UNIVERSITY OF KWAZULU-NATAL

THE PREVALENCE AND DEGREE OF DEHYDRATION IN RURAL SOUTH AFRICAN FORESTRY WORKERS

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DISCIPLINE OF DIETETICS AND HUMAN NUTRITION
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ABSTRACT

South African forestry workers are predisposed to dehydration due to the heavy physical activity they perform in impermeable regulation safety clothing in hot and often humid environments where the availability of a variety of suitable fluids at reasonable temperatures is limited. As dehydration reduces both physical and mental capacity the potential consequences include decreased productivity and an increased risk for injury. The aim of this cross sectional observational study was to determine the prevalence and severity of dehydration in rural forestry workers in both winter (minimum and maximum daily temperatures 3-22°C) and autumn (minimum and maximum daily temperatures 14-27°C).

The convenience sample included 103 workers in autumn (Nelspruit, n=64 males, n=39 females, mean age 37.32 years, mean BMI 22.3 kg/m^2) and 79 in winter (Richmond, n=68 males, n=11 females, mean age 25.85 years, mean BMI 22.2 kg/m^2). The sample included chainsaw operators, chainsaw operator assistants, debarkers and stackers. The risk of heat illness was moderate in Nelspruit (average daily temperature 21.1°C 67% rh) and low in Richmond (average daily temperature 17.0°C 39% rh).

The prevalence of dehydration was determined by urine specific gravity (USG) measurements. Percent loss of body weight in the course of the shift was used to determine the severity of dehydration.

In Nelspruit 43% (n=43) and in Richmond 47% (n=37) of the forestry workers arrived at work dehydrated (USG>1.020 g/ml). Pre break this had increased to 49% (n=49) in Nelspruit and 55% (n=33) in Richmond. By the end of shift the number of dehydrated forestry workers had significantly increased to 64% (n=64, p≤0.001) in Nelspruit and 63% (n=42, p=0.043) in Richmond. A minimum of 21% (n=2) in Nelspruit and 23% (n=15) in Richmond of the forestry workers had lost more than 2% of their body weight which could significantly decrease work capacity and work output as well as mental and cognitive ability. Dehydration was not related to season (winter/autumn), gender or job category.

In Nelspruit 23% (n=23) and in Richmond 13% (n=10) arrived at work overhydrated (USG<1.013 g/ml). Pre break this had decreased to 14% (n=14) in Nelspruit and 10% (n=6) in Richmond. By the end of shift 4% (n=4) in Nelspruit and 2% (n=1) in Richmond had remained overhydrated and without correcting for fluid and food intake, 5% (n=5) had gained over 2% of their body weight in Nelspruit while none had gained weight in Richmond. Overhydration was not related to season (winter/autumn), gender or job category.

Physical symptoms at the end of shift included tiredness (24%), toothache (13%) and headaches (10%) although these did not correlate to end of shift USG readings (p=0.221).

The fluid requirements for male workers (n=8) who did not eat or drink across the shift was 439 ml per hour.

The contractors were unaware of how much fluid should be supplied to workers and how much fluid they actually supplied. The only fluid provided by the contractors was water at the ambient air temperature which was the main source of fluid for the majority. Some forestry workers brought a limited variety of other fluids including amahewu, tea and cold drinks to work.

At least 40% of the work force investigated, started their shift already compromised to work to capacity (USG>1.020 g/ml). The prevalence of dehydration had increased by the break emphasizing the need to begin drinking early on in the shift. The majority of forestry workers were dehydrated at the end of the shift. A significant proportion was dehydrated to the extent (>2%) that both work capacity and mental ability would be significantly compromised. A select group of forestry workers were drinking excessive amounts of fluid and were therefore susceptible to potentially fatal dilutional hyponatremia especially as water was the primary source of fluid.

Dehydration in both autumn and winter was identified as being a significant but preventable risk. As a consequence of overhydration, a small group of forestry workers may be susceptible to dilutional hyponatremia. Fluid intake guidelines for males of 450 ml per hour appeared to be safe and were within the recommendations of the American College of Sports Medicine. Fluid guidelines for females need investigation.

DECLARATION

The work described in this dissertation was carried out in the School of Agricultural Sciences and Agribusiness, University of KwaZulu-Natal, Pietermaritzburg under the supervision of Professor Eleni Maunder and Dr Marie Paterson.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any University. Where applicable, the work of others is acknowledged in the text.

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CONTENTS **Page**

LIST OF FIGURES **PAGE**

LIST OF TABLES **PAGE**

APPENDICES **PAGE**

CHAPTER 1: INTRODUCTION, THE PROBLEM AND ITS SETTING

1.1 IMPORTANCE OF THE STUDY

In South Africa (SA) approximately 30 000 people, mainly rural, are employed by the forestry industry to plant, harvest and transport trees (Edwards 2006, DWAF 2005). As forestry is one of the most dangerous occupations in the world (Blombäck 2001) strict safety regulations are enforced to protect these workers from the obvious risks of tree felling (Director General 1995). However little emphasis has been placed on protecting the work force from the more obscure threats such as heat illness[1] and dehydration.[2] The heavy physical labour performed in a hot and often humid environment, the regulation impermeable safety clothing,[3] the limited availability of a variety of appropriate fluids at palatable temperatures as well as the labour force's suspicion that the fluid supplied by the forestry industry/contractors is poisoned, predisposes the SA forestry workers to dehydration (Van Daele 2005). Dehydration causes hyperthermia,[4] cardiovascular strain and a significant decrease in both concentration and coordination (Gopinathan, Pichan & Sharma 1988, Sharma, Pichan & Panwar 1986), possibly contributing to the high accident rate. Dehydration also results in the onset of early fatigue and an increased perception of effort, the consequence of which is a decreased output of work which in turn could cause a decrease in production (Mudambo, Leese & Rennie 1997). The combination of these effects may negatively impact both the health of the forestry workers and the health of the

1 Heat illness refers to heat exhaustion and heat stroke.

2 In this dissertation the term dehydration has been used to refer to a state of body water deficit.

3 The guidelines of the Occupational Safety and Health Act are enforced. Regulation protective clothing includes plastic gloves, safety helmets, leg protectors, closed safety boots and in some cases rubber aprons, face masks and chainsaw resistant leggings.

4 Hyperthermia is a rise in body core temperature above 40°C which occurs when the body retains more heat than it can dissipate through its heat regulating mechanisms. Untreated hyperthermia results in heat stroke.

forestry industry. These issues were brought to the attention of the SA forestry industry when a study this industry commissioned on ergonomics inadvertently established that significant dehydration occurred in SA forestry workers during an average morning shift in summer in Kwambonambi (Scott, Christie, James & Todd 2004). To establish the magnitude of the problem facing the industry and to offer possible preventative strategies, a study which specifically investigated the prevalence and degree of dehydration in forestry workers, harvesting different regions and seasons in SA, was essential.

1.2 PURPOSE OF THE STUDY

The purpose of the study was to ascertain the prevalence and degree of dehydration of rural forestry workers who were using motor manual methods[5] to harvest trees in the KwaZulu-Natal (KZN) uplands in winter and in Mpumalanga in autumn and to monitor both the type and amount of fluids available during harvesting as well as the type and amount of fluids that the workers were actually consuming during shifts.

1.3 TYPE OF STUDY

This was a cross sectional observational study. The decision to use a cross sectional study was based on the possibility that the subjects may have been non co-operative – in that case a cross sectional study would have resulted in a high attrition rate. In addition both the financial and time constraints favoured a cross sectional design. The advantages of the cross sectional design

[5] The harvesting of trees is either fully mechanized or fully manual or a combination of mechanization and manual referred to as motor manual – here machinery such as chainsaws are used to fell trees but the trees are debarked manually using hand held axes.

is that single measurements are conducted on a larger group of individuals reducing the attrition rate and the cost in terms of both time and money. The major disadvantage however is that natural variations in the behaviour of the individual are not controlled for (King 2001).

1.4 STUDY OBJECTIVES

In the study areas of Richmond (winter) and in Nelspruit (autumn) the objectives were:

1.4.1 To determine the amount of fluid supplied by the contractors and the forestry workers.

1.4.2 To determine the type of fluid supplied by the contractors and the forestry workers.

1.4.3 To establish and compare the prevalence and degree of dehydration occurring in forestry workers using urine specific gravity (USG) and to determine whether there were high risk categories according to gender and job category.

1.4.4 To establish and compare the prevalence and degree of dehydration occurring in forestry workers using percent loss of body weight and to determine whether there were high risk categories according to gender and job category.

1.4.5 To determine whether the forestry workers experienced symptoms of dehydration at the end of the shift.

1.4.6 To determine the forestry workers' fluid requirements.

1.5 STUDY PARAMETERS

Black adult chainsaw operators,[6] chainsaw operator assistants,[7] debarkers,[8] stackers[9] and rough liners,[10] both male and female, who were harvesting trees using motor manual methods, in Richmond in the winter of 2005 (July) and in Nelspruit in the autumn of 2006 (April) were included in the study (Appendix A).

1.6 STUDY LIMITATIONS

1.6.1 Due to the rural location of some of the forestry sites and the need for specialized vehicles to access them, the research sites were selected on the basis of convenience without any consultation with the researcher.[11]

1.6.2 The research sample was also selected on the basis of convenience by the forestry industry without input from the researcher.

1.6.3 Dehydration could not be measured using the more accurate haematological indices such as plasma osmolality, as the community health workers (CHW) who worked with the forestry workers in the research areas were adamant that the work force would not consent to blood being taken because they would be suspicious that their Human

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[6] Chainsaw operators use chainsaws to fell trees - they then remove the branches (debranch) and cross cut the debranched logs into stipulated lengths.
[7] Chainsaw operator assistants work together with the chain saw operators as a team. They use poles to push the trees so that they fall in the required direction.
[8] Debarkers peel the bark off the trees using a small axe.
[9] Stackers are responsible for stacking wood into piles for collection by the tractors.
[10] Rough liners are responsible for moving the trees closer together so that the stackers can put them in piles.
[11] The research sites and research samples were selected by Francois Oberholtzer (Institute of Commercial Forestry Research ICFR), Pierre van Daele (Mondi) and Andre Brink (South African Pulp & Paper Industry).

Immunodeficiency Virus (HIV) status was being investigated. The CHW's had frequently encountered this resistance from the workers at clinic visits.

1.7 STUDY ASSUMPTIONS

It was assumed that:

1.7.1 the research assistants (RA) recorded the data accurately and that they consistently performed the measurements as they had been trained to do.

1.7.2 an adequate number of proficient interpreters were on the team to cover the range of languages spoken by the forestry workers and that their interpretation was an accurate reflection of both the questions asked and the replies given by the forestry workers.

1.7.3 the forestry contractors and forestry supervisors supported and cooperated with the requirements of the study.

1.7.4 the forestry workers worked shifts of similar length and intensity each day.

1.7.5 the days sampled were representative of a normal working day.

1.7.6 the recording of the measurements did not interfere significantly with either the length of the shifts or the completion of tasks.

1.7.7 the forestry workers would not eat during their shifts, making the use of percent loss of body weight an appropriate tool.

1.7.8 the participating forestry workers were cooperative and truthful when answering the questions.

1.7.9 the fluid issued to the forestry workers could be accurately monitored.

1.7.10 the forestry workers drank only the fluid that they carried.

1.7.11 the forestry workers would agree to give urine samples and that they handed in their own urine samples and not those of other forestry workers and that urine samples would be attainable in spite of dehydration.

1.7.12 all factors affecting the accuracy of urine specific gravity (USG) eg diuretics as a measurement of hydration, had been taken into account.

1.7.13 the weather during the period of both studies was reflective of the weather conditions which normally occur at that time of year.

1.7.14 the forestry industry would supply the globe temperature, dry bulb temperature and wet bulb globe temperature for the research areas in general as was agreed before the studies commenced, and that these readings reflected the temperatures on the specific research sites within the area.

1.8 DEFINITION OF TERMS

Amahewu: a drink make from fermented maize meal.

Body mass index: ratio calculated by dividing the body weight (kg) by the height squared (m) (Whitney, Cataldo & Rolfes 2002 p251).

Break: the contractors in both study areas allocated the workers a morning break period of approximately 30 minutes. The timing of this tended to vary with the time that the shift began and was usually between 08h30 and 10h00.

Cardiovascular drift: is the relationship between the reduced cardiac output as a consequence of dehydration lowering the amount of blood pumped on each beat and the resulting increase in heart rate in an attempt to compensate (González-Alonso, Mora-Rodríguez, Below & Coyle 1997).

Chainsaw operators: are forestry workers who use chainsaws rather than axes to fell, remove branches (debranching) and cross cut the trees into specified lengths.

Cold drink: this is the South African term for a cordial or squash.

Dehydration: is when the person is in a state of fluid deficit or negative water balance (Sawka, Burke, Eichner, Maughan, Montain & Stachenfeld 2007). For the purposes of this dissertation the guidelines of the American College of Sports Medicine (2007) were used which state that a urine specific gravity (USG) reading of >1.020 g/ml or a percent loss of body weight >2% indicates a dehydrated state (Sawka *et al* 2007, Sakwa's comments in the Panel Discussion published in the paper by Armstrong 2005). This dissertation refers to serious dehydration as being measured by a urine specific gravity reading of greater than 1.030 g/ml or a loss of body weight of greater than 5% (Casa, Armstrong, Hillman, Montain, Reiff, Rich, Roberts & Stone 2000, Sawka *et al* 2007).

Euhydration: is when the person is in water balance as reflected by a urine specific gravity reading of 1.013 g/ml to ≤1.020 g/ml or by a change of body weight of plus one percent or minus one percent (Armstrong 2005, Sawka *et al* 2007, Casa *et al* 2000, Armstrong, Maresh, Castellani, Bergeron, Kenefick, LaGasse & Riebe 1994).

End of shift: was defined as the time that the forestry workers completed their harvesting task for the day. This was between 11h30 and 16h30 depending on the time that the shift started.

Heat exhaustion: is caused by a loss of salt and/or dehydration and results in fatigue, headaches, giddiness, dizziness/fainting, shortness of breath, paleness, sweating, nausea, vomiting and a raised body temperature (Casa, Clarkson & Roberts 2005, Binkley *et al* 2002)

Hyperthermia: is a rise in body core temperature above 40°C which occurs when the body retains more heat than it can dissipate through its heat regulating mechanisms. Untreated hyperthermia results in heat stroke (Armstrong, Casa, Millard-Stafford, Moran, Pyne & Roberts 2007).

Hyponatremia: is a drop in blood sodium levels to below 130 mmol/l (Sawka *et al* 2007).

Maas: sour milk similar to yoghurt.

Motor manual method of tree harvesting: is where the forestry workers use a combination of motorized equipment (motor), such as chainsaws, to fell trees as well as manual methods (manual) such as small axes, to peel the bark of the trees. Tree harvesting can be totally mechanized, or totally manual or motor manual.

Overhydration: is when the person is in a state of fluid excess or positive water balance from consuming more fluid than that lost in the sweat (hyperhydration). This was expressed as a gain in the percent change of body mass. There are no categories of overhydration according to percent gain in body mass although a 1% gain is considered the upper range of normal hydration (Casa *et al* 2000). According to Armstrong *et al* (1994: 2005) a urine specific gravity reading of <1.013 g/ml is indicative of overhydration.

Percent change of body weight: this was the change of body weight over a period of time, expressed as a percent of the pre shift weight.

Plasma volume: is the volume of plasma in the blood – plasma is the fluid in which blood cells are suspended in the body (Osol, Chase, Francis, Nelhaus, Prichard, Richardson & Wenger 1972).

Portable refractometer: is a portable digital instrument used to measure urine specific gravity.

Rest station: is an area designated by a red and white striped tape - kept within this area is the petrol, fire fighting equipment and fluid.

Shifts: the period of time that the forestry worker spends harvesting in the forest. These usually begin as soon as it is light enough to see which was approximately 5h00 in summer and 6h15 in winter. They end anytime from 11h30 to 16h30.

Tree harvesters: are those workers involved in the process of felling, debranching, debarking, crosscutting and stacking the trees for transport to the mills.

Temperature, dew point: is the temperature to which a volume of air must be cooled at constant pressure and constant moisture in order to reach saturation. If the air is cooled any further, condensation results (South African Weather Service 2007).

Temperature, dry bulb: this is the ambient air temperature (South African Weather Service 2007).

Temperature, globe: is the absolute temperature difference between the forestry worker and the surrounding surfaces such as heat radiating down from the sun and heat radiating up from the ground (South African Weather Service 2007).

Temperature, wet bulb: this is a measure of the relative humidity (South African Weather Service 2007).

Temperature, wet bulb globe: this is an index calculated as the $WBGT = 0.7_{\text{natural wet bulb temperature}} + 0.3_{\text{globe temperature}}$. The index is used to classify weather conditions into low, moderate, high and extreme high risk for sports practices and events (Binkley, Beckett, Casa, Kleiner & Plummer 2002).

Safety clothing: includes a plastic safety helmet, saw resistant footwear, protective leggings and gloves. In addition the chainsaw operators and assistants wear ear muffs and face masks. The stackers also wear plastic aprons.

Urine specific gravity: is the density of urine (g/ml) as measured by a refractometer (Armstrong 2005).

Water: refers to plain water with no electrolytes or carbohydrate added.

1.9 ABBREVIATIONS

ACSM:	American College of Sports Medicine
BMI:	Body mass index
CHO:	Carbohydrate
COHFE:	Centre for Human Factors and Ergonomics
CHW:	Community Health Workers
DB:	Dry bulb temperature
DME:	Department of Minerals and Energy
DWAF:	Department of Water Affairs and Forestry
ELI:	External Light Interference
g:	Gram
GDP:	Gross Domestic Product
GT:	Globe Temperature
HIV:	Human Immunodeficiency Virus
ID:	Identity

ICFR:	Institute of Commercial Forestry Research
ILO:	International Labour Organisation
IQR:	Inter quartile range
ISAK:	International Society for the Advancement of Kinanthropometry
kg:	Kilograms
KZN:	KwaZulu-Natal
m:	Metres
MID:	Mining Industrial Dowls which is the name of the Nelspruit contractor's company
ml:	Millilitres
meq:	Milliequivalents
n:	Number
NZ:	New Zealand
RA:	Research assistant
rh:	Relative humidity
SA:	South Africa
SAPPI:	South African Paper and Pulp industry
SD:	Standard deviation
SPSS:	Statistical Package for Social Sciences
US:	United States
USG:	Urine specific gravity
$V0_{2\ max}$:	The maximal uptake of oxygen
WB:	Wet bulb temperature
WBGT:	Wet bulb globe temperature

1.10 SUMMARY

SA forestry workers involved in harvesting are predisposed to dehydration due to the heavy physical activity they perform in impermeable safety clothing in hot and often humid environments where the availability of a variety of suitable fluids at reasonable temperatures is limited. Dehydration causes heart strain, an increased perception of effort, early fatigue and a loss of concentration and coordination. The potential consequences include a decrease in production and an escalation in the risk of injury. This in turn would detrimentally impact on the health of both the work force and the forestry industry. As dehydration is preventable and its effects minimized, it is important to establish its prevalence and degree among SA forestry workers so that the magnitude of the threat can be determined and suitable guidelines and possible preventative strategies can be developed.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

The forestry industry is responsible for 1.4% of the total formal employment in SA and as such offers an important source of income for the many poor people living in remote rural areas (DWAF 2005). Their restricted opportunities for employment leave the rural poor with little choice but to harvest trees as a means of earning a livelihood for both themselves and their dependents. Harvesting trees however is a very dangerous occupation (Blombäck 2001).

Protecting the health and therefore the productivity of their workers is of paramount importance as the forestry industry needs to remain profitable to continue operating in the rural areas. Although the forestry industry enforces safety regulations to protect their workers from the obvious dangers of tree felling (Director General 1995), the environment itself and the work conditions expose them to more subtle and often unrecognized dangers such as dehydration and heat illness.

This literature review will briefly explore the background of the forestry industry in SA, the risk of heat illness in forestry workers, major factors important for thermoregulation, the prevalence of dehydration as well as the consequences of both dehydration and hyperthermia. The potential factors contributing to dehydration, as well as recommendations concerning the appropriate amounts and types of fluid, will be explored. The most appropriate methods by which to measure dehydration will be discussed.

2.2. THE FORESTRY INDUSTRY IN SOUTH AFRICA

The forestry industry's contribution of 12.2 billion rand (1%) to the national Gross Domestic Product (GDP) in 2003 and 14 billion rand in 2006 was comparable to that of the mining and the clothing, textile and leather goods sectors, underlining its importance to the SA economy (Zalk 2007, DWAF 2005 citing Genesis 2005).[12] In 2006, the SA Accelerated and Shared Growth Initiative, driven by the Department of Trade and Industry, identified Forestry, Pulp and Paper as being one of four vital sectors essential to promote an annual economic growth of 6% by 2010 and to reduce poverty 50% by 2014 (Zalk 2007).

Forestry's role in the attenuation of poverty is unique in that the commercial plantations are primarily situated in rural locations thereby offering employment where other prospects are scarce (Edwards 2006, DWAF 2005, Director General 1995). Most of the commercial forests are situated in Mpumalanga and KZN (Figure 1) and rural people in these areas rely heavily on them for survival (DWAF 2005, Director General 1995).

According to Edwards (2006), in the order of 5% of rural South Africans directly or indirectly depend on this industry as a means of income. Approximately 200 000 to 260 000 are directly employed in sawmilling, pulp and paper manufacturing and secondary processing. They earn wages which comply with minimum regulations and are eligible for benefits such as schooling, medical facilities and pensions (Director General 1995).

[12] Unable to obtain the reference for Genesis 2005 as it was listed as Op. cit.

Figure 1: Location of commercial forests in South Africa (permission for use granted by the South African Forestry Magazine)

Unfortunately those employed indirectly[13] by the forestry industry are not as privileged. These include the very poor subsisting in the more rural areas as most of the planting, harvesting and transport operations have been subcontracted to independent concerns (Edwards 2006). The 300 contractors involved employ an estimated 30 000 people of whom 30 to 35% are women (Edwards 2006, DWAF 2005). Only those involved in harvesting were included in this study.

[13]The term "indirectly employed" refers to those labourers who work directly for the contractors who have been subcontracted to plant and harvest trees rather than being directly employed by the forestry industry itself.

Employment conditions vary between contractors. Eighty percent offer a reasonable working environment and pay wages of between R40 and R50 per day - the more skilled[14] may get up to R85 per day (DWAF 2005, Kamhoot 2005, Director General 1995). In addition some contractors give partial or full ration packs either weekly or monthly (Appendix B). Often a task system is used where, at the discretion of the contractor, the worker is allocated a specific number of trees to harvest per day. If this quota is not met, the shortfall is deducted from their wages (Appendix C). Others pay a basic wage and offer an incentive of a R1 per additional tree harvested above the target (Mining Industrial Dowls 2006, Kamhoot 2005, DWAF 2005). The workers are housed in villages but as the contractors are responsible for their upkeep, their living conditions vary greatly (Figure 2).

Figure 2: A typical example of a forestry village in Richmond SA

[14] For example the chainsaw operators.

Twenty percent offer unreasonable working conditions. These contractors pay wages below the minimum with no additional rations and sometimes do not follow standard operating procedures including those concerning safety (DWAF 2005, Director General 1995). As harvesting is one of the most dangerous occupations in the world, the contractors are expected to enforce the safety regulations as stipulated by the Occupational Safety and Health Act (Blombäck 2001, Director General 1995).

These regulations are designed to protect the work force from the obvious risks of tree felling, but do not take into consideration the more subtle but equally dangerous threats of heat illness and dehydration. Being very poor with no medical or other benefits (Edwards 2006) these workers' health is one of their few assets and it should be protected.

2.3 HEAT ILLNESS

Heat illness[15] is a potential risk due to the heavy physical activity being carried out in the hot and often humid environments[16] in which they work and because of the regulation protective clothing[17] that they are required to wear.

It is absolutely essential to maintain the body's core temperature during physical activity to ensure a continued productive work performance and to protect the workforce from heat illness

[15]Heat illness refers to both heat exhaustion and heat stroke.
[16]In summer in SA, temperatures can exceed 40°C - the highest temperature in SA of 48°C was recorded in Mpumalanga (near Nelspruit). The coastal areas of KZN sometimes experience relative humidity levels close to 100% (South African Weather Service 2007).
[17]Described in detail later on in the literature review.

(Maughan, Shirreffs & Leiper 2004). The workers gain heat from the environment and from the metabolic heat produced during hard physical labour. Core temperature rises if the heat gained is greater than the heat lost (Maughan *et al* 2004, Sawka & Montain 2000, Epstein & Sohar 1985).

The core temperature for optimal health and performance is 37°C (± 0.5°C). The body actively protects its core temperature in hot environments to prevent the onset of heat exhaustion and heat stroke (Bates, Parker, Ashby & Bentley 2001). Heat exhaustion occurs at core temperatures of ≤40°C. Symptoms include fatigue, headaches, dizziness, nausea, feeling hot or cold, muscle and stomach cramps, headaches, palpitations and/or heat syncope[18] (Casa *et al* 2005, Binkley *et al* 2002). If not reversed in time, heat stroke develops at core temperatures >40°C.[19] Symptoms include confusion, amnesia, ataxia, visual disturbances, disorientation, impaired concentration, headaches, dizziness, delirium, convulsions, stupor and/or coma followed by death (Casa *et al* 2005, Binkley *et al* 2002, Bates *et al* 2001). The incidence of heat illness amongst forestry workers is unknown as the industry does not require a record to be kept of these symptoms.[20]

The greatest threat to core temperature is physical activity in a hot environment – the risk of heat illness increases with duration of the activity, increasing ambient air temperatures[21] as well as high humidity levels (Maughan *et al* 2004, Binkley *et al* 2002).

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[18] Heat syncope or orthostatic dizziness is caused by peripheral vasodilation, lowered cardiac output, cerebral ischemia, reduced venous return and dehydration – persons at risk include those who are not acclimatized, those on diuretics and those with heart disease (Binkley *et al* 2002).

[19] Heat stroke can occur without the person initially suffering from heat illness.

[20] Records are kept of major injuries and deaths.

[21] Measured as the dry bulb (DB) temperature.

The ambient air temperature determines whether heat is removed from or transferred to the body via the process of convection (Bates *et al* 2001). When the air temperature is greater than the body temperature the worker will receive heat from the environment (Binkley *et al* 2002). In SA forests ambient air temperatures rise high enough (>35°C) to transfer heat to, rather than away from, the worker (Maughan *et al* 2004, South African Weather Service 2007).

Another route of heat gain is radiant heat[22] from the heat radiating down from the sun and up from the ground (Bates *et al* 2001). Most forestry workers are exposed to direct radiation from the sun for the duration of their shifts which last between 4 and 8 hours (Van Daele 2005, Bates *et al* 2001). If the workers take a regulation break[23] they often rest in the sun if the surrounding forest has been felled (Kamhoot 2005) (Figure 3). According to the National Athletic Trainers' Association (2002) rest breaks should be taken in the shade to reduce the risk of heat illness and should be scheduled often to allow the person to cool down during heavy physical activity (Binkley *et al* 2002).

[22] Measured as the globe temperature (GT) and is the absolute temperature difference between the forestry workers and their surroundings.

[23] These are not enforced by all contractors – the ½ hour break is scheduled once per day in the early to mid morning.

Figure 3: Debarker lying in the sun during the regulation rest break

High humidity levels[24] prevent sweat from evaporating from the body. Sweat is one of the major cooling mechanisms when environmental conditions are hot (Sawka *et al* 2007, Wildman & Miller 2004 p232-233, Epstein & Sohar 1985) and when sweat drips off the body instead of evaporating, heat loss is severely compromised (Bates *et al* 2001). According to Maughan *et al* (2004) high environmental temperatures in combination with high humidity levels inevitably result in a rise in core temperature, compromising work capacity and endangering health.

The workers' core temperature is also challenged by what they wear. Ironically the impermeable regulation protective clothing meant to protect the work force, increases their risk of heat illness by significantly impairing the loss of heat from sweating by reducing the body surface area exposed to the environment and wind (Bates *et al* 2001). Debarkers, rough liners and stackers wear rubber gloves, safety helmets, leg protectors and closed safety boots (Van Daele 2005). In

[24] Measured as the wet bulb temperature (WB) or relative humidity (rh).

addition the stackers wear rubber aprons and the chainsaw operators and chainsaw operator assistants wear face masks and chainsaw resistant leggings (Van Daele 2005) (Figure 4). It was suggested by Van Daele (2005) that the chainsaw operators and chainsaw operator assistants were possibly at a higher risk of dehydration and therefore heat illness because the ease of drinking may be hampered by the regulation face masks. In addition, they also get petrol on their hands which in turn can accidentally contaminate the mouth of their water container, altering the taste (Ashby & Parker 2003).

Figure 4: A South African debarker stripping bark at an ambient air temperature of 30°C and a relative humidity of 71%. She is wearing a double layer of clothing, a safety helmet on top of her own head gear, rubber gloves, protective pads and safety boots – the insert is of a chainsaw operator wearing the regulation face mask but not wearing the chainsaw resistant leggings.

Apart from the regulation gear the workers frequently wear 2 layers of their own clothing and long sleeved garments in summer as protection against being scratched (MID 2006) (Figure 4). The evaporation of sweat is further impeded by wearing layers of clothing (Maughan *et al* 2004, Epstein & Solgar 1985). Ideally those exercising in hot and/or humid conditions should wear loose fitting, lightly coloured clothing, preferably the mesh type which has been designed to promote more effective cooling (Wildman & Miller 2004 p243, Binkley *et al* 2002). This type of clothing however would offer no protection from being scratched by tree branches.

Apart from the environmental conditions and what the workers wear, other factors contribute to the development of heat illness. Some people appear to be predisposed to heat illness (Armstrong *et al* 2007). The higher the pace of the exercise, the greater the metabolic heat generated. Therefore stackers who work at a higher intensity than debarkers and chainsaw operators are at a higher risk. Those with a higher body mass index (BMI) are more at risk if they are obese as fat acts as an insulator, or if they have a high muscle mass as muscle generates heat from exercise. An adult older than 40 years seems to be less able to regulate their core temperature in the heat (Sawka *et al* 2007, Casa *et al* 2005).

Other risk factors include alcohol consumption (therefore heat illness is more likely after pay day), some medications such as diuretics, sleep deprivation (Armstrong *et al* 2007) and poor nutrition (Armstrong *et al* 2007). In addition, a series of very hot days and hot nights with inadequate daily hydration increases the risk of heat illness (Armstrong *et al* 2007).

The forestry workers' core temperature therefore is continually being challenged by the heavy physical activity they perform in many layers of clothing in hot and often humid environments. There are however well developed mechanisms that the body uses to regulate core temperature in these situations.

2.4 THERMOREGULATION

The 3 major factors important for core temperature thermoregulation are aerobic fitness, acclimatization to the environment and, very importantly, the state of hydration (Armstrong *et al* 2007, Coyle 2004).

2.4.1 Aerobic Fitness

Heat stress is a greater risk if the $V0_{2\ max}$ is ≤ 40 ml/kg/min (Armstrong *et al* 2007). Scott *et al* (2004) measured the maximal uptake of oxygen ($V0_{2\ max}$) as an estimate of aerobic fitness in SA forestry workers. The $V0_{2\ max}$ for chainsaw operators and stackers was 54.4 ml/kg/minute and 56.7 ml/kg/minute respectively. As the range for sedentary healthy people is 40 to 45 ml/kg/minute and the range for athletes is 50 to 70 ml/kg/minute, they concluded that these workers were aerobically fit. There are no other studies on the fitness levels of SA forestry workers.

2.4.2 Acclimatization

Acclimatization to heat results in a higher sweating rate which increases the need for fluid. It also results in increased sodium reabsorption from sweat, reducing sodium loss by up to 50% (Maughan *et al* 2004). Acclimatization takes approximately 10 to 14 days (Armstrong *et al* 2007).

2.4.3 Hydration

The advantages that being physically fit and acclimatized offer core temperature regulation are cancelled out by dehydration. Dehydration in turn increases the workers, susceptibility to heat illness (Casa *et al* 2005 Consensus Document).

Dehydration occurs when the fluid lost from sweating is not replaced in equal amounts (Sawka & Montain 2000, Paterson 1997). This fluid deficit reduces plasma volume. This in turn reduces peripheral blood flow to the skin which reduces heat loss via the evaporation of sweat and conduction, causing a rise in core temperature (Coyle 2004, Ryan, Lambert, Shi, Chang, Summers & Gisolfi 1998). Hyperthermia therefore is a highly probable consequence of dehydration when exercising at moderate intensity even in temperate and cold environments (González-Alonso *et al* 1998 cited by Coyle 2004).

According to Spioch & Nowara (1980) the importance of maintaining daily fluid balance in heat exposed industrial environments is not always recognized as these labourers work in heat challenging environments day after day, facing the risk of cumulative dehydration (Armstrong *et al* 2007).

2.5 PREVALENCE OF DEHYDRATION IN FORESTRY WORKERS

There are a few international studies which have investigated the occurrence of dehydration in forestry workers. In SA, however, there have been no studies where the primary aim was to determine the prevalence of dehydration in forestry workers. The only information which suggested that SA forestry workers might be experiencing significant dehydration was published by Scott *et al* (2004). Scott *et al* (2004) were commissioned by the forestry industry to conduct an ergonomics investigation into the task demands of forestry workers in the humid coastal forests of Kwambonambi. As part of this investigation they inadvertently found that the chainsaw operators (n=39) and stackers (n=46) were dehydrated 2.9% and 3.7%[25] respectively (Table 1). This study highlighted to the SA forestry industry that dehydration was a potential hazard that merited further investigation. The industry then commissioned this current study to explore the prevalence more comprehensively in an attempt to determine the prevalence, severity and implications.

[25] When using percent loss of body weight as the measure of dehydration it is acceptable to refer to the loss as a dehydration of "x" percent. For example a worker who lost 3% of their body weight can be referred to as having dehydrated 3%.

Table 1: Summary of forestry studies reporting dehydration

Study	**Number**	**Gender**	**Job category**	**Mean % loss of body weight end shift**
Scott *et al* (2004)	39	Males	Chainsaw operators	2.9%
	46	Males	Stackers	3.7%
Wigaeus *et al* (1985)	Unknown	Males, females	Silviculture	3.2%
Trites *et al* (1993)	13	Males	Silviculture	3.1%
	3	Females	Silviculture	3.1%
Paterson (1997)	8	Males	Fellers	1.2%[26]
				% with USG readings >1.020g/ml end shift
Parker *et al* (2001)	30	Males	Loggers	63%
Parker *et al* (2002)	24	Males	Loggers	"majority of the loggers"[27]

Similar findings were reported by studies done in other countries. In Vietnam, forestry workers (mainly women) who were involved in either harvesting or silviculture[28] lost 3.2% of their body weight[29] per working day as they neither ate nor drank during their shifts (Wästerlund, Chaseling & Burström 2004 citing Wigaeus Hjelm & Frisk 1985) (Table 1).[30] Trites, Robinson & Banister (1993) reported a loss of body weight of 3.1% across the day in male (n=13) and female (n=3) workers involved in silviculture in British Columbia, Canada (Table 1). In both of these studies the findings regarding dehydration were incidental to the primary purposes of the investigation.

[26]The mean % loss of body weight at the end of the shift is less because these workers ate and drank during the shift unlike the workers in the other studies.
[27]The actual number or percent was not mentioned in the report.
[28]Silviculture is the planting of forests as opposed to harvesting the planted forests.
[29]A percent loss of body weight as little as 1 to 2% has been shown to impact negatively on both physical and mental performance (Maughan *et al* 2004, Gopinathan *et al* 1988) and according to the American College of Sports Medicine (ACSM) Roundtable on Hydration and Physical Activity Consensus Statements, a body weight loss of greater than 2% can negatively affect exercise performance (Casa *et al* 2005).
[30]Unfortunately this reference (Physical strain on Vietnamese forest workers) was unattainable as it was published in the Undersokningsrapport 1985: 5. Arbetarskyddsstyr-elsen, Forskningsavdelningen, Solna which was not available in SA.

The only studies whose primary aim was to investigate the prevalence of dehydration in forestry workers were conducted in New Zealand (NZ). Paterson (1997) studied 8 fellers[31] (mean age 27.8 years) who were working in standard protective clothing[32] at ambient air temperatures of 10.3°C to 21.9°C. These temperatures were similar to those expected in winter in SA. Paterson (1997) found that they voluntarily consumed an average of 2.7 litres (SD±1.2) of fluid per 7 hour shift but still dehydrated 1.2% (Table 1). No mention was made of the type of fluid consumed.

Parker, Ashby & Bates (2001) conducted a preliminary observational study in NZ to investigate the occurrence of dehydration (as measured by USG) in 30 loggers[33] (mean age 34 years) wearing standard protective clothing who were working in moderate weather conditions. Although this NZ study was done in autumn the mean ambient air temperature was 19°C which in many areas of SA is more representative of winter. These conditions posed a moderate threat for heat illness as calculated by the Wet Bulb Globe Temperature (WBGT)[34] (Binkley *et al* 2002). Urine specific gravity was measured once at the end of a 5 hour shift. Parker *et al* (2001) concluded that 37% (n=11) were normally hydrated (USG≤1.020 g/ml), 60% (n=18) were dehydrated (USG>1.020 g/ml to ≤ 1.030 g/ml) and 3% (n=1) were seriously dehydrated (USG>1.030 g/ml) (Figure 5, Table 1).[35] Their state of hydration on arrival at work was not

[31] The nearest equivalent to fellers is chainsaw operators.

[32] Their protective clothing is similar to that worn locally and includes a helmet, ear muffs, high visibility shirt or vest, chainsaw resistant leggings and reinforced steel tipped rubber boots.

[33] Loggers referred to anyone involved in harvesting (Parker 2007).

[34] The Wet Bulb Globe Temperature (WBGT) is an index calculated as $WBGT = 0.7_{\text{natural wet bulb temp}} + 0.3_{\text{globe temperature}}$ which is commonly used as an indication of the environmental conditions (Spioch & Nowara 1980).

[35] There is some confusion in the literature about the interpretation of the USG results. This study has used the guidelines of the ACSM which states that a USG≤1.020 g/ml indicates a euhydrated state and USG>1.020 indicates a dehydrated state (Sawka *et al* 2007, Sakwa's comments in the Panel Discussion printed in the paper by Armstrong 2005). The category of serious dehydration (USG>0.030 g/ml) was taken from Casa *et al* (2000) to try and determine to some degree the extent of dehydration.

monitored. Most loggers drank 1 litre over a 5 hour shift. The fluids included water and/or tea, coffee and cola. This was substantially less than that found in the study by Paterson (1997).

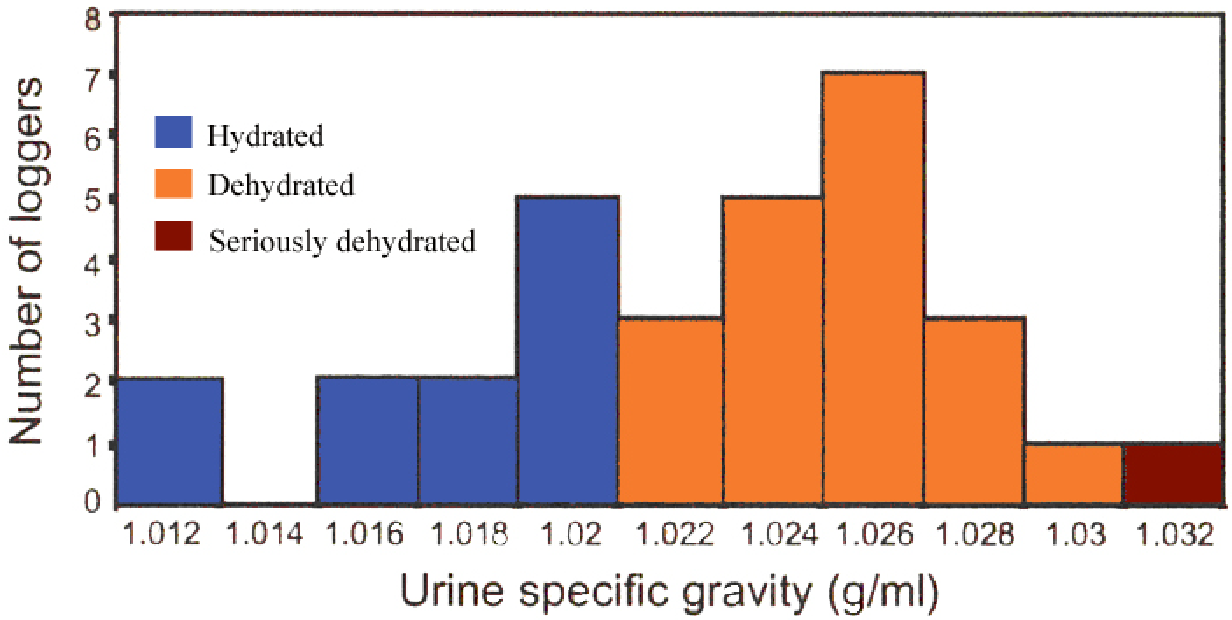

Figure 5: The end shift urine specific gravity measurement of 30 loggers (after Parker *et al* 2001)

Parker, Ashby & Bates (2002) conducted a follow up study in NZ to determine the effect of seasonal changes on dehydration in 24 loggers (mean age 35 years) wearing standard protective clothing. USG was measured pre shift, pre break and end shift over a period of 4 consecutive days in both winter (mean ambient air temperature 10.9°C) and summer (mean ambient air temperature 18.5°C). According to the WBGT, the risk for heat stress in both seasons was low (Binkley *et al* 2002 Position Statement). Parker *et al* (2002) reported that the mean USG (1.025 g/ml) was not significantly different between the seasons and that most were dehydrated, some seriously so (Figure 6). A number arrived at work dehydrated (USG 1.025 g/ml) – the article was not clear as to what proportion this was. They found that the mean hydration had improved by the break (USG 1.022 g/ml) and regressed again by the end of shift (USG 1.025 g/ml) (Table 1). Parker *et al* (2002) attributed the similar prevalence of dehydration between seasons to the fact that the loggers drank less in winter (1130 ml/shift) than in summer (1640 ml) as they perceived that dehydration was only a threat in the hotter weather. The loggers also wore more clothing to keep warm in winter, restricting the loss of heat (Ashby & Parker 2003).

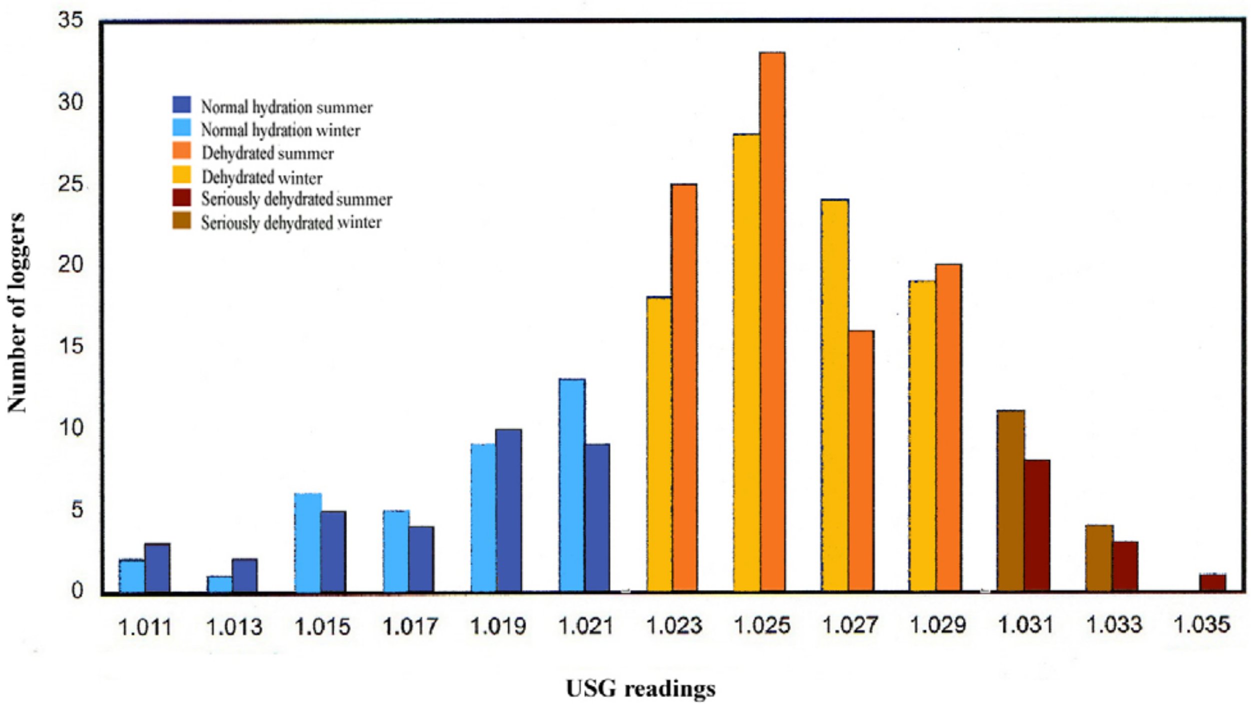

Figure 6: The effects of season on dehydration in New Zealand loggers (after Parker *et al* 2002)

The prevalence of dehydration in forestry workers has been confirmed by a number of studies in different countries. Dehydration, with or without hyperthermia, has serious health implications for these workers.

2.6 CONSEQUENCES OF DEHYDRATION AND/OR HYPERTHERMIA

The consequences of dehydration include an increase in cardiovascular strain, a decrease in work capacity and maximal aerobic power and a decrease in mental performance (Coyle 2004, Ainslie *et al* 2002, Craig & Cummings 1966).

No research could be found which investigated the consequences of dehydration specifically in forestry workers, and as those forestry workers involved in harvesting are endurance athletes in the sense that they perform intense exercise for extended periods of time, supporting literature was taken from studies in sports medicine.

2.6.1 Increased cardiovascular strain

A decrease in plasma volume from dehydration and a subsequent increase in blood viscosity plus an increased peripheral blood flow decreases venous return. This decreases stroke volume, thereby significantly reducing cardiac output (Casa *et al* 2005, Sawka & Montain 2000). This intensifies cardiovascular strain as the heart rate needs to increase to compensate for the reduced output, otherwise the distribution of blood to the muscles will be decreased (Wästerlund *et al* 2004, Coyle 2004, Wildman & Miller 2004 p245). As cardiac output decreases, blood flow to the muscles diminishes compromising performance, decreasing aerobic power and preventing heat from being transported away from the muscles (Wildman & Miller 2004 p245, Paterson 1997).

González-Alonso, Mora-Rodríguez, Below & Coyle (1997) investigated the separate and combined effects of a raised core temperature and a fluid deficit on cardiac output. In a randomized crossover trial, seven endurance trained acclimatized competitive cyclists (mean age 25 years, gender not stated) cycled at high intensity (71% $V0_{2max}$) for 30 minutes in the heat (ambient air temperature 35°C, rh 53%) with a raised core temperature (39.3°C) while either normally hydrated or 4% dehydrated. Dehydration reaching this magnitude was reported by Scott *et al* (2004) in SA stackers working in the Kwambonambi forests in KZN. The combination of dehydration and hyperthermia approximately doubled the effect on stroke volume and heart rate causing a significant decrease in cardiac output and blood pressure (Table 2).

Table 2: Effect of either dehydration or hyperthermia and a combination of dehydration and hyperthermia on stroke volume, heart rate and cardiac output of competitive cyclists (after González-Alonso *et al* 1997)

		Stroke volume	**Heart rate**	**Cardiac Output**
Effect of either dehydration or hyperthermia	**% change**	7 to 8% decrease	5% increase	No change
	Actual change	11 ml/beat (SD±3)	7 – 9 beats/min (SD±1-2)	No change
Effect of dehydration in combination with hyperthermia	**% change**	20% decrease	9% increase	13% decrease
	Actual change	26 ml/beat (SD±3)	14 beats/min (SD±1)	2.8 l/min (SD±0.3)

Cardiovascular strain results when the dehydration is less severe. Coyle & Montain (1992) studied athletes dehydrated by 1% to 4%, who exercised in the heat for 120 minutes and concluded that any loss of body weight resulted in a significantly higher heart rate (cited by Coyle 2004). Other studies have reported that the heart rate increases by 5 to 8 beats per minute for every 1% loss of body weight (Coyle 2004 citing Brown 1947; citing Coyle & Montain 1992, Adolf 1947).

Any degree of dehydration, especially when in combination with hyperthermia, imposes a level of cardiovascular strain. An increase in cardiovascular drift[36] as experienced by the cyclists in the study by González-Alonso *et al* (1997) results in an increased perception of effort for the same work load. In other words, as the cardiovascular strain increases the forestry workers will feel more fatigued at the same work pace or else they will reduce their work pace to compensate, thus decreasing production (Sawka *et al* 2007, Armstrong *et al* 2007, Hawley & Burke 1998 p283-285).

2.6.2 Effect on work capacity and maximal aerobic power

The effects of dehydration of 1% to 4% on work capacity has been reviewed as this was the range of dehydration demonstrated by the existing forestry studies. Craig & Cummings (1966) demonstrated that a loss of as little as 1% to 2% while walking on an inclined treadmill (n=9 males) decreased work capacity by 6% to 7% (Table 3).

[36] The relationship between the reduced cardiac output and increased heart rate is described as cardiovascular drift.

Table 3: Summary of studies demonstrating the consequences of 1% to 4% dehydration on physical performance

Study	**Number of subjects (n)**	**Dehydration (% change of body weight)**	**Consequence**
Craig & Cummings (1966)	9	1% to 2%	Decreases work capacity by 6% to 7%
Craig & Cummings (1966)	9	2% to 4% in hot environment	Decrease in maximal aerobic power of 10% to 27% and decrease in work capacity of 22% to 48%
ACSM (2005) Position Statement (Casa *et al* 2005)	-	2%	Compromises work performance
ASCM (2007) Position Statement (Sawka *et al* 2007)	-	2% in a hot environment	Decreases aerobic exercise ability
McLellan *et al* (1999)	10	2.3%	Decreased length of time subjects could walk for ie performance
Adolph (1947)	4	2.5% plus heat	Decrease work output by 50%.

In a hot environment the subjects (n=9 males) maximal aerobic power decreased 10% to 27% and work capacity decreased 22% to 48% with body weight losses of between 2% and 4% (Craig & Cummings 1966). According to the ACSM a loss of as little as 2% compromises occupational work performance (Casa *et al* 2005) and heat superimposed on >2% loss of body weight decreases aerobic exercise ability (Sawka *et al* 2007). McLellan, Cheung, Latzka, Sawka, Pandolf, Millard & Withey (1999) studied the effect of walking on a treadmill in impermeable nuclear, biological and chemical protective clothing in conditions similar to those experienced in the KZN forests (35°C, rh 50%) while their 10 male subjects were either euhydrated or dehydrated by 2.3%. They found that dehydration significantly decreased the length of time that the subjects could walk. A 2.5% dehydration in combination with an ambient temperature of 43°C resulted in a decrease of 50% of work output in 4 males (Adolph 1947). Exercising in hot environments, in combination with dehydration, results in a reduction in the ability to exercise at capacity (Galloway 1999).

These studies clearly demonstrated that the 2.9% to 3.7% dehydration experienced by SA forestry workers would have resulted in a decrease in work capacity, a decrease in maximal aerobic power and aerobic exercise ability, as well as a decrease in the length of time that they could have continued to work (Scott *et al* 2004). In turn, this would have resulted in a compromised work performance and a decreased work output which, in turn, could decrease productivity.

2.6.3 Effect on mental performance

The actual degree of heat stress that negatively affects mental performance seems to depend on the heat stress in combination with the length of exposure as well as the individual's response and acclimatization (Piwonka & Robinson 1967, Pepler 1958).

In a controlled cross over trial, Sharma *et al* (1986) investigated the effect of 1%, 2%, 3% or 4% dehydration on performance of psychological tests[37] performed by 8 healthy males (range 21 to 24 years). Sharma *et al* (1986) concluded that dehydration appeared to have no effect on routine

[37] These tests included a substitution test to test routine symbol classification work, a concentration test to measure running memory and a psychomotor test to test perceptual motor coordination.

mental work but caused a significant decrease in concentration and psychomotor function at 2% and 3% dehydration ($p<0.001$). Heat stress superimposed did not cause a further deterioration in performance on any of the tests except concentration which was even poorer in a hot humid environment (Table 4).

Table 4: Summary of studies showing the consequences of dehydration on mental performance

Study	**Number (n) of subjects**	**Dehydration**	**Consequence**
Sharma *et al* (1986)	8	2% and 3%	No effect on routine mental work. Caused a significant decrease in concentration and psychomotor function
Gopinathan *et al* (1988)	11	2%	Decreased short term memory, arithmetic ability and visual motor tracking
Wästerlund *et al* (2004)	4	?<1%	Found no effect
Ainslie *et al* (2002)	17	Urine osmolarity 1000 mosmol/kg H_20.	As dehydration increased cognitive processing time increased
ACSM (Sawka *et al* 2007)	-	>2%	Might decrease both mental and cognitive ability particularly attention and alertness

In a follow up study to Sharma *et al* (1986), Gopinathan *et al* (1988) studied 11 healthy soldiers (range 20 - 25 years) to investigate the effect of dehydration without heat exposure on short term memory, arithmetic ability and visual motor tracking. Gopinathan *et al* (1988) concluded that performance on all tests[38] decreased significantly as the level of dehydration increased and that at 2% the deterioration was highly significant (p<0.001) (Table 4).

[38]These tests included a word recognition test to measure short term memory, a serial addition test to measure arithmetic ability and a trail marking test to measure visual motor tracking.

Wästerlund *et al* (2004) conducted a crossover randomised trial on 4 healthy male forestry workers in North East Zimbabwe in October 1996 to determine whether the level of hydration affected the way in which tasks were problem solved. The workers were manually harvesting trees in moderate weather (ambient air temperature 22.5°C) where the risk of heat illness was low (Binkley *et al* 2005). No consistent effect of dehydration on problem solving was found (Table 4). However, on closer examination of the results, it was noticed that the dehydrated group lost 700 g which was a dehydration of only 1% to 1.2% assuming that the average worker weighed between 60 and 70 kg. The sample of 4 was not homogenous in that it included a 40 year old who was likely to react to heat stress differently from the others whose mean age was 24 years. The study size and percent dehydration was too small to draw conclusions or to measure small variations in behaviour.

Ainslie, Campbell, Frayn, Humpreys, MacLaren, Reilly & Westerterp (2002) noted in their study on 17 walkers that as dehydration increased over 10 days of strenuous hill walking, cognitive processing time[39] also significantly increased (Table 4).

The ACSM Position Paper on fluid replacement states that a dehydration of >2% might decrease both mental and cognitive ability, particularly attention and alertness (Sawka *et al* 2007, Casa *et al* 2005) (Table 4).

The degree of dehydration reported in the SA forestry workers by Scott *et al* (2004) would have resulted in a significant decrease in concentration, attention, alertness, visual motor tracking ability as well as an increase in cognitive processing time. Harvesting is a high risk occupation

[39]Cognitive processing time as measured by choice reaction time assessed on a laptop computer.

and the chainsaw operators and chainsaw operator assistants make critical decisions daily regarding the felling of trees. These decisions, if incorrect, would cause either the death of or severe injury to, themselves and those in the vicinity. These workers' ability to accurately and rapidly assess situations and arrive at safe decisions would be hindered by the degree of dehydration that was being experienced (Slappendel, Laird, Kawachi, Marshall & Cryer 1993). In turn this would increase the potential for injury and result in a loss of productivity. Dehydration therefore has the potential to harm both the work force and the industry. As the findings of the study by Scott *et al* (2004) were incidental, a study whose only purpose is to determine the prevalence, severity and causes of dehydration in local forestry workers is essential to establish the magnitude of the problem being faced by forestry.

2.7 POTENTIAL CAUSES OF DEHYDRATION FOR SOUTH AFRICAN FORESTRY WORKERS

2.7.1 Availability of fluid

The most compelling challenge for SA forestry workers is likely to be the availability of fluid. The forests are situated in areas where there is no piped water or safe natural water from rivers and there are no shops from which drinks can be purchased during the shift (Van Daele 2005).

The harvesting sites can be situated a few hours from the nearest water supply. The forestry contractors have to transport fluid on site daily, often over a terrain requiring vehicles with 4x4 capabilities (Kamhoot 2005).

There are no guidelines specific to forestry for contractors to follow which stipulate the amount and types of fluid that needs to be provided. There is also no system in place to ensure that fluid is being provided daily (Van Daele 2005).

Even when sufficient fluid is transported on to the site, it needs to be placed in locations accessible to the forestry workers during their shifts as they are spread out over the site, harvesting in different areas. The fluid needs to be placed in close proximity to the workers and not in a central location (Kamhoot 2005).

Even when the fluid is placed where the workers begin harvesting, as the shift progresses they move deeper into the forest and further away from the fluid supply. They therefore need to carry fluid with them in addition to chainsaws, axes and petrol cans. The availability of containers in which drinking fluid can be carried with them into the forest, is essential to ensure that they have fluid to drink during the shift.

2.7.2 Palatability of the fluid

For fluids to be ingested they must be both palatable and culturally acceptable. Therefore preventing dehydration is more complex than simply supplying adequate fluid at sites close to where the workers are harvesting. The type and characteristics of the fluids are critical (Burke 1998 p97-98).

Flavoured drinks (that are not too sweet) which contain small amounts of sodium and are kept at temperatures of 15 to 21°C are far more likely to be consumed and absorbed than plain water offered at the external ambient air temperature (Sawka *et al* 2007, Wildman & Miller 2004 p248 p336, Burke 1998 p97-98, Spioch & Nowara 1980). In addition, the intake of large volumes of plain water can result in gastrointestinal discomfort and dilutional hyponatremia (Sawka *et al* 2007, Mudambo *et al* 1997).[40] Variety is also important as the repeated exposure to the same fluid over a number of hours leads to taste fatigue and a refusal to drink and consequent dehydration.

2.7.3 Voluntary dehydration

Even when sufficient fluid is available that is palatable and culturally acceptable, people often drink insufficient amounts only, replacing approximately 50% to 66% of the fluid that has been lost, a phenomenon known as voluntary dehydration (Casa *et al* 2005, Brake & Bates 2003, Sawka & Montain 2000).

Although the reasons for voluntary dehydration are not clear, an important cause appears to be the reliance on thirst as a guideline for fluid replacement during exercise. Thirst is not useful as a dehydration of 1% to 2% already exists before desire to drink occurs (Wildman & Miller 2004 p245, Armstrong, Hubbard, Szlyk, Matthew & Sils 1985, Sawka, Francesconi, Young & Pandolf 1984). Thirst does not always promote an adequate fluid intake to replace that lost from sweating

[40] The subject of hyponatremia is discussed later on in this review.

(Armstrong, Costill & Fink 1985). Voluntary dehydration was confirmed in NZ forestry workers by Ashby & Parker (2003) who found that even when sufficient fluid was continuously available in the form of camelpacks, dehydration was not prevented as the workers still drank only when thirsty. Workers need to be trained to follow a regular drinking schedule (Sawka & Montain 2000) especially in the initial stages of exercise in the heat (Sawka & Neufer 1993).

2.7.4 Cultural beliefs

A final challenge to hydration in a situation unique to SA, is that forestry workers in specific areas have been known to refuse fluids supplied on site as they claimed that the contractors had poisoned the fluid (Van Daele 2005). This probably stems from the history of conflict in the country as claims have been made that the forests are planted on land that was taken away from the local people (DWAF 2005). Dissatisfaction has been expressed by the forestry workers concerning the unequal power relations between the forestry industry, the contractors and the work force and DWAF (2005) stated that the building of a "mutual trust …is a fragile process which takes considerable time."

2.8 FLUID RECOMMENDATIONS

To ensure that sufficient fluid is on site to prevent dehydration, guidelines need to be compiled for both the workers and the contractors as fluid needs to be taken prior to, during and after the shift to ensure good hydration (Sawka *et al* 2007, Casa *et al* 2000). The following sections detail fluid recommendations prior to, during and following shifts. As there are no specific recommendations available for SA, information from the international literature has been provided.

2.8.1 Fluid requirements prior to the shift

The ability to sustain heavy physical activity for long periods is decreased by the presence of dehydration before the shift. This is likely if the worker has been harvesting daily in a hot environment (Maughan *et al* 2004 citing Nielsen, Kubica, Bonnesen, Rasmussen, Stoklosa & Wilk 1980, Armstrong *et al* 1985). To promote adequate hydration before the shift, the workers should be encouraged to drink either 500 to 600 ml or 5 to 7 ml per kg of fluid 2 to 3 hours before the shift starts (Sawka *et al* 2007, Wildman & Miller 2004 p248). Drinks containing small amounts of sodium, or else fluids taken with small amounts of salty food, will encourage the absorption of the fluid from the gastrointestinal tract, further promoting good hydration (Sawka *et al* 2007). Ten to 20 minutes before the shift starts, the worker should be encouraged to drink a further 200 to 300 ml of fluid (Casa *et al* 2000, Burke 1998 p99).

2.8.2 Fluid requirements during the shift

2.8.2.1 *Timing of fluids*

The first drink needs to be taken within 20 minutes of beginning harvesting since measures need to be taken early to prevent dehydration (Burke 1998 p107, Sawka & Neufer 1993), as dehydration decreases blood flow to the gastrointestinal tract, further reducing the absorption of fluid resulting in progressive dehydration (Bates *et al* 2001). Fluid should be consumed every 10 to 20 minutes to encourage rapid gastric emptying (Burke 1998 p106). When gastric emptying slows, fluid is retained in the stomach which leads to discomfort and a decrease in fluid intake.

2.8.2.2 *Amount of fluid*

The amount that needs to be consumed per hour is less well established as optimal fluid intakes are far from being defined (Ritz & Berrut 2005). The volume required depends on genetics, the type, duration and intensity of the labour, the environment, the workers sweat rate, what they are wearing and their body weight and size (Sawka *et al* 2007, Casa *et al* 2005, Coyle 2004). This implies that at the same time on the same day and at the same forestry site, individual needs will differ. For example, a short, lean woman who is working less intensely in the shade debarking trees will require less fluid than the tall, normal weight stacker who is wearing 2 layers of clothing while working at high intensity in the direct sun.

Ideally, the individual fluid requirements for that particular task in that particular environment should be established by weighing the workers before and after the shift and then using the loss of body weight to calculate their individual needs (Sawka *et al* 2007). As regular monitoring of the forestry workers' body weights is not possible, the use of generalized rather than individualized fluid guidelines is necessary. Average sweat rates could be used to compile these guidelines but the data is limited and there are large individual variations in sweat lost. Paterson, (1997) in his study on 8 chainsaw operators in summer in NZ, found an average sweat rate of 3.5 litres per shift which was a loss of 500 ml per hour. He was careful to point out however the large individual variation that existed from 0.5 to 6 litres per shift. A review of the literature determined that the mean sweat rates of athletes varied from 400 to 1800 ml per hour (Sawka *et al* 2007). These wide variations limit their usefulness in the compilation of guidelines for forestry workers.

There are very few guidelines for fluid intake for those working in hot industrial environments. In SA, the Department of Minerals and Energy (DME) recommended the intake of 500 ml of water every 20 to 30 minutes (1 to 1½ litres per hour) for gold miners working in very hot areas underground (DME 2002). The International Labour Organisation (ILO) recommended 5 litres of water per day for people working in hot industrial environments (cited by Wästerlund *et al* 2004). Wästerlund *et al* (2004) tested these guidelines (1200 ml/hour) in a crossover randomized trial on four forestry workers harvesting manually in Zimbabwe. A weight gain of 700 g resulted (approximately 1% overhydration) indicating that these recommendations were too high. Twerenbold, Knechtle, Kakebeeke, Eser, Müller, von Arx & Knecht (2003) demonstrated that female athletes who drank 1 litre of water per hour during a 4 hour run in a hot environment became either mildly hyponatremic (92%) or severely hyponatremic (17%). The Centre for Human Factors and Ergonomics (COHFE) initially promoted a water intake of over 1 litre per hour regardless of environmental conditions for the NZ loggers. The net result was that the forestry workers did not feel well and experienced gastrointestinal discomfort (Ashby & Parker 2003). Apart from general gastrointestinal distress, overhydration, especially with low sodium fluids such as water, can result in dilutional hyponatremia.

The dangers of overhydration and dilutional hyponatremia[41] were highlighted by the United States (US) military (Montain, Latzka & Sawka 1999). When the army's 1998 fluid replacement guidelines for work in hot weather training (Appendix D) were developed, the basic premise was that if excess fluid was consumed it would be eliminated as urine (Kolka, Latzka, Montain, Corr, O 'Brien & Sawka 2003). No hourly or daily upper limits were imposed and climate only was considered and not the energy expenditure of the soldiers (Kolka *et al* 2003). After their implementation between 1989 and 1997, an average of 16 cases per year (total 142 cases) of hyponatremia/hypervolumemia requiring hospitalization were reported, one of which resulted in death (Gardner 2002, O'Brien 2001, Reynolds 1998). The precipitating factor was the consumption of large amounts of fluid (≥1500ml per hour) without being unaware that this could be detrimental (Gardner 2002, O'Brien 2001). Montain *et al* (1999) devised new guidelines for the US military (Appendix E) using 19 healthy acclimatized soldiers (range 18 to 29 years) who completed 12 heat stress trials in full battle dress uniform, plus cap, plus tennis shoes. The major difference between these guidelines was that the new ones recommended 710 to 946 ml of fluid

[41]Hyponatremia is described as blood sodium levels < 130 mmol/l - if not treated in time, the consequences include brain oedema, mental confusion, general weakness, collapse, seizure, coma and death (Coyle 2004 citing Montain *et al* 1991).

per hour as opposed to the old ones which recommended 473 to 1892 ml per hour. Kolka *et al* (2003) compared the old to the new guidelines in a summer study on 550 male recruits (range 18 to 40 years old). He concluded that the new guidelines prevented dehydration without causing hyponatremia. Since the implementation of these guidelines, the number of cases of hyponatremia has decreased significantly and those that occurred were a result of an intake above that recommended, for example 3750 ml over a few hours rather than up to 750 ml per hour (Gardner 2002).

The ACSM (2007) concluded that although dehydration was far more likely in exercise in hot environments, the consumption of too much fluid resulting in hyponatremia was more dangerous (Sawka *et al* 2007) and caution needs to be taken when recommending generalized guidelines. On this basis they recommended that sufficient fluid be consumed to limit body mass changes (Sawka *et al* 2007). The major risk factor for hyponatremia is drinking an excessive amount of hypotonic fluid such as water (Sawka *et al* 2007). Other risk factors include the excessive loss of sodium in sweat and exercising for longer than 4 hours (Sawka *et al* 2007, Casa *et al* 2005). Some workers are at a greater risk. The smaller, leaner individuals, those over 40 years old, and women seem to be more prone to dilutional hyponatremia (Sawka *et al* 2007, Casa *et al* 2005). The smaller individuals sweat less, the older individual’s reaction to both sodium and fluid loads is protracted and women both sweat less and have a lower total body water content (Greenleaf 1992, Paolone, Wells & Kelly 1978).

The current US military guidelines recommend 710 to 946 ml per hour and the ACSM recommends between 400ml and 800 ml per hour, with women and the smaller, less active individuals consuming the lower amounts (Sawka *et al* 2007, Montain *et al* 1999). Based on these recommendations, 400 to 600 ml would probably be appropriate for women, smaller individuals and those exercising less intensely such as the chainsaw operator assistants and some debarkers. The higher volumes of 600 to 800 ml would possibly be appropriate for the larger men and those exercising at high intensities such as the stackers and chainsaw operators. However, as there is no SA research investigating the fluid needs of local forestry workers and as the US military has clearly demonstrated that the ingestion of too much fluid can be life threatening, a study which measures the fluid requirements of the forestry workers is critical to enable safe recommendations to be compiled.

In addition to following the recommended general fluid guidelines, those exercising can be educated to drink sufficient fluid to produce a light coloured urine – a reading of ≤4 on the urine colour chart (Appendix F) is encouraged in the athletic setting (Casa *et al* 2000, Armstrong, Herrera Soto, Hacker, Casa, Kavouras & Maresh 1998). The Centre for Human Factors and Ergonomics (Appendix G) uses a modified version of this to encourage their loggers to monitor their hydration state (Parker *et al* 2001). Workers can also be encouraged to drink sufficient to urinate at least once during their shift (Parker *et al* 2001). Although urine volume and urine colour are useful tools, they can be misleading if the worker has already dehydrated and then consumed large volumes of water – in an attempt to defend blood sodium levels, large amounts of clear coloured urine will be produced – this could be mistaken for the return of good hydration (Sawka *et al* 2007).

2.8.3 Fluid requirements after the shift

In spite of good hydration strategies, it is possible for the workers to end their shift dehydrated. To ensure that they start the next day well hydrated they need to be encouraged to drink as soon as the shift has ended. The amount to drink is difficult to determine as it will depend on the fluid lost during the shift. Generally 1.5 litres of fluid is recommended for every 1 kg of weight lost (Sawka *et al* 2007). As forestry workers would not be able to measure their weight loss on a daily basis, they should be encouraged to drink 2 to 4 cups of fluid after finishing work (Wildman & Miller 2004 p248). Fluid taken with a meal containing a small amount of salt, or else small amounts of salt added to the fluid, not only promotes thirst but encourages rehydration without stimulating the production of large volumes of urine (Sawka *et al* 2007). The addition of small amounts of sodium to the fluid is not the only factor that needs to be considered when deciding on the composition of the fluid.

2.9 FLUID COMPOSITION

There is a common belief that water is the ideal fluid replacement solution during prolonged work in hot industrial environments (Clapp, Bishop, Smith, Lloyd & Wright 2002). According to Armstrong, Maresh, Gabaree, Hoffman, Kavouras, Kenefick, Castellani & Ahlquist (1997), the military, athletes and industry conventionally use water. The DME (2002) encouraged the SA gold miners to use plain water. Industry is likely to prefer water due to its cheaper cost, availability and convenience (Clapp *et al* 2002). According to Maughan *et al* (2004) “scientific evidence does not support the view that plain water is the best drink during exercise" and for productive work at heavy levels of physical activity water, as well as carbohydrates and electrolytes such as sodium, are required (Sawka *et al* 2007, Maughan *et al* 2004). The following sections present information from the sports medicine literature regarding the recommendations for fluid composition which would be suitable for the SA forestry workers.

2.9.1 Carbohydrate

The physical activity of SA forestry workers involved in motor-manual harvesting has been classified as being heavy to very heavy as they work at an average of 65% to 67% of their predicted maximal heart rate (119 to 122 heart beats per minute) for shifts lasting up to 8 hours (Scott *et al* 2004). Exercise at this intensity and duration requires the consumption of 30g to 60g of carbohydrate (CHO) per hour in a concentration of 5% to 8% to supply an external source of energy to maintain a productive output (Sawka *et al* 2007, Rosenbloom 2006, Coyle 2004, Wildman & Miller 2004 p248).

2.9.2 Sodium

According to Maughan *et al* (2004) the "dangers of ingestion of excessive volumes of fluid without adding salt has long been recognized in various industrial settings". Salt containing fluids (20 to 30 meq sodium per litre)[42] and/or salt and/or salty meals/snacks taken with fluid reduces the risk of hyponatremia in exercise lasting 3 to 4 hours or longer (Sawka *et al* 2007, Casa *et al* 2005, Maughan *et al* 2004, Twerenbold *et al* 2003). Furthermore the addition of small amounts of salt makes the drink more palatable, encouraging thirst, therefore promoting hydration and enhancing the absorption of both fluid and carbohydrate from the small intestine (Maughan *et al* 2004). The DME (2002) guidelines for SA gold miners discourage the use of salt, favouring plain water instead - they do concede that “some form of salt replacement is indicated following prolonged and profuse sweating”.

Considering the potential effect of dehydration on decreasing performance and increasing the risk of injury, the prevention of dehydration is crucial. As sufficient fluid of an appropriate composition is essential to promote hydration and continued heavy physical activity over extended periods of time, an investigation into both the volume and type of fluid, if any, supplied to the forestry workers is crucial.

2.10 METHODS FOR THE MEASUREMENT OF DEHYDRATION

Considering the fragile relationship between the forestry industry and the work force and the workers distrust and suspicion that the contractors want to poison them, the methods used to measure hydration needed to be acceptable and familiar to the workers without compromising accuracy and reliability.

[42]Examples of these would be Energade and Powerade. As salt effects the taste of the solution there is a limit to the amount that can be added.

The tests needed to be portable and quick to administer so that the shift length was interfered with as little as possible. They needed to be simple to perform so that skilled personnel were not required as the workers needed to be able to relate to those doing the testing. Due to the financial constraints the tests needed to be cost effective.

Tests used to measure hydration status include dilution techniques, neutron activation analysis, tracer appearance, bioelectrical impedance, haematological, monitoring changes in body weight and urinary indices (Armstrong *et al* 2005).

2.10.1 Dilution techniques, neutron activation analysis and tracer appearance

Although the dilution techniques, neutron activation analysis and tracer appearance tests' accuracy are considered to be good (gold standard), they are expensive, very time consuming, require sophisticated equipment and trained personnel, are not portable and would not be familiar to, and therefore not acceptable to, rural forestry workers (Sawka *et al* 2007, Armstrong *et al* 2005) (Table 5).

Table 5: Summary table of commonly used techniques for monitoring hydration and the cost, time needed, simplicity, accuracy, portability and acceptability to the forestry workers (adapted from Armstrong 2005, Sawka 2007)

Technique	**Cost**	**Time**	**Simple**	**Accuracy**	**Portable**	**Acceptable**
Isotope dilution, isotope appearance, Neutron activation analysis	High	High	No	Good	No	Poor
Plasma osmolality, haematocrit, haemoglobin	Moderate	Moderate	No	Good	No	Poor
Bioelectrical impedance	Moderate	Low	Yes	Easily confounded	Yes	Poor
Body weight change	Low	Low	Yes	Moderate	Yes	Good
USG	Low	Low	Yes	Moderate	Yes	Good
Urine osmolality	High	Moderate	No	Good	No	Good
Urine volume	Low	High	Yes	Poor	Yes	Poor
Urine colour	Low	Low	Yes	Moderate	Yes	Good

2.10.2 Plasma osmolality, haematocrit, haemoglobin

Although the plasma osmolality, haematocrit and haemoglobin tests' accuracy are considered to be good, they are invasive, moderately expensive and require skilled people to take blood (Table 5). They are not portable as the samples either need immediate analysis (plasma osmolality) or need to be kept on ice while awaiting analysis (Armstrong 2005). The nearest laboratory facility from the respective study sites was approximately 2 hours away. Ice would also not be available in all areas. The drawing of blood would interfere unacceptably with the length of the shift as the blood needs to be taken after the worker has been lying or sitting for 20 minutes (Kavouras 2002). The most important deterring factor however was the strong possibility of the work force refusing to have blood taken. Forestry's CHW's had experienced this in their clinics where workers had refused to give blood samples as they were suspicious that the forestry industry was testing them for HIV/AIDS and that on the basis of these tests they might lose their jobs.[43]

2.10.3 Bioelectrical impedance

Although the method of bioelectrical impedance is reasonably fast, simple and non invasive, the method is easily confounded as the measurements are affected by skin temperature, the consumption of food and drink as well as whether the worker was sitting or lying down when the test is done (Sawka *et al* 2007, Kavouras 2002) (Table 5). The use in this study appeared impractical as the forestry workers would have a high skin temperature from exercising in the sun. The technique was also not familiar to the workers so may have been viewed with suspicion, possibly resulting in a lack of cooperation.

[43]The forestry industry have done a survey of the prevalence of HIV/AIDS amongst the workers harvesting in several areas including Richmond and found that 40% tested positive (Van Daele 2005). These results are not published.

2.10.4 Changes in body weight

The most common assessment used when measuring hydration status in heat and/or exercise stressed individuals is changes in weight pre and post exercise as an estimate of total body water loss (Kavouras 2002). These weight shifts reflect rapid changes in hydration status over short periods of time. Unlike the other methods of assessing hydration, this method offers useful quantitative information as the amount of weight lost can be translated into the amount of fluid lost which in turn can be used to calculate fluid requirements (Wildman & Miller 2004 p243-244), whereas the other indices of hydration simply pinpoint the hydration status. The method is moderately accurate, fast, cost effective, does not require skill and is portable (Kavouras 2002). Furthermore the technique is familiar to the workers as they are used to being weighed at the clinics and therefore cooperation is more likely.

2.10.5 Urinary indices

Several urinary indices are thought to be closely related to hydration status – these include USG, urine osmolality, urine volume and urine colour (Armstrong *et al* 1998).

2.10.5.1 *Urine specific gravity*

Urine specific gravity measures the mass per volume (density) of a sample when compared to water (Armstrong 2005). According to Kavouras (2002), USG closely reflects hydration status and is the most commonly used urinary indicator. It is cost effective, fast, simple, moderately accurate, portable (Armstrong 2005) and acceptable to the forestry workers as urine samples are required as part of their compulsory medical examinations. Readings can be affected by diuretics such as caffeine (Kavouras 2002 citing Grandjean *et al* 2000) and alcohol (Kavouras 2002 citing Shirreffs & Maughan 1997) as well as by diuretic medications. Some vitamins increase the osmolarity, raising the USG reading.

2.10.5.2 *Urine osmolality*

Urine osmolality is another commonly used indicator (Kavouras 2002) and measures the total solute load in the urine (Armstrong 2005). Although accurate, this technique is costly, time consuming, requires skill and is not portable (Armstrong 2005) and is therefore not suitable for use (Table 5).

2.10.5.3 *Urine volume*

Although cost effective, simple, portable and non invasive, the collection of urine across a 24 hour period is time consuming, fraught with non compliance and a less accurate indication of hydration (Armstrong *et al* 1994). The amount of urine produced is not necessarily an indication of hydration state as the body will defend blood sodium levels as ingested fluid increases plasma volume, which in turn dilutes the blood sodium levels (Wildman & Miller 2004 p 245). When the sodium levels begin to drop, the frequency of urination and therefore urine volume increases even in the presence of inadequate hydration.

2.10.5.4 *Urine colour*

Another moderately accurate, cost effective, quick, simple, portable indication of hydration status is urine colour (Table 5). Armstrong *et al* (1994) compared urine colour to USG to determine whether urine colour was an effective method of hydration assessment. They concluded that urine colour was strongly significantly related to USG and concluded that it was an accurate measure. Armstrong *et al* (1998) compiled a urine colour chart which they concluded was a reasonable guide for athletes and industrial workers where close estimates of USG were acceptable but felt that the scale should not be used for research where greater accuracy is required (Armstrong *et al* 1998). COHFE uses a modified urine colour chart to educate the NZ forestry workers (Appendix G). The colour can be influenced by foods such as beetroot, rhubarb, carrot and senna (Pearcy, Mitchell & Smith 1991, Raymond & Yarger 1988), drugs such as rifampicin (Pearcy *et al* 1991, Raymond & Yarger 1988, Sivakumaran 1975) and illness (Raymond & Yarger 1988).

2.10.6 Methodology for the present study

Plasma osmolality, percent change of body weight and USG readings are the most commonly used methods to determine hydration status (Kavouras 2002). For the purposes of this study, since drawing blood was not considered feasible, all haematological markers such as plasma osmolality were not considered for use. Percent change of body weight and USG were chosen as the indicators of dehydration for use in this study.

It was decided to use the percent change of body weight as one of the techniques to assess hydration in this study because:

- studies measuring the effects of dehydration on performance correlated this back to percent loss of body weight and without this knowledge it would not have been possible to estimate the effect of the extent of dehydration on the work forces' ability to be productive.
- this would make this study's results comparable to those of the other forestry studies who used this method (Wästerlund *et al* 2004, Scott *et al* 2004, Trites *et al* 1993, Wigaeus *et al* 1985).
- it allows for the calculation of fluid requirements.

- the technique was likely to be well received by the forestry workers.
- problems were not anticipated with the technique as it was used by Scott *et al* (2004) in the study involving the SA forestry workers in Kwambonambi. These forestry workers did not eat or drink during the shift. Other forestry studies in Vietnam and British Columbia who used percent loss of body weight also reported that the forestry workers did not eat or drink across the shift (Wästerlund *et al* 2004 citing Wigaeus *et al* 1985; citing Trites *et al* 1993).
- body weight was being recorded as part of the nutritional assessment of study subjects. Therefore the equipment would be present on the study site.

It was decided to use USG as the other technique to assess hydration in this study because:

- the other urinary indicators are time consuming and/or not as accurate (Armstrong 2005).
- this would make this study's results comparable with those of the other forestry studies which used this method (Parker *et al* 2002, 2001).
- the forestry workers were familiar with giving urine samples as part of their medical assessments. As a result the technique would be acceptable to them.

2.11 CONCLUSION

The forestry industry has the unique potential to alleviate poverty in the very rural areas of SA and has been identified as a key factor in promoting future economic growth. To play a role in the economic development of SA, however, the industry needs to remain profitable. Identifying factors, therefore, which could impede the productivity of the workers and consequently impact on profitability, is vital.

Until recently the industry was unaware of the potential impact of dehydration on the workers' productivity and safety. The severity of dehydration experienced by the SA forestry workers in Kwambonambi has the potential to result in a significant decrease in both their physical and mental performance, with a subsequent drop in productivity and an increased risk of injury. It is crucial for the industry therefore to explore the prevalence and severity of dehydration experienced by the forestry workers in other areas in SA to determine the extent of the problem.

Although the very nature of the job exposes forestry workers to both heat-related illness and dehydration, a clear understanding of the precipitating factors is essential to enable the industry to take preventative measures to protect the work force. The availability of fluid is a crucial factor and the development of guidelines which specifies the amount of fluid necessary to minimize dehydration is essential.

The fragile relationship between the industry and the work force, as well as the workers suspicion of the industry's motives, precludes the use of the more precise haematological indices to identify dehydration. Although only moderately accurate, the use of USG and the percent change of body weight would be better received by the workers and would be appropriate for use as a screening tool. The forestry industry does not need scientific precision when determining the prevalence and severity of dehydration but rather a realistic estimate of the magnitude of the problem.

To protect both the health of the work force and the continued health of the industry, a study such as this one to determine the prevalence, severity and causes of dehydration in SA forestry workers is urgently required.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 INTRODUCTION

The heavy physical labour, the mandatory protective clothing, as well as the hot and often humid working environments predisposes the forestry workers to hyperthermia and dehydration. If the percent loss of body weight across the shift is greater than 2% or the USG reading is above 1.120 g/ml the associated dehydration significantly reduces the workers' physical and mental performance, hindering their ability to work productively and safely. This in turn impacts the health of the forestry industry which must remain profitable in order to offer employment to the rural poor and to promote economic growth in SA. Before the implementation of strategies to prevent or minimize dehydration, this study is essential to establish the magnitude of the problem amongst the SA forestry workers.

3.2 RESEARCH DESIGN

This study was a cross sectional observational study conducted on SA rural forestry workers in winter in KZN (2005) and in autumn in Mpumalanga (2006).

3.3 SAMPLE SELECTION

3.3.1 Region selection

Within SA, the regions of KZN and Mpumalanga were selected solely on the basis that the majority of the commercial forestry plantations are situated within these areas as illustrated by Figure 7 (South African Forestry 2006). Neither climate nor altitude was taken into consideration.

Figure 7: Location of commercial forests in South Africa (permission for use granted by the South African Forestry Magazine)

3.3.2 District selection

The districts selected within these regions were decided on the basis of convenience.[44] Richmond (KZN) and Nelspruit (Mpumalanga) were included because harvesting was occurring in these areas during the time of each study and there were contractors in these areas who employed sufficient labourers to meet the sample demands and who had the reputation of being both fair and reputable. The forestry industry was concerned that those contractors who did not meet the minimum wage and safety requirements would interfere with the execution of the study by being totally uncooperative and the industry felt that this study would be difficult enough to execute without additional resistance. The districts selected therefore represented the "best case scenario".

3.3.3 Study site selection

As each contractor was harvesting a large area of the forest, the study sites were again selected on the basis of convenience. To be considered for inclusion, the area needed to be within an hour's drive from where the research team was based, needed to be physically accessible without the use of 4x4 vehicles and needed to have enough forestry workers harvesting within the area to meet the sample demands.

[44] The research sites and research samples were selected by Francois Oberholtzer (Institute of Commercial Forestry Research), Pierre van Daele (Mondi) and Andre Brink (South African Pulp & Paper Industry).

3.3.4 Selection of study population

The participants were again selected on the basis of convenience. The Nelson Mandela Medical School statistician (Esterhuizen 2005) could not calculate a required sample size with any precision as there were no previous relevant studies using USG from which this could be extrapolated. As a result it was recommended "as large a sample size as possible". In each area the sample size was determined by the available funding[45] as well as the number and proficiency of the members in the research team.

The forestry industry had stipulated that the sample was to be comprised of chainsaw operators, chainsaw operator assistants, rough liners, debarkers and stackers. To ensure a representative sample of each job category, the method of selection differed slightly between the two areas.

In Richmond the forestry workers harvested in teams[46] comprising both males and females. The number of research assistants (RA's),[47] as well as the quantity of data to be collected, limited the sample number to 2 teams (n=20) per day. The first two teams who arrived at the site each morning who had not been included in the study on the previous days, were chosen (Table 6). Eight of the 10 teams harvesting in the area participated. The total sample number was 79. This consisted of 8 chainsaw operators, 8 chainsaw operator assistants and 63 rough liners.

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[45]The study was funded by ICFR.

[46]The members of each team were consistent. Each team comprised of 1 chainsaw operator, 1 chainsaw operator assistant and 8 rough liners.

[47]The term RA refers to all members of the team other than the supervisors regardless of whether they were dieticians, translators or CHW.

Table 6: Sample selection in Richmond

Job category	**Day 1 (n)**	**Day 2 (n)**	**Day 3 (n)**	**Day 4 (n)**	**Total (n)**
Chainsaw operators	2	2	2	2	**8**
Chainsaw operator assistants	2	2	2	2	**8**
Rough liners	16	15*	16	16	**63**
Total	**20**	**19**	**20**	**20**	**79**

***** There should have been 16 rough liners but one was absent due to illness.

In Nelspruit, rather than working in small teams, the workers harvested in large groups according to their job category. As there were a greater number of RA's in the Nelspruit research team, the sample number was increased from 20 to 25 per day. On Day 1 all the chainsaw operators and chainsaw operator assistants were included as well as 5 debarkers (Table 7). On Day 2 the first 25 female debarkers who arrived at the site, and who had not taken part the previous day, were included. On Day 3 a combination of debarkers and stackers were sampled in the same manner and on Day 4 stackers only were included. Female debarkers were selected to meet the forestry industry's stipulation that a representative sample of females was included. In this area females were only employed as debarkers. A hundred and three workers out of the total work force of 250 were sampled. These consisted of 11 chainsaw operators, 9 chainsaw operator assistants, 41 debarkers and 42 stackers. Although the sample size should have been 100, some workers were distressed at being left out of the study and were included to avoid unrest.

Table 7: Sample selection in Nelspruit

Job category	Day 1 (n)	Day 2 (n)	Day 3 (n)	Day 4 (n)	Total (n)
Chainsaw operators	11				**11**
Chainsaw operator assistants	9				**9**
Debarkers	5	25	11		**41**
Stackers			17	25	**42**
Total	**25**	**25**	**28**	**25**	**103**

There were no exclusion criteria for subject selection on either study site.

As this was an observational study, there was no control group.

3.4 DATA COLLECTION INSTRUMENTS AND TECHNIQUES

A questionnaire was used to collect sociodemographic data, medical data and to establish if symptoms of dehydration were experienced at the end of the shift. Weight and height were determined and used to calculate BMI. The amount and type of fluids provided by the contractors was determined by both observation and by asking the contractors how much they supplied each day. The amount of fluid brought by the forestry workers was weighed. The type of fluid was recorded at the same time. The prevalence and severity of dehydration was measured using the percent loss of body weight and USG readings.

The percent loss of body weight[48] was calculated from body weights measured pre shift, pre break and end shift. The USG readings were measured from urine samples taken pre shift, pre break and end shift. As this was only calculated for those who did not eat or drink across the shift, their fluid requirements were calculated from their weight change across the shift which was converted into volume lost and then divided by the number of hours that they had worked.

3.4.1 Questionnaire

A short close ended questionnaire was used to collect basic background data such as job category, gender, home language, age, clinic attendance, chronic diseases, use of chronic medications, use of vitamin supplements, the number of years that the workers had worked in this particular area, what town they considered to be their home town, whether they stayed in a compound and whether they cooked for themselves (Appendix H).[49]

3.4.2 Weight

Portable Masskot scales were used to determine weight. The range of the scales was a maximum of 150 kg and a minimum of 50 g. The scales were calibrated prior to the study by SA Scales. Because of the uneven surface on the forest floor, each scale was placed on a specially constructed weighing platform which had been leveled using the built in spirit level (Figure 8).

[48]The percent loss of body weight is also referred to as the percent dehydration.

[49]The questionnaire is found on the third page of the data collection booklet. Each worker had one data collection booklet in which all the information collected during the day was recorded.

Figure 8: Weighing platform with built in spirit level on bottom right corner

The forestry workers were weighed in minimal clothing[50] after urination pre shift, pre break and at the end of the shift. They were instructed to step onto the center of the scale, with their weight evenly distributed on both feet, looking directly ahead (Norton & Olds 1996). The RA then recorded their weight in the workers' data collection booklet (Appendix H). The worker was asked to step off the scale. The scale was zeroed. The worker was then reweighed. If the readings differed by 100g, the subjects were weighed a third time and the average was taken of the two closest readings.

[50]In both areas the females were weighed in lycra bras and pants. In Richmond the males were weighed in lycra pants. In Nelspruit the males were weighed in light cotton boxer shorts as a sufficient number of lycra pants were not available.

The pre shift readings were taken as the workers arrived at work just before they started their shift. Ideally this weight should have been recorded just after the worker got up in morning and after having urinated and defecated but before eating and/or drinking. This was logistically not possible as the workers lived in a number of forestry villages situated in different areas and they arose anytime from 3h30 to 5h30 depending on the distance to be travelled to the work site. There were not enough RA's or vehicles to measure the workers' weights in the different villages before the shift. More importantly, the research team was not permitted to go into the villages as the forestry industry felt that it would not be safe especially in the early morning. As the purpose of the study was to observe their normal behavior, it was considered inappropriate to ask the workers not to eat or drink before coming to work.

Approximately ¼ of the work force had consumed food and/or fluid before the shift. In Nelspruit 29% (n=29) and in Richmond 25% (n=20) had eaten small amounts of food[51] and drank small amounts of fluid approximately 2 hours before being weighed. According to Kavouras (2002), fluid taken up to 40 minutes prior to measuring the body weight does not significantly impact the reading. There are no guidelines as to the impact of food on body weight. It was thought unlikely however that these small intakes impacted significantly on the pre shift body weight.

The pre shift weight may have been significantly impacted by both dehydration and overhydration as 42% of the workers in both areas (Nelspruit n=42, Richmond n=33)

[51] Examples include 2 small bananas and a mug of tea or a chicken drumstick and a thick slice of bread.

were dehydrated pre shift (USG > 1.020 g/ml) and 23% (n=23) in Nelspruit and 13% (n=18) in Richmond were overhydrated pre shift (USG <1.013 g/ml). As a deficit of body water reflects as a loss of body weight, the weight recorded of those who were dehydrated would have been less than their weight when normally hydrated. As an excess of body water reflects as a gain in body weight, the weight recorded of those who were overhydrated would have been more than their weight when normally hydrated. As there was no validated method for the conversion of USG readings to percent change of body weight, it was not possible to estimate their normally hydrated body weight. Neither was it feasible or considered essential to the objectives of the study to rehydrate these workers and to monitor their pre shift body weights accurately over a period of 3 days to establish precisely their actual body weight (Sawka *et al* 2007).

The pre break body weights were recorded just prior to the start of the break before the worker had eaten and after urination. Most workers had consumed fluid from pre shift to pre break. Any fluid taken by the worker within 40 minutes of being weighed would still have been unabsorbed in the gastrointestinal tract (Kavouras 2002). It was not possible to accurately measure the fluid consumption during the shift[52] so that the weight of fluid consumed within the last 40 minutes could be subtracted from their recorded body weight. To ask the workers to stop drinking 40 minutes before the break was not feasible as the timing of the break varied for each worker depending on the number of trees felled, stripped or stacked. Also, most workers did not have watches so would not have been able to calculate 40 minutes before the break. The consumption of fluid and being unable

[52] This is explained in more detail later on in the dissertation.

to adjust for this would have resulted in the workers pre break weight being overestimated.

The workers' end shift weight would have been impacted by the amount of food taken during the break as well as any fluid consumed 40 minutes prior to ending the shift. During the break the workers in Nelspruit consumed 770 g (SD±601 range 0-2250) of food while the Richmond workers consumed 1400 g (SD±339 range 370-1944). The impact of this substantial amount of food on their weight at the end of the shift was unknown. The end shift weight therefore may have reflected both food and fluid in the gastrointestinal tract. Therefore the recorded weight was probably an overestimate.

3.4.3 Height

To ensure that the stadiometer approved by the International Society for the Advancement of Kinanthropometry (ISAK), was level, it was placed on a platform of the same design as that in Figure 8.

The forestry workers were asked to remove their shoes, socks and head gear and then to stand with their back to the stadiometer so that they were facing forward (Norton & Olds 1996). They were asked to stand erect with their feet together and flat on the centre of the base plate and their arms hanging naturally by their side. The RA ensured that their heels, buttocks, upper part of the back, as well as the back of the heads were in contact with the stadiometer and that the head was positioned in the Frankfort plane. The subjects were asked to take a deep breath and as they exhaled, the headpiece was lowered onto their vertex. They were asked whether the headpiece was resting on their head. The reading was recorded in the workers' data collection booklet (Appendix H). The measurement was repeated. If there was a difference of 0.2 cm, the reading was repeated a third time and the average of the two closest readings were used. The same RA took the height measurements in both Richmond and Nelspruit.

3.4.4 Collection of urine samples

The RA handed the worker a urine sample bottle wrapped in a large piece of paper towel. To obtain a mid stream urine sample the workers were instructed to allow a little urine to pass before half filling the bottle. They were asked to replace the lid firmly and to wipe the bottle with the paper towel before returning it to the RA who labeled the bottle with their identity (ID) code. As drinking a large amount of fluid prior to giving a urine sample can result in a dilute sample and the potential for a false negative result, they were asked to produce the samples before eating and drinking both pre break and end shift (Sawka *et al* 2007).

Pre shift and end shift urine samples were collected for the majority of the study participants in both areas. The pre break urine samples in Nelspruit were taken from the debarkers (females) (n=39) only, because the chainsaw operators, chainsaw operator assistants and stackers worked through the allocated rest break. A pre break sample was obtained from most of the participants in the Richmond study.

3.4.5 Urine specific gravity

The USG was measured using a portable digital urine refractometer, the Atago Uricon UG-1 D20. The techniques as laid out in the manual supplied with the refractometer were used. The range was 1.000 g/ml to 1.060 g/ml with an automatic temperature compensation of 10ºC to 35ºC. The temperatures did not exceed 32ºC or drop below 10ºC during either study. Before beginning a series of measurements, the refractometer was calibrated by cleaning the prism surface and then completely covering the prism surface with a few drops of distilled water. The ZERO setting switch was pressed. Once the reading 000 was displayed, the refractometer was switched off and the water was wiped off the prism using tissue paper. After putting on gloves, the supervisors placed enough urine to cover the prism surface on the refractometer. The Start/Off switch was pressed. The USG reading was recorded. The Start/Off switch was pressed again to switch the refractometer off. If the External Light Interference (ELI) message was displayed, the research supervisors used their hand to shade the prism surface and the reading was repeated (Figure 9). Between each sample the prism was cleaned with water and wiped with tissue paper. Each urine sample reading was repeated twice by the principal research supervisor and then repeated twice by the assistant research supervisor. If any readings differed by 0.001 g/ml, they were repeated and the 2 closest readings averaged.

Figure 9: The assistant research supervisor using her hand to shade the Uricon prism from light while recording the urine specific gravity readings (used with permission)

To account for factors that could influence the accuracy of the USG readings, the workers were asked about their intake of caffeine, alcohol and foods, eg beetroot, which affect urine colour as well as their use of chronic medications (particularly diuretics), vitamin supplements and herbs (Appendix H). The vitamins used as part of the fortification program in SA would not influence the USG readings (Robinson 2006). The workers were asked whether they had experienced pre shift vomiting and/or diarrhoea. If female they were asked whether they were menstruating. The exclusion of those workers who had used any of these substances or experienced pre shift gastro intestinal disturbances made no significant difference to the USG results (Appendix I). All workers therefore were included in the USG analysis.

The categories used to determine dehydration and overhydration were based on a number of reviews. A USG reading of≤1.020 g/ml indicated normal hydration (Armstrong *et al* 2007, Sawka *et al* 2007), a USG reading of >1.020 g/ml indicated dehydration (Armstrong *et al* 2007, Sawka *et al* 2007,), and a USG reading of >1.030 g/ml indicated serious dehydration (Casa *et al* 2002) (Figure 10).[53] A USG reading of <1.013 g/ml indicated overhydration (Armstrong *et al* 2005; 1994).[54]

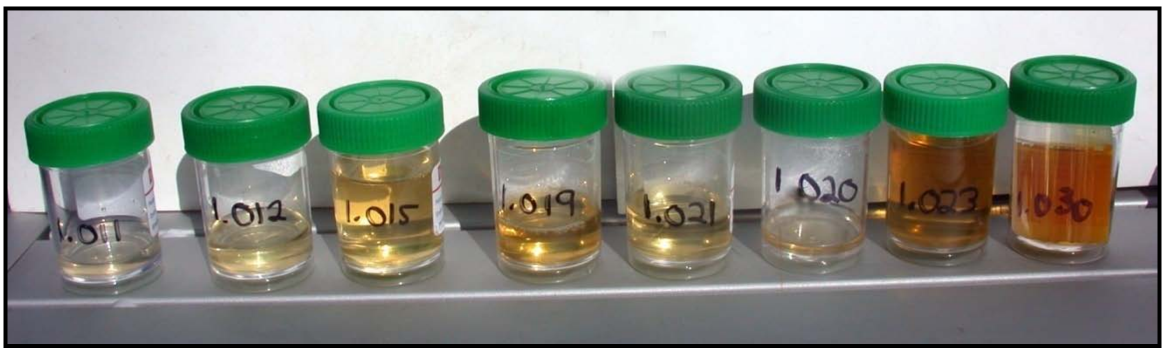

Figure 10: Variety of urine samples with urine specific gravity readings

3.4.6 Measurement of fluid supplied by the forestry workers

Phillips digital food scales, which measured between 1g and 5 kg, were used. These were calibrated by SA Scales before the study. They were placed on a stable and level table surface and switched on. An empty measuring jug was placed on the weighing platform and the scale zeroed. Fluid was poured from the worker's container into the measuring

[53]The category of >1.020 indicating dehydration by Sawka *et al* (2007) and Armstrong *et al* (2007) did not include the category of >1.030 as serious dehydration. This was only mentioned by Casa *et al* (2002) and was included in the study to as a guide to the extent of dehydration of the forestry workers.

[54]These papers by Armstrong *et al* (1994; 2005) appear to be the only studies that attempt to link overhydration to a USG reading.

jug and the weight and type of fluid was recorded in the worker's data collection booklet (Appendix H). If the volume exceeded the capacity of the measuring jug, an additional jug was used and the scale was zeroed in the manner described (Figure 11). Being very careful not to spill, the fluid was poured back into the containers and returned to the workers.

Figure 11: The contents (amahewu) of one worker's fluid container were weighed on the digital scales (left) and then carefully poured back into the original container (right) by an RA (photo used with permission)

3.4.7 Determination of type and amounts of fluid supplied by the contractors

The amounts of fluid supplied by the contractors were not measured. The contractors were asked how much fluid they supplied per worker per day and what type of fluid they supplied. The research team observed the placement of the white plastic fluid drums in relation to the areas in which the workers were harvesting.

3.4.8 Recording air temperatures at the study sites

The harvesting side of the forestry industry agreed to supply the DB, WB, rh and WBGT on each study site as they thought that silviculture monitored these on a daily basis in each area. This was a misunderstanding however as silviculture did not routinely record these temperatures and the SA weather station’s recordings were used instead for both areas.

3.5 TRAINING OF RESEARCH TEAMS

The research team in Richmond consisted of the principal research supervisor (dietician), the assistant research supervisor (dietician), 2 other dieticians and 5 translators. The translators were unqualified individuals who the Discipline of Dietetics and Human Nutrition at the University of KZN had used regularly to translate for the dietetic students during their internship training.

The research team in Nelspruit was comprised of the same principal research supervisor and assistant research supervisor, as well as 1 of the dieticians who had been involved in the Richmond study and 8 CHW on loan from both Mondi and Mining Industrial Dowls (MID).[55]

The same training methods applied to both study sites.

3.5.1 Training the dieticians

The dieticians were trained during a separate morning session as they were experienced in all the techniques required and training was primarily needed to ensure standardization of technique. The standardization of weight and height measurements was taught by the supervisors who were experienced in Level 2 anthropometry.[56] On completion, those being trained measured the heights and weights of 5 volunteers. Their readings were compared to those of the supervisors. Training was continued until the dieticians were competent. Competency was accepted when the weight measurements were identical or differed by less than 100g and when the height measurements were identical or differed by less than 0.2 cm.

To ensure standardization in the measurement of the weight of the drinking fluid, those being trained were asked to measure the contents of 10 containers, each of which held a known weight of fluid. Training was continued until the dieticians were competent. Competency was accepted if the weight measurements were identical or differed by 5 g or less.

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[55] Mining Industrial Dowls were the forestry contractors that the research team was working with in Nelspruit. There were no CHW in the Richmond area at all.
[56] They had both attended level 2 ISAK courses in anthropometry.

Each dietician produced a mid stream urine sample. Both the research supervisors independently determined the USG readings using a refractometer. Their readings were compared. Competency was accepted when the readings were identical or differed by less than 0.001 g/ml.

3.5.2 Training the translators of the Richmond team

A training day was held for the rest of the Richmond team approximately a week before the start of the study. The research dieticians were present to assist.

The principal research supervisor used a training manual (Appendix J) to demonstrate the techniques required to obtain an informed consent, request a urine sample, to allocate an ID code, to fasten the ID bracelet, to administer the questionnaire (Appendix H), to use the leveling platforms and to erect the tables and tents. After being shown each technique, the translators practised with the help of the research dieticians. Training was continued until competency was shown. Competency was accepted when the translator could carry out each technique to the satisfaction of either the principal research supervisor or the assistant research supervisor, using the same criteria as when training the dieticians.[57]

[57] The same standards were used as when training the dieticians eg weight measurements were not to differ by more than 100g and height by 0.2 cm.

3.5.3 Training the Community Health Workers of the Nelspruit team

As the research dieticians had taken part in the Richmond study there was no need for additional training.

The principal research supervisor used the same manual to train the CHW’s in the same techniques three days before the start of the Nelspruit study. The research dieticians were not present to help as many of the techniques were already familiar to the CHW's as they performed them daily during the normal course of their work. The emphasis was on standardization rather than training. Training was continued until competency was demonstrated. Competency was accepted by the principal research supervisor when the same levels of standardization as used previously were reached.

3.6 PILOT STUDY

This was conducted after the training of the translators of the Richmond team and before the first day of study at Richmond. The purpose was to ensure that the group was working together as a competent unit with regards to the flow, the use of equipment and using the questionnaire.

The research team ran the pilot study at the University of Kwa-Zulu Natal. The area in which the pilot study was conducted was set up with the equipment exactly as it would be on the study site. Ten black (African) females who formed part of the University cleaning staff volunteered to be the pilot subjects. The research team rehearsed the data collection process on each volunteer. The principal research supervisor checked that this was being carried out in accordance with the training manual. No problems were experienced in work flow and techniques.

3.7 COLLECTION OF DATA

The data was collected over a period of 4 consecutive days beginning on the Monday. In Richmond this was the week before payday and in Nelspruit the week after payday.

On arrival at the work site, those workers willing to participate were sent to the first work station where the consent form was explained to them by a RA in their home language (Figure 12). If agreeable to participate, the worker either signed or thumb printed the consent form (Appendix K) and was given a carbon copy duplicate. The RA then allocated the worker an ID code which consisted on letters followed by numbers. The letters identified the job category and the numbers the order in which the workers signed the informed consent. For example the 4^{th} stacker who signed the informed consent form was given the ID code S4. This code was written on the workers data booklet and no record was kept of their name thereby ensuring anonymity.

The worker’s ID code was then written on an ID bracelet which was securely and snugly fastened around the left wrist. Excess strap was cut off to prevent the bracelet from snagging on branches or machinery. Each worker was handed their data booklet (which was used to record all the data) and urine sample bottle and given instructions on how to collect a mid stream urine sample.

On returning from the forest with their urine sample they were directed to the second work station. The urine sample bottle, labeled with their ID number and time of receipt, was placed in a box in the shade. The production of a urine sample was recorded in their data booklet so that the RA measuring body weight could check that the worker had urinated before being weighed.

At the third work station, their height was measured after they had removed their shoes, socks and head gear. The men were then issued with either lycra pants (Richmond) or light weight boxer shorts (Nelspruit) while the females were given lycra shorts and a lycra bra (research outfits). The workers then removed all their own clothes and changed into the research outfits in the tent (work station four) where they were then weighed. After being weighed they put their own clothes back on over the research outfits to facilitate weighing later on in the day.

The questionnaire to determine sociodemographic and medical data was administered at work station five. The drinking fluid being taken into the forest was weighed at work station six. The principal research supervisor collected the data booklets, checked that everything had been correctly recorded and then stored the booklets in a box in preparation for the workers' return. The workers, just prior to leaving for the forest, were instructed to return to the research site at the beginning of their mid morning break before they had consumed any fluid or food.

Once the workers had left to begin harvesting, the USG measurements were processed and the urine samples discarded.

Figure 12: Flow diagram to illustrate the process of data collection pre shift

On their return at the beginning of the mid morning break, the workers were asked to produce another mid stream urine sample before they had anything to eat or drink. They were issued towels in exchange for their urine samples and directed to the weighing tent. They were instructed to remove their work clothes and thoroughly towel themselves dry before being weighed in their research outfits. After getting dressed they took their fluid containers to the next work station (Figure 13). The amount of fluid remaining in the bottles was weighed and they were asked whether they had drunk any additional fluid. Before the workers were allowed to eat and/or drink, the principal research supervisor checked that all the measurements had been carried out and correctly recorded in their data booklets. After eating and drinking the workers then returned to harvesting.

Figure 13: Data collected pre break

The USG readings were measured as described previously.

At the end of their shift, which was anytime between 11h30 and 14h30 the workers returned to the study site before eating or drinking. The same process was repeated as for the mid morning break (Figure 14). In addition in Nelspruit only, the workers were asked whether they were experiencing any signs of dehydration such as headaches (Appendix H).[58] The principal research supervisor checked that all the necessary readings had been

[58]This is found on the last page of the data booklet.

correctly recorded, collected the data collection booklets and thanked each person for taking part in the study.

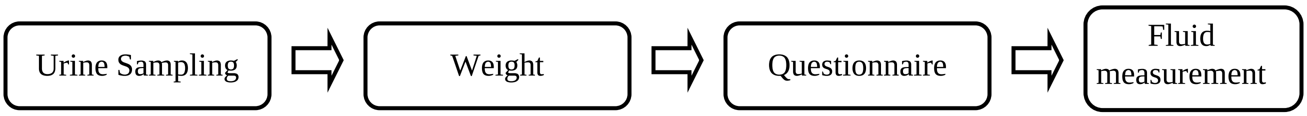


Figure 14: Data collected at the end of shift

While the research site was being dismantled at the end of the day, the USG readings were measured in the same manner as described previously.

3.8 DATA CAPTURING, EDITING AND CLEANING OF DATA

To minimize errors associated with data, measurements such as weight, height and USG readings were repeated twice. A third measurement was taken if the initial measurements were not similar enough (as described in Section 3) and the 2 closest readings were averaged. Due to severe time constraints the measurement of the fluid was not repeated. The urine specific gravity readings were rerun twice by each research supervisor.

Within 2 weeks of the completion of each study, the data was captured into the Statistical Package for Social Science (SPSS) version 11.5 (SPSS inc., Chicago, Ill, USA) by the principal research supervisor and then reentered by the assistant research supervisor to minimize errors. All data was checked at the time of measurement and data that was felt to be questionable was remeasured. All USG readings were between 1.005 to 1.034 g/l.

All body weight changes were between +3% to -3%. These were all considered to be acceptable limits and no data was rejected. The statistician reviewed the SPSS data base and felt that no cleaning of the data was required.

3.9 REDUCTION OF BIAS

To reduce bias the RA's were trained before the study to ensure competency and standardization. A pilot study was conducted to determine whether the RA's could perform measurements competently under similar conditions to that which they would experience in the forest.

The same pieces of equipment were used for both studies. Where possible, the same people were responsible for the same measurements in both studies.

The RA's were trained in the technique of conducting the interview schedule. The workers were asked the questions in their mother tongue in a manner which they could understand. None of the questions were leading.

After each set of measurements, the principal research supervisor checked the data booklets to ensure that all the measurements had been done and clearly and correctly recorded. If there was doubt, the measurement was repeated on the worker before they left the study site.

“The validity of a test or instrument refers to its ability to measure the phenomenon it intends to measure” (Monsen 1992). To ensure the data was valid the scales were calibrated before the study by a reputable company. Before each set of urine samples were run the refractometer was calibrated against distilled water.

“The reliability of a test or instrument is determined by its consistency of results when applied to the same specimen repeatedly, administered by either the same or different persons” (Monsen 1992). Each USG reading was repeated twice by each research supervisor. All readings were identical during the study indicating a 100% reliability. For weight and height reliability was determined at the end of the training session. For weight all readings were identical indicating a 100% reliability. For height the maximum difference in readings between the research assistant and research supervisor was 0.1 cm.

3.10 DATA ANALYSIS

3.10.1 Calculation of Body Mass Index

The BMI was calculated by dividing the weight (kg) by the height (m) squared (Wildman & Miller 2004 p197). For example, a worker who weighed 60 kg and who was 1.54 m tall would have a BMI of 60/(1.54 x 1.54) = 60/2.37 = 25.3 kgm^2.

The ranges used to classify malnutrition according to BMI are found in Table 8.

Table 8: Body mass index ranges as a classification of malnutrition (after Golden & Golden 2000 p515)

BMI	Classification
17.0 to 18.4	Mild malnutrition
18.5 to 19.9	Marginal malnutrition
20.0 to 24.9	Normal Range
25.0 to 29.9	Overweight
30.0 to 34.9	Obese Class 1

The BMI was probably underestimated in those who were dehydrated and overestimated in those who were overhydrated on each study site, as illustrated by the examples which follow.

A worker whose pre shift weight was 60 kg when 2% dehydrated actually weighs 60 kg x 1.02 = 61.2 kg. If their height was 1.64 m, their BMI when dehydrated would be 60/(1.64x1.64) = 60/2.69 = 22.3 kg/m^2. However, their BMI when rehydrated would be 61.2/2.69 = 22.8 kg/m^2. Likewise, a worker who weighed 61.2 kg and was overhydrated 2% would have a BMI of 22.8 kg/m^2 when their actual BMI was 22.3 kg/m^2.

There was no method to quantify the effect of overhydration and dehydration on the BMI. The precise measurement of the BMI however was not considered essential to the objectives of the study.

3.10.2 Percent change of body weight

The percent change of body weight from pre shift to pre break was calculated by subtracting the workers' pre break weight from their pre shift weight and then dividing this by their pre shift weight and multiplying by a 100 (Table 9).

The percent change of body weight from pre shift to end shift was calculated by subtracting the end shift weight from the pre shift weight, then dividing this by the pre shift weight and multiplying by 100 (Table 9).

Table 9: Examples of calculations for percent change of body weight pre break and end shift

Pre shift weight (kg)	**Pre break weight (kg)**	**Equation**	**Percent change of weight**	**Conclusion**
66	64	[(66 kg – 64 kg)/66 kg] x 100	3	Dehydrated
66	68	[(66 kg – 68 kg)/66 kg] x 100	-3	Overhydrated
Pre shift weight (kg)	**End shift weight (kg)**	**Equation**	**Percent change of weight**	**Conclusion**
66	62	[(66 kg -62 kg)/66 kg] x 100	6	Dehydrated
66	70	[(66 kg -70 kg)/66 kg] x 100	-6	Overhydrated

There are no definite cut off points for either dehydration or overhydration. For the purpose of this study, when using percent change of body weight to determine hydration status, the results were categorized as in Table 10. The column entitled "motivation" describes the rationale for the categorization.

Table 10: Interpretation of percent change of body weight

Percentage loss of body weight	**Motivation**
≥ 1% to ≤ 2%	Although the optimal goal during exercise is to replace fluid to maintain the same body weight, a loss of ≤ 2% is still considered to be euhydrated (Armstrong *et al* 2007, Sawka *et al* 2007, Casa *et al* 2005).
> 2% to < 3%	A > 2% loss has been referred to as "the critical water deficit for most people" and decreases both aerobic performance and mental and cognitive functioning and increases perception of effort and lowers heat tolerance (Armstrong *et al* 2007, Sawka *et al* 2007, Casa *et al* 2005).[59]
≥ 3% to < 4%	Further degradation of aerobic ability (Sawka *et al* 2007, Casa *et al* 2005).
≥ 4%	Further degradation of aerobic ability (Sawka *et al* 2007, Casa *et al* 2005).
% gain of body weight	
≥ 1% to < 2%	There are no categories classifying the effects of percent gains in body weight and cut off points. These categories were included to highlight the extent of overhydration.
≥ 2% to < 3%	
≥ 4%	

To accurately determine the percent change in body weight, the body weight pre shift, pre break and end shift needed to be correctly determined. The fluid and food that the workers consumed during the shift was weighed.[60] However the impact of this on their body weight could not be adjusted for, as there are no realistic data on how to correct for this. The recorded weights at the end of shift, therefore, were possibly an overestimation

[59]These three papers were used as the basis of these categories as all three are Position Papers from the ACSM.

[60] Another study was running concurrently which measured the nutritional intakes of the forestry workers.

for those who ate and drank. This meant that the percent loss of body weight would be underestimated and that the percent gain of body weight would be overestimated as illustrated in the examples which follow.

If a worker who was normally hydrated pre shift, weighed 65 kg and at the end of the shift without eating or drinking weighed 63.7 kg, the percent loss of body weight would be [(65-63.7)/65]x100] = 2%. Therefore this worker had dehydrated 2%.

However, if a worker who was normally hydrated pre shift weighed 65 kg and at the end of the shift after eating and drinking weighed 63.7 kg, the uncorrected percent loss of body weight would be [(65-63.7)/65]x100] = 2%. Therefore this worker has dehydrated a minimum of 2% as the end shift weight would have been less than 63.7 kg if the food and fluid had been subtracted.

The practical implication for this hypothetical example, therefore, was that the percent loss of body weight being calculated was in fact the minimum amount of dehydration the worker was experiencing. The implication of this was that a greater percentage of workers would have been found to be more than 2% dehydrated if the fluid and food that they consumed could have been corrected for.

3.10.3 Calculation of fluid intake and fluid requirements

The fluid was weighed pre shift and this weight recorded in the Data Collection Booklet. The fluid was then reweighed just prior to the break (pre break) and at the end of the shift. The amount consumed during the break was calculated as the amount pre shift (ml) minus the remainder pre break (ml). For example, if the worker took 2 litres of water into the forest and the remaining fluid pre break was 1.5 litres, the worker had consumed 0.5 litres. This was repeated at the end of the shift.

However workers did not drink only from their water bottles – fluid was shared and also used to splash over themselves in an attempt to keep cool. In Richmond workers were "sneaking"[61] additional water from other water stations when they realised that the research team was monitoring their fluid intake. In Nelspruit the contractor delivered cold fluid directly to the workers in the forest at random times across the shift – the workers would "grab" the fluid and share it amongst themselves, drinking directly out the containers. Therefore it was not possible to determine with precision what each worker consumed.

The above in turn affected the calculation of the fluid requirements, as the amount of fluid consumed by the worker was added to the amount of weight lost by the worker. For example, a worker who had lost 500 g over the 2 hour period and who had consumed

[61] They were getting water from other teams in the area or else asking them to fetch water for them from water stations further away. The reason for this could not be determined.

1000 ml of water, needed to drink 500ml plus 1000 ml ie 1500 ml over 2 hours ie 750 ml per hour to prevent dehydration.

As it was not possible to determine the fluid intake accurately during the shift, the fluid requirements could not be determined except for those who had reported that they had not taken any fluid or food across the shift. Their fluid requirements were calculated by converting their weight change across the shift directly into volume (1 gram being equivalent to 1 millilitre) and then dividing the amount by the number of hours they had worked.

3.11 COLLATION OF DATA

Data was 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, standard deviations (SD) and ranges. Abnormally distributed quantitative variables were described using medians, standard deviations and inter quartile ranges (IQR). Groups were compared using independent sample t-tests in the case of 2 unmatched groups, paired sample t-tests in the case of two paired groups, and ANOVA in the case of greater than 2 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 multiple comparison tests and Wilk’s Lamba.

Table 11: Statistical analysis used for each study objective and variable

Study objective		Variable	Statistical analysis
1.1.1	To determine the amount of fluid supplied by the contractors and the forestry workers.	Amount of fluid	Descriptive statistics.
1.1.2	To determine the type of fluid supplied by the contractors and the forestry workers.	Type of fluid	Descriptive statistics.
1.1.3	To establish and compare the prevalence and degree of dehydration occurring in forestry workers using USG and to determine whether there were high risk categories according to gender and job category.	USG Gender Job category	Descriptive statistics for USG readings pre shift, pre break and end shift. Paired sample t-test to compare change in USG readings pre shift to pre break and pre break to end break and pre shift to end shift. McNemar Chi square for the change in the classification of dehydration measured using USG between pre shift and end shift and between break and end shift. Repeated measures of ANOVA to assess quantitative USG changes over two time points ie pre shift to pre break and pre break to end shift. Wilk's Lamba to assess the influence of job category and gender on USG readings over time.

Table 11: Statistical analysis used for each study objective and variable continued

Study objective		Variable	Statistical analysis
1.1.4	To determine whether the forestry workers experienced symptoms of dehydration at the end of the shift.	Symptoms USG	Descriptive statistics. Paired t-test to determine whether symptoms were related to USG readings. Independent t-test to determine whether symptoms were related to gender.
1.1.5	To determine the forestry workers' fluid requirements.	Body weight	Descriptive statistics.

3.12 PERMISSION TO CONDUCT STUDY AND ETHICS APPROVAL

Ethical approval was obtained from the Nelson Mandela School of Medicine (Protocol E045/05) (Appendix L).

To comply with the ethics requirements, a week before the study commenced on each site, forestry supervisors, who were known and respected by the workers, went to talk to those who were harvesting in the areas to be included in the study. They explained the purpose of the study in the workers' home language, what would be expected of them if they agreed to participate and when the study was taking place. In addition, the workers were handed out information sheets written in their home language (Appendix M).

On the first day of the study, the same forestry supervisors were present to remind the workers about the study and to answer any additional questions and to emphasize the fact that participation was voluntary. Those who were willing to participate had the informed consent read to them in their own language before being asked to either sign or thumbprint it.

3.13 SUMMARY

The study aimed to investigate the prevalence and degree of dehydration experienced by forestry workers harvesting trees during autumn and winter in SA. The samples were selected on the basis of convenience and included 79 workers in Richmond (winter) and 103 workers in Nelspruit (autumn). The participants were black African males and females who were employed as chainsaw operators or chainsaw operator assistants or rough liners or debarkers or stackers. The research teams comprised of dieticians and/or translators and/or CHW's. After the Richmond research team's initial training, a pilot study was conducted to ensure that the team was competent to collect data accurately and that the work flow was appropriate. No problems were experienced with the pilot study. The data was collected over a period of 4 consecutive days, beginning on the Monday at each study site. The workers signed the informed consent if willing to participate after having the study explained to them in their own language. The prevalence and degree of dehydration was measured using USG readings as well as percent loss of body weight (Sawka *et al* 2007). A questionnaire was used to obtain sociodemographic data, medical data and whether the worker experienced symptoms of dehydration at the end of the shift. Fluid brought by the workers was weighed using food digital scales. The type of fluid consumed was recorded. Data was entered into SPSS version 11.5 within 2 weeks of completion of the study. The data was entered twice to ensure accuracy. A 2 sided p value of <0.05 was considered as statistically significant. Groups were compared using sample t-tests, ANOVA and repeated measures of ANOVA for quantitative variables and the McNemar's Chi Square tests, Bonferroni multiple comparison tests and Wilk's Lamba for categorical variables.

CHAPTER 4: RESULTS

4.1 INTRODUCTION

This study investigated dehydration in forestry workers. The heavy physical labour, the mandatory protective clothing, as well as the hot and often humid working environments, predisposes forestry workers in SA to hyperthermia and dehydration. Dehydration, as represented by a >2% percent loss of body weight across the shift or a USG reading >1.020 g/ml, significantly reduces the workers' physical and mental performance hindering their ability to work productively and safely.

4.2 RESEARCH SITE CHARACTERISTICS

This study was conducted in the research sites of Richmond (July 2005) and Nelspruit (April 2006). The mean ambient air temperatures, the rh, the highest recorded temperature, the daily average minimum, the daily average maximum and the lowest recorded temperature from 1961 to 1990[62] are found in Table 12 (SA Weather Service 2007). Unfortunately the WBGT could not be calculated as the Weather Station did not keep a record of the dew point temperature.[63]

[62]These are the most recent average minimum and maximum temperatures for South Africa according to the SA Weather Service 2007.

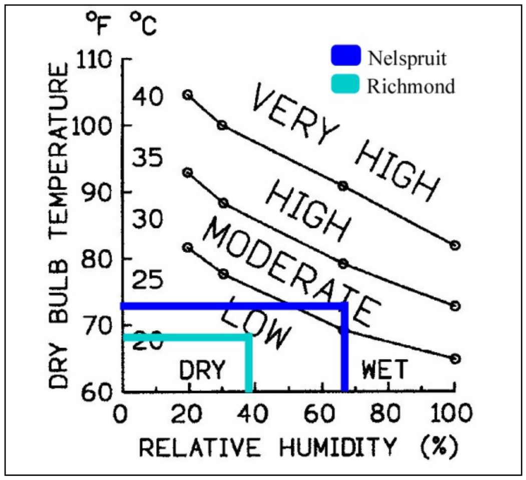
[63]The dew point is the temperature to which a volume of air must be cooled at constant pressure and constant moisture in order to reach saturation. If the air is cooled any further condensation results.

Table 12: Mean ambient air temperatures and relative humidity levels during shifts[64] (South African Weather Service 2007)

		Nelspruit (Autumn 2006)	Richmond (Winter 2005)	Nelspruit (Autumn 2006)	Richmond (Winter 2005)
		Ambient air temperature (°C)	Ambient air temperature (°C)	Relative Humidity (%)	Relative Humidity (%)
Day 1	**Mean**	19.3	19.5	73	26
	SD	±1.71	±2.59	±8	±4.4
	Range	13.9-21.5	14.2-22.7	65- 90	21-33
Day 2	**Mean**	21.1	20.1	63	17
	SD	±3.11	±8.16	±13	±26
	Range	15.5–24.6	2.8–26.6	41-91	IQR 14-52
Day 3	**Mean**	22.8	14.4	62	53
	SD	±3.62	±6.01	±16	± 20
	Range	13.4–26.3	3.3 – 21.9	45-90	27-84
Day 4	**Mean**	21.0	14.0	71	61
	SD	±2.67	±6.95	±12	±24
	Range	14.7–23.2	1.9-20.0	58-92	41-98
Study mean		**21.1**	**17.0**	**67**	**39**
Highest recorded temperature (°C).		36 (April)	30 (June)		
Daily average minimum and maximum (°C).		14-27 (April)	3-22 (June)		
Lowest recorded temperature (°C).		5 (April)	-4 (June)		

Based on the mean ambient air temperature and mean rh reading, the risk of heat illness/heat exhaustion in Nelspruit was moderate and the risk in Richmond low (Figure 15). The altitude was 671 m at the Nelspruit study site and 1315 m at the Richmond site (Figure 16). The trees being harvested in both areas were 10 year old *Eucalyptus grandis* trees.

[64]The temperature and rh was averaged for 7h00 to 4h00 as this was the average duration of a shift.



<u>Figure 15:</u> Risk of heat illness/heat exhaustion while exercising in hot environments (Convertino, Armstrong, Coyle, Mack, Sawka, Senay & Sherman 1996)

<u>Figure 16</u>: Richmond forestry site, altitude 1315m

4.3 SAMPLE CHARACTERISTICS

4.3.1 Number

One hundred and three people were included in the Nelspruit study and 79 in the Richmond study (Table 13). The majority of the sample were males. The number of males in Nelspruit was 63% (n=64) and in Richmond 86% (n=68). The number of females in Nelspruit was 38% (n=39) and in Richmond 14% (n=11).

The number of chainsaw operators in Nelspruit was 11 and in Richmond 8 (Table 13). The number of chainsaw operator assistants in Nelspruit was 9 and in Richmond 8. The Richmond sample consisted of workers who both rough lined and debarked (n=63)[65] (Figure 17) in contrast to the Nelspruit sample whose workers were either stackers (n=42) (Figure 17), or debarkers (n=41) (Figure 18). In the Richmond sample, the females worked either as chainsaw operator assistants or rough liners while in the Nelspruit sample, all the females worked as debarkers. In the Richmond sample, males worked as chainsaw operators, chainsaw operator assistants and rough liners. In the Nelspruit sample, males worked as chainsaw operators, chainsaw operator assistants, debarkers and stackers. Job category was significantly associated with gender ($p<0.001$).

[65] The rough liners did a combination of debarking and stacking – the debarking was the same task as in Nelspruit but the stacking in Richmond involved tidying the logs into rows whereas the stackers in Nelspruit stacked into large piles.

Table 13: Sample characteristics

		Nelspruit	Richmond
		Number (n)	Number (n)
All	Chainsaw operators	11	8
	Chainsaw assistants	9	8
	Stackers	42	63[66]
	Debarkers	41	
	Total	**103**	**79**
Male	Chainsaw operators	11	8
	Chainsaw assistants	9	4
	Stackers	42	56[66]
	Debarkers	2	
	Total males	**64**	**68**
Female	Chainsaw operators	0	0
	Chainsaw assistants	0	4
	Stackers	0	7[66]
	Debarkers	39	
	Total females	**39**	**11**

[66] These figures represent the rough liners.


Figure 17: Rough liners (Richmond) stacking the logs into neat lines (left) as opposed to stackers (Nelspruit) who stacked logs into large piles (right)


Figure 18: Female debarker (Nelspruit) using a small hand held axe to debark the log

4.3.2 Age

The Nelspruit workers (37.32 years) were significantly older ($p<0.001$) than those in Richmond (25.85 years) (Table 14). In general the Nelspruit workers were 34 years and older while the Richmond workers tended to be between 22 years and 27 years old. The oldest were the Nelspruit females whose mean age was over 40 years.

Table 14: Age of sample

		Nelspruit Age (years)	Richmond Age (years)
All	**Mean**	37	25
	SD	±9.39	± 5.6
	Range	21-61	18-23
	Number	103	79
	*Comparison	p≤0.001	
♂	**Mean**	**35**	**26**
	SD	±9.70	± 5.56
	Range	21-61	19-23
	Number	64	68
	*Comparison	p≤0.001	
♀	**Mean**	**41**	**22**
	SD	±7.77	± 4.80
	Range	24-57	18-36
	Number	39	11
	*Comparison	p≤0.001	
CS	**Mean**	**36**	**30**
	SD	±5.82	±5.99
	Range	25-46	22-40
	Number	11	8
	*Comparison	p≤0.001	
Ass	**Mean**	**36**	**23**
	SD	±9.32	±2.56
	Range	24-50	20-26
	Number	9	8
	*Comparison	p≤0.001	
Sta	**Mean**	**35**	**26**
	SD	±10.68	±5.62
	Range	21-61	18-53
	Number	41	63
	*Comparison	p≤0.001	
Deb	**Mean**	**40**	**25**
	SD	±8.13	±5.62
	Range	22-57	18-53
	Number	41	63
	*Comparison	p≤0.001	

All includes all workers in either group - ♂ includes male workers - ♀ includes female workers – CS = chainsaw operator – Ass = chainsaw operator assistant – Sta = stackers – Deb = debarkers. The Richmond rough liners' data has been repeated for the stackers and debarkers.
* Comparison was the statistical difference in age between the Nelspruit and the Richmond sample using an independent t-test.

4.3.3 Pre shift weight

The mean pre shift weight in Nelspruit (61.3 kg) was not significantly different (p=0.588) to the mean pre shift weight in Richmond (60.9 kg) (Table 15). There was no significant difference in pre shift weight between the 2 areas with respect to gender or job category (Table 15).

Table 15: Pre shift weight, height and body mass index

		Pre shift weight (kg)		Height (m)		BMI (kg/m^2)	
		Nelspruit	Richmond	Nelspruit	Richmond	Nelspruit	Richmond
All	**Mean**	**61.3**	**60.9**	**1.66**	**1.66**	**22.3**	**22.2**
	SD	±8.9	±6.9	±0.08	±0.06	±3.1	±2.4
	Range	43.3-86.4	44.0-79.8	1.47-1.89	1.51-1.81	17.2-34.2	17.9-31.2
	Number	103	79	102	79	102	79
	*Comparison	p=0.588		p=0.785		p=0.697	
♂	**Mean**	**62.3**	**60.6**	**1.70**	**1.67**	**21.4**	**21.9**
	SD	±7.9	±6.1	±0.07	±0.06	±2.1	±1.9
	Range	43.5-86.4	47.9-71.1	1.53-1.89	1.55-1.81	17.2-27.5	18.1-26.5
	Number	64	68	63	68	63	68
	*Comparison	p=0.183		p≤0.001		p=0.199	
♀	**Mean**	**60.1**	**62.5**	**1.59**	**1.60**	**23.7**	**24.3**
	SD	±10.2	±11.1	±0.05	±0.05	±3.9	±4.1
	Range	43.4-85.1	44.0-79.8	1.47-1.68	1.51-1.68	17.6-34.2	17.9-31.2
	Number	39	11	39	11	39	11
	*Comparison	p=0.423		p=0.327		p=0.859	
CS	**Mean**	**66.3**	**63.5**	**1.73**	**1.69**	**22.1**	**22.4**
	SD	±9.1	±4.8	±0.08	±0.03	±2.2	±1.8
	Range	55.4-86.4	54.6-70.5	1.58-1.85	1.64-1.73	18.6-26.0	19.6-25.0
	Number	11	8	11	8	11	8
	*Comparison	p=0.124		p=0.155		p=0.790	
Ass	**Mean**	**57.3**	**59.9**	**1.69**	**1.61**	**20.1**	**22.7**
	SD	±7.7	±8.8	±0.07	±0.06	±1.7	±3.0
	Range	43.5-65.8	49.8-76.9	1.57-1.78	1.51-1.68	17.7-22.9	19.2-28.9
	Number	9	8	9	8	9	8
	*Comparison	p=0.533		p=0.020		p=0.460	
Sta	**Mean**	**62.6**	**60.7**	**1.70**	**1.66**	**21.6**	**22.2**
	SD	±7.1	±6.9	±0.07	±0.06	±2.00	±2.48
	Range	46.3-80.7	44.0-79.8	1.53-1.89	1.53-1.81	17.2-27.5	17.9-31.2
	Number	42	63	41	63	41	63
	*Comparison	p=0.427		p=0.327		p=0.433	
Deb	**Mean**	**59.5**	**60.7**	**1.59**	**1.66**	**23.5**	**22.2**
	SD	±10.0	±6.9	±0.06	±0.06	±3.9	±2.48
	Range	43.3-85.1	44.0-79.8	1.47-1.68	1.53-1.81	17.6-34.2	17.9-31.2
	Number	41	63	41	63	41	63
	*Comparison	p=0.427		p=0.327		p=0.433	

All includes all workers in either group - ♂ includes male workers - ♀ includes female workers – CS = chainsaw operator – Ass = chainsaw operator assistant – Sta = stackers – Deb = debarkers. The Richmond rough liners' data was repeated under stacker and debarker.
* Comparison was the statistical difference between Nelspruit and Richmond using an independent t-test.

4.3.4 Height

In both Nelspruit and Richmond the mean height was 1.66 m (Table 15). In Richmond the Xhosa and Zulu workers (1.66 m) were taller than the Sotho workers (1.63 m) although this difference was not significant (p=0.981).

4.3.5 Body mass index

Although the mean BMI in both Nelspruit (22.3 kg/m^2) and in Richmond (22.2 kg/m^2), regardless of gender or job category, fell within the normal range of 20.0 to 24.9 kg/m^2 subgroups were of concern (Table 15, Table 16). On each study site 3 workers were experiencing mild malnutrition and 11 were suffering from marginal malnutrition (Table 16). In Nelspruit 15 workers were overweight and 4 obese and in Richmond 7 were overweight and 1 obese (Figure 19).

Table 16: Classification of malnutrition according to body mass index

BMI	**Classification***	**Nelspruit**		**Richmond**	
		Number	**Percent**	**Number**	**Percent**
17.0 to 18.4	Mild malnutrition	3	3	3	4
18.5 to 19.9	Marginal malnutrition	11	11	11	14
20.0 to 24.9	Normal Range	65	66	57	72
25.0 to 29.9	Overweight	15	16	7	9
30.0 to 34.9	Obese Class 1	4	4	1	1
Total		98	100	78	100

* Classification of malnutrition after Golden & Golden (2000 p 515)

Figure 19: To show the range of body mass index of the Nelspruit debarkers

4.3.6 Work experience

The median number of years worked in the area was significantly higher ($p<0.001$) in Nelspruit (5.11 years SD±2.91 IQR 3.00-6.00) than in Richmond (1.6 years SD±2.47 IQR 0.58-3.00). In both Nelspruit (6.28 years) and Richmond (5.05 years) the chainsaw operators were the most experienced.

4.3.7 Wages

The wages[67] in Nelspruit were R40 per day regardless of job category. In Richmond the chainsaw operators were paid R85 per day and the other workers R46 per day. All workers on both study sites regularly received ration packs (Appendix B).

4.3.8 Home

In Nelspruit the majority of the forestry workers (63%) were from Mpumalanga (local) or from the Limpopo Province (32%) with a few from Lesotho (1%) and the Western Cape (4%). In Richmond the majority (53%) were from Lesotho and the remainder were either local (KZN 25%) or from the Eastern Cape (22%).

4.3.9 Language

The predominant language spoken in Nelspruit was Shangaan (43.7%) followed by a wide variety of other languages (Table 17). In Richmond Sotho (62%) was the most commonly spoken, followed by Zulu (29%) and then Xhosa (9%). All the Richmond women spoke Zulu and came from KZN.

[67] The wages vary between the contractors. The contractors involved in these studies were considered to treat their work force well. As a result other forestry workers working for other contractors may earn less.

Table 17: Languages spoken in Nelspruit and Richmond

	Nelspruit		Richmond	
	Number	**Percent**	**Number**	**Percent**
Zulu	4	4	23	29
Sotho	19	18	49	62
Xhosa	0	0	7	9
Tsonga	15	15	0	0
Shangaan	45	44	0	0
Ndebele	2	2	0	0
Swazi	16	15	0	0
Portuguese	1	1	0	0
Sepedi	1	1	0	0
Total	**103**	**100**	**79**	**100**

4.3.10 Literacy

In each study site the only indicator of levels of literacy were the workers' ability to sign the informed consent form as well as knowledge of their date of birth. In Nelspruit 10 (10%) used their thumb print instead of signing the consent form and 4 (4%) did not know their birth date. In Richmond 46% used their thumb print and 44% were unsure of their date of birth.

4.3.11 Living quarters

In Nelspruit the majority (89%) resided in the forestry villages, while the remaining 11% lived at home. In Richmond 97% lived in the forestry villages and 3% lived at home.

4.3.12 General health

When asked about their general health, 54% of the Nelspruit workers felt that they were healthy, compared to 86% in Richmond. Only 15% regularly attended the health clinic in Nelspruit versus 32% in Richmond. None of the females on either study site admitted to being pregnant. There was no significant difference (p=0.157) in the number of people experiencing chronic diarrhoea in Nelspruit (9% n=9) and in Richmond (17% n=13). In Nelspruit chronic episodes of vomiting (2%) and constipation (10%) were reported – this was not asked in the Richmond study.

Self reported health conditions included one known[68] diabetic on diet control alone (Richmond) and 2 known diabetics in Nelspruit, one of whom was on diet control alone and the other on both diabetic and hypertensive medication (Table 18). All were male stackers/rough liners. There were 8 known hypertensives in Nelspruit of whom 4 took hypertensive medication (Table 18). Neither of the 2 hypertensives in Richmond took medication. Six (Nelspruit) and 8 (Richmond) claimed to have blood in the urine or urine

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[68]The term “known” was used as some of the forestry workers had never been tested for diabetes or hypertension, therefore there may have been unknown diabetics and/or hypertensives in the sample.

that was difficult or painful to pass. Three (Nelspruit) and four (Richmond) felt that there was something wrong with their heart – no further detail was asked (Table 18).

Table 18: Responses to general questions regarding health

		Diagnosed/ self reported	Not tested	Tested and healthy
Diabetes	**Nelspruit**	2	18	83
	Richmond	1	17	59
High blood pressure	**Nelspruit**	8	8	87
	Richmond	2	7	59
Urinary problems	**Nelspruit**	6	3	94
	Richmond	8	2	68
Heart problems	**Nelspruit**	3	3	97
	Richmond	4	3	53
Constipation	**Nelspruit**	10	0	89

On being asked whether they had any other health problems, the majority (58%) felt that they did not. The rest listed headaches (n=11), coughing (n=3), toothache (n=2), feeling weak (n=2), nose bleeds (n=2), back pain (n=2), leg pains (n=1), stress (n=1), blocked nose (n=1), ear problems (n=1) and tonsillitis (n=1).

The Nelspruit workers were more forthcoming about their intake of alcohol in comparison to the Richmond workers. The majority of the Richmond workers claimed that they never drank during the week (99%) or on weekends (93%). In Nelspruit the majority of males (94%) did not drink during the week and 54% drank over weekends. None of the Nelspruit females consumed alcohol.

4.4 AMOUNT OF FLUID SUPPLIED BY THE CONTRACTORS AND FORESTRY WORKERS

As the research site in Nelspruit was much closer to the forestry villages than that in Richmond, the workers brought fluid from home in their own containers. All Nelspruit workers brought containers. These were usually 2 litre recycled cold drink bottles or 5 litre car oil containers (Figure 20).

Figure 20: Selection of fluid containers in Nelspruit

The Nelspruit workers took on average 2.55 litres of fluid into the forest with them to drink during their shift. In addition, the contractor delivered 2 litre cold drink bottles or milk containers containing frozen water at intervals across the day (Figure 21). The contractor and staff froze water in a variety of recycled containers using the staff's household fridges. The Nelspruit contractor had no idea how much fluid was supplied per worker per day in total.

Figure 21: Truck delivering extra frozen fluid (right) to the workers in the forest

As the site being harvested in Richmond was very remote, most of the fluid was supplied by the contractor. When asked how much fluid was supplied, the contractor, after a lot of hesitancy, settled on a figure of 1 litre of water per worker per day. The water was supplied in large plastic containers which usually stood in the sun. The Richmond workers decanted this fluid into containers that they brought from home. Eleven percent (n=7) did not bring containers and therefore did not carry any fluid into the forest – others used a variety of plastic containers which either held a volume of ½ litre or 1 litre or 2 litres while others used more unusual containers (Figure 22). They took on average 1.44 litres into the forest with them to drink during their shift. The container size reflected the amount that was actually carried into the forest. In Richmond where the workers used smaller containers 78% took in less than 2 litres compared to only 17% in Nelspruit.

Figure 22: Examples of a typical (left) and less typical container (right) in Richmond

Some rest stations[69] had what appeared to be adequate fluid while others did not (Figure 23). The number of containers at each rest station was haphazardly determined by whichever forestry supervisor was responsible for fluid delivery on the day. If the fluid was not sufficient, the workers walked long distances to fetch fluid which they then carried back on their heads (Figure 24).

[69] A rest station is an area designated by the red and white striped tape – the petrol, fire fighting equipment and fluid are kept within this area – these stations are meant to be situated in close proximity to the workers.

Figure 23: Different rest stations to show the number of white plastic fluid filled drums contained within each area – both stations were supplying the same number of workers with fluid

Figure 24: Debarker fetching water while being careful to comply with the safety regulations requiring the wearing of helmets while working in the forest

4.5 TYPE OF FLUID SUPPLIED BY THE CONTRACTORS AND FORESTRY WORKERS

In general the variety consumed was very limited (Table 19). In Nelspruit 75% (n=75) drank only water. Other fluids that the workers brought included cold drink, tea, amahewu, milk and maas (Figure 25). Only 2% (n=2 both males) did not bring anything. The males preferred amahewu and cold drink. The females enjoyed a greater variety, including tea.

The variety in Richmond was even more limited (Table 19). Water only was consumed by 62% (n=47), amahewu by 27% (n=21) and cold drink by 3% (n=2). Eleven percent (n=7) did not take fluid into the forest at all.

The contractors in both areas supplied only water.

Table 19: Type of fluids consumed by the forestry workers

Type of fluid		Nelspruit	Richmond
Water only	Percent	75	62
	Number	75	47
Water plus other fluids	Percent	23	28
	Number	22	22
Cold drink	Percent	8	3
	Number	8	2
Amahewu	Percent	7	27
	Number	7	21
Milk	Percent	4	2
	Number	4	1
Nothing	Percent	2	11
	Number	2	7
Tea	Percent	7	0
	Number	7	0
Maas	Percent	2	0
	Number	2	0
Sugar water solution	Percent	0	1
	Number	0	2

Figure 25: Female debarker with cold drink

4.6 HYDRATION STATUS AS DETERMINED BY URINE SPECIFIC GRAVITY

4.6.1 Pre shift hydration status (urine specific gravity)

Although the mean USG readings in Nelspruit (1.018 g/ml) and Richmond (1.020 g/ml) showed both groups to be adequately hydrated (USG≤1.020 g/ml) at the start of the shift (Table 20), 42% of workers in each area arrived at work dehydrated (Table 21, Figure 26, Figure 27, Appendix N, Appendix 0). In addition, a further 1% (n=1) in Nelspruit and 5% (n=4) in Richmond were seriously dehydrated. The percent seriously dehydrated may have been higher as 4% (n=4) in Nelspruit and 4% (n=3) in Richmond could not produce a urine specimen – these individuals were not included in the analysis. Although the prevalence of dehydration did not appear to be related to gender (p=0.316) or job category (p=0.956), the group of chainsaw operator assistants and females in Richmond were dehydrated pre shift (Table 20). In Nelspruit 23% (n=23) and in Richmond 13% (n=10) had USG readings that indicated overhydration (USG<1.013 g/ml). This was not related to gender (p=0.660) or job category (p=0.811).

Table 20: Urine specific gravity readings pre shift, pre break and end shift

		Pre shift USG		Pre break USG		End shift USG	
		Nelspruit	**Richmond**	**Nelspruit**	**Richmond**	**Nelspruit**	**Richmond**
All	**Mean**	**1.018**	**1.020**	**1.019**	**1.021**	**1.022**	**1.022**
	SD	±0.007	±0.006	±0.005	±0.006	±0.005	±0.005
	Range	1.004-1.032	1.006-1.033	1.005-1.027	1.006-1.033	1.008-1.034	1.005-1.033
	Number	99	78	35	63	99	67
	*Comparison	p=0.291		p=0.203		p=0.679	
♂	**Mean**	**1.018**	**1.020**	**-**	**1.021**	**1.021**	**1.022**
	SD	±0.007	±0.006		±0.006	±0.005	±0.005
	Range	1.004-1.032	1.006-1.033		1.006-1.033	1.008-1.031	1.005-1.033
	Number	62	67		56	62	56
	*Comparison	p=0.114				p=0.975	
♀	**Mean**	**1.018**	**1.021**	**1.019**	**1.023**	**1.023**	**1.024**
	SD	±0.006	±0.007	±0.005	±0.006	±0.005	±0.006
	Range	1.006-1.027	1.011-1.031	1.005-1.027	1.013-1.029	1.009-1.034	1.013-1.029
	Number	37	11	34	7	37	11
	*Comparison	p=0.270		p=0.128		p=0.758	
CS	**Mean**	**1.018**	**1.019**	**-**	**1.019**	**1.022**	**1.019**
	SD	±0.007	±0.004		±0.002	±0.008	±0.004
	Range	1.007-1.028	1.015-1.025		1.016-1.022	1.007-1.028	1.014-1.023
	Number	11	7		6	10	7
	*Comparison	p=0.956				p=0.165	
Ass	**Mean**	**1.018**	**1.024**	**-**	**1.024**	**1.021**	**1.029**
	SD	±0.009	±0.005		±0.004	±0.007	±0.004
	Range	1.005-1.032	1.018-1.028		1.018-1.028	1.008-1.030	1.023-1.033
	Number	8	8		6	9	7
	*Comparison	p=0.956				p=0.165	
Sta	**Mean**	**1.018**	**1.020**	**-**	**1.021**	**1.022**	**1.021**
	SD	±0.007	±0.007		±0.006	±0.005	±0.005
	Range	1.004-1.030	1.005-1.035		1.006-1.033	1.010-1.031	1.005-1.032
	Number	42	63		51	42	53
	*Comparison	p=0.956				p=0.165	
Deb	**Mean**	**1.018**	**1.020**	**1.019**	**1.021**	**1.023**	**1.021**
	SD	±0.006	±0.007	±0.005	±0.006	±0.005	±0.005
	Range	1.006-1.027	1.005-1.035	1.005-1.027	1.006-1.033	1.009-1.034	1.005-1.032
	Number	38	63	35	51	41	53
	*Comparison	p=0.956		p=0.302		p=0.165	

All includes all workers in either group - ♂ includes male workers in the group - ♀ includes females workers in the group – CS = chain saw operator, Ass = assistant, Sta = stacker, Deb = debarkers. The Richmond rough liners' results were repeated under stacker and debarker.
*Comparison was the statistical difference between Nelspruit and Richmond using an Independent t-test for the group as a whole as well as for males and females – the job categories were analysed using ANOVA.

Table 21: Percent overhydrated, percent hydrated, percent dehydrated and percent seriously dehydrated pre shift, pre break and end shift

		Pre shift		Pre break		End shift	
		Nelspruit (n=99)	**Richmond** (n=78)	**Nelspruit** (n=35)	**Richmond** (n=63)	**Nelspruit** (n=99)	**Richmond** (n=67)
Overhydrated (<1.013 g/ml)	Percent	23	13	14	10	4	2
	Number	23	10	14	6	4	1
Hydrated (1.013 -≤1.020 g/ml)	Percent	34	40	37	35	32	35
	Number	34	31	37	22	32	24
Dehydrated (1.021-1.030 g/ml)	Percent	42	42	48	53	60	52
	Number	42	33	48	33	60	35
Seriously dehydrated (>1.030 g/ml)	Percent	1	5	1	2	4	11
	Number	1	4	1	1	4	7
Total	Percent	100	100	100	100	100	100

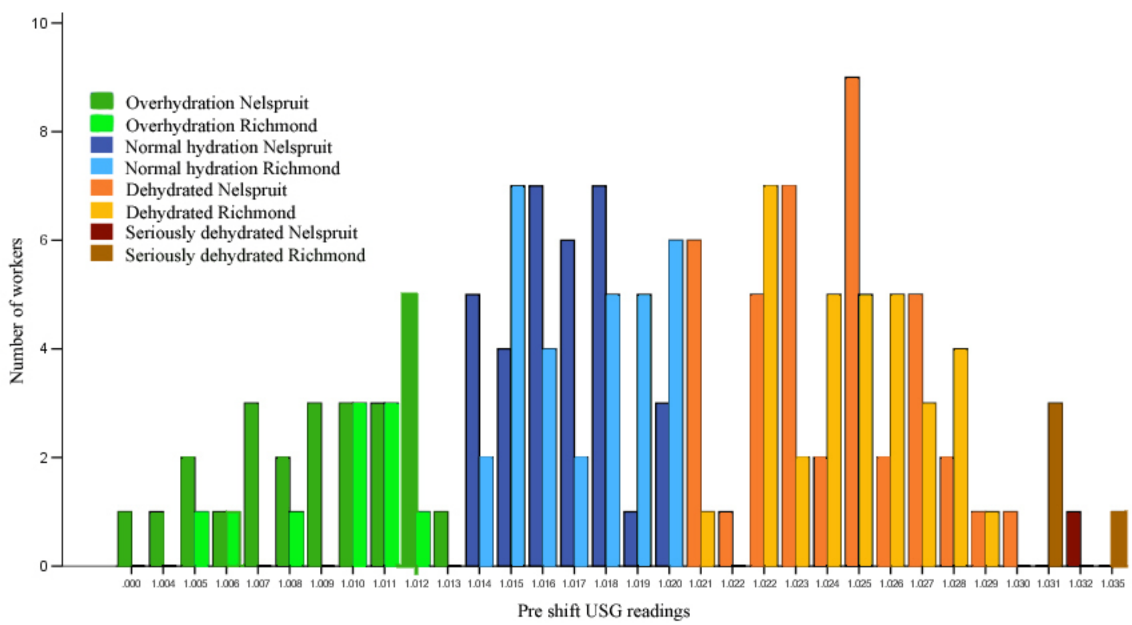

Figure 26: Detailed pre shift urine specific gravity (USG) readings

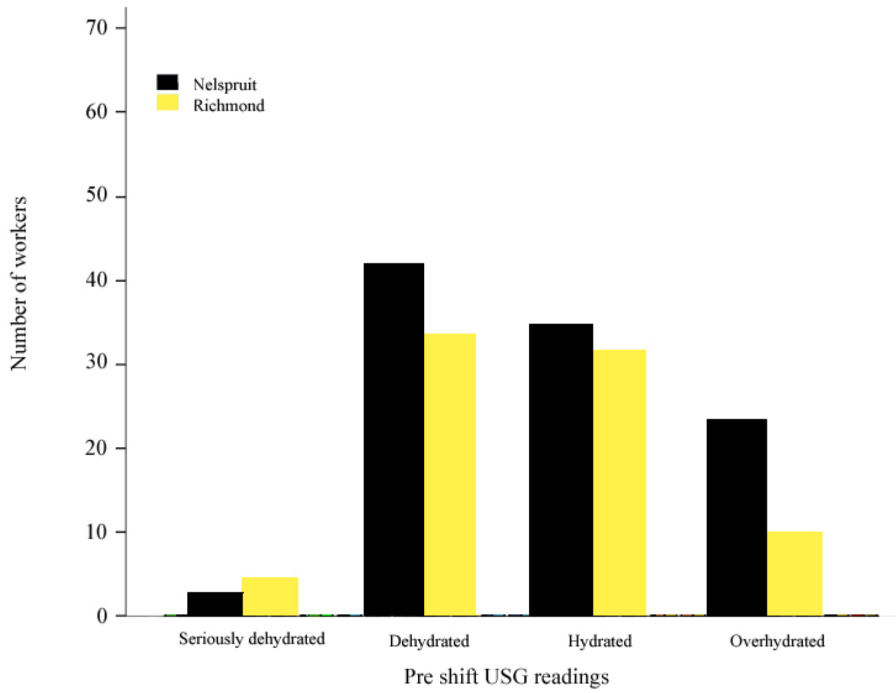

Figure 27: Mean pre shift urine specific gravity readings

4.6.2 Pre break hydration status[70] (urine specific gravity)

At the start of the break, 48% in Nelspruit and 53% in Richmond were dehydrated (Table 21, Appendix N). A further 1% in Nelspruit and 2% in Richmond were seriously dehydrated (Figure 28, Figure 29, Table 20). In Richmond the number seriously dehydrated had decreased, indicating an improvement in those individual's hydration status by the break. Although the deterioration in the mean hydration status from pre shift to pre break in Nelspruit (p=0.301) and in Richmond (p=0.422) was non-significant, the Richmond group on average had become dehydrated (1.021 g/ml).

[70] Pre break refers to just prior to the break – the measurements were done on the workers as they returned from the forest to begin their break before they had anything to eat and/or drink.

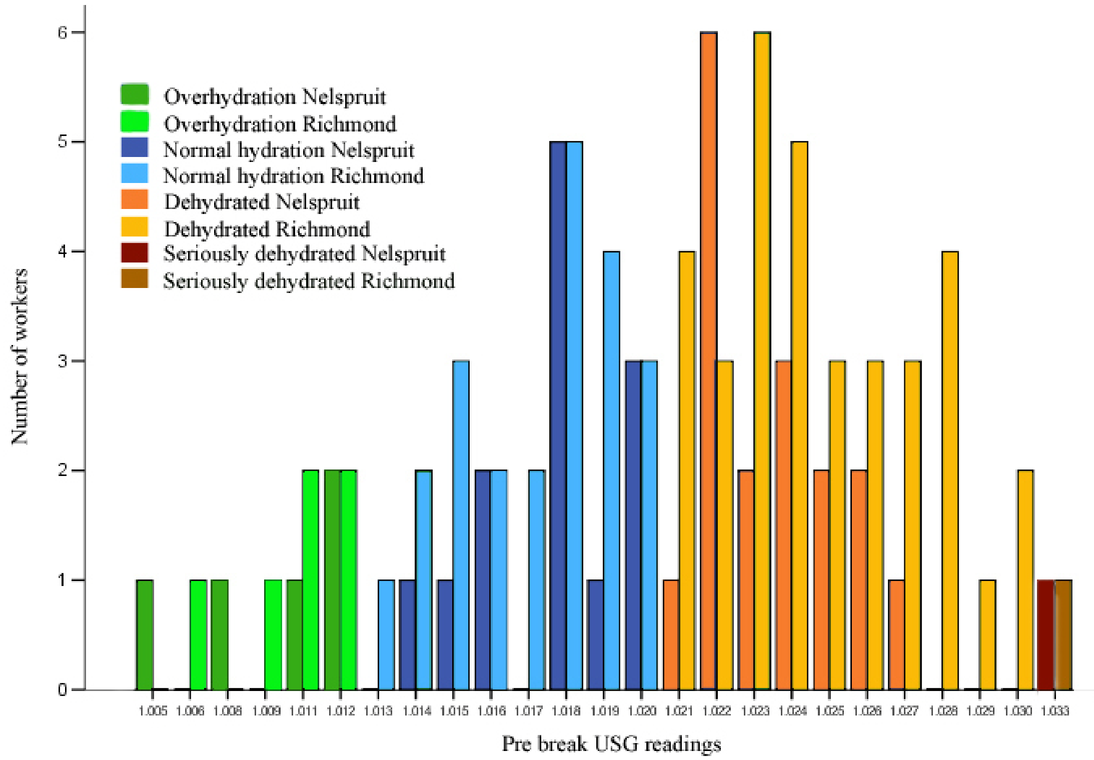

Figure 28: Detailed pre break urine specific gravity readings

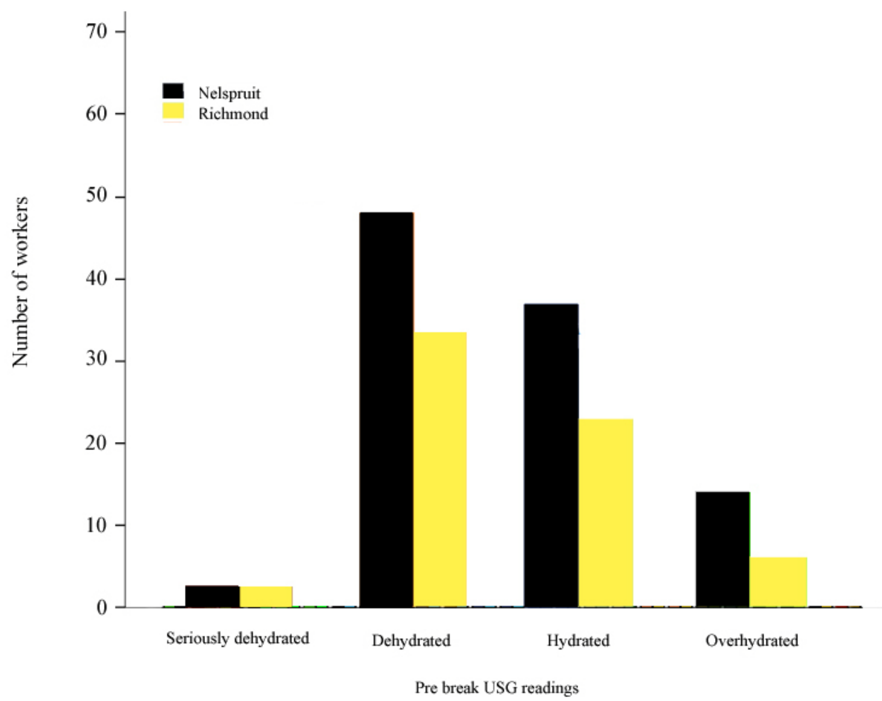

Figure 29: Mean pre break urine specific gravity readings

The likelihood of being dehydrated was not related to season (p=0.194), gender (p=0.609) or job category (p=0.913) in either area. However, in Richmond the chainsaw operators were normally hydrated (1.019 g/ml) while the females (1.023 g/ml) and the chainsaw operator assistants (1.024 g/ml) were the most poorly hydrated.

In Nelspruit the number overhydrated had decreased from 23% (n=23) to 14% (n=14) and in Richmond from 13% (n=10) to 10% (n=6) (USG<1.013 g/ml). This was not related to gender (p=0.799) or job category (p=0.612).

4.6.3 End shift hydration status (urine specific gravity)

In Nelspruit 60% and in Richmond 52% of the workers were dehydrated at the end of the shift (Figure 30, Figure 31, Table 20). In addition a further 4% in Nelspruit and 11% in Richmond were seriously dehydrated. The proportion of workers seriously dehydrated was probably higher since those who could not produce urine in Nelspruit (n=3) and Richmond (n=4) were not included in the analysis. Two tried to disguise this by handing in urine bottles filled with spit or portable toilet disinfectant (Figure 32). The blue disinfectant had been scooped out of the bottom of the portable toilets being used in the study. Other causes of blue urine such as Clorets breath mints, magnesium salicylate, guaiacol (cough remedies) and thymol (Listerine) were excluded (Raymond & Yarger 1988).

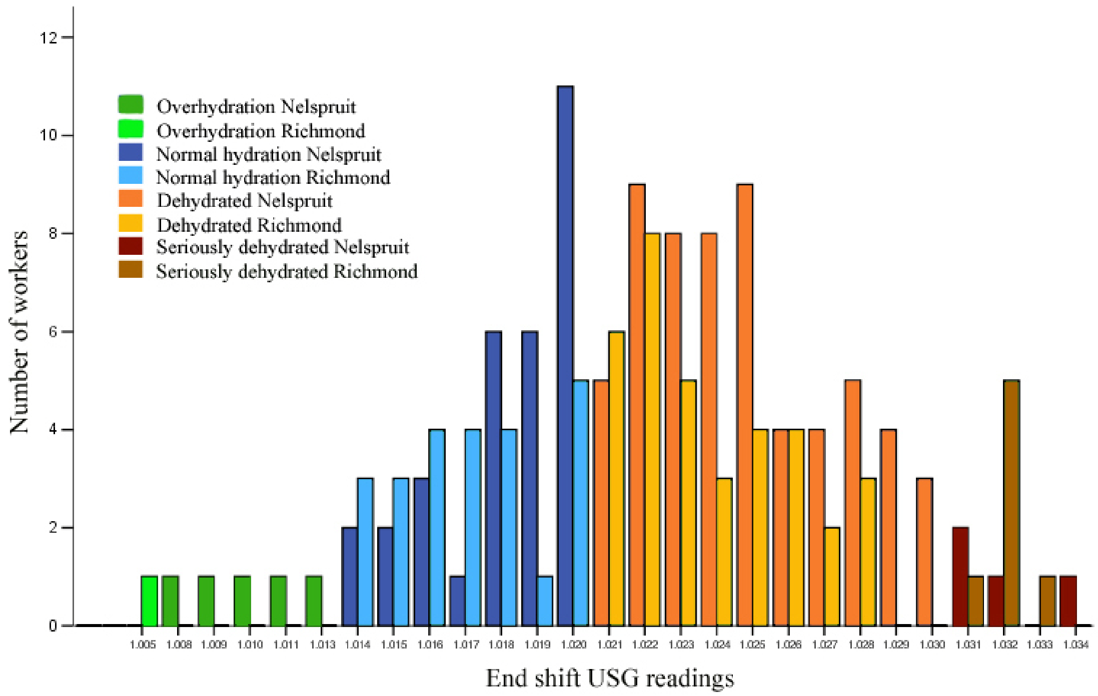

Figure 30: Detailed end shift urine specific gravity readings

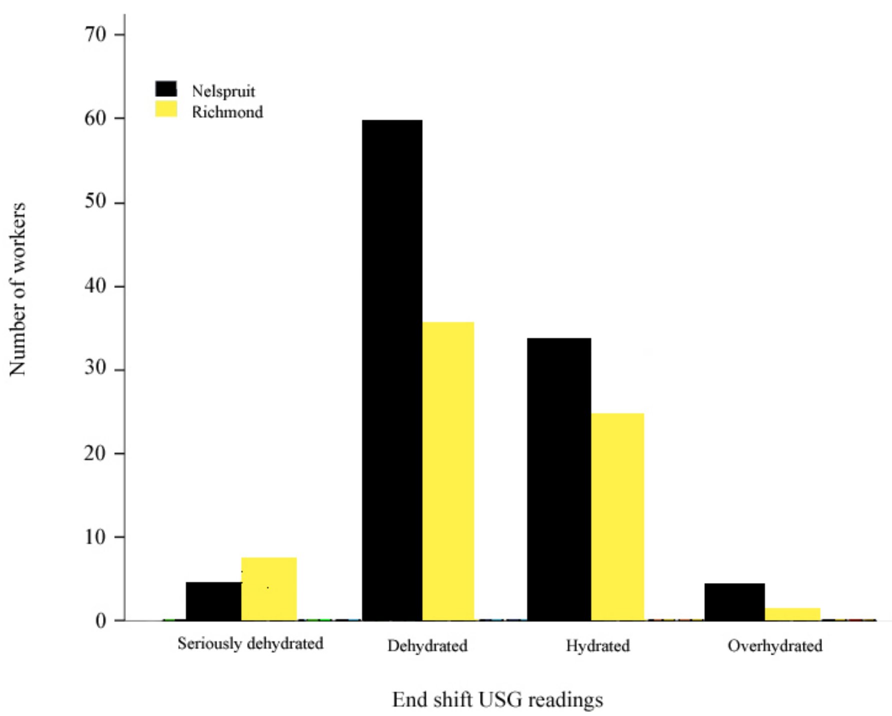

Figure 31: Mean end shift urine specific gravity readings

From the break to the end of shift, there was a highly significant deterioration in hydration status in Nelspruit (p≤0.001) and Richmond (p≤0.001). On average both groups were dehydrated (1.022 g/ml) (Table 20). This was not related to gender in Nelspruit (p=0.089) or in Richmond (p=0.191). Although not related to job category in Nelspruit (p=0.641), the chainsaw operator assistants in Richmond were significantly more dehydrated than the other groups (p≤0.001).

Figure 32: Urine sample bottles containing disinfectant (left) and urine (urine specific gravity>1.030 g/ml) (right)

Overhydration had decreased in Nelspruit to 4% (n=4) and in Richmond to 2% (n=1) (USG <1.013 g/ml). This was not related to gender (p=0.619) or job category (p=0.770). Although 4 out of 5 who were overhydrated were from Nelspruit, this did not reach statistical significance (p=0.330).

4.6.4 Change in hydration status from pre shift to end shift (urine specific gravity)

The mean USG readings significantly increased in Nelspruit ($p \leq 0.001$) and in Richmond ($p=0.043$) from the beginning to the end of shift (Table 20, Figure 33). In Nelspruit ($p=0.887$) and in Richmond ($p=0.763$) the USG readings increased similarly over time for both males and females. In both areas the rate of increase for females appeared slightly steeper than for males but this did not reach significance. In Nelspruit there was no significant difference in the hydration status between the job categories ($p=1.000$). In Richmond the chainsaw operator assistants were significantly more dehydrated than the chainsaw operators ($p=0.002$) and the debarkers/rough liners ($p=0.001$).

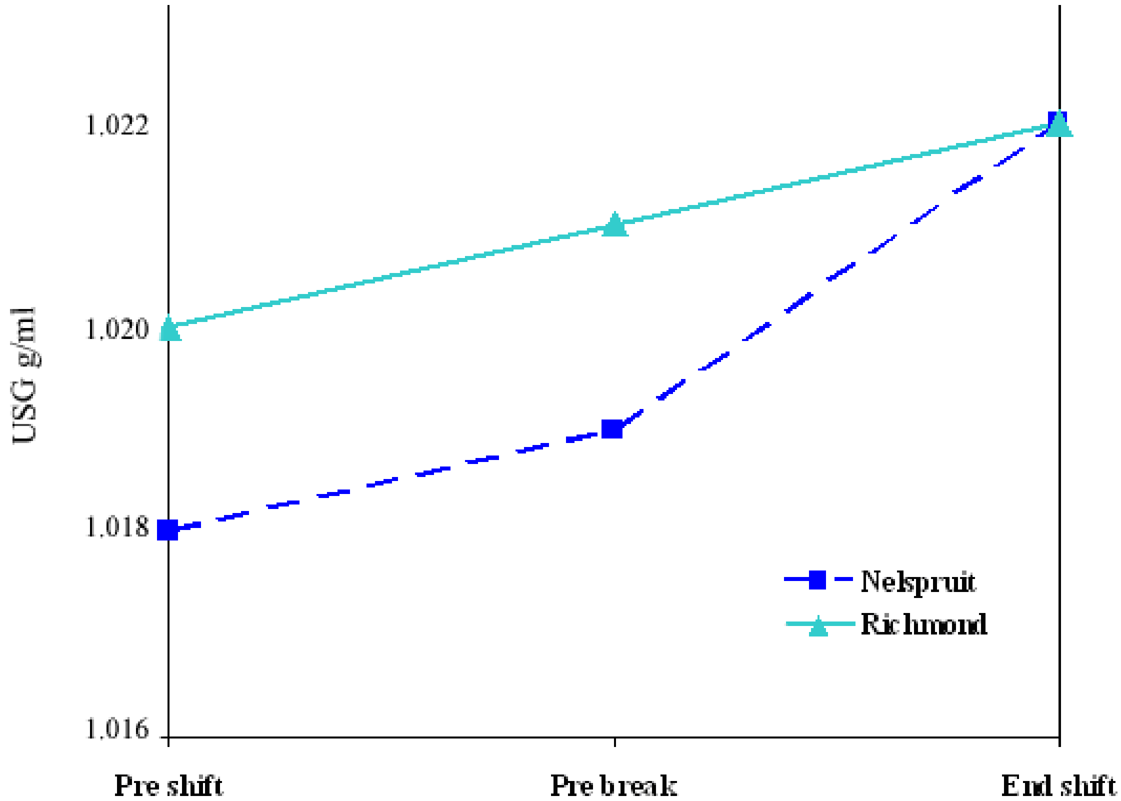

Figure 33: Mean urine specific gravity readings pre shift, pre break and end shift

4.7 HYDRATION STATUS AS DETERMINED BY PERCENT LOSS OF BODY WEIGHT

The percent change of body weight was calculated from pre shift to pre break to determine the change in hydration which had already occurred by the time of the break and from pre shift to end shift to determine the change in hydration across the whole shift.

4.7.1 Percent change of body weight pre shift to pre break

As for the USG, the percent change of body weight was calculated only for the females in Nelspruit. All the females (n=34) drank fluid after starting the shift and before the break. Of these, 53% (n=18) lost 0.8% weight, 9% (n=3) maintained their weight and 38% (n=13) gained 1.2% weight (Table 22). One gained as much as 2.4% and one lost as much as 3.1%.

Table 22: Percent change in body weight pre shift to pre break

		Nelspruit	Richmond
		% change	**% change**
No fluid consumed	**Mean**	**-**	**1.4**
	SD	-	±0.1
	Range	-	1.3-1.5
	Number	0	3
Fluid consumed and weight loss	**Mean**	**0.8**	**0.6**
	SD	±0.75	±0.764
	Range	0.3-3.12	IQR 0.2-1.5
	Number	18	10
	*Comparison	p=0.524	
Fluid consumed and no weight loss	**Mean**	**0**	**-**
	SD	-	-
	Range	-	-
	Number	**3**	-
Fluid consumed and weight gain	**Mean**	**-1.2****	**-0.5****
	SD	±0.75	±0.330
	Range	-2.38 –0.21	0.2-0.7
	Number	13	4
	*Comparison	p=0.020	

* Comparison was done using an independent t- test to compare the difference in percent change between Nelspruit and Richmond

** Due to the nature of the calculations, a – (minus) value indicates a gain in weight.

As for the USG, it was only possible to calculate the percent loss of body mass pre shift to pre break for the first day in Richmond. Of the total of 19 workers sampled on the first day, the females (n=2) were excluded from the analysis due to the small number. Of the 17 males, 18% (n=3) did not consume any fluid and lost 1.4% before the break (Table 22). The remaining 82% (n=14) had consumed fluid from the start of the shift up until the break, although none had maintained their hydration status. Of these, 59% (n=10) had lost 0.6%. One lost 2.7%. The remaining 24% (n=4) who had consumed fluid gained 0.5% of their body weight.

Although there was no significant difference in the percent lost between the Nelspruit and Richmond workers (p=0.524), the Nelspruit workers gained significantly more than those in Richmond (p=0.020).

4.7.2 Percent change of body weight pre shift to end shift

In Nelspruit 5 stackers did not consume any fluid or food during their 4 hour shift[71] (SD±1.15 range 3-5) – they lost a mean of 3.0% of their body weight (SD±0.65 range 2.3-3.8). Without correcting for the food or fluid consumed during the shift, 21% (n=21) of the Nelspruit workers lost more than 2% of their body weight (Table 23, Table 24) and 5% (n=5) had gained over 2% of their body weight.

[71] On this particular day the entire duration of their shift was 4 hours – they did not take a break.

In Nelspruit the males tended to lose weight (0.9%) while the females tended to gain weight (0.2%) (p=0.003), although there was no statistical difference between the mean USG readings of females (1.024 g/ml) and males (1.022 g/ml). According to job category, the debarkers (female) appeared to be more likely to gain weight (p=0.001).

By the end of the shift, all the workers in Richmond had consumed fluid and/or food. Without correcting for this, 23% (n=15) had lost over 2% of their body weight although none had gained weight (Table 23). The loss of body weight was not related to gender (p=0.946) or job category (p=0.767).

Table 23: Classification of percent change of body weight from pre shift to end shift

% loss of body weight		**Nelspruit**	**Richmond**
≥ 1% to < 2%	Percent	19	32
	Number	19	22
≥ 2% to < 3%	Percent	14	19
	Number	14	13
≥ 3% to < 4%	Percent	7	2
	Number	7	1
≥ 4%	Percent	0	2
	Number	0	1
% gain of body weight			
≥ 1% to < 2%	Percent	23	0
	Number	23	0
≥ 2% to < 3%	Percent	5	0
	Number	5	0
≥ 4%	Percent	0	0
	Number	0	0

Table 24: Percent change of body weight pre shift to end shift

		Nelspruit	Richmond
		% change in body weight	**% change in body weight**
All	**Mean**	0.6	1.2
	SD	± 1.53	±1.04
	Range	-2.53-3.70	-0.75 to 4.17
	Number	101	68
	*Comparison	p=0.001	
Males	**Mean**	0.9	1.3
	SD	±1.54	±1.07
	Range	-2.53 to 3.70	-0.67 to 4.17
	Number	62	57
	*Comparison	p=0.142	
Females	**Mean**	-0.2**	0.9
	SD	±1.34	±0.84
	Range	-0.94 to 0.73	-0.75 to 2.06
	Number	39	11
	*Comparison	p=0.047	
Chainsaw operator	**Mean**	1.0	1.5
	SD	±1.58	±0.76
	Range	-2.22 to 3.09	-0.47 to 2.66)
	Number	11	7
	*Comparison	p=0.514	
Chainsaw operator assistant	**Mean**	0.1	1.1
	SD	±1.41	±0.65
	Range	-2.53 to 2.34	0.16 to 1.94
	Number	9	7
	*Comparison	p=0.103	
Stacker	**Mean**	1.2	1.2
	SD	±1.47	±1.11
	Range	-1.94 to 3.70	- 0.75 to 4.17
	Number	40	54
	*Comparison	p=0.415	
Debarker	**Mean**	-0.4**	1.2
	SD	±1.36	±1.11
	Range	-2.27 to 2.90	- 0.75 to 4.17
	Number	41	54
	*Comparison	p=0.032	

* Comparison was the statistical difference using an independent t-test and ANOVA between Nelspruit and Richmond.

** Due to the nature of the calculations a – value indicates a gain in body weight.

As the percent change of body weight was not adjusted for the fluid and food consumed the percent loss of weight was probably underestimated and the percent gain of body weight over estimated.[72]

4.8 SYMPTOMS OF DEHYDRATION END SHIFT

In Nelspruit (but not in Richmond) the workers were asked how they felt physically after the shift ended to determine whether they were experiencing any symptoms of dehydration (Table 25). The most common symptoms reported included tiredness (24%), toothache (13%) and headaches (10%). The end shift USG however was not significantly correlated to the symptoms (p=0.221). Reporting symptoms was significantly related to gender (p=0.030) with the females (49% n=19) being the most likely to have experienced symptoms rather than the males (28% n=18). There did not appear to be any relationship between the reporting of symptoms and the job category (p=0.996).

[72] The reasons for this and the calculations were presented in the methodology.

Table 25: Symptoms experienced at the end of shift in Nelspruit

	Number (n)	**% of total (n=101)**
Very tired	24	24
Toothache	13	13
Headaches	10	10
Appetite loss	6	6
Dry mouth	6	6
Dizziness	5	5
Muscle cramps	5	5
Diarrhoea during shift	3	3
Muscle weakness	3	3
Feeling faint	1	1
Shortness of breath	1	1
Nausea	0	0
Vomiting	0	0

4.9 FLUID REQUIREMENTS

It was only possible to calculate the fluid requirements for those who had not consumed food or fluid during the shift, since it was impossible to monitor the workers actual fluid intake during the shift with any degree of accuracy.

4.9.1 Pre shift to pre break

In Richmond the workers (n=3) who lost 1.4%, because they did not drink pre shift to pre break, lost a mean of 823 g over a 2 hour period and therefore needed to drink 412 ml per hour (Table 26). They carried 994 ml of fluid with them into the forest.

Table 26: Body weight change, fluid required per hour and amount carried into the forest

Percent change of body weight		**Change of weight (g)**	**Fluid required per hour (ml)**	**Fluid carried into forest (ml)**
Lost 1.4% pre shift to pre break in Richmond	**Mean**	**823**	**412**	**994**
	SD	±110	±55	±29
	Range	750-950	375-475	962-1040
	Number	3	3	3
Lost 3% pre shift to end shift in Nelspruit	**Mean**	**1860**	**465**	**1000**
	SD	±288	±121	±567
	Range	1500-2300	375-625	500-1500
	Number	5	5	5

4.9.2 Pre shift to end shift

In Nelspruit the workers (n=5) who lost 3% because they did not eat or drink over their 4 hour shift, lost a mean of 1860 g (SD±298 range 1500 to 2300), indicating that they needed to consume 465 ml per hour to have maintained hydration (Table 26). They took an average of 1 litre into the forest with them.

4.10 SUMMARY

The contractors were unclear about the amount of fluid that they actually supplied per person per day. Those who worked in the less remote areas (Nelspruit) brought their own fluids in addition to what the contractor supplied, while those who worked in the more remote areas (Richmond) depended heavily on what was supplied. Although fluid was left over on each site at the end of the shift, implying that sufficient fluid had been supplied, often the fluid was not placed in close proximity to the harvesting sites and the workers therefore could not access it easily. To decant this fluid so that they were able to take it with them into the forest, the workers needed to supply their own containers. The size and availability of these dictated the amount of fluid that they could carry. The contractors supplied water only either at the ambient air temperature or else frozen. The workers supplemented this with a limited variety of fluids such as tea.

According to the USG readings, over 40% of the workers arrived at work already dehydrated. The dehydration progressively worsened across the day and by the end of the shift over 60% were dehydrated. The risk of dehydration did not appear to be related to season or job category or gender. At the break the mean percent loss of body weight was under 2%. By the end of the shift at least 20% of the workers on each study site were dehydrated a minimum of >2%. Overhydration may be a risk for some (23% Nelspruit, 13% Richmond). End shift symptoms of dehydration could not be related to the USG reading and females were more likely to complain of symptoms. The fluid requirements of male rough liners and stackers appeared to be 412 to 465 ml per hour.

CHAPTER 5: **DISCUSSION**

5.1 INTRODUCTION

The heavy physical labour, the mandatory protective clothing, as well as the hot and often humid working environments, predisposes forestry workers to hyperthermia and dehydration. The aim of the study was to determine the amount and type of fluid supplied by the contractors and the forestry workers in 2 study sites, to establish and compare the prevalence and degree of dehydration in rural SA forestry workers in both autumn and winter and to determine whether there were high risk categories according to gender and job category, to determine the forestry workers fluid requirements and whether they experienced symptoms of dehydration at the end of the shift.

5.2 THE PREVALENCE AND SEVERITY OF DEHYDRATION IN SOUTH AFRICAN FORESTRY WORKERS

At least 40% of the work force in each area was dehydrated on arrival at work in the morning (USG >1.020 g/ml). The importance of this finding was that these workers started their shift already compromised to work to capacity (Casa *et al* 2005), the implication of which was decreased productivity. This was the first SA study which identified that a number of forestry workers were already in a poor state of hydration before the shift. The only other forestry study which measured the hydration status pre shift (Parker *et al* 2002) found similar results as they reported that a number[73] of NZ forestry workers arrived at work dehydrated when working in environmental conditions similar to those in Richmond. The implication was that both locally and internationally a proportion of forestry workers were not drinking sufficient fluid after completing their shift the previous day and when getting up in the morning before leaving for work.

Two hours into the shift, at the time of the morning break, approximately 50% of the work force in each area was dehydrated (USG >1.020 g/ml). It was important to establish this early regression in their hydration status as the contractors involved in each study believed that it was unnecessary to take fluid before the break, since they perceived dehydration to be a risk during the hotter periods of the day only. Those workers who did not eat or drink before the break lost 1.4% of their body mass. This potentially decreased their work capacity by a further 6 to 7% and potentially increased their heart rate by a further 5 to 8 beats per minute (Craig & Cummings 1965). The percent dehydration that these workers experienced was underestimated as they were already dehydrated on arrival at work (mean USG 1.022 g/ml). The implications were that from early on in the shift, the capacity of half the work force was compromised both physically and mentally. As dehydration decreases both physical coordination and mental concentration (Gopinathan *et al* 1988, Sharma *et al* 1986, Craig & Cummings 1965) the importance of this finding was the increased potential for injury and decreased productivity. These findings were in contrast to the only other study which looked at the pre break hydration status (Parker *et al* 2002). Parker *et al* (2002) inexplicably found that the mean hydration

[73]The publication did not specify the number.

levels in the NZ forestry workers actually improved by the break before regressing again by the end of the shift.

At the end of the shift nearly two thirds of the work force (63%) was dehydrated (USG >1.020 g/ml). These results were comparable to those of Parker *et al* (2001), who found that in weather conditions similar to Richmond, 63% of the NZ forestry workers were dehydrated at the end of the shift. Interestingly the NZ forestry workers end shift USG readings of 1.025 g/ml, recorded by Parker *et al* (2002), were higher than those in both Nelspruit and Richmond (1.022 g/ml). The implication was that the SA forestry workers finished their shift in a better state of hydration than the NZ loggers. This finding was unexpected as, unlike the SA forestry workers, the NZ loggers had received education on the importance of adequate hydration, guidelines as to how much fluid to drink as well as education on the signs/symptoms of an inadequate fluid intake (Bates *et al* 2001). The high prevalence of dehydration at the end of the shift was a serious concern both locally and internationally as these workers would need to actively focus on recovery and rehydration to be in optimal condition for the harvesting the next day.

One fifth of the SA forestry workers in each area who had consumed either fluid or food during the shift, had dehydrated by over 2% at the end of the shift. As it was not possible to correct these results for either fluid or food intake or for their state of hydration prior to the shift, this figure was a conservative estimate. In Nelspruit in autumn the 5% who did not eat or drink across the shift dehydrated 3%. These results were similar to the report by Scott *et al* (2004), who found that the SA forestry workers in Kwambonambi dehydrated approximately 3% to 4% over a shift in summer (December, January 32°C, rh 79%).[74] Internationally forestry workers in both Vietnam and Canada were shown to lose approximately 3% of their body mass over a shift (Wästerlund *et al* 2004 citing Wigaeus *et al* 1985, Trites *et al* 1993). The implications of this could have far reaching effects on both productivity and safety as dehydration greater than 2% decreases maximal aerobic power and aerobic exercise ability, thereby decreasing work capacity and work output by up to 50% (Sawka *et al* 2007, Craig & Cummings 1966, Adolph 1947) and significantly decreases both mental and cognitive ability (Gopinathan *et al* 1988, Sharma *et al* 1986). Impaired judgment on the part of the chainsaw operators could result in the death, not only of themselves, but of many of the workers in the surrounding area. Both locally and internationally, the degree of dehydration experienced at the end of the shift was severe enough to significantly impact on the physical and mental abilities of forestry workers, which in turn would deleteriously impact on their safety and their productivity, significantly compromising both their health and livelihood.

Interestingly there was no effect of season on the prevalence and degree of dehydration in the SA forestry workers. This finding was unexpected as the Nelspruit group was thought to be at a higher risk for dehydration due to a number of contributing factors. For example, the environment was hotter with higher rh levels, the study was conducted after a pay day weekend where the consumption of alcohol (a diuretic) was thought to be high and, in addition, they were older. (The ability to withstand heat deteriorates with increasing age) (Sawka *et al* 2007, Casa *et al* 2005). These workers should also have

[74]The forestry workers in the studies by Scott *et al* (2004), Wigaeus *et al* (1985) and Trites *et al* (1993) did not eat or drink across the shift.

been at a higher risk to arrive at work dehydrated after having been exposed to much hotter temperatures and rh levels overnight (autumn). However no relationship was found between the levels of pre shift dehydration and season. These findings concur with that of the only other forestry study that considered the effect of season on hydration status. Parker *et al* (2002) found no seasonal impact on the prevalence of dehydration and concluded that the NZ forestry workers dehydrated as much in winter as in autumn because dehydration was not perceived to be an issue in winter and so they paid less attention to their fluid intake. The importance of this finding was that in spite of the cooler conditions in winter, dehydration and its consequences remained a serious challenge.

This was the only SA study to consider the prevalence of dehydration in female forestry workers. This was very important as approximately one third of the local work force is comprised of women (Edwards 2006, DWAF 2005). No relationship was found between the prevalence and degree of dehydration and gender. This finding was unexpected as the females (mean age 40.85 years, mean BMI 23.7 kg/m^2) in Nelspruit appeared to be at a greater risk as those over 40 years old with a higher BMI are less able to regulate their core temperature in the heat (Sawka *et al* 2007, Casa *et al* 2005).

This study concluded that job category did not affect the risk of dehydration in Nelspruit. This was unexpected as it was predicted that the chainsaw operators and stackers would be more dehydrated. The chainsaw operators were suspected to be at a higher risk due to wearing regulation masks and having petrol contaminated hands. The stackers were considered to be more likely to dehydrate, because it was observed during the study, that they tended to ignore the regulation breaks and they also worked at a higher intensity. This finding was in contrast to the SA study by Scott *et al* (2004) who reported that the stackers in Kwambonambi dehydrated more than the chainsaw operators, although these researchers did not explore the reasons for the difference. In Richmond only the chainsaw operator assistants were shown to be at a higher risk. The reason was unclear as, although they wore the same masks as the chainsaw operators, they wore less protective clothing and did lighter physical work.

The findings of this study, which was the largest in the current scientific literature, focused on hydration in industrial situations and showed that dehydration was prevalent at the start of the shift and that the incidence and severity increased across the shift. At the end of the shift the majority of workers were dehydrated. The degree of dehydration experienced was severe enough to significantly impact on the workers' ability to work productively and to make sound decisions where safety was concerned. Dehydration therefore was identified as being a significant but preventable risk to the well being of the forestry industry. However, by far the greatest danger facing the forestry industry in this regard, was the ignorance surrounding the importance of adequate hydration. This was initially demonstrated in the publication by Trites *et al* (1993) who, when investigating cardiovascular and muscular strain in silviculture, omitted to report the findings of dehydration of 3.1% in either the abstract or the conclusion of the article. Scott *et al* (2004) in their study in SA, attributed the percent loss of body mass across the shifts to be more related to a nutritional deficit than that of inadequate hydration. Although their recommendations to the SA forestry industry included the “supply of fresh, cool water at regular (hourly) intervals during the work shift”, their emphasis was the importance of supplying adequate nutrition rather than adequate hydration. The high working heart rate of the forestry workers in their study was attributed to poor nutrition rather than poor hydration.

5.3 THE PREVALENCE OF OVERHYDRATION

The presence of overhydration was an unexpected but critical discovery. In both Nelspruit (23%) and in Richmond (13%) a number of workers were overhydrated on arrival pre shift (USG <1.013 g/ml). This prevalence decreased by the break (Nelspruit 14%, Richmond 10%) and had further declined at the end of the shift (Nelspruit 4%, Richmond 2%). The implication therefore was that a number of workers were drinking too much prior to the shift and drinking insufficient amounts during the shift. Of paramount importance, however, was that some of the workers who were overhydrated at the end of the shift were also overhydrated at the beginning of the shift. The implication was that a select group of forestry workers were consuming excessive amounts of fluid and were therefore susceptible to potentially fatal dilutional hyponatremia. According to Sawka *et al* (2007), overhydration is less likely than dehydration but is far more dangerous. This was the first study to identify overhydration as a potential risk in industrial situations such as forestry, although the occurrence and consequences had been well established in the military as early as 1998 (Gardner 2002, O’Brien 2001, Reynolds 1998).

Overhydration was also reflected by a gain in the percent body mass. By the break in Nelspruit, 38% had gained 1.2% and in Richmond, 24% had gained 0.5% of their body mass.[75] Although these results were not corrected for the fluid consumed during this period, these findings implied that some workers were drinking too much fluid from their arrival at work up until the period of the break. By the end of the shift, without correcting for their fluid or food intake, over 5% of the workers in Nelspruit had gained over 2% of their body weight. As the body weights could not be corrected for their fluid or food intake, the degree of overhydration was exaggerated. However, the Richmond workers did not gain weight by the end of the shift even though they ate double the weight of food that the Nelspruit workers ate during the shift and were weighed in a similar fashion. The implication was that overhydration in Nelspruit was probably true overhydration although the severity could not be gauged with accuracy. This finding was very important as a small percent of forestry workers were inadvertently being exposed to a potential life threatening condition by drinking too much, probably in an attempt to protect their health by avoiding dehydration.

The risk of overhydration was not related to either gender or job category. Although no significant relationship was found between the risk of overhydration and the area of the study, four out of the five who were overhydrated (USG <1.013 g/ml and percent gain of body mass) were from Nelspruit. From personal observation, the probability of overhydration in Nelspruit was more likely due to the large volumes of fluid being taken

[75]Although the percent gain of body mass indicated that a larger percent were overhydrated at the break than the number indicated by the USG readings some of these workers were dehydrated on arrival at work. Therefore the increased fluid load would not have diluted the USG readings sufficiently to increase them into the range for overhydration.

into the forest by the workers for consumption during the shift. In addition, many of the risk factors for hyponatremia were present in Nelspruit. These included consuming large amounts of hypotonic fluids, since the contractors supplied only water to drink, exercising for periods of over 4 hours, and in some cases, of being over 40 years old and female (Casa *et al* 2007, Sawka *et al* 2007, Casa *et al* 2005). The CHW's in the Nelspruit area encouraged the forestry workers to drink as much water as possible as they thought the practice was safe and that any excess fluid would be urinated (Kolka *et al* 2003). In addition, as part of their education program for the prevention of hypertension, they actively discouraged the use of salt by the forestry workers.

Ironically overhydration and dilutional hyponatremia may be a very real probability for those workers in Nelspruit who followed the CHW's advice closely and increased their consumption of hypotonic fluid (water) to prevent dehydration and decreased their consumption of salt to prevent hypertension (Sawka *et al* 2007, Casa *et al* 2005, Maughan *et al* 2004).

5.4 TYPE OF FLUID CONSUMED

Most of the forestry workers primarily drank the water supplied by the contractors, although some brought a limited variety of other fluids including amahewu, tea and cold drink. A limited variety of fluid promotes taste fatigue and a decreased fluid consumption. Water is not the optimal fluid as it does not contain the necessary CHO and electrolytes (sodium) required for prolonged physical activity. The consumption of large amounts promotes the risk of dilutional hyponatremia (Sawka *et al* 2007, Maughan *et al* 2004, Clapp *et al* 2002).

Amahewu was an excellent choice of fluid as it is a culturally acceptable 7% flavoured CHO solution which contains 26 mg of sodium per 100 ml[76] (Sawka *et al* 2007, Wildman & Miller 2004 p248). In previous years, the Richmond contractor supplied locally made amahewu to the forestry workers (Kamhoot 2005). After a while the workers refused the drink as they claimed that the amahewu gave them diarrhoea because the contractor had poisoned it (Kamhoot 2005). The high incidence of diarrhoea (9% - 17%) in both areas was more likely to have been a consequence of HIV/AIDS and/or food poisoning.[77] Regardless of the cause, the diarrhoea further increased the risk of dehydration by increasing water loss from the body and by the workers' reluctance to drink the fluid supplied by the contractors. The implication was that, although amahewu was a suitable solution for the workers, the forestry industry would need to implement an innovative method of providing the solution since this could not be supplied directly by the contractors due to the level of suspicion of the work force.

The cold drinks that the forestry workers brought to work tended to be 4 to 6% CHO solutions and, although sodium free, they were appropriate choices. Judging from the amounts that the forestry workers carried into the forest, neither the amahewu or cold drinks were consumed in sufficient quantities to supply adequate CHO.

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[76] Amahewu is a fermented mealie meal drink with CHO and sodium concentrations similar to that found in Energade and Powerade.

[77] A small study done by the forestry industry in the Richmond area showed the incidence of HIV infection to be 4 out of 10 (Van Daele 2005). Food poisoning was a high risk as hot food was sealed in containers and then left to stand in the heat for the duration of the shift.

Tea sweetened with sugar was also a good CHO source, although the amount of CHO contained in the solution was difficult to determine as the workers were unclear as to how much sugar they had added. Although the literature previously discouraged the intake of tea and coffee because of the caffeine content and the potential diuretic effect (Parker *et al* 2001), the ACSM Position Paper (2007) stated that the ingestion of caffeine in amounts less than 180 mg/d would be unlikely to exacerbate dehydration (Sawka *et al* 2007). As the mean amount of caffeine (150 mg) contained in the volume of tea consumed by the workers in Nelspruit was less than this, the consumption of tea would have had no impact on hydration and may have increased their physical performance.

Even if water was the only fluid that the industry could supply, the temperature at which it was provided would either encourage or deter the intake, as fluid supplied at 15°C to 21°C is more likely to be consumed (Wildman & Miller 2004 p248). In Richmond no effort was made to place the water containers in the shade, therefore by midday the temperature of the water was unpalatable. In contrast, the Nelspruit contractor went to great lengths to supply as much frozen water as possible, even with very limited facilities. This was greatly appreciated by the workers who came running to get the frozen water whenever they saw the truck approaching from a distance. This demonstrated clearly that even with similar restricted facilities, the attitude and effort on the part of the individual contractors could influence the fluid intake of the workers.

5.5 FLUID REQUIREMENTS

Fluid requirements could only be determined on a subsection of the male workers in this study. The mean fluid requirements per male worker were estimated at 439 ml per hour[78] which extrapolated to 3.5 litres per 8 hour shift. These findings were similar to those of the only other study which investigated the fluid requirements of forestry workers (Paterson 1997). Based on average sweat rates, Paterson (1997) concluded that the NZ chainsaw operators required 500 ml of fluid per hour (4 litres per 8 hour shift). These amounts were lower than that of the ILO (5 litres per worker per day), the DME (1 to 1½ litres per hour) and the US military revised guidelines (710 to 946 ml per hour) (Montain *et al* 1999) but within the lower recommendations of the ACSM (400 to 800 ml per hour) (Sawka *et al* 2007). The implication was that the DME and the ILO recommendations for industry were unrealistic as were those of the US military with the possibility of promoting overhydration if followed locally.

This was the first study in SA to provide fluid guidelines suitable for local conditions in forestry. Being able to recommend a constructive guideline of 450 ml per male worker per hour, was a very important outcome of this study as contractors such as those in Nelspruit, had absolutely no perception of the amount needed or in fact how much they actually supplied. The one litre per worker per day supplied by the Richmond contractor was inadequate.

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[78] This was calculated by adding 412 ml per hour for those in Richmond who did not drink before the break and 465 ml per hour for those in Nelspruit who did not drink across the shift and then dividing this by 2 to get an average.

Although these guidelines were based only on the 8 male workers who did not eat or drink during the day, the size of other international studies investigating fluid requirements were comparable. Paterson (1997) arrived at a similar conclusion in his study based on 8 NZ male loggers. The widely applied revised US military guidelines were based on research conducted on 19 male soldiers. What does need to be taken into account, however, was the fact that these recommendations were based on data from male workers only – they may therefore be too high for female workers as females in general require less fluid and appear to be more susceptible to overhydration and dilutional hyponatremia (Twerenbold *et al* 2003). It should also be kept in mind that there is a wide individual variation in sweat rate, therefore, some workers may need to drink more and others less.

5.6 SYMPTOMS OF DEHYDRATION

As there was no relationship found between those workers who experienced symptoms of dehydration and their USG readings, it cannot be stated with any degree of conviction that symptoms of dehydration were experienced at the end of the shift.

5.7 STRENGTHS OF THE STUDY

This study's results were robust due to:

5.7.1 the large sample size and the repetition of the study over two seasons (winter and autumn) and in two different forestry areas (Nelspruit and Richmond) in collaboration with two independent contractors (Kamhoot and MID). This was the largest study to date, both locally and internationally, investigating the prevalence and severity of dehydration in an industrial setting.

5.7.2 the inclusion of a large sample number of both males and females as well as workers from all the job categories.

5.7.3 the use of two techniques to determine the presence of dehydration. This was the only study in forestry to use more than one technique. This enabled a more accurate determination of the state of hydration and allowed the comparison of this study's results to those of all the other forestry studies as well as those in sports medicine.

5.7.4 the weighing of the forestry workers before and after the shift in minimal clothing. All the other studies weighed the forestry workers fully clothed before and after which would have resulted in an underestimation of the degree of dehydration.

5.7.5 the weather during the study being representative of average weather conditions in both areas.

5.8 LIMITATIONS OF THE STUDY

5.8.1 Relying on the data supplied by the SA Weather Service instead of on site monitoring was unsatisfactory as ambient air temperatures in Nelspruit rose as high as 31°C daily, according to readings taken from the thermometer in the research vehicle, whereas the SA weather services highest recorded temperature in Nelspruit was 26.3°C. This difference was important as it meant that the risk of heat-related illness in Nelspruit could be reclassified as high and not moderate during the hottest periods of the day. To enable a more accurate determination of the risk for heat illness, the temperatures (WB, DB, rh and WBGT) should have been measured on site using a slingometer.

5.8.2 Being unable to effectively monitor the fluid intake across the shift. To monitor the fluid intake would require the allocation of 1 RA to 2 to 3 workers which would be very labour intensive and costly.

5.8.3 The use of less accurate measures of hydration status instead of haematological parameters such as using plasma volume.[79]

[79] Plasma volume is the volume of plasma in the blood – plasma is the fluid in which blood cells are suspended in the body.

5.8.4 The conditions experienced on the two forestry sites that were studied were probably not representative of the situation in forestry as a whole. The study was conducted in collaboration with contractors who had the reputation of being both fair and reputable. The forestry industry felt that those contractors who did not meet the minimum wage and safety requirements would either not agree to the study or would interfere with the execution of the study by being totally uncooperative. It was felt that this study would be difficult enough to execute without additional resistance. The conclusions of this study therefore were based on the best possible scenarios in SA.

5.9 IMPLICATIONS FOR FURTHER RESEARCH

5.9.1 To investigate the possibility of overhydration and dilutional hyponatremia.

5.9.2 To investigate the reasons for dehydration. Since there was fluid left over at the end of the shifts, workers were choosing not to adequately hydrate.

5.9.3 To investigate why dehydration in winter was as prevalent as in autumn.

5.9.4 To investigate the impact of a program (which educates the forestry contractors and workers about the importance of proper hydration) on the prevalence of dehydration.

5.9.5 To determine the fluid requirements of female forestry workers.

5.9.6 To investigate means of supplying fluids at more appropriate temperature.

5.9.7 To investigate the provision of more appropriate fluids such as amahewu in a way that would be acceptable to the forestry workers.

5.10 SUMMARY

Almost half of the forestry workers were already physically compromised on arrival at work as they came to work dehydrated, implying that they were drinking insufficient amounts of fluid after finishing work the previous day and before work the next morning. Early on in the shift, by the time of the regulation break, the number of dehydrated workers had increased to half. This highlighted the fact that dehydration occurred early on in the day which emphasized the importance of starting to drink before the beginning of the shift. Two thirds were dehydrated at the end of the shift. Of these at least 20% had dehydrated by over 2%. This potentially dropped their work output by 50% and increased their risk of injury. There was no effect of season, gender or job category on the risk of dehydration.

A smaller percentage of workers (12 to 20%) arrived at work overhydrated. This number had decreased by the break and by the end of shift, implying that some were drinking too much before the shift and not drinking adequately during the shift. Of critical concern however was the 5% who both started and finished the shift in an overhydrated state. These workers were at risk of dilutional hyponatremia. The risk was probably exacerbated in Nelspruit where the CHW's encouraged the liberal intake of water and discouraged the use of salt to prevent hypertension.

Most of the workers primarily drank water which was the only fluid supplied by the contractors. Some supplemented their intake with a limited variety of other fluids which included amahewu, tea and cold drink. Although both the amahewu and cold drink were appropriate choices to meet the increased CHO needs from prolonged physical activity, neither were brought by the workers in sufficient quantities.

To meet average fluid requirements in local weather conditions during both winter and autumn, the male workers need to drink 450 ml of fluid per hour. As these recommendations were based on data obtained from the male workers only, they may be too high for the female workers as women tend to require less fluid and appear to be more susceptible to dilutional hyponatremia.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

The heavy physical labour, the mandatory protective clothing, as well as the hot and often humid working environments, predisposes forestry workers to hyperthermia and dehydration. The purpose of the study was to ascertain the prevalence and degree of dehydration of rural forestry workers who were using motor manual methods[80] to harvest trees in the KwaZulu-Natal uplands in winter and in Mpumalanga in autumn. The aim of the study was to determine the amount and type of fluid supplied by the contractors and the forestry workers, to establish and compare the prevalence and degree of dehydration in rural SA forestry workers in both autumn and winter and to determine whether there were high risk categories according to gender and job category, to determine the forestry workers' fluid requirements and whether they experienced symptoms of dehydration at the end of the shift.

6.2 CONCLUSIONS

Dehydration was a major challenge to the health of the work force and the health of the SA forestry industry. The many workers who arrived dehydrated were disadvantaged before beginning work and would have been unable to work to their full capacity and productivity during the day. As the prevalence of dehydration increased across the shift,

[80] The harvesting of trees is either fully mechanized or fully manual or a combination of mechanization and manual referred to as motor manual – here machinery such as chainsaws are used to fell trees but the trees are debarked manually using hand held axes.

the workers capacity to work decreased. The majority were dehydrated at the end of the shift. The severity of dehydration experienced could have resulted in a drop of up to 50% in the their work output, with an accompanying escalation in the risk of injury as a consequence of the impaired mental concentration and coordination. If these workers did not attain a good state of hydration prior to the shift the next day, a negative cycle of progressive dehydration and its consequences would be perpetuated.

The conclusion that the prevalence and severity of dehydration was as much of a concern in winter as in autumn was a revelation to the forestry industry as initially they were reluctant to fund a study in winter as they felt that dehydration was not an issue. This was very important to establish so that the prevention of dehydration was not overlooked in the cooler months in SA. Neither gender nor job category increased susceptibility to dehydration. This reinforced the fact that the prevention of dehydration needs to be enforced in all job categories. Prior to the study the SA forestry industry assumed that the chainsaw operators and the stackers were the high risk sub groups.

The most critical finding however was the potential for overhydration which had not previously been suspected in forestry and other industrial settings. An excessive consumption of hypotonic fluid (water), possibly in combination with a reduction in salt intake to prevent hypertension, exposed an important minority of the work force to the potentially fatal risk of dilutional hyponatremia. It is crucial that the forestry industry understands this risk because the implementation of an inappropriate intervention program to prevent dehydration which emphasises the excessive consumption of water and discourages the use of salt on food, may well result in an escalation of the risk of dilutional hyponatremia and a scenario similar to that experienced by the US military.

Fluid guidelines applicable to local SA conditions such as determined by this study and which err on the conservative side are necessary. When compared to the other international fluid guidelines, this study's finding of a fluid requirement of 450 ml of fluid per hour appears to be both sensible and safe as it is on the lower limit of the most recent recommendations by the ACSM. These recommendations will enable the contractors to be more precise in their determination of the amounts they need to supply, as the Nelspruit contractor had no idea what he supplied and the Richmond contractor supplied inadequate amounts. If implemented these recommendations should minimize the incidence of dehydration without promoting overhydration.

Supplying adequate amounts of fluid however does not automatically reduce the prevalence of dehydration as the variety and temperature of the fluid are some of the many factors which affect the palatability. The forestry workers supplemented the water supplied by the contractors with a limited variety of other fluids. Of these fluids amahewu was identified as a promising solution, both to prevent dehydration and to contribute to the CHO needs of the workers. Innovative methods of supplying amahewu to the work force need to be pursued as the inherent suspicion of the work force decreases the ease of implementation. The sustainable supply of cold fluids during autumn and hot fluids during winter to all forestry areas appears to be an insurmountable challenge as there is no electricity on site and the more remote sites are very difficult to access with costly generator powered refrigeration units.

However the major barriers to resolving the hydration imbalance, thereby protecting the health of both the work force and industry, were ignorance and resistance on the part of the forestry industry. Fluid was not perceived as a critical nutrient. In spite of education in this regard, the solution appeared to be too simple and the industry could not come to terms with the fact that the provision of adequate amounts of appropriate fluids were more critical and would contribute more to the workers' health and productivity than the provision of a nutritional supplement.

6.3 RECOMMENDATIONS

6.2.1 Education of the forestry industry regarding the important consequences of both dehydration and overhydration and the steps required to minimize the prevalence.

6.2.2 Compilation, implementation and enforcement of a policy which determines the amount and type of fluid the contractors need to supply to the workers.

6.2.3 The design and implementation of an education program for the contractors, workers and the CHW's which includes the benefits of adequate hydration, the consequences of dehydration as well as related symptoms; the dangers of overhydration and appropriate fluid guidelines which emphasize the need to start drinking early on during the shift. The contractors themselves set a poor example as they openly claimed to deliberately dehydrate when they were in the forest as it was too inconvenient to interrupt their work and find a private place to urinate.

6.2.4 The design and implementation of an education program for the forestry workers which includes the benefits of adequate hydration, the consequences of dehydration as well as related symptoms, the dangers of overhydration and appropriate fluid guidelines which emphasize the need to start drinking early and at frequent intervals across the shift. They also need to be educated to drink on completion of shift, again in the evening and again when getting up in the morning.

6.2.5 The morning rest break needs to be enforced. Shade should be provided if the surrounding trees have been harvested. Additional rest breaks should also be enforced to allow the workers to cool down and recover.

6.2.6 The forestry industry could supply an adequate number of 2 litres containers for use by the forestry workers.

6.2.7 Investigate the provision of amahewu or another culturally acceptable CHO solution. To counteract the suspicion, amahewu made commercially and not locally and supplied in the original commercial packaging, may be acceptable.

6.2.8 The distribution of fluid within the harvesting sites needs to be more closely supervised.

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APPENDIX A: JOB CATEGORIES

Found on the disk is a movie clip which demonstrates the work done by the chainsaw operator, the chainsaw operator assistant, the debarkers and the stackers. Computer sound enhances the appreciation of the clips.

APPENDIX B: RATION PACKS

The contractors involved in this study did give ration packs and both offered what was considered to be reasonable working conditions.

The Richmond workers received a weekly ration pack consisting of soya mince similar to Toppers (½ kg raw), sugar beans (1 kg raw), cake flour (½ kg raw), maize meal (5 kg raw), salt (200 g) and brown sugar (½ kg).

The Nelspruit workers received a monthly ration of 25 kg of maize meal only.

APPENDIX C: THE WOMEN BARK STRIPPERS OF KWAMBONAMBI: CAN JOBS ALONE ALLEVIATE POVERTY?

(directly extracted from the DWAF report 2005)

A group of women working for forestry harvesting contractors on company owned plantations in Kwambonambi were interviewed to assess the extent to which contract jobs in forestry contribute to poverty reduction. The interview took place in the plantation company's forest village, where they are accommodated. The village comprises solidly built brick houses and communal cooking and washing facilities, set in well maintained and attractive grounds. However, inside these houses you get a feeling that it is more of a sleeping than living space, as the only items you find inside is a mattress or piece of cardboard on the floor with a blanket or cloth to cover them. Home to these women is where their children are back in the rural village with their extended family. Children are allowed to visit but not live in the village. All the women are single, aged between 19-40 years, with an average of four children each. They are the sole breadwinners providing support for their children and other members of the extended family back in the rural areas.

The women are all "strippers"; their job is to strip the bark off felled trees. Stripping is physically demanding and carries a high risk of injury. They begin work at six in the morning, and return at around three or four in the afternoon. The daily wage rate currently is at R42.50, but from this R6.50 is deducted for housing, leaving a daily rate of

R36.00. At this rate, working 5 days a week, a worker should expect a wage of around R780 a month, but in reality their pay is between R500 and R720.

The reason for this is the performance based system, or “task system” the women work to. To earn the day wage, they must complete their task, which is to strip 35 trees. If they do not complete their task, it is carried over to the next day. Most of the women said they do not complete their task allocations and they use the Saturdays to narrow the backlog.

Aside from wages, the women have very few employment benefits and no mechanisms for collective bargaining. As contract workers, they do not have access to pension funds, medical care, or paid annual leave. If they fall ill, they need to produce a doctor’s certificate to access paid sick leave. A visit the doctor costs R100, which most are unable to afford. If they are injured on duty the contractor pays a limited number of leave days and thereafter the injured worker must rely on payout from UIF. If they are no longer employed, they are given 10 days to vacate their accommodation.

With HIV/AIDS infections rates running at an estimated 39% amongst forestry workers, a distressing picture emerges of scores of penniless, ill, and malnourished workers being sent back to die in rural areas, without any benefits from their years of employment.

The women go home once a month on Sunday after they are paid. This is the only time they have to spend time with their children and families, and to take home food and cash. The women listed the basic food items they take home every month, the cost of which amounts to around 60% of their earnings. They also need to leave money at home for school fees and transport, and other day-today purchases, leaving very little left for them to live off for the rest of the month. Most of the women said they get credit to buy food and other necessities for themselves from the local general dealer. When the next month wages come in they first must pay back this debt. Debt traps such as these are an indicator of chronic poverty.

Undoubtedly, forestry contracting provides jobs to the rural poor and particularly women. However, under the current conditions, and with no mechanisms in place for collective bargaining, the prospects for the majority of forest workers to get out of chronic poverty and indebtedness appear bleak (DWAF 2005).

APPENDIX D: 1988 US MILITARY FLUID REPLACEMENT GUIDELINES FOR HOT WEATHER TRAINING (after Montain *et al* 1999 citing the United States Army Medical Centre 1988).

Criteria		**Controls**	
Heat condition category	**WBGT index (degrees C)**	**Water intake (ml/hour)**	**Work-Rest Cycle (min)**
1	25.5 - 27.7	At least 473	continuous
2	27.8 - 29.3	At least 473	50/10
3	29.4 - 31.0	At least 946	45/15
4	31.1 - 32.2	At least 1419	30/30
5	32.3 -	More than 1892	20/40

APPENDIX E: HOT WEATHER TRAINING FLUID REPLACEMENT GUIDELINE FOR AN AVERAGE ACCLIMATED SOLDIER WEARING BATTLE DRESS UNIFORM (after Montain *et al* 1999).

		Easy Work		Moderate Work		Hard Work	
Heat category	WBGT Index (C)	Work-rest Cycle (min)	Water Intake (ml/hr)	Work-rate Cycle (min)	Water Intake (ml/hr)	Work-rate Cycle (min)	Water Intake (ml/hr)
1	25.5 - 27.7	NL	473	NL	710	40/20	710
2	27.8 - 29.3	NL	473	50/10	710	30/30	946
3	29.4 - 31.0	NL	710	40/20	710	30/30	946
4	31.1 - 32.2	NL	710	30/30	710	20/40	946
5	32.3 -	50/10	946	20/40	946	10/50	946

APPENDIX E: HOT WEATHER TRAINING FLUID REPLACEMENT GUIDELINE FOR AN AVERAGE ACCLIMATED SOLDIER WEARING BATTLE DRESS UNIFORM CONTINUED (after Montain *et al* 1999).

The work-rest times and the fluid replacement volumes will sustain performance and hydration for at least 4 hours of work in the specified heat category. Individual water needs will vary ±237 ml/h.

NL, no limit to work time per hour. Rest means minimal physical activity (sitting or standing) and should be accomplished in shade if possible.

Caution: Hourly fluid intake should not exceed 1419 ml.

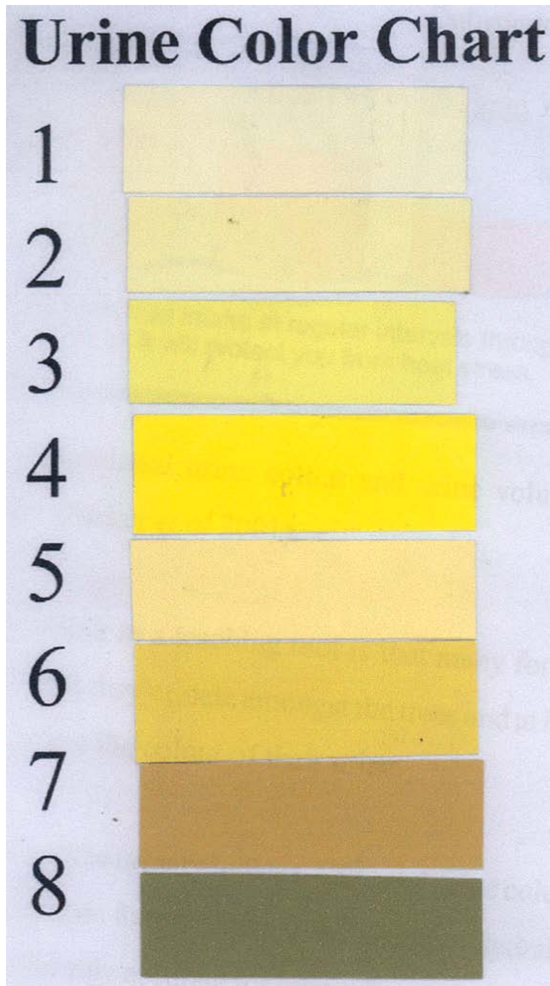
Daily fluid intake should not exceed 11352 ml

Mission-Oriented Protective Posture gear adds 10 to WBGT index.

Examples of work intensities are shown below.

Easy Work	Moderate Work	Hard Work
Weapon maintenance Walking hard surface at 2.5 mph, #30 lb load. Manual of arms Marksmanship training Drill and ceremony	Walking loose sand at 2.5 mph, no load Walking hard surface at 3.5 mph, #40 lb load Calisthenics Patrolling Individual movement techniques, i.e., low crawl, high crawl Defensive position construction Field assaults	Walking hard surface at 3.5, ∃40 lb load Walking loose sand at 2.5 mph, with load

APPENDIX F: URINE COLOUR CHART (Armstrong *et al* 1998)



APPENDIX G: MODIFIED URINE COLOUR CHART USED BY THE CENTRE FOR HUMAN FACTORS AND ERGONOMICS (Parker *et al* 2001)

APPENDIX H: DATA COLLECTION BOOKLET

<u>Preshift</u> Data Collection Form

Date			Identity code	___ ____ ____

Chainsaw operator 1	Assistant 2	Peeler 3	Stacker 4

Urine Sample

Obtained urine sample:	Yes 1	No 2	
If no state reason:			

Have you had anything to eat or drink this morning?		Yes 1	No 2
If yes what time did you eat or drink?			
What did you have to eat and/or drink?			
Did you have diarrhoea last night or this morning?		Yes 1	No 2
Did you vomit last night or this morning		Yes 1	No 2
Are you menstruating?	Does not apply 3	Yes 1	No 2

Body Weight (kg)

1st measure	2nd measure	3rd measure	Average

Body Mass Index
___ ____.___

Height (m)

1st measure	2nd measure	3rd measure	Average
__ . __ __ __	__ . __ __ __	__ . __ __ __	__ . __ __ __

Total fluid weighed in morning before starting the shift

Description of Fluid	Weight (g)

Questionnaire

Zulu 1	**Sotho** 2	**Xhosa** 3	**Other** 4

Date of birth	___ ___	___ ___	___ ___ ___ ___	**OR**	**Approximate age in years**	

Do you regularly attend a clinic?	Yes 1	No 2	**Do you feel that you are healthy?**	Yes 1	No 2

Have sugar? (diabetes)	Yes 1	No 2	Don't know 3	**Have pressure?**	Yes 1	No 2	Don't know 3

Have diarrhoea often?	Yes 1	No 2	**Vomit often?**	Yes 1	No 2	**Pregnant**	Yes 1	No 2	Not applicable 3

Anything wrong with kidneys?	Yes 1	No 2	Don't know 3	**Anything wrong with heart?**	Yes 1	No 2	Don't know 3

If yes to kidney or heart problems please describe

Do you take any medicine regularly? If yes please list.

Do you take any vitamins, food or herbal supplements regularly? List.

How many years or months have you worked in the forest in this area?	____ ____ years	AND/ OR	____ ____ months

Which area/province do you think of as home? Where does your family live?

Gauteng 1	Limpopo 2	Mpuma Langa 3	Swazi Land 4	KZN 5	Free State 6	North West 7	Lesotho 8	East Cape 9	North Cape 10	West Cape 11

Stay in the compound 1	Stay at home 2	Other 3	If other please specify.

What type of alcohol do you drink at night during the week?	
What amount of alcohol do you drink at night during the week?	

What type of alcohol do you drink during the week end?	
What amount of alcohol do you drink at the week end?	

Fluid intake during the shift

Time of intake	Description of fluid ie drank half their bottle

Body Weight (kg)

1st measure	2nd measure	3rd measure	Average

End shift data collection form

Urine Sample	Obtained urine sample:	Yes 1	No 2	
	If no state reason:			

Body Weight (kg)	1st measure	2nd measure	3rd measure	Average

Did they feel any of the following during the day?

Headache 1	Dizzyness 2	Appetite loss 3	Nausea 4
Vomiting 5	Feeling faint 6	Short of breath 7	Very tired 8
Dry mouth 9	Toothache 10	Diarrhoea 11	Muscle cramps 12
Muscle weakness 13	Other		

Total fluid left over at end of shift

Description of Fluid	Weight (g)

APPENDIX I: FACTORS WHICH COULD HAVE POTENTIALLY IMPACTED ON THE URINE SPECIFIC GRAVITY READINGS AND THE INFLUENCE THEY ACUTALLY HAD ON PRE SHIFT, PRE BREAK AND END SHIFT ANALYSIS

	Chronic medication (number)*	**Difference in pre shift analysis**	**Difference in pre break analysis**	**Difference in end shift analysis**
Nelspruit	4	p=0.924	p=0.680	p=0.816
Richmond	1	p=0.738	p=0.400	p=0.403

	Vitamin and/or herbal preparations (number)	**Difference in pre shift analysis**	**Difference in pre break analysis**	**Difference in end shift analysis**
Nelspruit	3	p=0.888	p=0.321	p=0.854
Richmond	6	p=0.559	p=0.190	p=0.678

	Pre shift diarrhoea/ vomiting (number)	**Difference in pre shift analysis**	**Difference in pre break analysis**	**Difference in end shift analysis**
Nelspruit	4	p=0.740	p=0.920	p=0.910
Richmond	1	p=0.564	p=0.236	p=0.993

	Menstruating (Number)	**Difference in pre shift analysis**	**Difference in pre break analysis**	**Difference in end shift analysis**
Nelspruit	2	p=0.504	p=0.659	p=0.185
Richmond	1	p=0.286	p=0.225	p=0.067

	Use of caffeine (tea) (number)	**Difference in pre shift analysis**	**Difference in pre break analysis**	**Difference in end shift analysis**
Nelspruit	35	p=0.434	p=0.848	p=0.660
Richmond	9	p=0.568	p=0.943	p=0.679

* This column in all these tables represents the **number** and not the percent of the sample.

APPENDIX J: TRAINING MANUAL

What is the study about?

The study is being done to find out what forestry workers are drinking over a day.

Why is the study being done?

Since the forestry workers harvest in hot areas where there is often little to drink, dehydration is very likely to occur. Dehydration causes both short term and long term health problems and interferes with their ability to work, especially to work safely - it is important therefore to establish whether dehydration is a serious problem among the forestry workers and if so to find possible solutions. From this study guidelines will be developed to help the forestry industry know how much fluid their workers need to stay healthy and work efficiently.

Who is doing the study?

The Discipline of Dietetics and Human Nutrition from the University of KwaZulu Natal Pietermaritzburg in conjunction with the Institute of Commercial Forestry Research.

Who is in the team?

Apart from you guys there will be three of us from the University. All three of us are dieticians - Shanine and I lecture dietetics and human nutrition at the University and Mandy lectures part time and also works for a large hospital in Durban.

I designed the study and am responsible for the organization and successful implementation. If you don't understand something or want something explained please ask me to help you.

How many forestry workers will be measured and for how long?

I am aiming to study 25 forestry workers each day over a total of 4 (Monday to Thursday). Each forestry worker will only take part in the study for one day so a total of 100 different forestry workers will be studied. Some of these will be chainsaw operators and stackers - the rest will be debarkers.

What does the study involve?

Apart from hard work and some fun..........

It is absolutely essential that the measurements are taken as accurately and as efficiently as possible to prevent unnecessary disruption to the shifts as the study needs to measure what is actually happening on an average working day.

The team will need to get into the forest and set up before the forestry workers arrive - a very early start each day.

Obtaining informed consent and urine samples

Before the team can start any measurements in the morning, the reason for the study and what participation involves needs to be explained in their own language to the workers who want to take part in the study. Those who are agreeable will then be asked to sign the informed consent form. No one can take part in the study until they have signed this form - there will be ink pads for thumb printing for those who cannot write.

Therefore, on arrival, one of you will briefly explain what we want to do and how we want to do it and then all of you will get the informed consents while the university staff are setting up the equipment for the testing. We will have gas lights as this needs to be done before it is light.

Once the person has signed the consent form, a numbered identity tag needs to be securely fastened around their left wrist.

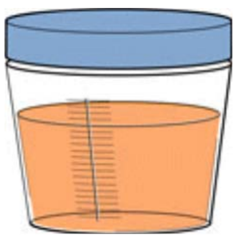
IF THE FORESTY WORKER DOES NOT HAVE AN IDENTITY BRACELET AROUND THEIR LEFT WRIST THEY HAVE NOT SIGNED INFORMED CONSENT - DO NOT PROCEED - REFER THEM BACK TO THE INFORMED CONSENT TABLE IMMEDIATELY!

Write their identity number on the front of the data sheet and on a urine sample bottle. Give them the urine sample bottle with a piece of paper towel, explain that they need to discard the first bit of urine and then wee into the bottle - they need to give about a third of a bottle of urine. It is important that they do the urine sample immediately after the informed consent as they must have urinated before being weighed.

To do this you need to make sure that when you arrive in the morning you have the consent forms, pens, ink pads, clipboards, identity wrist tags and the data files.

Please make sure that you keep all the consent forms and give them to me as soon as you have managed to get them all signed.

Collecting urine samples



The forestry worker should approach you with a urine sample bottle clutched in a paper towel. Dry the urine sample bottle with a paper towel, check that the lid is properly closed (not too tight) and put it in the box. Make sure that the bottle is labeled. Fill in on their data sheet whether you have obtained a urine sample or not.

Ask the worker whether he/she ate or drank in the morning before work, whether they had any diarrhoea or vomiting the night before and whether they are menstruating. If yes, please notify a supervisor.

Once the urine samples have been collected, the worker is then sent to the tent where the weights and heights are being measured.

Measuring body weights and heights

Hand the forestry workers their lycra outfits or underpants. Explain that they need to go inside the tent and take off all their clothes and put on the lycra outfits only. They will need to call you when they are ready. It is very important that you weigh them in lycra only (no shoes, socks etc) and if they are hot and sweaty please ask them to towel dry.

The scales will be placed on top of leveling platforms to make sure that the scales are level and steady so accurate weights can be taken.

Switch on the scale and wait for the scale to zero. Ask them to stand flat footed on the centre of the scale without support. Their feet need to be slightly apart and their weight evenly distributed. They must look straight ahead. Record the measurement on the data collection form. Ask them to step off the scale. Wait for the scale to switch off. Switch the scale back on. Repeat the measurement. These readings should not differ by more than 0.1 kg. If they do, take a third measurement. Average the 2 closest measurements.

The height measured will be placed on top of a leveling platform to ensure that the height stick is stable on the ground.

The person must be bare foot. They must stand with their back to the height measure with their legs together, feet flat, their heels touching each other and the base of the height measure. Their buttocks and back of shoulders must be against the height measure. Their arms need to be relaxed at their sides. They must stand up straight looking straight ahead with their head aligned in the Frankfurt plane. If the person is very tall, you may need to stand on a chair to take the reading. Ask the person to breathe in and then gently lower the height measure onto the crown of their head making sure that the hair is compressed. The other CHW needs to stand in front and check that the height measure is on the crown of the head. Take the reading at the bottom of the head piece to the nearest 0.1 cm. Record the measurement on the data collection form and repeat the reading. The readings should not differ by 0.2 cm. If they do take a third measurement. Average the 2 closest measurements.

Once the heights and weights have been taken, please ask them to put their clothing back on over the lycra outfits/underpants. When they have finished the shift, they will be weighed again in the same outfits.

Once their heights and weight have been done, they can either answer the questionnaire or bring their fluid to be weighed.

Asking the questionnaire

Please ask the questions in the manner and order in which they appear on the questionnaire.

If they do not know their date or year of birth then you need to ask them how old they are and fill this in the block on the far left. If they attend a clinic regularly then they should have health problems which you need to establish. Being pregnant would affect their body weight and so impact the study results. They will probably know what sugar (diabetes) and pressure (high blood pressure) are. A yes to either the diarrhoea and/or vomiting means this happens frequently. They probably will not know what kidney and heart problems are - these questions, however, need to be asked as these conditions affect dehydration and the study needs to be able to state that these were controlled for.

The amount of water needed to prevent dehydration is affected by how long the person has worked in the area and whether they are used to the weather conditions and also by how often they have done this type of work. The question "Where do you think of as home? Where does your family live?" is to establish where they come from, as many of the forestry workers are migrant laborers staying in the compounds and going home for a 3 day weekend every 2 weeks.

If they refuse to answer a question, then go onto the next question and make a note on the questionnaire that they refused to answer.

Before letting a forestry worker begin work please send them to either myself, Mandy or Shanine so that their forms can be checked before they go off.

Following the workers into the forest

Take your fluids and lunch with you and go with the workers into the forest. Each of you will need to watch 4 people. The purpose is to write down exactly what they had to drink and at what times. You need to record whether they throw away the water instead of drinking it or else spit it out ie rinse their mouth or whether someone else drinks their water. It is very important that good records are kept as to exactly how much they are drinking.

APPENDIX K: CONSENT FORM

Consent to Participate in Research

You have been asked to participate in a research study. Ethics approval has been received from the University of Natal, Nelson Mandela School of Medicine Ref.: E045/05

You have been informed about the study by Mr Michael Hlengwa.

You have been informed that you will be fully compensated for any inconveniences.

You may contact Chara Biggs (principal investigator) at 0825750029 any time if you have questions about the research.

You may contact the Medical Research Office at the Nelson R Mandela School of Medicine at 031-2604604 if you have questions about your rights as a research subject.

Your participation in this research is voluntary, and you will not be penalized or victimised in any way or lose any benefits if you refuse to participate or decide to stop. The information collected during the study will not be used to punish you and will not negatively affect your job in any way. The results which relate to you individually will not be told to anyone else.

If you agree to participate, you will be given a signed copy of this document and the participant information sheet which is a written summary of the research.

The research study, including the above information, has been described to me orally. I understand what my involvement in the study means and I voluntarily agree to participate.

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Signature of participant Date

-- -----------------

Signature of Witness Date

--- -----------------

Signature of Translator Date

APPENDIX L: ETHICS APPROVAL FORM

UNIVERSITY OF
KWAZULU-NATAL

25 April 2005

Ms C Biggs
Department of Dietetics
PIETERMARITZBURG

Dear Ms Biggs

PROTOCOL : The dietary intake and the prevalence and degree of dehydration in South African forestry workers and the effect of replacement solutions on heart rate, perception of effort, coordination, grip strength and blood sugar levels. C Biggs, Dietetics. Ref.: E045/05

The Biomedical Research Ethics Committee considered the abovementioned application and the protocol was approved at its meeting held on 1 March 2005 pending response to queries raised on 10 March 2005. These conditions have now been met, the study is give full ethics approval and may begin as at today's date : (25 April 2005)

This approval is valid for one year from 1 March 2005 To ensure continuous approval, an application for recertification should be submitted a couple of months before the expiry date.

May I take this opportunity to wish you everything of the best with your study. Please send the Biomedical Research Ethics Committee a copy of your report once completed.

Yours sincerely

PROFESSOR A DHAI
Chair : Biomedical Research Ethics Committee

Nelson R Mandela School of Medicine, Faculty of Health Sciences,
Head: Bioethics, Medical Law and Research Ethics

Postal Address: Private Bag 7, Congela 4013, South Africa

Telephone: +27 (0)31 260 4604 **Facsimile:** +27 (0)31 260 4529 **Email:** dhaia1@ukzn.ac.za **Website:** www.ukzn.ac.za

Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville

APPENDIX M: INFORMATION SHEET

A STUDY ON WHAT FORESTRY WORKERS DRINK

THE PREVALENCE AND DEGREE OF DEHYDRATION IN SOUTH AFRICAN FORESTRY WORKERS.

Why are we doing a study?

There are many different studies that are done in work places. Studies are done to learn answers to questions. You will remember that there was an HIV infestation study done up to January this year to help our industry. In this new study we want to learn about what you drink every day both during work time and at home in the evenings.

Who is doing the study?

The study is being done by the Forestry Industry and the Discipline of Dietetics and Human Nutrition from the University of KwaZulu Natal in Pietermaritzburg.

Who is being studied?

The study is on people who chop down trees, cut off branches, take off bark and stack logs together.

How many are being studied?

We want to study eight teams. The study will last for 4 days with 2 teams taking part each day. Your team will be studied for 1 day so your measurements will be taken for one day only.

<u>What will happen when you are being studied?</u>

To make the results of the study accurate so that the information can be helpful to you and the forestry industry, we need to do our measurements very carefully and in a very specific way – please be patient!

Before you start work in the morning you will be asked a short questionnaire which will include questions about where your home is and what medicines you take often. If you are on medication of some sort, please bring it with you so we can write the name down. If you use any bottle of medicine from your traditional healer, please bring this if possible. There will be personal questions asked particularly of the ladies. Please feel free to give factual responses.

We then need you to give us a urine sample. A tent will be on site. We will ask you to go into the tent, take off your clothes and put on a special pair of pants. You will then be weighed in the tent in these pants without other clothes or boots on so we can measure very accurately what you weigh. This is very important. You will then put your other clothes on over these pants. Each time we weigh you it will be in these pants without other clothes and shoes. You may keep these pants at the end of the day. Your height will be measured without shoes on. The team will also record how much water you are taking into the forest with you.

After this you will go in the forest and begin a normal days work. The people doing the study will be in the forest with you so they can get a good understanding of exactly what type of work is done by forestry teams.

At the morning break you will be weighed again in your special pants after drying yourself with a small hand towel. You may keep the towel at the end of the day. The team will first measure what you drank if anything while you were working. The team will then measure what you drank, if anything, while you were working. Remember that the team needs to know about everything you drink. Please help the team here by making sure that they have measured everything that you have taken. Before you go back into the forest, please show the team how much water you are taking with you to drink so they can write this down.

After the rest break you will go back into the forest and work as usual.

At the end of your shift you will give a urine sample and be weighed again in your special pants after drying yourself with a small hand towel.

<u>How will this effect my work and pay?</u>

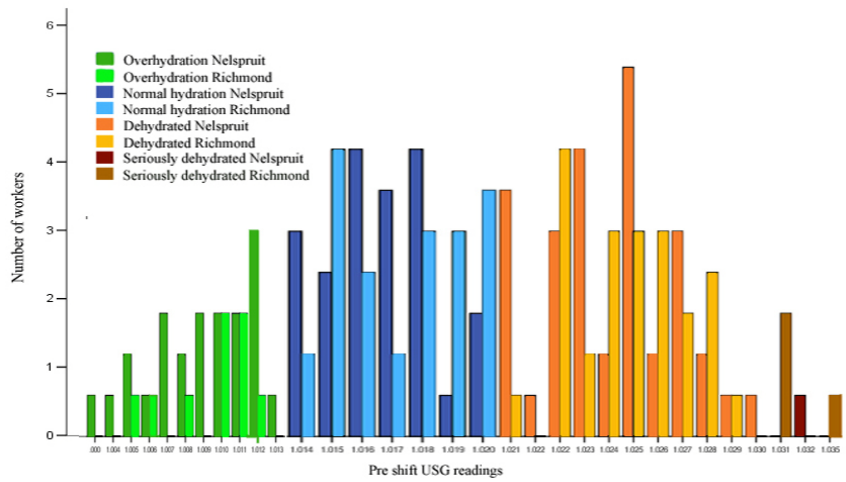
The measurements will be done as quickly as possible so as to interfere very little with the time that you have to work. We need you to work normally at your task finishing pace, otherwise the information gathered will be misleading.

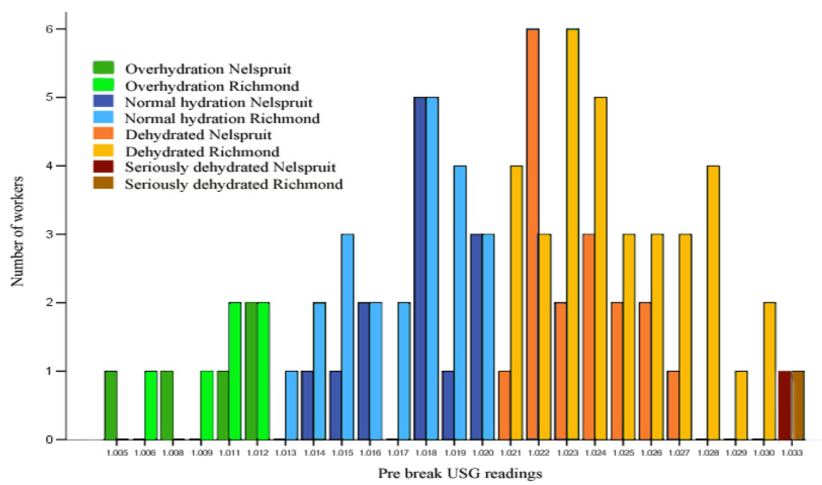
There is no risk in participating in the study. You are being asked to take part in this study.

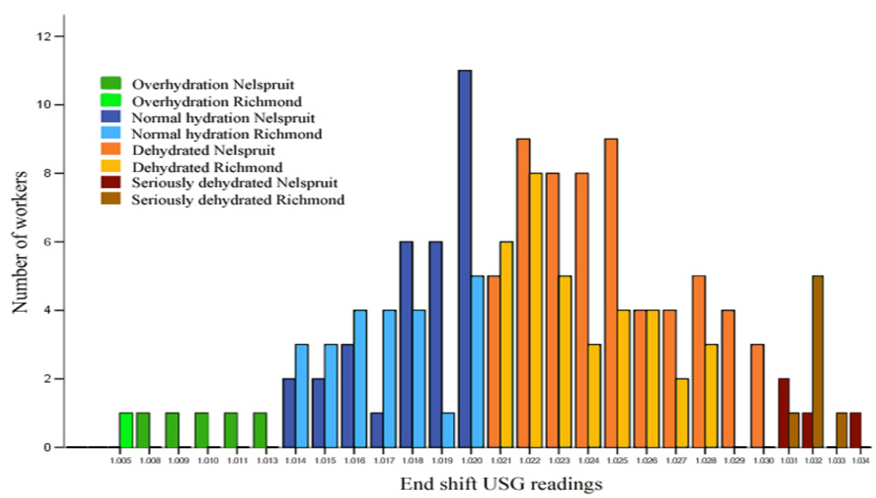
All information gathered will be for this study only and it will be kept confidential. We may give out personal information only if we are legally bound but nothing personal will be available to any employer. Organizations that may want to see what we did and how, include Research Ethics Committee. We have obtained approval from the University of Natal and Nelson Mandela Medical School (Protocol E045/05), who have satisfied themselves that we are doing the study in a correct and humane manner that respects human dignity.

The main researcher is Chara Biggs 033 2606153 or 0825750029. If you are unhappy, report to Ethics Committee 0312604604.

APPENDIX N: DETAILED URINE SPECIFIC GRAVITY READINGS PRE SHIFT, PRE BREAK AND END SHIFT







APPENDIX O: MEAN URINE SPECIFIC GRAVITY READINGS PRE SHIFT, PRE BREAK AND END SHIFT