of water across the gut wall is 1.5 L/hr so any sweat loss beyond this rate may result in gradual dehydration regardless of the quantity drunk. Dehydration also affects blood flow to the intestines in order to maintain the circulating volume of plasma that is essential to perfuse the working muscles. This in turn effects the absorption rate of fluid from the gut further increasing the possibility of dehydration.

Not all secreted sweat evaporates from the skin. In climatic conditions where the relative humidity is high, such as a forest, the sweat drips from the skin. This is caused by the reluctance of the already near saturated air to take up additional moisture from the skin. This loss of fluid from the body serves no cooling effect on the body but can severely deplete the body's fluids.

Where fluid lost through sweat loss is not replaced, the circulating plasma volume decreases resulting in a decline in the physical and cognitive ability of the worker. Body water deficits from sweating of a mere 1%-2% of body weight results in a 6%-7% reduction in physical work capacity in a moderate environment [3]. Water deficits of 3%-4% in the same environment results in a 4%-8% reduction in maximal aerobic power, and a 22% reduction in physical work capacity. Body water losses of 4% in a hot environment results in a 25% reduction in maximal aerobic power with a physical work capacity reduction of approximately 50% [11], [2]. Mental performance begins to show a decrement at 2% hypohydration, with further mental impairment being proportional to the degree of hypohydration [7]. In short, it is reasonable to state that complex tasks may not be adequately or safely accomplished when cognitive and physical capacity is impaired by thermal stress or hypohydration and that the worker will be more prone to seemingly unrelated accidents.

The thirst mechanism cannot be relied upon to combat hypohydration. By the time thirst is experienced, the body is already 2% dehydrated. A 5% fluid loss can cause heat stress or illness, and a 15% loss can lead to convulsion and heat stroke.

Forestry workers, especially chainsaw users, are required to wear protective clothing that imposes a significant thermal insulation. Although this may be welcome in the winter months it does impede heat dissipation during hot summer days. In addition the significant metabolic work rate of these workers adds to the thermal demands of the body [9]. In these circumstances the possibility of heat illness with associated cognitive and or physical decrement dehydration is substantially increased. These effects are in addition to a reduction in productivity [12].

Heat illness can be described within three categories - heat cramps, heat exhaustion, and heat stroke. It is now generally believed that muscle cramping is far more complicated than mere salt depletion, it may well be due to regional circulatory changes. Heat exhaustion is very well documented in other industries that involve manual work in thermally stressful environments [4]. However neither the prevalence or risk of suffering this condition has been assessed in forestry workers. Those persons who are unacclimatised, unfit, obese or dehydrated are most at risk, with weakness, inability to continue working, frontal headache, and faintness being some of the usual signs. Often drinking water and rest in a cool place will be sufficient for recovery of the individual. Prickly heat (skin inflammation following profuse sweating) results from sweat gland ducts becoming blocked and so the sweat is forced out the sweat duct into the tissue under the skin. The ability of the body to maintain body temperature is compromised in this state.

Heat stroke, where the body gets to a temperature that causes tissue damage (principally the brain, liver and kidneys) has a mortality rate of around 80% and is a possibility in persons who are highly motivated or for those in paced labour in the heat. Although heat stroke in forestry workers is very rare in New Zealand, the lesser condition of dehydration induced heat exhaustion is much more likely.

A further, but long-term, health consequence of heat exposure/ inadequate fluid intake is development of kidney stones (renal calculi). It is estimated that one million Australians suffer from renal stones. The incidence in New Zealand may not, as a percentage of population, be as high due to the milder climate, however, it is regarded as a major health problem and on the increase. Another recent report identifies a clear relationship between poor fluid intake and cancer of the bladder [6].

These short term and long term consequences of under-hydration, have lead to some efforts to address the problem. An indicator of sweat loss has been developed by US Army scientists [8] who use the index to maintain troop fluid levels when they are deployed to hot climates, for example during the Gulf war. This algorithm measures all relevant physical environmental factors and together with input for clothing type and work rate computes and displays the maximal exposure limit, should one exist, and the calculated sweat rate. The value of this thermal index is that a comparison can be established between sweat loss and fluid replacement being consumed.

To determine the hydration status of forestry workers and establish if they are working in a dehydrated state, the specific gravity of urine was measured. Urine is a good marker of hydration: when it is of high osmolarity (dark, odorous) it indicates the body is under-hydrated and is conserving all fluids to maintain blood pressure and prevent hyperthermia. The urine can be used therefore as a "window" to evaluate hydration of the workers. In summary, the current study was designed to establish whether forestry workers are performing high risk and manually demanding tasks in a hypohydrated state, firstly by using specific gravity as a marker, and secondly to compare fluid intake with the US Army model to calculate daily fluid deficit.

METHOD

During Autumn, 2000 (March, April and May), 31 male loggers were selected at random from available logging crews and asked to provide a sample of urine in a plastic screw top bottle. A sub sample of urine was taken by disposable pipette and placed on the viewing platform of a refractometer (Atago instruments) to determine specific gravity. Researchers wore disposable rubber gloves throughout the procedure, following which the urine sample was then discarded. In a questionnaire, the loggers were asked to record the quantity and type of fluid consumed up until the urine sample was measured, along with their height, weight and age.

The US Army model was calculated and recorded. Values for clothing ensemble and energy requirements of the task (skidwork and machine operating) were estimated from previous studies [10]. The fluid intake for each logger was compared with the required fluid estimate from the model.

RESULTS

Thirty one loggers supplied a sample of urine for determination of specific gravity. The loggers were representative of the broad range of ages found in the New Zealand forest workforce (Table 1).

Table 1. Physical characteristics of the 31 loggers sampled.

	Mean	SD	Min	Max
Age (years)	34	9	17	53
Height (m)	1.78	0.1	1.53	1.91
Weight (kg)	89	12	70	113

All loggers wore the personal protective equipment ensemble required for work in New Zealand forests:

- Helmet
- Ear muffs
- High visibility shirt or vest
- Chainsaw cut resistant legwear (chaps or trousers) - if using a chainsaw
- Leather or chainsaw cut resistant rubber boots with steel crush resistant toe caps.

The wide range in temperatures experienced at the time of sampling reflects the highly variable daily weather conditions normally experienced in New Zealand (Table 2). The loggers were acclimatised to working in these conditions. The high globe temperatures indicate heat being radiated from the highly reflective pumice soils of the Central North Island forests.

Table 2. Environmental conditions recorded at the time of urine specific gravity readings.

	Mean	SD	Min	Max
Dry bulb (°C)	19.0	4.7	12.5	26.5
Wet bulb (°C)	15.7	4.3	9.7	20.7
Globe (°C)	24.1	3.2	20.1	29.3
WBGT[1] (°C)	17.6	3.9	12.4	21.7

[1]WBGT = Wet bulb globe temperature

Of the 31 loggers, seven (23%) had drunk only caffeinated beverages (coffee, tea and/or cola) up until the time of urine sampling. Sixteen (52%) had drunk both water and caffeinated drinks and seven (23%) had drunk only water.

On average, loggers had consumed a little more than one litre of fluid (in addition to fluid in food) in the first five hours of work (0700 hrs to 1210 hrs). One logger had consumed no fluid in that time (Table 3).

Table 3. Self-reported fluid intake of loggers and measured urine specific gravity.

	Mean	SD	Min	Max
Fluid intake (ml)	1124	822	0	3000
Time of sampling (hrs)	1210	0155	920	1500
Specific gravity (g/ml)	1.022	0.005	1.012	1.031

Loggers urine specific gravity ranged from 1.012 to 1.032 g/ml with the single greatest number of loggers having a urine specific gravity of 1.026 g/ml (Figure 1). This indicated that some loggers were in a dehydrated state (>1.030 g/ml, Royal College of Pathology, Australia) at the time of sampling. The majority of workers (between sg 1.016-1.030 g/ml) were marginal to hypohydrated. Desired sg should be approximately 1.015 g/ml or below [4]. The required hourly fluid intake for skid workers and machine operators were calculated from the US Army model using a metabolic power output of 400 Watts (24 kJ/minute) and 300 Watts (18 kJ/minute) respectively [10]. The machines did not have air conditioned cabs.

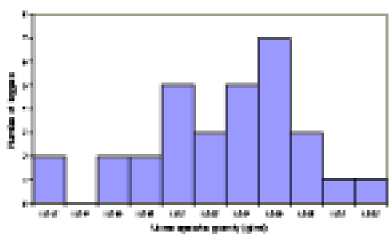

Figure 1. Distribution of urine specific gravity for 31 loggers.

Loggers were under consuming water when their self-reported fluid intakes were compared with required fluid intake from the US Army model. Figure 2 shows the distribution of fluid intake deficits (ml/hr) for individual loggers. Most loggers were found to have a fluid deficit of at least 50 ml/hr. The maximum deficit was 250 ml/hour, some however consumed adequate but inappropriate fluids such as caffeinated or high sugar beverages.

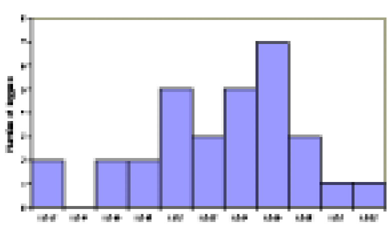

Figure 2. Comparison of the required (derived from US Army model) and actual fluid intake of loggers.

DISCUSSION

The study investigated fluid status of a sample of workers using three indicators. Firstly specific gravity was used as a tool to estimate logger hydration; secondly, subjective information estimated the types and amount of fluids being consumed, and thirdly required fluid intake was estimated though the US Army model and compared with actual volumes consumed.

Specific gravity was demonstrated to be a good screening tool for hydration rather than using complicated and time consuming formulations. However some problems when using this system are recognised. Should large volumes of caffeinated fluids be consumed then the diuretic effect will result in a dilute urine, indicating a well hydrated individual whereas they may be hypohydrated. In contrast, the intake of high doses of vitamins and other commonly used health aids may indicate high specific gravity, as any excess to maximum absorption will be excreted in the urine and thus increase the osmolarity of the urine. However if the fluid type and intake of workers is recorded, some of these inherent problems can be considered in the data interpretation.

The benefits of this method are: it is cheap and very easy to perform, it is highly mobile and takes very little time, large groups can be screened at one time. The workers can be immediately informed of the result of the test, and shown the colour of the urine matched with the specific gravity. During daily testing of the urine, the worker can begins to correlate the colour of their urine to their hydration status. Therefore the test works extremely well as an educational tool, the intent being to have the worker check the colour of the urine in the morning prior to the commencement of work [1]. Should the colour be dark and opaque then additional fluid can be consumed before the start of the work shift.

It is evident that workers are ill-informed as to the most appropriate fluid replacement that should be consumed when working at high metabolic rates in the heat. Commercial drinks such as lemonade and cordials have approximately 10% sugar content and if these are used as a sole replacement can significantly increase the daily kilojoule intake of the worker. During the summer when sweat rates are high, and it is not uncommon for loggers to consume 5-6 litres of fluids in the working day. The daily sugar intake in this instance would be as high as one kilogram. In addition cola and recently released “designer drinks” have a moderate to high concentration of caffeine. This adds to the fluid loss (diuresis) rather than replace the sweat loss. Coffee and to a lesser extent tea are also caffeinated beverages, and large consumption (more than two cups per work shift) should be avoided especially during the summer when sweat rates are high. Some sports drinks have a low pH (acidic) and while they may be appropriate for short duration sport sweat loss, they are not recommended for daily high volume consumption. The workers were generally unaware of these facts and many used the above mentioned expensive commercially available beverages to rehydrate. It is clear that an education program is needed to better inform these workers about the most appropriate replacement fluids to counteract the current preferred fluid replacement. This is particularly true at the beginning of summer when they are unacclimatised to the heat.

The most appropriate drink to consume is water or low joule cordial. Slices of lemon or weak cordial can be added for flavor to reduce the boredom of drinking water in large quantities (for example in excess of 4 litres a day). The drink should be cool thus insulated containers are advised. Fluid containers should be appropriate for the environment: loggers handle petrol and oil for their chainsaw and can easily contaminate the neck of any fluid container that must be opened with their hands. An alternative is the “Camelbak” type fluid carrier with a flexible tube and mouth-piece which can be worn on the back or left with the chainsaw fuel and oil. Machine operators are not as effected as the loggers carrying out manual work due to the significantly lower metabolic work rate and therefore sweat rate.

CONCLUSIONS

This study was a preliminary investigation to determine if logger hydration status warranted further investigation. Fluid intake was found to be less than that estimated as required for the conditions. Many workers were found to be either hypohydrated or dehydrated. Poor hydration of forestry workers may present a short or long term health risk. Field measurement of urine specific gravity was found to be a rapid and simple method to provide the logger with feedback on his personal hydration status. Further work is needed to quantify the effects of caffeine intake on logger urine specific gravity and the effects of different fluid delivery devices on logger hydration status under operational conditons.

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