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Supporting healthy lifestyles in the mining industry: a focus on nutrition, physical activity, hydration and heat stress

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SUPPORTING HEALTHY LIFESTYLES IN THE MINING INDUSTRY: A FOCUS ON NUTRITION, PHYSICAL ACTIVITY, HYDRATION AND HEAT STRESS

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By

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CERTIFICATION

I, Vinodkumar Gopaldasani declare that this thesis, submitted in fulfilment of the requirements of the award of Doctor of Philosophy in the School of Health and Society, University of Wollongong, is my own work unless otherwise referenced or acknowledged. This document has not been submitted in whole, or in part, for qualifications at any other academic institution.

Dr Vinodkumar Gopaldasani

On the 29th of July, 2016

DEDICATION

To my wonderful father, Kishinchand, whose patience, persistence and dedication to his children and their education inspired me to pursue my PhD. Your steadfast belief in me, and your support and love, allowed me to complete this journey.

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BOOK CHAPTERS, PRESENTATIONS AND REPORTS ARISING FROM THIS RESEARCH

Book Chapter

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Flood, V. and Gopaldasani V. 2013, "Extending knowledge of food components", In: Tapsell L. ed. Food, Nutrition and Health, First Edition. Oxford University Press.

Presentations

Gopaldasani V., Flood, V. Davies, B., Whitelaw, J, “Hydration that works”, accepted for presentation at the Australian Institute of Occupational Hygienists 34th Annual Conference, Melbourne, Dec 2016.

Gopaldasani V., Flood, V., Davies, B., Whitelaw, J. and Kelly, B., "Putting "Health" back into Occupational "Health" and Safety", Australian Institute of Occupational Hygienists 32nd Annual Conference, Melbourne, Nov-Dec 2014.

Gopaldasani V. and Hodgetts, W. "Overview of Healthy Miner Research", presentation to the NSW Metalliferous Industry Safety Advisory Committee (MISAC), May 2014.

Unpublished report

Gopaldasani V., Davies, B., Kelly, B., Whitelaw, J. and Flood, V. "Heat Stress at Barrick Cowal Gold Mine", a preliminary report, 2014.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACGIH – American Conference of Governmental Industrial Hygienists

BEVQ – Beverage intake questionnaire

BMI – Body mass index

bpm – beats per minute

°C – degrees Centigrade

CHEW – Checklist for health promotion environments at worksites

CI – Confidence interval

DB – dry bulb temperature

ET – Effective temperature

FFQ – Food frequency questionnaire

FIFO – Fly-in Fly-out

FR – Food record

g – Gram

GT – Globe temperature

HBM – Health belief model

ISO – International Standards Organisation

Kg – Kilogram

KJ – Kilojoule

LOA – Limits of agreement

m – Metre

MET – Metabolic equivalent of tasks

µg – microgram

mg – milligram

mL – millilitres

mmHg – millimetres of mercury

mmol/L – millimoles per litre

PHS – Predicted heat strain

RH – Relative Humidity

SCT – Social cognitive theory

SD – Standard deviation

TBW – Total body water

TWL – Thermal work limit

USG – Urine specific gravity

W/m^2 – Watts per metre square

WB – wet bulb temperature

WBGT – Wet bulb globe temperature

ABSTRACT

The high prevalence of overweight and obesity among workers in the mining industry in Australia poses a significant public health risk. There is a high burden associated with overweight and obesity among this cohort of workers to both the employer and the worker in terms of productivity loss, absenteeism, presenteeism (attending work while sick) and increasing risk of chronic diseases such as diabetes, hypertension and cancer. Therefore, a workplace health promotion program was identified as important and worthy of further investigation. The aim of this thesis was to determine the feasibility and effectiveness of a one year workplace health promotion program that aimed to reduce the overweight and obesity rates, and to improve the hydration status of a cohort of workers in the mining industry.

A pre-experimental study was conducted to investigate the feasibility and effectiveness of a one-year workplace health promotion program to reduce the body mass index (BMI) and improve hydration status among participants. The results of this study showed that among study completers (n=83), 83.2% of participants were either overweight or obese (42.2% overweight and 41% obese) at baseline. After one year of the workplace health promotion program, 80.7% of participants were either overweight or obese (38.6% overweight and 42.1% obese) resulting in a 2.5% decrease in the overall overweight and obesity rates. There was an increase in the consumption of core foods, especially fruit intake, from a mean of 1.1 serves per day to a mean of 1.9 serves per day (P=0.0249), nearly meeting the

Australian Dietary Guidelines and the Australian Guide to Healthy Eating of 2.0 serves per day. Reported physical activity improved in females from 303 MET minutes / day to 331 MET minutes / day (P=0.738) but decreased in males from 391 to 367 MET minutes / day (P=0.751). There was an improvement to the work environment at the mine site in terms of being a 'health promoting worksite'. Specifically, the number of posters and signage about healthy nutrition, physical activity, smoking and alcohol increased throughout the year. Contents of the vending machines and refrigerators at the site were reviewed and an increased number of healthier options was included.

With regards to dehydration and heat stress, 73% of participants started their shift dehydrated. By the end of the one-year health promotion program, only 31% of participants started their shift dehydrated, an improvement of 58% from baseline. Correlation of hydration status of workers with potential risk factors such as age, gender, BMI, educational level, physical activity level and smoking status showed no significant correlation with any of these risk factors. There was no change in the reported average daily fluid consumption from baseline, suggesting underreporting as hydration status of participants improved. Among participants who were at risk of heat related illness (n=13), identified through a Basic Thermal Risk Assessment, the mean urine specific gravity (USG) was 1.021 (Range 1.010 to 1.027) pre-shift and 1.024 (Range 1.019 – 1.032) post-shift. Eight were dehydrated pre-shift and 12 were dehydrated post-shift. All 13 participants had at least two heat strain symptoms, namely headache and fatigue. Environmental temperatures during summer with no cloud cover indicated that these workers were at a high risk of heat related illness with the predicted heat strain (PHS) index predicting a core temperature of 38 degrees being reached within the first two hours of work following lunch break. Considering that workers still have to work for five hours after the lunch break, this finding is significant for these workers. Under these working conditions, hydration status plays a very crucial role in heat dissipation from the core of the body. This was clearly demonstrated as correlation of core body temperature with potential risk factors such as BMI, pre- and post-shift hydration status, fluids consumed during the shift and heat strain symptoms showed significant correlation for pre-shift hydration status only ($P<0.05$).

The findings presented in this thesis provide evidence that a long term workplace health promotion program at an open cut mine site is feasible and improved the control of overweight and obesity rates, hydration status and some aspects of lifestyle choices. The results suggest that tailored programs can be effective, when the nature of the workplace and workers are taken into consideration. In addition, this thesis also provides evidence that pre-shift hydration status is the key factor determining a worker's susceptibility to heat stress, and should be addressed as a priority for any hydration management guideline for working in hot environments.

CHAPTER 1 – INTRODUCTION AND THESIS CONTEXT

1.1 Introduction

The mining industry is one of the largest industries in Australia, employing a cohort of workforce with the highest weekly wages of any industry (ABS 2012). Preliminary work done at two underground mines in regional New South Wales prior to commencement of this research showed that up to 91% of workers in this industry were overweight or obese (Polkinghorne et al. 2013). This was higher than the national average of 62.8% at that time (ABS 2013). Furthermore, workers in this industry had a higher rate of inadequate fruit and vegetable intake and higher alcohol consumption than the national averages at that time (Department of Health 2012). It was therefore important to trial a health promotion intervention in this workplace, targeting this unique cohort of workers who are at a higher risk of the chronic health effects of overweight and obesity, such as heart disease, diabetes and cancer, than any other cohort of workers. This was the genesis of this PhD research.

Workplace health promotion has been established by the World Health Organization as one of a number of priority settings for health promotion in the 21st century (WHO 2015). The workplace is where over half the global population spends anywhere from a third to half of their day. Thus the workplace has become the primary hub that influences the physical, mental, economic and social well-being of workers, their families, their communities and the society. The workplace therefore provides the setting and foundation to support the promotion of health of a large captive audience. Based on this context, this research examined the mining industry as a setting in which workplace health promotion interventions to support healthy lifestyles can be implemented. This is presented in chapter two of this thesis. Chapter three presents the general overview of the literature on workplace health promotion programs and their effects on health status, especially overweight, obesity and physical activity.

Many workplace health promotion programs have identified nutrition and physical activity as key components that can be targeted for improving overweight and obesity within the workforce (Oberlinner et al. 2007, Ni Mhurchu et al. 2010, Quintiliani et al. 2010, Christensen et al. 2011, Verweij et al. 2011, Robroek et al. 2012). However, within the mining industry, another important component that deserves attention as a target for health promotion programs is hydration status. Studies have shown that workers in the mining industry tend to start their shift in a dehydrated state (Carter and Muller 2007, Peiffer and Abbiss 2013, Polkinghorne et al. 2013, Hunt et al. 2014). This has potential health effects with regard to heat stress and heat strain, and should be included in health promotion programs for the mining industry, along with nutrition and physical activity.

This thesis therefore examines nutrition, physical activity and hydration status in a context of overweight and obesity among the mining workforce. In addition, heat stress and heat strain are also included as a context, given that work in the mining industry is often in hot humid environments, which may be a risk factor for heat related illness in overweight and obese workers (Savastano et al. 2009).

1.2 Health problems of workers in the mining industry

1.2.1 Overweight and obesity

Overweight and obesity is a global problem. The prevalence of overweight or obese men and women in America is 74% and 64% respectively; the prevalence of overweight men and women in Europe is 50% while the prevalence of obese men is 20% and obese women is 23%; the prevalence of overweight or obesity in Middle East and North African men is between 69% and 77% while in women it is between 74% and 86%; in Southeast Asia the prevalence of overweight men is between 8% and 30% while in women it is between 8% and 52% (WHO 2016). A meta-analysis of body mass index and all-cause mortality among people who never smoked and without any chronic diseases across four continents – Asia, Australia and New Zealand, Europe and North America showed a high hazard ratio for all-cause mortality among overweight (HR = 1.07 – 1.22) and obese (HR = 1.45 – 2.76) people compared to normal weight people (Global BMI Mortality Collaboration 2016). According to the 2011-2012 Australian Health Survey, 62.8% of Australian adults (69.7% men and 55.7% women) were either overweight or obese (ABS 2013). The rate of overweight and obesity by occupation shows that the highest proportion of overweight or obese workers are machinery operators and drivers (74%) followed by managers (66%) and technicians and trade workers (63%) (ABS 2011). All three of these occupations are prevalent in the mining industry. Other workplaces are not exempt from this global pandemic. The construction, electricity, gas and water, government administration and defence, education and health and community services industries have also recorded high proportions of overweight and obese workers (ABS 2008). Furthermore, there is a high association between overweight and obesity and the development of chronic diseases such as heart disease, type 2 diabetes and some cancers (Willcox 2014). It is important to note that differences in age and sex of workers across industries and occupations impact on these data. Nonetheless, it does reflect the growing problem of overweight and obesity in the workplace setting, and in particular in the mining industry in Australia. Chapter four of this thesis looks at the nutrition and physical activity aspects of the workplace health promotion intervention.

1.2.2 Dehydration

Dehydration is a persistent health problem of workers in the mining industry and in other workplaces as well. The rate at which miners start work in a dehydrated state ranges from 60% to 91% (Hunt et al. 2013, Montazer et al. 2013, Peiffer and Abbiss 2013, Polkinghorne et al. 2013, Mears and Shirreffs 2015). This is a cause for concern as dehydration has been shown to be associated also with cognitive impairment, which may lead to increased risk of adverse workplace incidents (Lieberman 2007, Ganio et al. 2011, Adan 2012). In addition, dehydration also increases the risk of developing heat stress and heat related illness (Brake and Bates 2003, Bates et al. 2010, Montazer et al. 2013), which is a significant health concern for workers in the mining industry, who often work in hot and humid conditions.

While different workers have different levels of physiological coping mechanisms to work in hot humid conditions, it is still important to identify dehydrated workers in such environments and monitor them closely for signs and symptoms of heat strain. Therefore, a quick reliable tool to collect fluid consumption data is useful along with checking workers' hydration status. Chapters five and seven present the study on dehydration, and the validity of a short FFQ and a fluid frequency questionnaire used to collect fruit and vegetables, and fluid consumption data respectively.

1.2.3 Heat stress and heat strain

Overweight, obesity and dehydration may invariably contribute to the development of potentially fatal heat related illness through heat stress and heat strain (Armstrong et al. 2007, Arbury et al. 2014). Possible mechanisms for this include heat storage in fatty tissue and lack of enough body water to sweat effectively and efficiently (Nadel 1979, Cheung et al. 2000, Savastano et al. 2009). Furthermore, the time taken to reach exhaustion and fatigue is considerably faster for workers whose core body temperature is between 38 and 40 degrees celsius (Sawka et al. 1992, Montain et al. 1994, Latzka et al. 1998). Hence a mining specific workplace health promotion intervention should target overweight and obesity, hydration status and heat stress/strain so as to maximise the positive health outcomes for workers, both in terms of heat related illness and chronic disease prevention. Chapter six presents the study on heat stress and heat strain.

1.3 Research hypotheses

Workplaces provide an excellent means by which to reach a wide adult audience through targeted health promotion programs. The mining industry is a unique workplace that, in Australia, mostly operates on a 12-hour shift roster such that workers have little time to engage in any health promoting activity, either during work or outside of work. This thesis aims to demonstrate that simple health promotion interventions can be implemented in a mining worksite despite the many structural and administrative limitations inherent in such a workplace. This view is based on an initial hydration intervention in an underground mine site, which resulted in improvement in hydration status while also highlighting the problem of overweight and obesity among workers in the mining industry (Gopaldasani et al. 2012). The main research hypotheses are as follows:

1. *Workplace intervention program that targets the mining workers' lifestyle and their work environment is feasible in the mine site as a workplace.*
2. *Workplace intervention program that targets the mining workers' lifestyle and their work environment will increase water consumption thus improving the hydration status of the workers and decreasing heat related illness.*
3. *Workplace intervention program that targets the mining workers' lifestyle and their work environment will decrease consumption of discretionary foods while increasing consumption of core foods and promoting household and leisure time physical activity thus reducing body mass index.*

1.4 Research aims and objectives

The overall aim of this research was to develop, implement and evaluate the feasibility and effectiveness of a workplace health promotion intervention program among employees of an open cut mining site. The specific aims of the study were to:

- Reduce overweight and obesity rates in the mining workers by 5% after a one-year follow-up period.
- Improve the hydration status of the mining workers by 15% from the baseline after a one-year follow-up period.

The research objectives were to:

- Improve diet of workers by increasing consumption of core food and decreasing consumption of discretionary foods to meet the Australian Dietary Guidelines of 2.0 serves of fruit per day, 5.0 serves of vegetables per day, 5.5 serves of breads and cereals per day, 2.5 serves of meats and alternatives per day, and 3.0 serves of milk and dairy products per day.
- Improve physical activity of workers to meet the Australian Physical Activity and Sedentary Behaviour Guidelines for Adults of 150 to 300 minutes of moderate intensity physical activity per week or 75 to 150 minutes of vigorous intensity physical activity per week.
- Increase water intake and decreasing unhealthy drinks to a level that results in a urine specific gravity of below 1.020.

- Investigate the association of overweight, obesity and dehydration on employee risk of heat related illness.

1.5 Conceptual framework for the study

Poor diet quality (excess consumption of energy dense nutrient poor foods and limited consumption of core foods), lack of physical activity (including sedentary work conditions) and dehydration can collectively contribute to overweight and obesity, and dehydration and heat stress among workers in the mining industry. These health problems can then predispose to the development of chronic diseases, which will add to the burden of disease for the workers, the employer, the community and the country. The conceptual framework outlined in Figure 1-1 draws on the literature review and the risk factors that contribute to the potential health problems of workers in a workplace. Healthy nutrition, physical activity and staying hydrated appear to be the key to maintaining a healthy workforce in any workplace (Anderson et al. 2009, Groeneveld et al. 2010, Morgan et al. 2011). Monitoring on its own, where this is communicated back to employees, can potentially become an indirect intervention as the act of monitoring itself may increase workers' mindfulness of their nutrition, physical activity levels and hydration status, thus encouraging them to continuously improve their overall health.

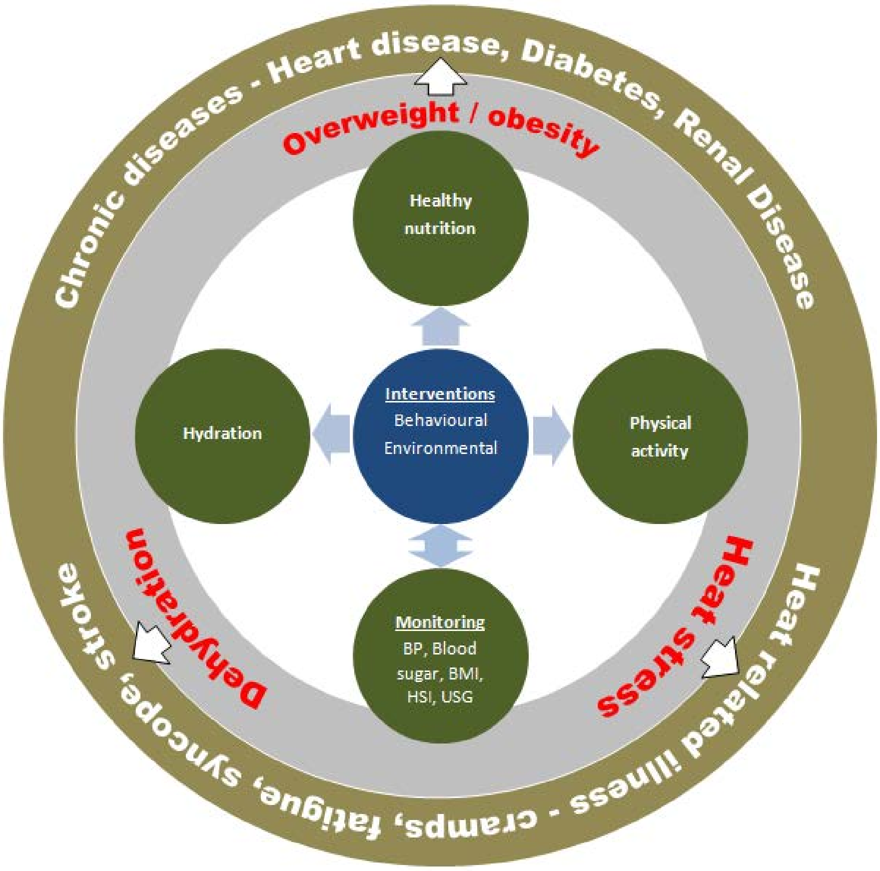

Figure 1-1: Conceptual framework for the study

1.6 Theoretical framework for health promotion intervention

Health promotion is the process of enabling individuals to increase control over their health and its determinants, thereby improving their health (WHO 2005). In the context of this definition, workplace health promotion can be defined as the concerted efforts of employers, employees and the society to improve and maintain the health and wellbeing of people at work (European Network for Workplace Health Promotion 2007). The responsibility of workers' health therefore falls on the employers and the employees and, by extension, on society. The European Network for Workplace Health Promotion (European Network for Workplace Health

Promotion 2007) through the Luxembourg Declaration highlights three key ways through which workplace health promotion can be achieved. These are:

1. Encouraging personal development of workers,
2. Improving the work environment; and
3. Improving the work organisation.

Dodson et al (2008) also highlights the importance of complementing workplace health promotion interventions with environmental interventions and organisational policy to ensure viability and long-term sustainability. Clearly three domains can be identified and targeted for workplace health promotion programs to maximise the outcome from such programs. These include: the worker, the work environment and the organisation. However, it must be noted that organisational policy changes usually happen after demonstration of effectiveness of the health promotion intervention on the worker and the work environment. Thus the workplace health promotion intervention in this study mainly focused on the worker and the work environment.

Several theories and models have been used in health promotion at the individual level and interpersonal level (Health Belief Model, Social Cognitive Theory and Social Support Theory), environmental level (Social Cognitive Theory), and at the community/organisational level (Organisational Change Theory). For this research, the Health Belief Model (HBM) and the Social Cognitive Theory were used at the individual level, and the Social Cognitive Theory (SCT) at the environmental level.

1.6.1 The Health Belief Model (HBM)

The HBM is one of the oldest and most widely recognised health promotion models used to target individual behavioural change. The model predicts that for individuals to adopt recommended behaviours, their perceived threats of diseases and its severity, as well as the benefits of actions, must outweigh their perceived barriers to action (Rosenstock 1974, Green and Murphy 2014). Figure 1-2 summarises the HBM.

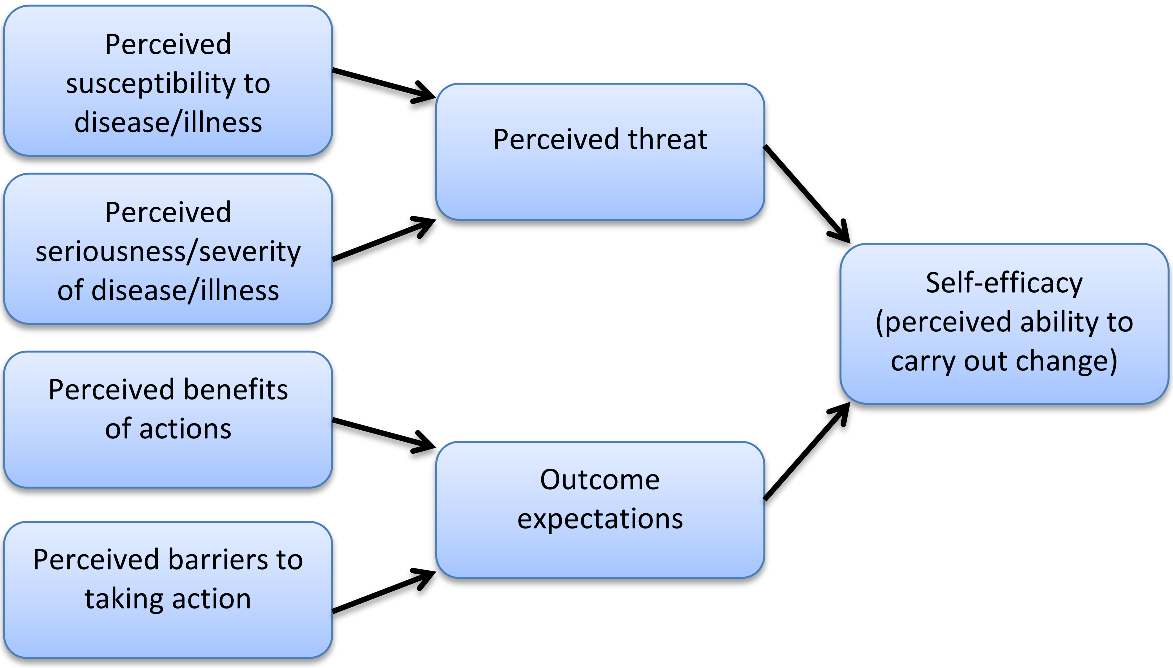

Figure 1-2: Health Belief Model (Nutbeam et al. 2010)

In the HBM, an individual's perceived susceptibility to disease or illness, as well as perceived severity of the disease or illness, are governed by many modifying factors (Egger et al. 1999). These modifying factors include the age of the individual, the gender, ethnicity and personality, the socioeconomic status and the knowledge base. Egger (1999) goes on to state that of all these modifying factors, the knowledge base is one that can be significantly influenced externally through education and information. Hence if the perceived threat, which is guided by perceived susceptibility and seriousness of a disease or illness, is high but the benefits or outcome expectations outweigh the perceived threat, there will be a shift towards adoption of a behavioural change. It is important to note that the HBM has been found to be more useful when applied to traditional preventative health behaviours such as screening and immunisation, but less useful in interventions for complex, long term behaviours such as alcohol and tobacco use (Janz and Becker 1984). Research has shown that the HBM has been used to improve the usefulness of nutrition intervention research (Glanz et al. 1994, Trudeau et al. 1998, Tanagra et al. 2013). In this study, the nutrition and physical activity intervention components were based on the HBM constructs outlined in Table 1-1. Specific intervention components were mapped with the HBM constructs as shown in Table 1-1.

1.6.2 The Social Cognitive Theory (SCT)

The SCT states that behaviour and learning occur within a social context, with a dynamic and reciprocal interaction between the individual, their behaviour and the environment (Bandura 1986). Like the HBM, the interaction between the individual, the behaviour and the environment is demonstrated by constructs. These include:

- Outcome expectations – a belief about the value of the consequences of behavioural change.

- Self-efficacy – confidence or belief in the individual’s ability to perform a given behaviour.
- Collective efficacy – confidence or belief in the group’s ability to perform behaviours that bring about a desired change.
- Self-regulation – controlling oneself through self-monitoring, goal-setting, feedback, self-reward, self-instruction and social support.
- Behavioural/facilitation capability – providing the tools, resources and/or environmental changes that make new behaviours easier to perform.
- Observational learning – belief based on observing similar individuals or role models perform a new behaviour.
- Incentive motivation – the use and misuse of rewards and punishment to achieve the desired behaviour.
- Reinforcement – which can be external, internal, positive or negative.

Of the various constructs of the SCT, this thesis focused on outcome expectations, self-efficacy, self-regulation, behavioural capability, incentive motivation and reinforcement. Studies have demonstrated the usefulness of SCT in facilitating the adoption of new healthy behaviours towards healthy eating and physical activity (Amaya and Petosa 2012, Dennis et al. 2012, Lubans et al. 2012, Morgan et al. 2014, Moyer 2014, Hamilton et al. 2015). The SCT constructs used in this thesis have been mapped with the intervention components used as shown in Table 1-1. It is important to note the overlap between constructs in the HBM and the SCT.

In summary both the HBM and the SCT models were used to inform the intervention components in this study, which were comprised of individual behavioural and environmental interventions.

Table 1-1: Mapping of HBM and SCT constructs for the workplace intervention program

Intervention component	HBM construct	SCT construct	Description of component
Information and education sessions	• Perceived susceptibility • Perceived severity	• Self-efficacy • Behavioural capability	Information and education sessions on various health topics related directly and indirectly to the work and the workplace
Handouts	• Perceived susceptibility • Perceived severity	• Self-efficacy • Self-regulation • Behavioural capability • Reinforcement	Printed materials in the form of handouts and booklets on the various health topics
Individualised participant feedback	• Perceived benefits of action • Perceived barrier	• Outcome expectations • Self-efficacy • Self-regulation • Incentive motivation • Reinforcement	Feedback on weight, BMI, blood pressure, blood glucose, hydration status, nutrition, and physical activity
Referral to NSW Get Health information and coaching service	• Perceived benefits of action	• Outcome expectation • Self-efficacy • Self-regulation • Reinforcement	A six month free weight management coaching service
Pedometer challenge	• Perceived barriers • Perceived benefits of action	• Self-efficacy • Collective-efficacy • Behavioural capability • Incentive motivation	Pedometers were provided to all participants and a challenge was set up between individuals and between crews with prizes for best performances
Provision of drink machines	• Perceived barriers	• Self-efficacy	Drink machines were provided at various

	• Perceived benefits of action	• Behavioural capability	parts of the site to facilitate hydration
Review of vending machines and refrigerated beverages	• Perceived barriers • Perceived benefits of action	• Outcome expectation • Self-efficacy • Self-regulation • Behavioural capability	Vending machine contents were reviewed and healthy food options included, to provide an alternative to the unhealthy contents across the site. Skim and light milk were provided in addition to full cream milk in refrigerators across the site
5-star healthy rating labelling system	• Perceived severity • Perceived benefits of action	• Outcome expectations • Self-efficacy • Self-regulation • Behavioural capability • Reinforcement	All beverages and food items across the site were labelled with a 5-star healthy rating labelling system, in which the highest number of stars denotes the healthiest option

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CHAPTER 2 – THE MINING INDUSTRY – A UNIQUE WORKPLACE

2.1 Introduction

Understanding the workplace of miners is important in defining the scope of the potential health problems of workers in the mining industry. Such problems can include overweight and obesity, dehydration and thermal stress and strain as they relate to heat illness. Tracing the history of the development of the mining industry from its historic to its present day operations provided an insight into the various barriers that today's workers in the mining industry face, that potentially prevent them from adopting healthy dietary habits, engaging in physical activity and staying hydrated at all times.

In order to provide a clear context of the mining industry as a unique workplace, a literature review was undertaken. Information from peer reviewed and non-peer reviewed sources were included to provide a general overview of the work environment in the mining industry. This review also highlighted the lifestyle of workers in the mining industry, past and emerging health issues and the mining industry's response to these emerging health issues. This chapter presents the results of the review.

2.2 A brief history of mining: pre-modern to modern era

Mining has played an important role in the evolution of civilisation since its inception. Humans have used stones, ceramics and metals that have been mined close to the surface of the earth (Hartman 1992). Examples of such mining include flint (a type of quartz) used to create tools, ceramics used to make a variety of objects ranging from bricks to pottery products and metals such as hematite. The oldest documented mining site is the "Lion Cavern" found on the Ngwenya mountain range in Swaziland dating back 43,000 years (Dart and Beaumont 1967, Swaziland_National_Trust_Commission 2014). Red ochre and hematite were the minerals of interest having been found at this site. Red ochre was a pigment used as body paint for rituals. Hematite is being mined in the region around the Lion Cavern today, thus making it the oldest continuously mined region in the world. The primitive mining tools used were made of a particular type of stone called dolerite and tools consisted of choppers, picks and hammer stones. Up until the industrial revolution, these tools persisted in the mining industry. Miners were often required to work hard manually digging, shovelling and transporting to the surface ores and minerals using wheelbarrows and carts. Young boys at the surface would then sort out rocks from solid minerals such as coal.

The industrial revolution, which began in the 18th century in Britain and later spread to the world changed the mining industry radically, with rapid growth and technological advances over the ensuing 100 years. Early technological advances in the mining industry included the fabrication of better hand held tools from more durable metals. This enhanced the manual mining process, resulting in small increments in productivity. It also increased the exposure of workers to more dust and diseases. Due to the nature of mining during this era, workers had a considerably shorter life span than workers in other industries (Burke and Richardson 1978, Brundage and Shanks 2008).

Further technological advances in the 20th century included advances in machinery and related equipment for the mining industry, which converted the mostly manual job to a semi-automated one. This meant that miners no longer had to work with manual tools but could use machinery that was manually operated by a miner to assist in improving efficiency and productivity. Examples of such machinery included drills and power tools. This again increased the amount of dust exposure and subsequent lung diseases such as chronic obstructive pulmonary diseases (COPD) and lung cancers.

The most recent technological advances of the late 20th and early 21st centuries have made most of the mining work fully automated, with miners now relegated to the job of overseeing the smooth running of the machines by sitting in the cabin of a machine and pushing buttons that allow the machine to do the work. More recent advances in technology have successfully eliminated the human factor entirely by introducing a fully autonomous mining system, that is, without the need for operator intervention (Bellamy and Pravica 2011). It is important to note that humans are, however, required to carry out maintenance activities on the automated machines to ensure smooth operation.

2.3 Mining sites and towns

Mining sites can be categorised either according to their location or according to the mining technique employed at the mine site. Categorising by location, mining sites can be either fly-in fly-out (FIFO) or drive-in drive-out (DIDO). Categorising by the mining technique employed, mining sites can be either surface or underground.

2.3.1 Fly-in fly-out (FIFO) mine sites

FIFO mine sites are sites located in remote areas of the world where employees are flown in to work temporarily, often on a roster basis (Moore 1999). This is now the preferred method of getting workers to remote areas where the cost of establishing a permanent community exceeds the cost of airfares, temporary housing and feeding at the work site. FIFO jobs involve working 8-12 hour shifts each day for a number of days followed by days off from work, when workers are flown back to their homes.

2.3.2 Drive-in drive-out (DIDO) mine sites

DIDO mine sites are sites located within 1-2 hours' drive from a local town. The job pattern is similar to FIFO mine sites, involving working 8-12 hour shifts each day for a number of days followed by days off from work. DIDO mine sites do not incur the costs of airfares, temporary housing or feeding at the work site. Employers may however provide bus shuttle services to transport workers to and from the mine site and nearby towns.

2.3.3 Surface mining sites

Surface mining sites include open cut (open pit) mining sites, strip mining sites and mountaintop removal mining sites. Surface mining involves removal of the soil and rocks that overlie a mineral deposit using heavy machinery such as excavators, bulldozers and loaders.

2.3.4 Underground mining sites

Underground mining sites can be either hard rock or soft rock mining sites. Hard rock mining refers to mining metal ores such as iron, copper, tin, lead, gold and silver, while soft rock mining refers to mining coal, salt or oil sands. Access to underground mining sites can be either through steady declines via tunnels, vertical declines via shafts, or via horizontal excavation into a mountain or hill side. Minerals are then extracted using machinery and transported to the surface (Hoek et al. 2000).

2.4 Lifestyles of workers in the mining industry

The nature of the work in the mining industry in the pre-industrial era was that of hard labour using tools such as picks, shovels, wheelbarrows and carts to mine and transport minerals. This activity involved significant physical strain on the body and as such miners were mostly physically fit to be able to carry out the job. In those times miners had control over their working hours. Senior miners could choose when they wanted to go into the mine and when they wanted to come out (Metcalfe et al. 1992). Miners generally had no regimented shift hours to work and thus the workday and hours were flexible. With the industrial revolution and the increased demand for mineral resources, especially coal, employers were in favour of fixed working hours and thus miners no longer had control over their work hours. This has persisted, and miners typically now work a 12 hour shift roster with days off for a combined total of 41 hours or more per week (Heiler et al. 2000). Common working rosters include 2 weeks on and 1 week off, 3 weeks on and 1 week off and 6 weeks on and 1 week off (Watts 2004). With only enough time to eat and sleep after a shift, this work lifestyle has created a host of new health issues for the modern miner, compared to the health issues of the pre-industrial miner.

2.5 Historic legacy of health issues among miners

Physicians and employers of ancient civilisation were not concerned with the health of their workers, as there were no laws that mandated this. As a result, no records of workers' illnesses were kept. Nonetheless, the Greek philosopher Nikander of Colophon in 250 BC described his observation of an occupational disease (colic) that may have been attributed to exposure to lead (Needleman 1999). Mercury poisoning as a disease of slaves was described by Pliny the Elder, in the 1st century CE when slaves worked the mines that were contaminated with mercury vapour (Emsley 2005). During the middle ages, Georgius Agricola described the primitive methods of ventilation and personal protective equipment (PPE) that were in use by miners working in metalliferous mines (Weber 2002). Bernardino Ramazzini, who is regarded as the father of occupational medicine, described over 54 different occupations that were associated with disease (Felton 1997). With the industrial revolution, technological advances and industrial growth had a deep impact on occupational related diseases. The most common of these diseases were those associated with dust. For example, Percivall Pott, a London surgeon, described the association between soot and scrotal cancer among chimney sweeps while Charles Thackrah, a physician, described the association between dust and several lung diseases (Brown and Thornton 1957, Cleeland and Burt 1995). These various health issues were not confined to adult men, but included both women and children.

In early mines in the United Kingdom, whole families often worked at the mines for 12 hours or more at a time to earn better wages by the hour. The father and the boys would cut the coal from the seams using picks while the mother and daughters would transport the coal to the surface by carrying them in baskets on their backs. These baskets were held in place by straps that wound around the front of their foreheads causing these areas to become bald. The sheer weight of the baskets caused severe disfigurements of the back and pelvis of young girls, most of whom died during childbirth later in life (Coal Mine History Resource Center n.d.). Physical abuse was also quite common, as miners would beat the children if they fell asleep at the job. Death of miners was also common as miners were taken underground and brought to the surface using wooden buckets lowered and raised using a rope. Rope breaks and windlass mistakes often led to miners falling to their deaths. As news of mining accidents became known, a commission was set up to investigate the working conditions in the mines. After confirming the shocking working conditions of miners, the Mines Act of 1842 was implemented, which saw the prohibition of all females and boys under ten years of age from working in coal mines (Scottish Mining 2015). Several industrialised countries followed suit and Mining Acts now help to protect vulnerable members of the community.

2.6 Emerging health issues in the mining industry

By the 20th century, classic occupational diseases such as coal workers pneumoconiosis, anthrax and mercury and lead poisoning had declined in incidence in industrialised countries, although had not been eradicated. In addition, new technology and new materials introduced several new diseases such as asbestosis, silicosis, occupational asthma, noise induced hearing loss and chronic obstructive pulmonary disease (COPD) all of which are still in existence today although their incidence has declined. In most industrialised countries the responsibility for health and safety at work is placed on the employer and reinforced by legislation and safety standards. This has led to the overall reduction of workplace contaminants such as coal dust among others, and thus the overall reduction of the classic occupational diseases. In addition, increasing mechanisation and automation of the mining industry has led to reduced exposure of workers to possible contaminants further reducing the risk of developing an occupational disease. However, with improved technology, mechanisation and automation, other health issues are increasingly being seen among workers in the mining industry, namely overweight and obesity, and musculoskeletal disorders.

Over the last half-century, the nature of work and the workplace have changed significantly. The introduction of computer technology into the workplace in the 1960s and 1970s, followed by globalization in the 1980s, resulted in increased economic competitiveness (Cooper and Jackson 1997), putting more pressure on workers to deliver more profits for industries. This has resulted in mental and physical health problems at the workplace, which continue to occur to this day (Kahn and Langlieb 2003). Increasing mechanization of many industries has dramatically changed the workforce from one that previously had active work habits to a passive or even sedentary work lifestyle. Furthermore, new patterns of working have emerged, such as 8-hour and 12-hour shift working (with irregular work hours and disturbed sleep patterns), which have been associated with biological and social problems such as fatigue, insomnia, mood disorders, increased cardiovascular disease risk, proneness to accidents and overweight and obesity (Harrington 2001, Choobineh et al. 2012).

Considerable research has been undertaken on the mental and physical health problems of workers across multiple workplaces today (Kahn 2003, Choobineh et al 2012, Harrington 2001, Pollack et al 2007). With modern lifestyles having become very busy with family, work, sports/physical activity, leisure and social commitments to fit into a limited time, there is a need to be healthy to cope with the demands of daily life. An unhealthy worker is likely to be less productive thus increasing the cost of presenteeism (the practice of coming to work despite illness often resulting in reduced productivity) for the employer and increasing the cost of lost productivity from absenteeism (Scuffham et al. 2013). In considering this, workplace health promotion has become very relevant to both employers and workers. For employers, a workplace health promotion program may decrease costs associated with presenteeism and absenteeism while for the workers, the same health promotion program may improve their general health and wellbeing.

Apart from the health problems associated with shift working mentioned above, overweight and obesity, dehydration and heat related illnesses from heat stress are specific health problems among workers in the mining industry in Australia (Polkinghorne et al. 2013). Another significant health problem among workers in the mining industry is musculoskeletal disorders (Aickin et al. 2010, Vearrier and Greenberg 2011, Kunda et al. 2013, Saha and Sadhu 2013).

2.6.1 Overweight and obesity

Data from a 2004-2005 survey showed that in the Australian mining industry, 76% of workers were either overweight or obese (ABS 2008). This is higher than the 53% national overweight and obesity rates of adult Australian males for that year. Overweight and obesity can potentially lead to the development of chronic diseases such as type 2 diabetes, hypertension, hypercholesterolemia, diseases of the musculoskeletal system, cardiovascular disease and some cancers (WHO 2003). The estimated cost of overweight and obesity to the Australian economy in 2008 was $58.2 billion in both direct and indirect healthcare costs, and over $35.6 billion in government subsidies (Colagiuri et al. 2010).

2.6.2 Dehydration

A pilot study conducted in underground mines in temperate regions of Australia showed that up to 61% of workers come to work in a dehydrated state

(Polkinghorne et al. 2013). Studies conducted in tropical regions of Australia also showed that the majority of underground miners are dehydrated prior to commencing work (Brake and Bates 2003). Both of these studies showed that workers start their shift dehydrated and tend to remain dehydrated by the end of their shift. Dehydration worsens the effects of heat stress on the body and also limits effective physiological response to heat stress (Shahid et al. 1999, Donoghue et al. 2000). The physiological responses to heat stress by the human body is termed heat strain and the main responses include increased skin blood flow (vasodilatation) and sweating; the evaporation of which results in a cooling effect. However, these responses do have a limit and as core body temperature increases due to environmental effects these physiological responses cease to be effective.

2.6.3 Heat related illness from heat stress

A number of studies have been undertaken in tropical regions of Australia to assess the association between heat strain and heat stress of underground miners, to determine the extent and the limits of the human body's ability to cope with the demands of thermoregulation in hot working conditions. Heart rate and core body temperature monitoring have indicated that short bursts of moderate to intense work in hot working environments provide more challenge to thermoregulation than self-pacing of work (Brake and Bates 2001, Brake and Bates 2002). An increase in heat stress predisposes a worker to the development of heat related illness (Mirabelli et al. 2010). Heat related illness includes heat rash, heat cramps, heat syncope (fainting), heat exhaustion and heat stroke, which could be potentially fatal

(Donoghue et al. 2000, Rae et al. 2008). The first recorded mining-related fatality from heat stroke occurred in 1924 in a South African underground gold mine and by 1930 the recorded mortality rate from heat stroke was 1.5 per 1000 workers per year (Wyndham 1974). Between 1930 and 1935 heat stroke had become a major health hazard in the underground mining industry. By 1935 artificial ventilation of underground mines was introduced, which decreased the incidence of heat stroke (Pogue 2006). Nonetheless, heat stroke is still a valid concern in the mining industry and more so in overweight and obese workers who have impaired physiologic heat dissipation mechanisms due to the subcutaneous layer of fat which acts as a thermal insulator (Savastano et al. 2009). Little research has been done to determine the association between heat strain and dehydration, and also between heat strain and body mass.

2.6.4 Musculoskeletal disorders

Diseases of the musculoskeletal system were the highest reported chronic condition among overweight and obese Australians, followed by respiratory and cardiovascular diseases in 2008 (ABS 2008). In the mining industry, 56% of workers' compensation claims are for musculoskeletal injuries (SafeWork Australia 2013). Musculoskeletal system injuries have been reported to be more common among overweight and obese workers (Pollack et al. 2007), predisposing to absenteeism from work and leading to increased utilization of workers' compensation, decreased productivity for the employer and increased costs of managing such workers (Cawley et al. 2007, Ostbye et al. 2007).

2.7 Summary

The mining industry has undergone significant change over the last century. It has continued to evolve from a workplace that relied on hard manual work to one that now consists predominantly of heavy industrial machines that do the actual mining work, to a future that promises to have fully automated mines (though this is nearing reality now). Analogous to this evolution of the mining industry is the changing health status of workers from fit and healthy workers, who were at risk of occupational diseases from dust and toxic substances exposure, such as pneumoconiosis, to overweight and obese workers who are at risk of chronic diseases such as Type 2 diabetes, heart disease and musculoskeletal disorders.

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CHAPTER 3 – GENERAL OVERVIEW OF LITERATURE AND METHODS

3.1 Introduction

This chapter describes the literature review and methodology of a pre-experimental study, with a treatment group only, that assessed a multi-faceted workplace-based health promotion program targeting nutrition, physical activity, hydration and heat stress. The study was conducted between April 2013 and April 2014 in an open cut metalliferous mine. The University of Wollongong's Human Research Ethics Committee (HE13/014) approved the study (Appendix 1). A synthesis of the literature behind workplace intervention programs guided the study context, including intervention components applicable to a mine site as a workplace, research design, recruitment of study participants and the initial preparation work required for the study to commence. Subsequent chapters include sections that describe reviews of the literature and methodological approach for specific components of the intervention study related to nutrition, physical activity and hydration.

3.2 Literature review

A full review of the literature on workplace health promotion interventions was undertaken and the results are summarised in Table 3-1. There has been very little published research on health promotion intervention programs specific to the mining industry. With emerging health issues in the mining industry becoming more prominent (discussed in section 2.6) and studies showing that overweight and obese workers were more likely to have increased morbidity and use of health services leading to increased workers compensation claims (Cawley et al. 2007; Ostbye et al. 2007), it is important to look at the mining industry as a workplace for health promotion programs, as these are likely to benefit both the employer and the employees. There are numerous published studies on workplace health promotion intervention programs across many other workplaces that could potentially be applied to the mining industry. A review of the effectiveness of such workplace health promotion programs (WHPP) has been reported in three systematic reviews by Rongen et al (2013), Geaney et al (2013) and Gudzune et al (2013). Upon appraising these reviews and the associated studies in them, it was evident that the programs in other workplace settings would be relevant and applicable to the mining industry. A detailed review is now provided.

Rongen et al (2013) investigated the effectiveness of WHPP, looking at the influence of study population, study intervention characteristics and study quality on the overall effectiveness of WHPP. A total of 18 studies describing 21 interventions were included in the review (Rongen et al. 2013). Included studies were those that described a primary prevention WHPP aimed at healthy nutrition, physical activity, and weight loss or smoking cessation. Only those studies that applied in a randomised controlled trial design were included.

Geaney et al (2013) reviewed the effectiveness of workplace dietary modification interventions alone (for example food provisioning) or in combination with nutrition education on employees' dietary behaviour, health status and nutrition knowledge, among other outcomes. A total of six studies was eligible for the review (Geaney et al. 2013). To be eligible for the review, the studies had to describe changes in dietary content of available food, changes in portion size or changes in food choices available by increasing availability of healthy options in the workplace or workplace canteens or workplace vending machines. Studies also had to be either a randomised controlled trial or a quasi-experimental study.

Gudzune et al (2013) reviewed the effectiveness of dietary, physical activity and environmental strategies for the prevention of weight gain among adults in the workplace. A total of seven WHPP studies was reviewed (Gudzune et al. 2013). To be included in the review, the studies had to evaluate dietary, physical activity and environmental interventions on the outcome of body mass index, weight or waist circumference change at 12 months or greater. Studies that specifically focused on weight loss interventions as opposed to prevention of weight gain were excluded from the review.

All three reviews included findings for nutritional/dietary interventions. Two of the reviews included findings for physical activity interventions (Gudzune et al. 2013; Rongen et al. 2013) and two of the reviews included findings for environmental interventions (Geaney et al. 2013; Gudzune et al. 2013).

Table 3-1: Summary of literature review on workplace health promotion programs on nutrition, body weight and physical activity

Authors	Study	Settings	Types of intervention	Duration	Impact on health status/behaviour
Atlantis et al. (2004)	An effective exercise-based intervention for improving mental health and quality of life measure. A randomized controlled trial.	73 participants from the Gaming industry (Casino) in Australia.	Group physical activity, health education and counselling sessions.	24 weeks.	9.9% (P<0.009) overall improvement in general health.
Bandoni et al. (2011)	Impact of an intervention on the availability and consumption of fruits and vegetables in the workplace. A randomized controlled trial.	2,510 workers from 29 workplaces in Brazil.	Individual – educational materials e.g. posters, flipcharts etc. Environment – workplace cafeteria food program and culinary workshops.	6 months.	15% (P<0.05) increase in fruit and vegetables consumption in the intervention group between baseline and follow-up.

Beresford et al. (2001)	Seattle 5 a Day Worksite Program to Increase Fruit and Vegetable Consumption. A cluster randomized controlled trial.	2,732 workers from various workplaces including healthcare and education in Seattle, USA.	Individual – information and education of workers using posters, brochures and other media. Environmental – training cafeteria staff, vending machine modification to include fruit and vegetables choices and nutrition resource kiosk.	2 years.	0.5 serves/day (P=0.06) increase in fruit and vegetables consumption between baseline and follow-up.
Block et al. (2008)	Development of Alive! (A Lifestyle Intervention Via Email), and Its effect on health-related quality of life, presenteeism, and other behavioural outcomes. A randomized controlled trial.	787 workers from a health insurance company in USA.	Individual – electronic media (internet and email).	4 months.	OR = 1.57 (P<0.01) for improvement in perceived health status between intervention and control group. OR = 1.47 (P=0.02) for decrease in presenteeism between intervention and control group.

Braeckman et al. (1999)	Effects of a low-intensity worksite-based nutrition intervention. A quasi-experimental study.	638 male blue-collar workforce in Belgium.	Individual – education program using various mass media, health check including weight, height, BMI, lipid profile.	3 months.	51% increase (P<0.001) in nutrition knowledge but no change in lipid profile.
Dekkers et al. (2011)	Comparative effectiveness of lifestyle interventions on cardiovascular risk factors among a Dutch overweight working population A randomized controlled trial	276 overweight workers from seven workplaces including IT companies, hospitals, an insurance company, a bank and a police station in Netherlands.	Individual – Self-help materials. Phone and Internet based lifestyle intervention on physical activity and nutrition	2 years with 6 months intervention	At 6 months – non-significant average of 700g decrease in body weight. At 2 years – no difference from baseline.

Goetzel et al. (2009)	First-year results of an obesity prevention program at The Dow Chemical Company. A quasi-experimental study.	8,013 workers from nine chemical factories in USA.	Individual – information and education on physical activity and weight management using various media Environmental – Environmental prompts and point-of-choice messaging in vending machines and cafeteria	1 year	No observed effect on prevalence of overweight and obesity.
Goetzel et al. (2010)	Second-year results of an obesity prevention program at The Dow Chemical Company. A quasi-experimental study.	8,013 workers from nine chemical factories in USA.	Individual – information and education on physical activity and weight management using various media Environmental – Environmental prompts and point-of-choice messaging in vending machines and cafeteria	2 years	Intervention group able to maintain weight i.e. prevent weight gain. Control group gained weight with a non-significant increase in BMI of 0.2.

Jeffrey et al. (1993)	Effects of work-site health promotion on illness-related absenteeism. A randomized controlled trial.	1,242 workers from 32 workplaces in USA.	Individual – professional behaviour change classes and voluntary negative incentive via pay deduction for not meeting set goals	2 years	3.7% (P=0.04) reduction in sick days.
Kwak et al. (2010)	Changes in skinfold thickness and waist circumference after 12 and 24 months resulting from NHF-NRG In Balance project. A randomized controlled trial.	553 workers from six workplaces in Netherlands.	Individual – pedometer, tailored advice on nutrition and physical activity. Environmental – changes in food products at cafeteria, environmental prompts.	2 years	Reduction in skin fold thickness and waist circumference (Cohen's d of 0.26 at 12 months (P<0.001) and 0.44 at 24 months (P=0.005) but no changes in weight or BMI.

Lemon et al. (2010)	Step ahead a worksite obesity prevention trial among hospital employees. A cluster randomized controlled trial.	806 workers in six hospitals in USA.	Individual – information via newsletter, website and other printed materials. Environmental – environmental prompts at stairwells and cafeteria, changes to cafeteria food.	2 years	No changes in BMI.
Linde et al. (2012)	HealthWorks: results of a multicomponent group-randomized worksite environmental intervention trial. A randomized controlled trial.	1,747 workers across six workplaces in USA.	Individual – information on healthy eating via newsletters, pedometers. Environmental – increase availability of healthy food at reduced prices in cafeteria and vending machines, point-of-purchase promotional materials, environmental prompts.	2 years	No changes in BMI or weight.

McEachen et al. (2011)	Testing a workplace physical activity intervention. A cluster randomized trial.	1,260 workers from 44 worksites in the UK.	Individual – information and education on physical activity, reminders and fridge magnets to track physical activity, team challenges.	12 months with a 3 month intervention component	No changes in physical activity compared to baseline. Non-significant increase in BMI of 0.22 from baseline.
Nurminen et al. (2002)	Effectiveness of a worksite exercise program with respect to perceived work ability and sick leaves among women with physical work. A randomized controlled trial.	260 female workers in dry-cleaning services industry in Finland.	Individual – Physical activity counselling sessions by physiotherapist.	15 months with 8 month intervention component	11% improved perceived work ability but no difference in sick days.
Puig-Ribera et al. (2008)	Change in workday step counts, wellbeing and job performance in Catalan university employees. A randomized controlled trial.	70 university workers in Spain.	Individual – information and education on physical activity and walking routes. Provision of pedometer.	9 weeks	Increased step count (+659 steps, P<0.01) for sedentary participants.

Robroek et al. (2012)	Cost-effectiveness of a long-term Internet-delivered worksite health promotion programme on physical activity and nutrition. A cluster randomized controlled trial.	924 workers from six workplaces in Netherland.	Individual – internet program tailored to individual including self-monitoring, action oriented feedback and contact with health professionals.	2 years	Increase in vegetables intake only (OR of 1.43). No increase in fruit intake or physical activity.

3.2.1 Effectiveness of individual targeted nutrition intervention strategies

Nutritional/dietary interventions included a focus on increasing fruits and vegetables consumption and decreasing fat, sugar and alcohol intake. To achieve these outcomes, interventions used strategies such as food labelling, nutrition education and counselling. Rongen et al (2013) included two studies that had nutritional/dietary intervention as a focus of the WHPP (Robroek et al. 2012, Block et al. 2008). Both studies were randomised controlled trials that utilised electronic media (Internet and email) as tools to administer the interventions. Both studies showed a small effect on outcomes following the intervention, with the Internet based intervention study having a non-significant increase in vegetables consumption after two years of the study (effect size of 0.15 (CI -0.28, 0.57)) and the email based study having a significant increase in behavioural change towards increased fruit and vegetables consumption (effect size of 0.25 (CI 0.11, 0.39)). This could be explained by the study period as the Internet based intervention was conducted over a two-year period while the email based intervention study was conducted over a three-month period. Research has demonstrated that short-term interventions tend to have relatively more success than long-term interventions but are not sustainable over a long period (Jeffery et al. 2000). It is therefore important to cautiously interpret results of short-term intervention studies when comparing against the outcomes of long-term intervention studies. Intervention studies of greater than 6 months highlight the importance of long-term sustainability of behavioural and dietary changes.

Geaney et al (2013) included six studies all of which had dietary intervention as a focus of the WHPP. Two studies increased availability and accessibility of fruit and vegetables at vending machines (Beresford et al., 2001; Sorensen et al., 1999), two studies used food labelling for fruit and vegetables at canteens (Bandoni et al., 2010; Steenhuis et al., 2004), one study increased the availability of low-fat products, and fruit and vegetables (Steenhuis et al., 2004) while one study offered taste tests for healthy foods (Sorensen et al., 1999). Five of the six studies introduced nutrition education programmes with menu planning, educational materials in the form of posters, presentations and newsletters, individual nutrition counselling and personal advice (Beresford et al., 2001; Sorensen et al., 1999; Steenhuis et al., 2004; Braeckman et al., 1999; Bandoni et al., 2010). The primary outcome for all six studies was changes in dietary behaviour. Dietary intakes were assessed using food frequency questionnaires in four studies (Backman et al., 2011; Beresford et al., 2001; Sorensen et al., 1999; Steenhuis et al., 2004), one-day food records in one study (Braeckman et al., 1999) and a survey to calculate portions of fruit and vegetables consumed in one study (Bandoni et al., 2010). No pooled effect size analysis was done due to heterogeneity of the studies. However, five of the studies investigated fruit and vegetables consumption as part of the primary outcome, with four of the studies reporting a significant increase in fruit and vegetables consumption. The four studies with a significant increase in fruit and vegetables consumption had different intervention durations ranging from three months to 24 months, with higher effect sizes observed in short duration interventions and lower effect sizes with longer term follow-up (Backman et al., 2011; Beresford et al., 2001; Sorensen et al., 1999; Steenhuis et al., 2004). This provides evidence that short duration interventions are relatively more successful than long duration interventions but the sustainability of the program is questionable.

Gudzune et al (2013) included five studies with dietary intervention components. Two studies utilised diet and nutritional counselling (Dekkers et al. 2011, Goetzel et al. 2010), one study changed the food content of vending machines and cafeteria to healthy options (Linde et al. 2012), and two studies utilized nutrition education delivered through nutrition education displays and newsletters (Lemon et al. 2010, McEachen et al. 2011). All five studies had a primary outcome of preventing weight gain. There were no active weight loss programs in any of the five studies. Primary outcome measures in all five studies were changes in BMI at 12 and 24 months, weight change at 12 and 24 months and waist circumference change at 12 and 24 months. Gudzune et al. (2013) defined the meaningful difference between groups as 0.5kg of weight change or 0.2 kg/m^2 BMI or 1.0 cm of waist circumference change per year based on Williamson's epidemiologic description of weight change (Williamson 1993). Using the criteria, only one of the five studies was able to show a meaningful change from baseline (Goetzel et al. 2009). This same study succeeded at preventing increased BMI and weight gain at 24 months. This study utilized an individualized dietary intervention component comprising mostly of dietary counselling (Goetzel et al. 2010). Using the criteria of waist circumference change of

1.0 cm over 12 months, only one of the five studies was able to show this change from baseline (Kwak et al. 2010). This study succeeded at preventing waist circumference increase at 24 months. In addition, this study utilized personalized food diaries, calorie advice and education on maintaining energy balance, dietary behaviours and self-monitoring. It is clear from this review that dietary intervention programs that are specifically tailored to individuals are more effective than a generalized group level intervention. However, it is also well known that individually tailored dietary interventions are very expensive and time consuming to run, especially in workplaces that employ a large workforce. Generalized group level dietary interventions may be effective if combined with other elements of a WHPP, such as physical activity and environmental strategies.

3.2.2 Effectiveness of individual targeted physical activity intervention strategies

Physical activity interventions included a focus on increasing leisure time physical activity in addition to increasing workplace physical activity. Components of the interventions included walking, active commuting, exercise education and counselling, use of pedometers, periodic campaigns and challenges targeting physical activity and use of on-site gymnasiums. Rongen et al (2013) included 14 studies with physical activity as a focus of the WHPP. Four studies used group physical exercise programs, six studies used education and counselling sessions on physical activity and four studies used individualized exercise programs with or without a pedometer. The duration of the physical activity intervention programs ranged from four months to two years. Eight of the 14 studies had health status (subjectively determined through short questions) as an outcome measure. Five of the eight studies had statistically significant changes in perceived health status with the highest change in the short-term studies of up to six-month duration (Nurminen et al. 2002, Atlantis et al. 2004, Block et al. 2008, von Thiele Schwarz et al. 2008, Robroek et al. 2012). Ten of the 14 studies had sickness absence/productivity as an outcome measure. Four of those 10 studies had significant decreases in sickness absence translating to increased productivity (Jeffery et al. 1993, Block et al. 2008, Puig-Ribera et al. 2008, Zavanela et al. 2012). In summary, the effect size for health status as an outcome ranged from 0.0 to 0.58 while the effect size for sickness absence/productivity ranged from 0.03 to 1.33. The duration of the intervention of the studies with statistically significant effect sizes ranged from nine weeks (effect size 1.33) to 24 months (effect size 0.69). This demonstrates that short duration physical activity interventions may have a larger effect size but may not be more sustainable than long duration physical activity interventions. However, it is still important to note that there is an effect size with long-term physical activity interventions that, if sustainable, could lead to cumulative health benefits for workers.

Gudzune et al. (2013) included seven studies with diet and physical activity as a focus of the WHPP. These studies combined physical activity and a dietary intervention component to further strengthen the primary outcome measure of changes in BMI, weight and waist circumference changes at 12 and 24 months. Six studies used exercise education and counselling sessions (Dekkers et al. 2011, Goetzel et al. 2010, Lemon et al. 2010, Linde et al. 2010, Hivert et al, 2007 and Matvienko et al. 2001) and four studies used periodic physical activity challenges with or without a pedometer (Kwak et al. 2010, Lemon et al. 2010, Linde et al. 2012 and McEachen et al. 2011). The duration of these intervention programs ranged from three months to 24 months. Of the seven studies, two studies were able to demonstrate a statistically significant change in BMI, one after 12 months of intervention (McEachen et al. 2011) and the other after 24 months of intervention (Goetzel et al. 2009). Only one study had statistically significant change in weight gain prevention at both 12 and 24 months after the intervention (Goetzel et al. 2009). Lastly, only one study had statistically significant change in prevention of waist circumference increase at 24 months after the intervention (Kwak et al. 2010). With regard to physical activity interventions, it would appear that while short duration intervention programs have a large effect size, a long duration intervention program is likely to be more effective, if sustainable, and have a better health outcome than a short duration program.

3.2.3 Effectiveness of environmental intervention strategies

Environmental interventions included training cafeteria workers, new company catering policies, modified selections in vending machines, point-of-choice labelling, environmental prompts to increase awareness of healthy eating, walking groups, indoor and outdoor walking routes and increasing availability and decreasing price of healthy food options in cafeteria and vending machines. Geaney et al (2013) included four studies that utilized environmental changes in addition to dietary components of the WHPP (Braeckman et al. 1999, Sorensen et al. 1999, Beresford et al. 2001, Bandoni et al. 2011). All four studies used a number of environmental interventions, as mentioned above. Three of these studies measured fruit and vegetables consumption as an outcome of the intervention program (Sorensen et al. 1999, Beresford et al. 2001, Bandoni et al. 2011) and one study measured BMI, blood lipids and dietary changes as outcomes (Braeckman et al. 1999). Fruit and vegetable consumption increased significantly in all three studies that measured this as an outcome. It is important to note here that dietary interventions supported by environmental changes in a WHPP may be more effective than dietary interventions alone as highlighted by the three studies that utilised both environmental changes as well as individual behavioural changes (Sorensen et al. 1999, Beresford et al. 2001, Bandoni et al. 2011).

Gudzune et al (2013) included five studies in their review that had an environmental component of the WHPP. These studies had a duration ranging from three months to 24 months. Two studies showed improvements in BMI and weight status of participants, but these improvements were not significant. One study showed a significant improvement in BMI and weight of participants (Goetzel et al. 2009). This study utilized an individualized diet and physical activity intervention component comprised mainly of diet and physical exercise counselling and an environmental intervention comprising point-of-choice messaging in cafeteria and vending machines, environmental prompts to encourage employees to make healthy food choices, setting health objectives as a component of the sites' management goals, providing training on health-related topics and compiling and sharing feedback to worksite. Another study showed significant improvement in waist circumference with no changes in weight or BMI (Kwak et al. 2010). This study utilized environmental interventions comprising changing food options to healthy options at cafeteria, workshops and signs promoting healthy eating and instructions on keeping a food diary.

From these reviews, there is a moderate level of evidence that individually targeted dietary and/or physical activity interventions combined with environmental interventions can prevent weight gain and help make the WHPP sustainable over a long period. However, preventing weight gain and getting workers to reduce their weight are two very different outcomes. It would seem that preventing weight gain is easier than getting workers to reduce their weight. Nonetheless, this should be seen as a first step in getting workers back to their healthy weight.

Following the review of literature, successful workplace interventions were identified and shortlisted as possible interventions in this study to be trialled in a mine site (Appendix 4). Details of the general methodology for this study will now be discussed.

3.3 Methodology

3.3.1 Study context

This study was carried out at Cowal Gold Mine (CGM), a drive-in drive-out (DIDO) open cut metalliferous mine site. The mine is operated by Barrick (Australia Pacific) Limited. It is located approximately 40 kilometres northeast of West Wyalong and approximately 350 kilometres west of Sydney, New South Wales (Figure 3-1). The process for the extraction of Gold at CGM involves drilling, blasting, leaching, extraction, and smelting. Workers in outdoor processing areas are therefore exposed to very hot environmental temperatures during the summer months, while workers in the smelting room are exposed to bursts of very high environmental temperatures during the smelting process.

Figure 3-1: Map showing location of Cowal Gold Mine, NSW, Australia (Source: Google maps)

3.3.2 Research design

A pre-experimental study design was utilised. The choice of a pre-experimental study was determined by a lack of a control site that was willing to participate in the study, due to the fact that the mining industry was moving into a period of cost cutting and consolidation at the time of the project planning. Another factor that informed the choice of the study design was that it was impossible to accurately match two mines due to their individual design, size of the mines, the workforce and the management structure. For example, the test mine selected for this study was a non-unionised open cut mine whereas most other mines in NSW are unionised. It was considered that this study design would provide information about the feasibility and effectiveness for a specific type of mining worksite (open cut mine) and the model may then be able to be used to build future research for other mine sites. The main criterion for selection of the study site was a willingness to participate in the study and an interest in the health of workers at the site. Pre- and post-intervention measures were conducted at the study site. The primary outcomes or dependent variables for this study were: changes in BMI; and hydration status. Secondary outcomes included: dietary habits, specifically fruit, vegetable, core foods, discretionary foods and fluids consumption; changes in physical activity patterns; and heat stress assessments. All participants passed through the same study protocol (Figure 3-2). All measures were taken for each participant at baseline and at six and 12-month follow-up to evaluate short and mid-term effects of the health promotion program.

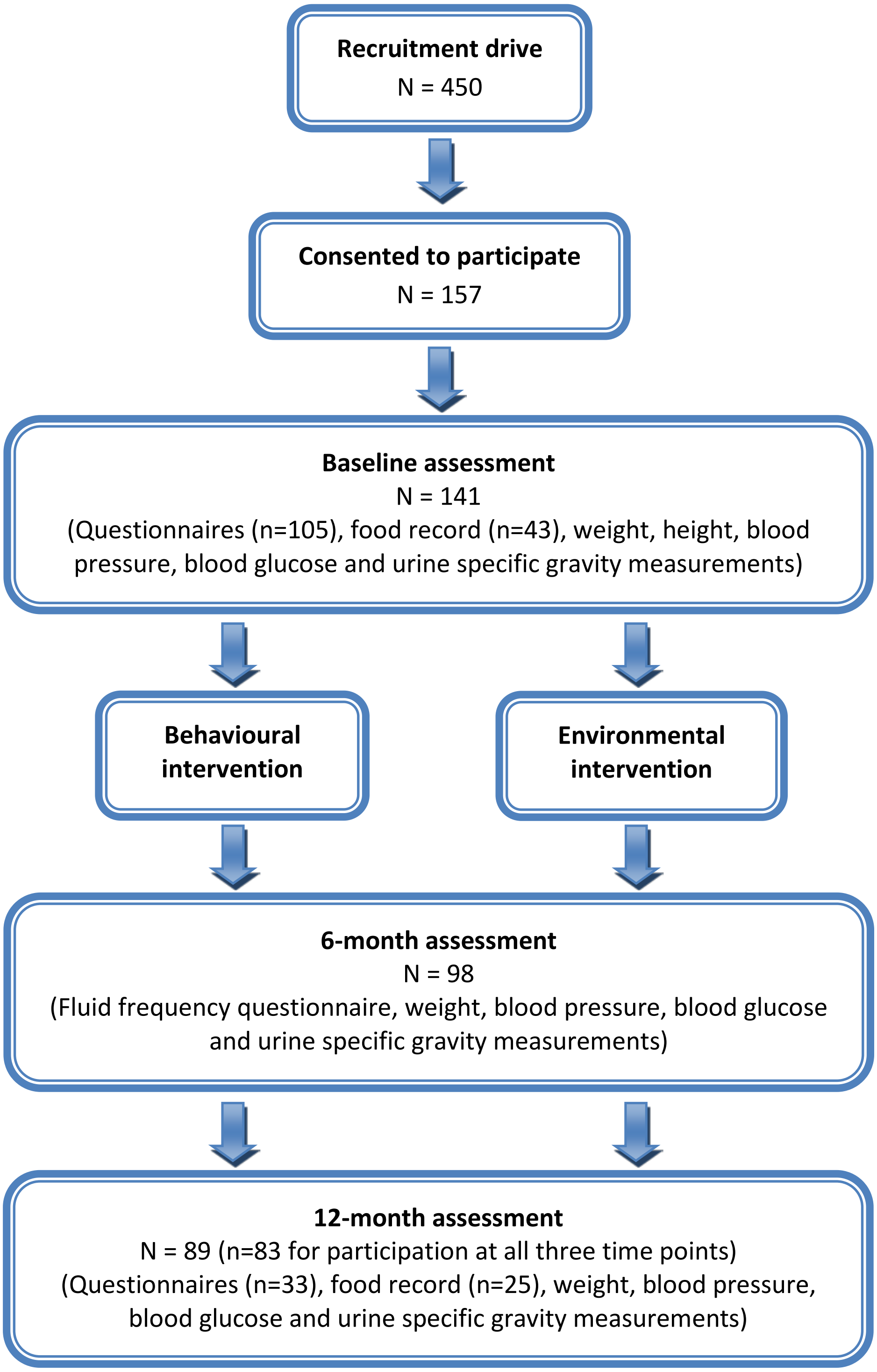

Figure 3-2: Study protocol

3.3.3 Participants

CGM has about 450 workers, including contractors. Workers were required to drive to the mine site as this was a DIDO site. Majority of the workers commuted to the mine site on shuttle buses with transit times of 1-2 hour one-way with a total transit time of 2-4hrs in a day. Workers worked either an 8-hr shift or a 12-hr shift. A cross-section of the workforce showed that workers could be categorised into indoor workers (administrative /office staff) and outdoor workers (truck drivers, drillers, other heavy machinery operators, surveyors and field workers). Outdoor workers are further divided into four crews – A, B, C and D – with each crew working a four days-on and four days-off (one cycle) roster throughout the year, with alternating cycles of day and night shifts.

3.3.4 Eligibility criteria

Workers were considered eligible for the study if they worked at the mine site either as a primary employee of CGM or as a contractor. All workers were invited to participate in the study and no one was excluded from the study unless they voluntarily opted not to partake. Severe disability and other health conditions that may exclude participants were not anticipated in the workforce, as workers at the mine were required to be in a reasonably healthy condition to work at the mine.

3.3.5 Sample size calculation

The sample size determination for this study was based on a previous study of health promotion intervention in the mining industry (Polkinghorne et al. 2013) where 13% of workers adopted the health promotion intervention at the study site.

Using data from the study of Polkinghorne et al (2013), for an infinite population, the sample size (n) was calculated as follows:

$$n = \frac{Z^2pq}{e^2}$$

Where Z = 1.96 (95% confidence level), p = 0.13, q = 0.87 and e = 0.05 (precision of 5%)

n = 174

Correcting for the finite population from which available to sample, the following corrected sample size has been calculated as follows:

$$N = \frac{n}{1 + \frac{n-1}{S}}$$

Where N = corrected sample size, n = sample size for infinite population, S = population size available (450 workers)

N = 125

To account for a 10% attrition rate during the study, a sample size of 137 was anticipated. This represented about one-third of the number of workers at the mine site.

3.3.6 Recruitment

All potential participants were informed about the study three months prior to the study commencing. Strategies to maximise participant recruitment included:

- Information bulletins being circulated during weekly safety meetings and monthly training sessions;
- Shift supervisors on each crew also informing potential participants of the study during the pre-shift meetings; and
- A participant information sheet detailing the study objectives, procedures and what would be required of participants being made available to all potential participants and posted on all notice boards.

Participation in the study was completely voluntary.

3.3.7 Consent, privacy and confidentiality

All workers who agreed to participate in the study were given a participant information sheet (Appendix 2) along with an informed consent form (Appendix 3). Upon reading the participant information sheet, workers signed the attached informed consent form, thus completing their recruitment into the study. The participant information sheet contained a paragraph on confidentiality, stating how information collected from participants would be secured and de-identified. In addition, the informed consent form explicitly stated that participants were free to withdraw from the study at any time, taking any data with them, thus covering consent, privacy and confidentiality of data.

3.4 Initial preparation

3.4.1 Meeting with stakeholders

Prior to commencing the research study, meetings were held with the work, health and safety team at the mine site. The members of the team included the health and safety manager, the health and safety advisor and two health and safety officers. At this initial meeting, the broad aims of the research were discussed, including the pool of employees from which the participants of the study would be drawn, the feasibility of the different components of the study, the onsite facilities available and the onsite support that would be provided. A key point from the discussion was that the daily running of mine operations would not be compromised in any way. That meant that all aspects of the research would have to be worked around the daily routine activities of the mine.

Another series of meetings was held with each of the four crews on their respective training days. During these training days, each one week apart, a presentation was made to the crews introducing the research study and explaining the aims of the study, what would be required by participants and the benefits of the study to employees. Opportunity to ask questions from the researcher was also provided to clarify any aspect of the research study. Once all questions had been answered, employees were given a participant information sheet and an informed consent to participate in the study. This process was repeated for all crews, and participants were thus recruited from within each crew.

3.4.2 Mine site induction and team training

A compulsory two-day mine site induction for the researcher was funded by the management, to enable the researcher to have access to all areas of the mine site. For any sensitive areas of the mine, the researcher was accompanied by a representative of the mine. In addition, support was provided to the researcher by two members of the health and safety team, each with certified first aid training, to enable collection of some health data under supervision by the researcher. The researcher ensured that the two members of the health and safety team were adequately trained to use the same protocol as the researcher, to collect data.

3.4.3 Implementation of the study

The thesis consisted of two studies. The first study consisted of two separate processes. The first process was the participants' measures, which included completion of a questionnaire, a food record, measurement of the weight, height, blood pressure, blood glucose and hydration status. Specific details of these measurements are provided in chapters four and five. The second process was the implementation of the intervention component, which consisted of: information and education sessions based on diet and nutrition, hydration, heat stress, fluid/water consumption, physical activity and chronic diseases such as diabetes, heart disease and cancer; detailed individual feedback on hydration status, dietary habits and physical activity levels; presentations and information booklets and posters on healthy nutrition, physical activity, hydration and heat stress; use of e-bulletin boards and notice boards to disseminate health promotion information as well as referring participants to the free NSW Get Healthy information and coaching service for weight management; review of vending machines and refrigerated beverages on site to provide healthier food options; using the 5-star healthy rating labelling system to encourage healthy choices; and a pedometer challenge between the crews to facilitate physical activity on and off site.

The second study was the assessment and measurement of heat stress and heat strain among high-risk workers such as the shot firers and the processing workers. Heat stress and heat strain measurements were conducted during the summer months when the pre-shift and post-shift hydration status, the fluids consumed during the shift, the tympanic temperature (surrogate for core body temperature), and the heart rate and assessment of heat strain symptoms were measured. Details are provided in chapter six.

3.4.3.1 Implementation of participants' measures

During the meeting with the work, health and safety team, it was determined that all participants' measures would be collected prior to the start of the shift, as participants reported to the front gate. A first aid room was located at the front gate prior to entering the mine site. This first aid room consisted of three separate areas, a reception area, an examination/treatment area and a toilet. The reception area was used by participants to complete the questionnaires while waiting to measure their weight, height, blood pressure, blood glucose and hydration status. Upon their completing the questionnaires, instructions on completing the food record were given to participants, who were then ushered to the examination/treatment room to complete all other measures.

3.4.3.2 Implementation of intervention components

At the meeting with the work, health and safety team, it was determined that some of the proposed intervention components of the study were feasible, while others were not. Appendix four provides the full list of proposed interventions. Presentations on health themes/topics would be included in all department safety meetings, which occurred on a fortnightly basis. In addition, the mine site e-bulletin board and the various notice boards around the mine site would be used to promote the health theme of the month. Contents of vending machines would remain the same, with respect to the removal of unhealthy food and drink choices but allowance would be made to include healthy options, commensurate with labelling of contents using the 5-star healthy rating labelling system. Details of the rating system are provided in chapter four. The onsite gymnasium facilities would not be made available for promoting physical activity as this was reserved for training of emergency rescue personnel, and no time would be given to workers to make use of the onsite gym during their shift. The use of pedometers during work was considered inherently safe for use by participants while working at the mine. Provision of more water drinking stations around the mine site was also feasible as this was already being planned by management though yet to be implemented.

3.4.3.3 Implementation of heat stress and heat strain measurements

At the meeting with the work, health and safety team, it was determined that access and transportation to any area of the mine where workers were at risk of heat stress and heat strain would be granted for the purpose of monitoring and evaluation. During this part of the study, the researcher was accompanied at all times by a representative of the mine, for health and safety reasons.

3.5 Limitations

Several proposed intervention components were not implemented (Appendix 4): due to the sensitive nature of the mining operation at this mine site; due to the limited resources that could be provided by the mine site during a time of cost cutting and industry consolidation; and due to lack of available time for the participants during their shift to engage in some of the active intervention components such as use of the onsite gym to increase physical activity. While these limitations did not allow for the full suite of proposed interventions to be implemented, a good number of health promotion interventions were able to be implemented, centred on the individual participant and the work environment. In addition, as a result of cost cutting and consolidation, a number of participants were lost, leading to a reduced number of participants at the end of the study.

3.6 Summary

The reviews of the literature highlight the effectiveness of workplace health promotion programs (such as construction, health care, transportation and manufacturing industry) across different worksites, using different strategies. The main strategies used were dietary, physical activity and environmental interventions. To achieve health status outcomes, notably BMI and weight changes, dietary interventions alone were less effective than a combination of dietary and physical activity interventions (Gudzune et al. 2013, Rongen et al. 2013). In previous research, the introduction of a supportive environment through incorporation of changes in the workplace proved more effective when combined with dietary and/or physical activity interventions targeted at individuals (Geaney et al. 2013, Gudzune et al. 2013). There is also evidence to suggest that while short duration interventions may have an apparently initial success, gradually they tend to attenuate, thus questioning long-term sustainability and effectiveness. Long duration interventions may not appear to be as effective as short duration interventions but the cumulative effect of long duration interventions, especially with frequent contact to ensure engagement in the program, the overall health status of workers would make this more sustainable in terms of improving health of workers as well as improving productivity (Rongen, Robroek et al. 2013).

For the current study, 35% (n = 157) of the available workers from the mine site were successfully recruited into the study. This number exceeded the required sample size of 137. While the full suite of proposed health promotion interventions could not be implemented, a good number of interventions was implemented within the confines of the operations of the mine, with as much support as possible from the work, health and safety team at the mine site.

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CHAPTER 4 – FEASIBILITY AND EFFECTIVENESS OF THE INTERVENTION ON THE OUTCOME OF OVERWEIGHT AND OBESITY AMONG SURFACE MINE WORKERS

4.1 Introduction

Overweight and obesity are directly dependent on nutrition and energy intake, as well as energy expended through physical activity. Healthy nutrition depends on a number of personal and environmental factors such as nutrition, knowledge and literacy and the types of foods and beverages available, including through worksite canteens and vending machines. Lack of physical activity and increased sedentariness through sedentary leisure-time behaviour or sedentary work roles have been associated with overweight and obesity (Choi et al. 2010; Stewart-Knox et al. 2012). This chapter presents the findings of the workplace health promotion intervention program and the impact of the program on selected health measures including weight, BMI and physical activity.

4.2 Literature review

According to the World Health Organization (WHO) and the Australian Commonwealth Government, the workplace has been recognised as a priority setting for health promotion programs, including workplace nutrition and physical activity programs (WHO 2007, National Preventative Health Taskforce 2008). The workplace has been identified as an ideal health promotion setting in which to target adults. This is because adults spend more than half of their waking life at work (Malik et al. 2014, Reed et al. 2014). Workers in the mining industry spend considerably more hours at work if they work a 12-hour shift, thus making their workplace the main avenue for any health promotion intervention programs for this cohort of workers. These workers are a particularly difficult cohort of workers to gain access to (George et al. 2012), and they generally tend to be overweight or obese and physically inactive (Joyce et al. 2013, Polkinghorne et al. 2013) thus increasing their risk of chronic diseases. This makes the mine site an ideal workplace setting for health promotion, especially for nutrition and physical activity programs.

A detailed literature review on workplace health promotion programs and their effects on health outcomes and behaviours was presented in section 3.2. The rest of this literature review will highlight individual components of workplace health promotion programs and their importance in influencing workers' behaviours and practices as well as their relevance to the employer.

4.2.1 Diet and nutrition

Worksites that have canteens and that provide food to workers can directly influence their food and nutrient intake (Previdelli et al. 2010). Provision of energy-dense nutrient-poor foods could potentially contribute to overweight and obesity at the workplace, particularly where other options are limited. Vending machines are often stocked with energy-dense nutrient-poor food choices that could potentially contribute excess dietary energy among workers (Lawrence et al. 2009, Kelly et al. 2012). Workers' knowledge, perceptions of, and barriers to, healthy nutrition are also crucial in promoting health of workers (Sabinsky et al. 2007, Escoto and French

2012, Escoto et al. 2012). This knowledge may influence what workers eat at home, what foods they bring to work and their choices from food outlets (French et al. 2007 and Devine et al. 2003).

4.2.2 Physical activity

Physical activity is defined as "any activity that gets your body moving, makes your breathing become quicker and your heart beat faster." (Department of Health 2014). In essence physical activity involves movements produced by skeletal muscles that result in energy expenditure (Caspersen et al. 1985). The domains of physical activity include – occupational (at the workplace), household and leisure time (for example, recreational activities, exercise and sports) (Samitz et al. 2011). Sedentary behaviour on the other hand is defined as prolonged time spent sitting or lying down (except for sleeping) (Department of Health 2014). Physical activity and sedentary behaviour can be considered polar opposites and Ekelund et al. (2016) have shown that the detrimental effects of daily sedentary behaviour can be eliminated by engaging in moderate intensity physical activity for 60-75 minutes per day. Owen et al. (2000) have shown that environmental determinants of lifestyles, especially in a workplace setting, can influence both habitual physical activity through active use of workplace environment (for example, staircases) and facilities (for example, workplace gym) and even habitual sedentary activity through the workplace environment (for example, use of elevators) and facilities (for example, use of emails and telephones rather than walking to colleagues' offices).

The mining industry as a workplace poses a considerable challenge with regards to engaging workers in physical activity. Many occupations in the mining industry have become sedentary in nature and this has been elaborated on in Chapter 2. As such many workers now lack the daily-recommended physical activity in their everyday work, predisposing them to chronic diseases such as hypertension and diabetes, thereby increasing their morbidity and mortality (McEachan et al. 2008). Lack of physical activity and increased sedentariness through sedentary behaviour or sedentary work roles have been associated with overweight and obesity (Choi et al. 2010; Stewart-Knox et al. 2012). Occupational physical activity that meets the national guidelines for physical activity may be protective against overweight and obesity in the absence of leisure time physical activity (LTPA). On the other hand, low LTPA coupled with a sedentary work role will contribute to overweight and obesity (Steeves et al. 2012). It could be argued that workers in the mining industry are exposed to high job loads that are physically demanding in nature, but this is not necessarily applicable to all workers as many processes in the mining industry are automated. For example, workers in an open cut mine are usually sitting inside an air-conditioned cabin of the heavy machine they are operating. This could be contributing to the very high rates of overweight and obesity in the mining industry. Furthermore, the mining industry utilises shift working, which may limit opportunities to engage in sufficient physical activity both at work and at home. In addition, the lack of physical activity can lead to work-related illnesses and prolonged recovery, which increases the financial burden of the employer from absenteeism, sick days, lost productivity and cost of hiring and training new employees (Medibank 2005). Workplace physical activity programs are thus a sound investment for employers: to reduce the financial burden of poor employee health; to be seen as being more socially responsible towards their employees; and to improve corporate image and be a workplace of choice for highly qualified and experienced employees.

Such a workplace physical activity program can reduce sick leave and absenteeism by 25%, decrease workers compensation costs by 40%, decrease disability management costs by 24% and improve productivity of both the employer and the employee (HAPIA 2010). Research has also demonstrated that for every $1 spent on workers' health, a return on investment of up to $4 is seen (Henke et al. 2011 and Baicker et al 2010). As such, planning and implementation of a workplace health promotion program focusing on nutrition and physical activity are beneficial to both the employer and the employee.

4.2.3 Summary

Individual behavioural (knowledge, attitudes and practices) as well as environmental (worksite canteens and vending machines) components of a workplace health promotion program may be synergistic in improving the health status of miners with respect to overweight and obesity. Such a synergy may be instrumental in the long-term sustainability of a workplace health promotion program. In addition, it would appear that the benefits to the employer far outweigh the costs of running such a program. The detailed methodology of such a program is outlined below.

4.3 Methodology

4.3.1 Design

Two formal measurement periods were selected for diet, nutrition and physical activity measures, while three formal measurement periods were selected for weight, height, body mass index, blood pressure and blood glucose measurements. The baseline measure for diet, nutrition and physical activity was conducted in April 2013, with one-year follow-up in May 2014. The baseline measure for weight, height, body mass index, blood pressure and blood glucose level was conducted between January and March 2013. The second measure for weight, height, body mass index, blood pressure and blood glucose measurements was conducted in August 2013. The third and final measure for weight, height, body mass index, blood pressure and blood glucose measurements occurred after one year, between January and March 2014. Further details are provided in figure 3.2, above.

4.3.2 Participants

A total of 157 participants consented to participate in the study, of which 141 provided baseline data. Of these 141 participants, 105 completed the diet, nutrition and physical activity questionnaire and 69 of these also completed the 3-day food record. At the one-year follow-up, 89 participants took part in the study measures (36.9% attrition rate). Of these 89 participants, 33 completed the diet, nutrition and physical activity questionnaire and 25 also completed the 3-day food record. Further details are provided in figure 3.2, above.

With regard to measures of weight, height, body mass index, blood pressure and blood glucose measurements, 141 participants completed these measures at baseline, 98 participants completed these measures at the mid-point of the study and 89 participants completed these measures at the one-year follow-up. Further details are provided in figure 3.2, above.

4.3.3 Measures – instruments and procedures

4.3.3.1 Questionnaires

A) General questionnaire

A general questionnaire was developed comprising seven sections using validated questions from the 2011 New South Wales Population Health Survey which were originally based on the Active Australia Survey developed and validated by the Australian Institute of Health and Welfare (Appendix 5 footnotes).

- **Section 1** collected demographic information from participants, including age, gender, suburb of home address and educational qualifications, as well as non-demographic information, including clothing worn at work, number of hours worked, part of body used most during work and any work-related injuries.
- **Section 2** collected information on smoking status. The already validated questions in this section were adapted from the 2011 New South Wales Population Health Survey.

- **Section 3** collected information on hydration perception, practices and barriers to hydration at work. The already validated questions in this section were adapted from the 2011 New South Wales Population Health Survey.
- **Section 4** collected information on health status, focusing on diabetes and hypertension. The already validated questions in this section were adapted from the 2011 New South Wales Population Health Survey.
- **Section 5** collected information on physical activity. The already validated questions in this section were adapted from the 2011 New South Wales Population Health Survey.
- **Section 6** collected information on fruit and vegetable consumption. A validation of this part of the questionnaire was undertaken comparing the responses from the 3-day food record. Details of this validation study are presented in chapter seven.
- **Section 7** collected information on fluid consumption using a Fluid Frequency Questionnaire. A validation of this part of the questionnaire was undertaken comparing the responses from the 3-day food record. Details of this validation study are presented in chapter seven.

B) 3-day food record

In addition to the general questionnaire, participants were also given a 3-day food record to complete (Appendix 6). This food record consisted of instructions, an example of how and what to fill in the record, and three days (two weekdays and one weekend day) of record sheets to be used to record food and drinks consumed.

A Microsoft Excel 2010 database was created and used to document all nutrition decisions regarding the food record if food items in the FoodWorks software did not directly correlate with an item recorded by participants. This decision was then used throughout the data entry process for all similar food record entries into the FoodWorks software (Appendix 20). Of the 69 participants who completed the 3-day food record at baseline, 26 were unusable as their average energy intake was lower than their basal metabolic rate, leaving 43 useable food records.

C) <u>Type 2 Diabetes risk assessment questionnaire</u>

The Australian Type 2 diabetes risk assessment questionnaire was also given to participants to take home and return upon completion (Department of Health 2013).

D) <u>Administration of questionnaires</u>

The general questionnaire was administered to all participants by the primary researcher. Upon completing this questionnaire, participants were given the 3-day food record and instructed on how to complete it using the example provided in the food record as a guide. The general questionnaire was administered prior to shift commencement. The 3-day food record and the diabetes risk assessment questionnaires were given to the participants to take home and return upon completion.

4.3.3.2 Physical measures

The weight, height, body mass index, blood pressure and blood glucose measurements were undertaken by the primary researcher with assistance from two members of the mine site's health and safety team who had certified first aid training. These measures were collected prior to shift commencement after completion of the general questionnaire. All physical measures were undertaken in accordance with the World Health Organisation's stepwise approach to chronic disease risk factor surveillance guidelines (WHO 2013). Measures taken included: height and weight from which the body mass index was calculated (weight in kilograms (kg) divided by height in metres squared); and blood pressure and blood glucose.

A) Height

The height was measured using a portable stadiometer (Wedderburn Portable Stadiometer). The stadiometer was setup against a wall to provide support during measurement. Participants were asked to remove their footwear and headgear before standing on the stadiometer board. However, none of the participants agreed to remove their footwear as the standard issued steel capped boots were too cumbersome to remove and put on again. The primary researcher reviewed the time required to remove and put on the steel capped boots and concluded that the time taken to remove and put on the boots would increase the transit time for each participant. This would not be favourable to mine operations, as it would delay the start of shift work. Participants were therefore allowed to stand on the stadiometer with their boots on and subtractive corrections were made with regard to the additional height contribution from the boots for both males and females. This was considered reasonable, as all boots were standard issue and had the same height contribution from the soles of the boots for both males and females. The procedure followed to measure the height was in accordance with the Guide to Physical Measurements of the WHO steps manual (WHO 2013).

B) Weight

The weight was measured using a digital precision weighing scale with 50 gram increments (A & D Precision Scale UC-321). The scale was placed on an even, firm, flat surface. Participants were asked to remove any accessories they carried that would contribute to their weight. These included utility belts, helmets and radios. Participants weighed in with boots. This was necessary in order to keep to the time constraints of starting the shift on time, as discussed above. As the boots were standard issue, a representative sample of the boots was taken and each pair was weighed and the average weight calculated for the boots. The weight of the boots was then subtracted from the recorded weight to get the actual weight without the boots. No correction factor was applied for the standard issue clothing worn (shirt and trouser) for two reasons. First, the weight of the clothing was negligible and secondly, participants were always weighed in their standard issue clothing before starting their shift and would thus nullify the weight contribution of the clothing in relation to change of weight between the measures. Otherwise, participants' weight was measured in accordance with the Guide to Physical Measurements of the WHO steps manual (WHO 2013).

C) Body Mass Index

The body mass index was calculated from the weight and the height using the following formula:

$$\text{Body Mass Index} = W / H^2$$

Where W = Weight in kilograms and H = Height in metres

The body mass index was then used to classify participants' weight and the risk of associated health problems, as shown in table 4.1

Table 4-1: Classification of body mass index (BMI)

CLASSIFICATION	**BMI**	**RISK OF OTHER RELATED HEALTH PROBLEMS**
Underweight	< 18.50	Low (but risk of other clinical problems increased)
Normal range	18.50 - 24.99	Average
Overweight	25.00 – 29.99	Increased
Obese	30.00 +	Moderate to Severe

D) Blood pressure

Both the systolic and diastolic blood pressures were measured using a vital signs monitor (WelchAllyn Spot Vital Signs Device). Four cuff sizes were used ranging from small to extra-large depending on the circumference of the participant's upper arm. The blood pressure was measured in accordance with the Guide to Physical

Measurements of the WHO steps manual (WHO 2013). The systolic and diastolic blood pressures were used to categorise participants into a blood pressure category, as shown in table 4-2.

Table 4-2: Categorisation of blood pressure

CATEGORY	SYSTOLIC BLOOD PRESSURE (mmHg)	DIASTOLIC BLOOD PRESSURE (mmHg)
Low Blood Pressure (Hypotension)	< 90	< 60
Desired	90 - 119	60 - 79
Pre-hypertension	120 - 139	80 - 89
Hypertension	> or = 140	> or = 90

E) <u>Blood glucose</u>

The blood glucose was measured using a glucometer (Accu-Chek Advantage). Participants were asked to state how long prior to testing they had eaten any food, or drunk any fluid other than water, prior to testing. This information was used to categorise the blood glucose into fasting blood glucose (FBG), two-hour post prandial (2HPP) and random blood glucose (RBG) as shown in table 4-3.

Table 4-3: Categorisation of blood glucose

CATEGORY	Blood Glucose Range (*mmol/L*)
Random blood sugar	3.9 - 7.8
Fasting blood sugar	5.0 - 7.2
2-hr post prandial	< 10

4.3.4 Measures – Intervention

The health promotion intervention program was implemented from two perspectives: the individual participants and the work environment. The components of the health promotion intervention program that targeted individual participants were information and education, focused with reinforcement of positive dietary and physical activity behaviours through individualised participant feedback of their nutrient consumption, physical activity levels, physical measures (weight, body mass index, blood pressure and blood glucose levels), and through the Type 2 diabetes risk assessment tool. Participants also were referred to the free NSW Get Healthy Information and Coaching Services if they were identified as being overweight. A pedometer challenge was established, involving healthy competition between groups as well as individuals, using a pedometer to record the step count at the end of the day just before retiring to bed. The components of the health promotion intervention program that targeted the work environment, included provision of drink machines around the site, a review of the vending machines and refrigerated beverages on site and use of a 5-star healthy rating labelling system for food and beverages.

4.3.4.1 Intervention strategies focusing on individuals

A) <u>Information and education</u>

Specific information and education sessions were delivered to the participants over the study duration. Handouts of education sessions were also provided to participants. Topics of the focus included:

- Diet, nutrition and chronic diseases risk (Appendix 7) – This topic discussed food intake goals for adult Australians, recommendations for preventing diet-related chronic disease risk, tips to add variety to meals, tips to limit added sugar consumption, tips to limit excess salt consumption and tips to eat less-saturated fats.
- Physical activity and its importance (Appendix 8) – This topic discussed the health benefits of physical activity, the national physical activity guidelines and how to stay physically active.
- Physical activity and chronic disease risk (Appendix 7) – This topic discussed the four steps for better health for Australian adults with regard to physical activity. Information on types of physical activity was also provided and categorised into sedentary, light, moderate and vigorous activities.
- Heart disease (Appendix 9) – This was one of two chronic diseases topics that were covered in the information and education interventions. This topic discussed the risk factors for development of heart disease, including high blood pressure, high cholesterol level, overweight and obesity and physical inactivity. The topic showcased heart attack as the most common

manifestation of heart disease and how to recognise an imminent heart attack.

- Diabetes (Appendix 10) – This was the second chronic diseases topic that was covered in the information and education interventions. This topic discussed what diabetes is, the types of diabetes, recognising symptoms of diabetes, knowing the risk of diabetes by using the Type 2 Diabetes Risk Assessment Tool and management of diabetes.

B) *Individualised participant feedback*

- Nutrition – Each participant was given nutritional feedback based on both the questionnaire and the 3-day food record. Feedback included number of serves of fruits and vegetables consumed per day compared with the Australian Dietary Guidelines and the Australian Guide to Healthy Eating (NHMRC 2013a and 2013b); percentage of total and saturated fats and carbohydrates consumed, compared with the Macronutrient guidelines of the Nutrient Reference Values for Australia and New Zealand, to reduce the risk of chronic disease (NHMRC 2015); grams of dietary fibre consumed compared with the Macronutrient guidelines of the Nutrient Reference Values for Australia and New Zealand (NHMRC 2015); amount of sodium consumed compared with minerals and trace elements guidelines of the Nutrient Reference Values for Australia and New Zealand (NHMRC 2015) and finally, the amount of alcohol consumed compared with the Australian guidelines to reduce health risks from drinking alcohol (NHMRC 2009). The feedback also contained general recommendations and guides to serve sizes for core food groups such as vegetables, fruits, breads and cereals, meat and alternatives, and milk and dairy products.

- Physical activity – Each participant was given feedback on their physical activity levels based on the answers provided in the questionnaire. The questions used to assess and categorise physical activity were based on the National Australian Health Survey Users' Guide 2011-2013 (ABS 2013). Table 4-4 outlines the calculation and categorisation of physical activity levels used to provide feedback to participants.

Table 4-4: Calculation and categorisation of physical activity levels

EXERCISE LEVEL	**Scoring criteria**
Sedentary	Score less than 50
Low	Score 50 to <800
Moderate	Score 800–1600, or >1600 but with less than 2-hrs of vigorous exercise
High	Score >1600 and with 2-hrs or more of vigorous exercise
Formula for calculating score: *No. of times activity undertaken in last week x average time per activity (minutes x intensity)* *Intensity* value was estimated based on the three categories of exercise as follows (Ainsworth et al 2000): • 2.5 for walking • 5.0 for moderate exercise • 7.5 for vigorous exercise	

- Physical measures – Each participant was given feedback on their BMI, blood pressure and blood glucose levels using the categories outlined in tables 4-1 to 4-3.

C) *Other interventions*

- Referral to NSW Get Healthy Information and Coaching Services – Each participant whose BMI was in the overweight and obese category were given an optional referral to the NSW Get Healthy Information and Coaching Service delivered by NSW Health, a six month free coaching service aimed at helping individuals reduce weight.
- Pedometer challenge – To encourage physical activity, a pedometer challenge was organised as part of the intervention program. The challenge was to do at least 10,000 steps per day. It is recognised that walking 10,000 steps per day is likely to meet the current physical activity guideline of 30 minutes of moderate intensity physical activity per day for at least 5 days of the week (Le-Masurier et al. 2003). The cohort of workers in this workplace were mostly sedentary hence during the analysis 5,000 steps was used as the cut-off instead of 10,000 steps as research has shown that this is a good benchmark for Step-defined sedentary lifestyle index in adult population (Tudor-Locke et al. 2010). The challenge was organised between each of the four crews A, B, C and D as a group challenge to facilitate peer support of participants within each of the crews. Prizes such as t-shirts and caps were awarded for the most physically active crew and a $50 sports shop voucher was awarded for the most physically active person overall.

4.3.4.2 Intervention strategies focusing on the work environment

The work environment was assessed using the Checklist for Health Promotion Environments at Worksites (CHEW) (Oldenburg et al 2002). Based on the baseline information obtained from the CHEW, the following interventions were implemented:

- Provision of drink machines around the site – water bubblers were provided and strategically placed across the entire site to ensure ready availability for workers without having to go to the break room to replenish water supplies.
- Review of the vending machines and refrigerated beverages – a review of the contents of the vending machine and refrigerated beverages was conducted using the Checklist of Health Promotion Environments at Worksites (CHEW) and healthier snack (popcorn, weight watchers bars and tuna lunch) and drink options (water, reduced fat and skim milk) were introduced in all vending machines and in all refrigerators across the work site.
- Use of a 5-star healthy rating labelling system for food and beverages – A 5-star healthy rating labelling system for foods and beverages was used to inform participants about their choices of healthy food and drinks. This labelling system was developed by the Australian government in collaboration with industry partners and public health and consumer groups. The labelling system rated the overall nutritional profile of packaged foods. At the time of the study, this labelling system was being proposed by the

Australian government and was thus trialled in this study with permission. Healthier food and beverages were defined as having 3.5 stars and above. Figures 4-1 and 4-2 illustrate the 5-star healthy rating labelling system for selected vending machine and refrigerated products.

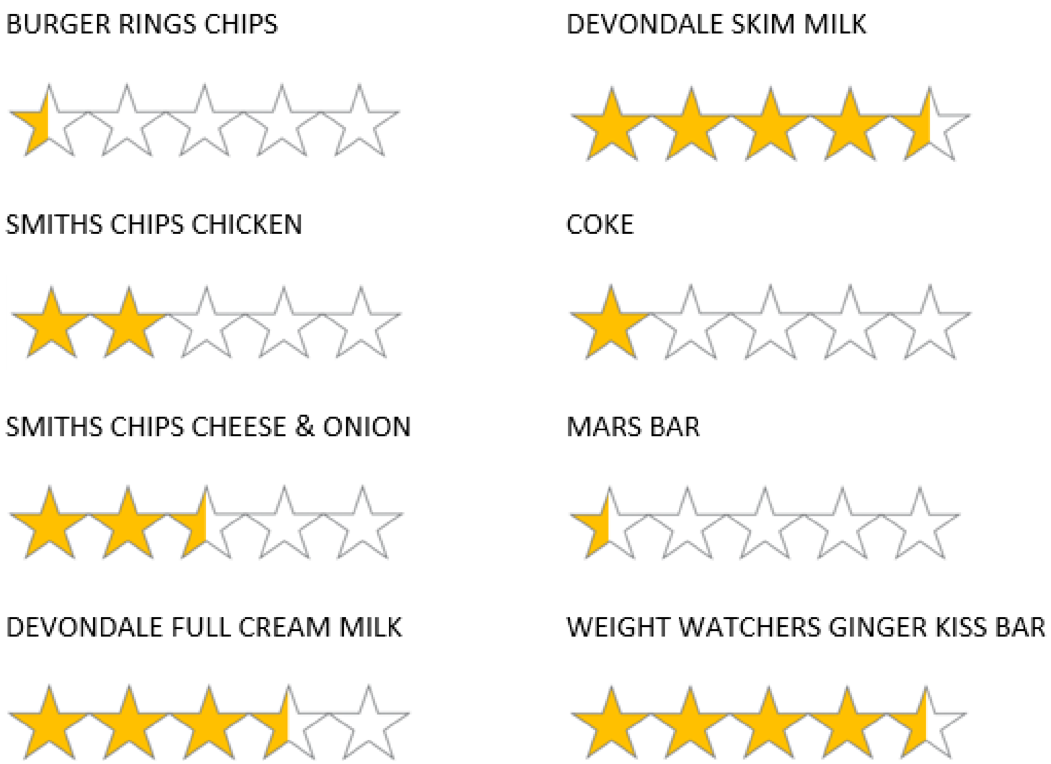

Figure 4-1: The 5-star healthy rating labelling system for selected vending machine products

Figure 4-2: Beverage and Snack vending machine before (left) and after (right) the 5-star healthy rating labelling system

4.3.5 Data processing and analysis

All data were entered into the statistical software IBM SPSS version 21 with the exception of the 3-day food record data, which was entered into the software FoodWorks version 7 (Xyris Software) using the Ausnut 2007 food database to analyse the food record entries. Mean, median and standard deviations are provided as summary indices for all data. Independent and paired sample t-test, chi square test and ANOVA were used to compare means across different time points of data collection with respect to weight, body mass index, blood pressure and blood glucose levels. Correlation analysis was used to assess the magnitude and direction of relationships between dependent and independent variables including age, gender, body mass index, crews and work location. Post-hoc statistical power was calculated for student t-Test using the observed effect size. The last observation data for participants who dropped out of the study were retained and used as their final data point where possible, making this an intention-to-treat analysis. A One-sample t-test was used for comparison of serves to the Australian Dietary Guidelines and the Australian Guide to Healthy Eating. Statistical significance was set at a P-value of <0.05.

4.4 Results

A total of 157 participants was recruited through a recruitment drive, as previously outlined in figure 3.2. At the baseline assessment, 141 participants (109 males and 32 females) out of the 157 recruited into the study participated. However, during each data collection phase not all participants completed all sections of the questionnaire. Hence data are presented for the number of participants who were able to provide complete data sets.

4.4.1 Anthropometric measures

The average age of all participants was 39 years with a range of 20 to 64 years. Males constituted 77% of this population (n=109) while females constituted 23% (n=32). The average weight of the participants was 95.8kg (95% CI 92.8, 98.7) and 78.8kg (95%CI 72.7, 84.8) respectively in males and females. The average body mass index was 30 kg/m^2 (95% CI 29.1, 30.8) in males and 28 kg/m^2 (95% CI 26.2, 30.2) in females. Table 4-5 outlines the baseline measures of anthropometric variables.

Table 4-5: Baseline measures of participants

	Males (*n* = 109)		**Females (*n* = 32)**	
	Mean	*SD*	*Mean*	*SD*
Age (years)[a]	39	11	40	11
Weight (kg)	95.8	15.4	78.8	16.9
Height (cm)	178.8	6.2	167.0	5.8
BMI (kg/m^2)	29.9	4.4	28.2	5.5
Systolic blood pressure (mmHg)	130.7	12.6	126.5	19.7
Diastolic blood pressure (mmHg)	82.1	8.4	79.3	11.6
Blood glucose (mmol/L)	6.4	1.4	5.7	1.5

SD – standard deviation, BMI – body mass index
[a] *n* = 78 males and 26 females

At the start of the study, 83% of the participants who completed anthropometric measures at all study times were overweight or obese. This is not surprising given that 90% of workers in an underground mine in a similar geographic region were overweight and obese (Polkinghorne et al. 2013). As overweight and obesity are risk factors for chronic diseases, including diabetes and hypertension, blood pressure and blood glucose measurements were also relevant. The average blood glucose, systolic and diastolic blood pressures were within the normal range for participants' ages. Over the study period, for male participants, there were minimal changes in weight, body mass index, systolic blood pressure and blood glucose levels as indicated by the negligible effect size ranging from 0.04 to 0.12. Among female participants, there were changes in weight and body mass index, with small to moderate effect size across the group. In addition, there were no differences between those workers who predominantly worked in an office (mainly administrative staff) and those who worked in the field (truck drivers, drillers and maintenance personnel). Shift timing did not appear to influence any measured parameters. Figure 4-3 presents the trend in changes in body mass index of the study population at baseline, the midpoint of the study and at the end of the study, while table 4-6 presents the changes in the anthropometric measures over the study period.

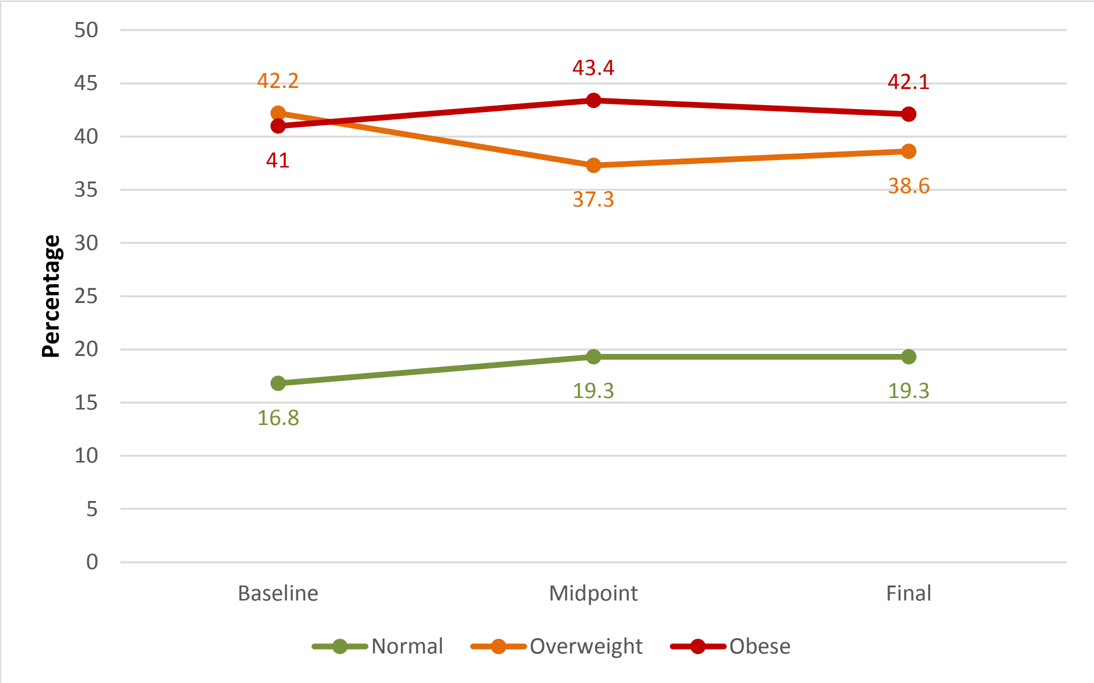

Figure 4-3: Change in BMI Category (%) from baseline to midpoint (6-month) and final (12-month) (n = 83, P = 0.113 (Chi squared analysis for BMI category))

Table 4-6: Changes in anthropometric measures from baseline at 6-month and 12-month follow-up

	Baseline *Mean (SD)*	**Midpoint (6-month follow-up)** *Mean (SD)*	**Final (12-month follow-up)** *Mean (SD)*	*F (df)*	*P-value*[b]	*Effect size (Cohen's d)*
Weight (kg)						
Males (n = 65)	95.9 (15.5)	95.8 (15.2)	96.5 (15.5)[a]	3.578 (2, 63)	0.034	0.10
Females (n = 18)	79.2 (17.2)	79.2 (17.5)	80.3 (17.8)	4.519 (2, 16)	0.028	0.36
BMI (kg/m^2)						
Males (n = 65)	29.6 (4.3)	29.6 (4.3)	29.8 (4.4)[a]	3.485 (2, 63)	0.037	0.10
Females (n = 18)	28.5 (5.6)	28.5 (5.8)	28.8 (5.8)	4.774 (2, 16)	0.024	0.37
Systolic blood pressure (mmHg)						
Males (n = 65)	130 (12)	130 (10)	133 (11)[a]	3.944 (2, 63)	0.024	0.11
Females (n = 18)	127 (21)	123 (16)	123 (18)	1.217 (2, 16)	0.322	0.13
Diastolic blood pressure (mmHg)						
Males (n = 65)	81 (8)	82 (7)	82 (7)	1.388 (2, 63)	0.257	0.04
Females (n = 18)	81 (14)	80 (11)	80 (11)	0.226 (2, 16)	0.800	0.03
Blood glucose (mmol/L)						
Males (n = 65)	6.7 (1.5)	6.6 (1.6)	7.3 (2.0)[a]	1.110 (2, 63)	0.021	0.12
Females (n = 18)	5.5 (1.1)	5.9 (0.7)	5.7 (1.1)	0.883 (2, 16)	0.433	0.10

[a] Significantly different from midpoint (6-month follow-up) after adjusting for age and socioeconomic status, [b] ANOVA

4.4.2 Diet and nutrition measures

At baseline, the reported average daily serves of fruits were the same in males (n=109) as in females (n=32) (Mean – 1.5 serves/day for both, SD – 1.3 and 1.0 respectively) while the reported average daily serve of vegetables was higher in females (1.9 serves/day, SD – 1.3) than in males (1.6 serves/day, SD – 1.0).

Over the study period, there was a trend towards a reported increase in consumption of fruits and vegetables serves, though this was not statistically significant (Table 4-7).

Table 4-7: Changes in self-reported fruits and vegetables over the study period using data from the short FFQ

	Baseline	Final (12-month follow-up)	
	Mean (SD)	*Mean (SD)*	*P-value*[b]
Fruits (serves / day)			
Males (n = 20)	1.8 (2.0)	2.0 (1.5)	0.428
Females (n = 10)	1.5 (1.0)	1.2 (0.5)	0.306
Vegetables (serves / day)			
Males (n = 20)	1.4 (0.9)	1.9 (1.2)	0.065
Females (n = 10)	1.6 (1.4)	2.3 (1.4)	0.054

[a] based on a 5-day week, [b] Paired t-test

Table 4-8 presents the baseline intake of macronutrients and micronutrients among male and female participants. Of the 141 participants in the baseline assessment, 69 completed the 3-day food diary, of which 43 were usable. Among male participants, carbohydrates contributed 40% of total energy intake, fats contributed 30% of total energy intake, proteins contributed 20% of total energy intake and alcohol contributed 10% of total energy intake. Among female participants, carbohydrates contributed 43% of total energy intake, fats contributed 32% of total energy intake, proteins contributed 21% of total energy intake and alcohol contributed 4% of total energy intake.

Table 4-8: Mean daily macronutrient and micronutrient intake (95% CI) at baseline using data from the 3-day FR

	Male (n = 30)	**Female (n = 13)**
Macronutrients		
Energy (KJ)	9915 (8753, 11078)	7235 (5836, 8634)
Carbohydrate (g)	255 (219, 290)	195 (144, 247)
Total Fat (g)	84 (71, 97)	65 (50, 79)
Saturated fat (g)	35 (29, 41)	28 (22, 35)
MUFA (g)	32 (27, 37)	23 (17, 28)
PUFA (g)	11 (9, 13)	9 (6, 12)
LC n-3 PUFA (g)	0.43 (0.26, 0.60)	0.17 (0.08, 0.26)
Protein (g)	126 (112, 140)	90 (74, 106)
Sugars (g)	120 (91, 149)	104 (70, 138)
Fibre (g)	27 (23, 31)	21 (17, 25)
Alcohol (g)	14.0 (5.0, 23.0)	2.0 (-0.1, 3.9)
Micronutrients		
Sodium (mg)	2863 (2447, 3278)	2359 (1940, 2779)
Potassium (mg)	3857 (3376, 4339)	3004 (2499, 3509)
Calcium (mg)	872 (746, 997)	827 (676, 978)
Iron (mg)	15 (13, 18)	14 (10, 18)
Zinc (mg)	19 (15, 22)	12 (9, 14)
Folate (DFE) (µg)	502 (380, 623)	453 (310, 596)
Niacin (mg)	68 (61, 76)	48 (38, 58)
Thiamin (mg)	3.0 (2.0, 4.1)	1.7 (1.1, 2.2)

Figures 4-4 to 4-9 present comparisons of baseline and final average daily serves of core foods between the Australian National Health Survey (ABS 2016), and the Australian Dietary Guidelines/Australian Guide to Healthy Eating (NHMRC 2013a and 2013b). Recommended guidelines were set for persons by averaging male and female recommendations.

There was a statistically significant difference in the average per consumer daily serves of vegetables at baseline and at the end of the study when compared with the National average (P=0.004 and P=0.005 respectively).

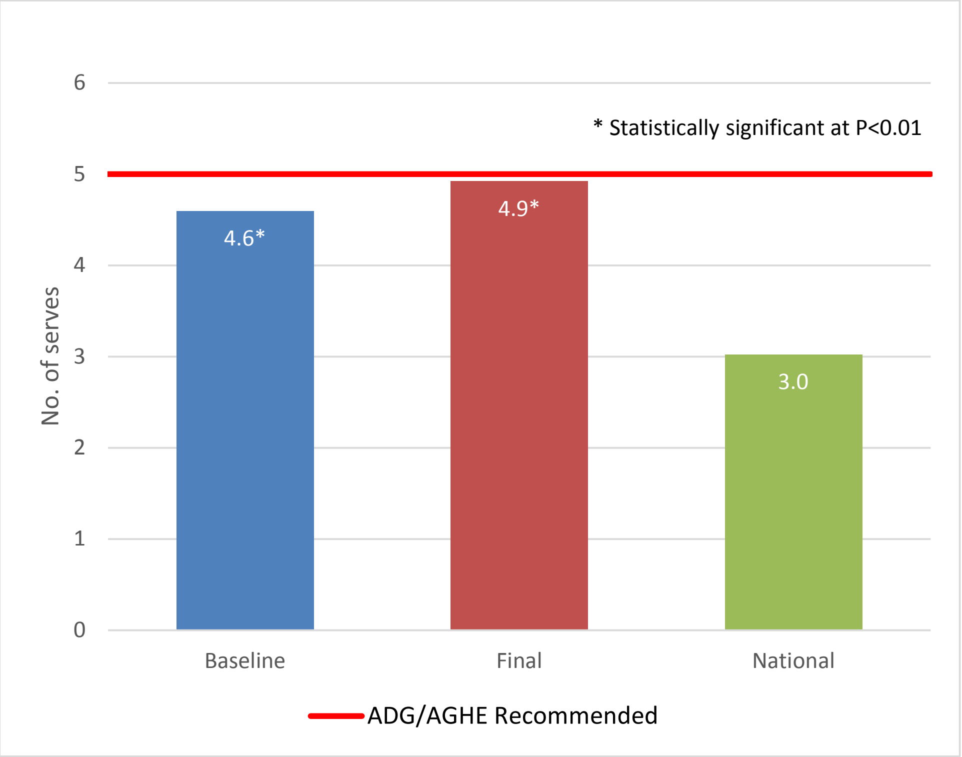

Figure 4-4: Comparison of average daily serves of Vegetable with Australian National Health Survey and Australian Dietary Guidelines/Australian Guide to Healthy Eating

Average daily serves of fruits were calculated with and without fruit juice contributions. With fruit juice contributing to the average daily serve of fruit, there was a statistically significant increase of 0.8 serves from the baseline (P=0.0249).

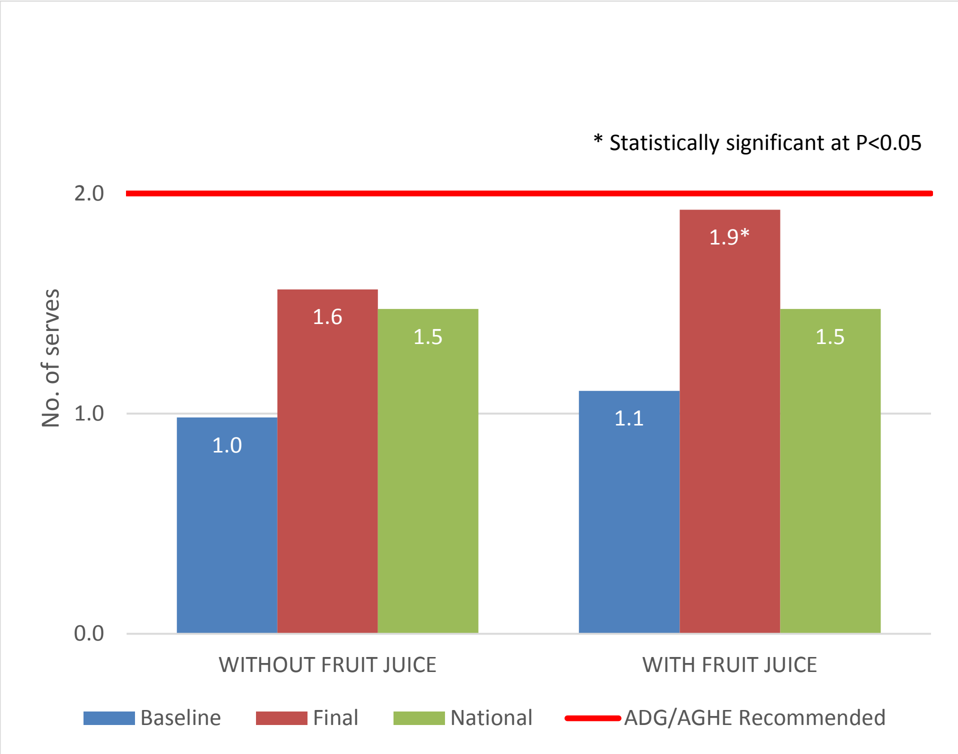

Figure 4-5: Comparison of average daily serves of Fruit with Australian National Health Survey and Australian Dietary Guidelines/Australian Guide to Healthy Eating

Average daily serves of breads and cereals increased by 0.5 serves from baseline, though this was not statistically significant (P=0.471).

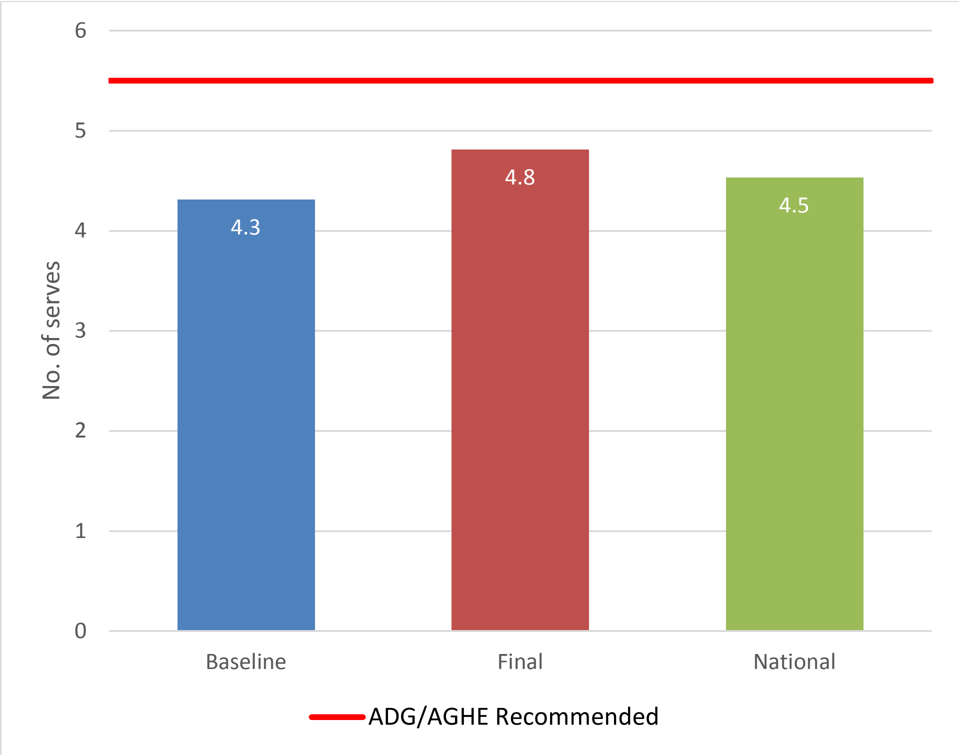

Figure 4-6: Comparison of average daily serves of Breads and Cereals with Australian National Health Survey and Australian Dietary Guidelines/Australian Guide to Healthy Eating

Average daily serves of meat and alternatives increase by 0.4 serves from baseline though this was not statistically significant (P=0.570).

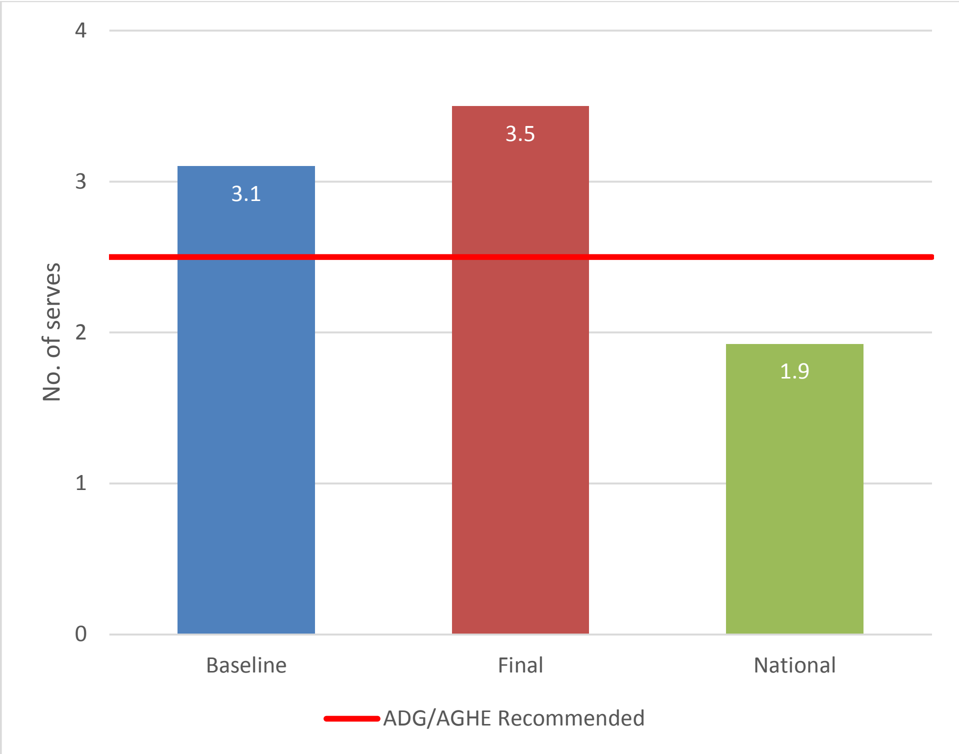

Figure 4-7: Comparison of average daily serves of Meat and alternatives with Australian National Health Survey and Australian Dietary Guidelines/Australian Guide to Healthy Eating

Average daily serves of milk and dairy products decreased by 0.1 serves from baseline (P=0.868).

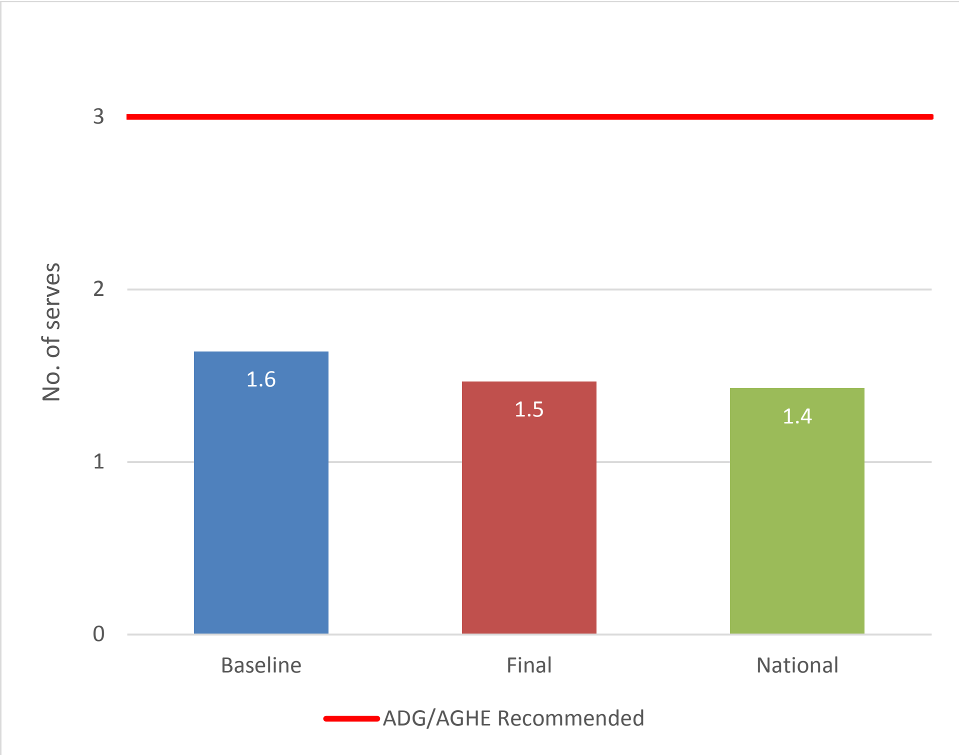

Figure 4-8: Comparison of average daily serves of Milk and dairy products with Australian National Health Survey and Australian Dietary Guidelines/Australian Guide to Healthy Eating

There was a decrease in the average daily consumption of discretionary foods of 355 grams from the baseline, though this was not statistically significant (P=0.0838). There was also a non-significant decrease in the average daily serves of discretionary foods (P=0.133).

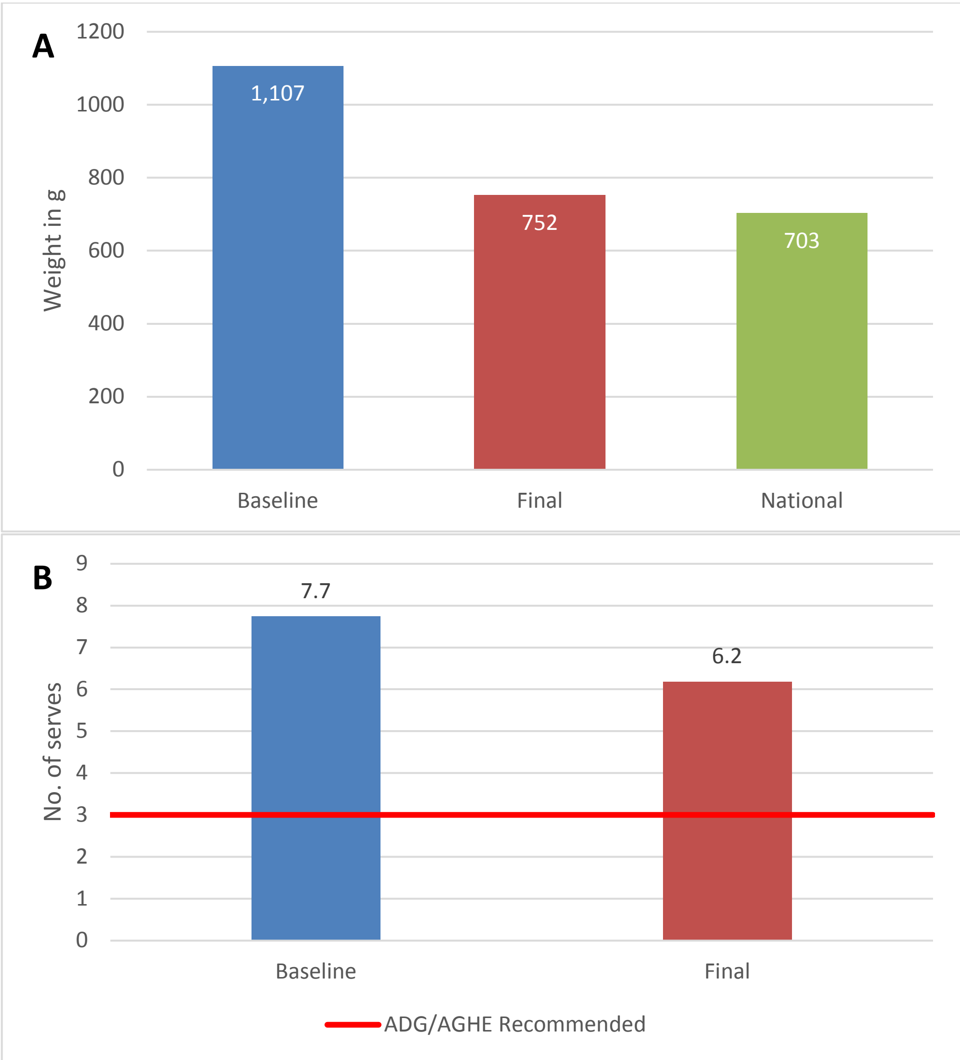

Figure 4-9: (A) Comparison of average daily consumption of Discretionary foods in grams with Australian National Health Survey. (B) Comparison of average daily serves of Discretionary foods with the Australian Dietary Guidelines/Australian Guide to Healthy Eating

Table 4-9 presents the mean intake of core food groups, beverages and discretionary foods per consumer. While there were increases in consumption of core foods, only the increase in fruit consumption was statistically significant (P=0.00839 with fruit juice and P=0.0359 without fruit juice).

Table 4-9: Mean intake of food groups (grams, 95% CI) per consumer per day using data from the 3-day FR

	Baseline	**Final**	**Gram difference**	**P-value[b]**
Core food groups				
Vegetables	345 (264, 425)	369 (277, 461)	24	0.679
Fruit				
- With fruit juice	144 (108, 180)	275 (187, 363)	131	0.00839*
- No fruit juice	129 (93, 164)	230 (141, 319)	101	0.0359**
Breads and cereals	194 (156, 232)	238 (169, 306)	44	0.252
Meats, alternatives	216 (172, 260)	245 (165, 325)	29	0.516
Milk, dairy product	272 (216, 327)	284 (206, 362)	12	0.791
Beverages				
Water	1086 (688, 1483)	1266 (865, 1667)	180	0.508
Non-alcoholic[a]	859 (654, 1065)	595 (370, 820)	-264	0.0772
Alcoholic	695 (262, 1129)	595 (234, 956)	-100	0.697
TOTAL	2062 (1600, 2524)	1951 (1607, 2296)	-111	0.693
Discretionary foods	1107 (818, 1395)	752 (452, 1052)	-355	0.0838

[a] includes Tea/Coffee, Cordial, sports/energy drinks, and fruit juice, [b] Student t-Test

* Statistically significant at P<0.01 ** Statistically significant at P<0.05

4.4.3 Physical activity measures

At baseline, the reported average daily physical activity levels were comparable between males (n=109) and females (n=32) (Mean – 324 and 321 MET minutes/day respectively, SD – 354 and 395 respectively). Over the study period, the reported overall daily mean physical activity levels and physical activity levels across the domains of leisure time and household physical activities did not change significantly in males and females (Table 4-10). The average number of hours spent in sedentary behaviour during workdays was 11 hours while the average number of hours spent in sedentary behaviour during days off was 5 hours.

Table 4-10: Changes in self-reported physical activity over the study period

	Baseline	**Final (1yr follow-up)**	
	Mean (SD)	*Mean (SD)*	*P-value*[c]
OVERALL PHYSICAL ACTIVITY			
Physical activity (MET mins/week)[a]			
Males (n = 20)	2737 (3217)	2571 (2270)	0.751
Females (n = 10)	2123 (1155)	2315 (2359)	0.738
PHYSICAL ACTIVITY DOMAINS			
Leisure time (mins/week)[a]			
Males (n = 20)	1524 (2144)	1555 (1420)	0.920
Females (n = 10)	1637 (1115)	1249 (1108)	0.293
Household (mins/week)[a,b]			
Males (n = 20)	1472 (1891)	1388 (1510)	0.809
Females (n = 10)	975 (1184)	1253 (2274)	0.591
OTHER PHYSICAL ACTIVITY			
Sedentary activity (mins/week)[a]			
Males (n = 20)	1883 (1080)	1893 (1087)	0.889
Females (n = 10)	2233 (795)	1889 (887)	0.426

[a] Based on a 5-day week, [b] Includes household chores, [c] Student t-Test

Table 4-11A and 4-11B presents the results of the pedometer challenge as a physical activity intervention component. Participants in the C crew had the highest average step count and were the only crew to exceed the 7,500 step a day thus being classified as leading physically active lifestyles.

Table 4-11A: Pedometer challenge results: categorised by ranking and average daily step count

Rank	Crew	Average daily step count (Standard deviation)
1st	C crew (n = 10)	10,250 (± 660)
2nd	A crew (n = 6)	7,728 (± 836)
3rd	Office workers (n = 43)	7,529 (± 4173)
4th	D crew (n = 14)	7,515 (± 3490)
5th	B crew (n = 8)	4,813 (± 746)

Table 4-12B: Pedometer challenge results, categorised by sedentary, low and physically active lifestyle (based on SDSLI, Tudor-Locke et al 2013)

	<5,000 steps/day (Sedentary lifestyle)	5,000 – 7499 steps/day (Low active lifestyle)	>7,500 steps per day (Physically active lifestyle)
Field workers (n = 38)	18.4% (n = 7)	31.6% (n = 12)	50.0% (n = 19)
Office workers (n = 43)	9.3 % (n = 4)	48.8 % (n = 21)	41.9 % (n = 18)
Field workers by crew			
C crew (n = 10)	-	-	100.0 % (n = 10)
D crew (n = 14)	14.3 % (n = 2)	28.6 % (n = 4)	57.1 % (n = 8)
A crew (n = 6)	-	83.3 % (n = 5)	16.7 % (n = 1)
B crew (n = 8)	66.7 % (n = 5)	33.3 % (n = 3)	-

4.4.4 Health promoting environmental measures

With regard to the workplace, Table 4-12 presents the different environmental characteristics across the entire worksite compiled from the Checklist of Health Promotion Environments at Worksites (CHEW) across the study period. Within the physical environment domain, there were 16 bulletin boards, 1 electronic bulletin board, 3 water stations, 3 changing rooms and 8 toilets at the start of the study across the worksite. By the end of the study, the number of water stations increased to 10 across the worksite. All other physical environment domain components such as showers, elevators and bicycle racks were neither present nor introduced into the worksite. Within the nutrition environment domain, there were six vending machines located at the worksite. Four of these were cold beverage vending machines which offered a variety of soft drinks and no water, while two were snack vending machines which offered a variety of sweet and savoury snacks. In addition to the vending machines, there were three refrigerators across the site that offered full fat milk. At the start of the study, there were no observed posters or signs of any kind about healthy food. By the end of the study, there were 38 observed posters or signs about healthy food including encouraging more fruit and vegetables consumption, encouraging dietary fat reduction, notices about dietary information of vending machine contents and notices about the relationship between diet and chronic diseases such as diabetes and heart disease. Within the physical activity domain, there were one fitness centre, four stairways and two posters about onsite physical activities at the start of the study. By the end of the study, there were 18 different posters and signs about physical activity including fun runs, community sporting events, gym membership subscriptions and increasing daily step count, among others. Within the alcohol environment domain, there were no posters or signs about responsible drinking. This increased to six by the end of the study and included information about standard drinks, recommended standard drinks per day and the association of alcohol with chronic diseases, among others.

Table 4-13: Statistics on the observed environment characteristics of the worksite at the start of the study (Baseline) and at the end of the study (Final) based on the CHEW tool

Characteristic	**Count (n)**	
	Baseline	**Final**
Physical environment		
Bulletin boards	16	16
eBulletin boards	1	1
Water stations	3	10
Number of changing rooms	3	3
Number of toilets	8	8
Nutrition environment		
Snack vending machines	6	6
Beverage vending machines	4	4
Posters/signs about healthy food	0	38
Microwave	2	2
Oven/toaster	2	2
Fridge	6	6
Physical activity environment		
Fitness centre	1	1
Stairways	4	4
Posters/signs about physical activity	2	18
Smoking		
Posters/signs about smoking restrictions	7	14
Posters/signs about smoking cessation	2	14
Number of designated smoking areas	1	1
Alcohol		
Posters/signs about responsible drinking	0	6
Posters/signs about alcohol restrictions	1	1

Table 4-13 presents the different beverages and snacks offered in the vending machines and in refrigerators at the site. At the start of the study, the vending machines contained predominantly less healthy items, with chips and extruded snacks occupying the majority of the slots (44 slots overall) followed by chocolates (37 slots overall) and confectionary (24 slots overall). There were no other healthier items in the vending machines other than low fat chips (24 slots overall). At the end of the study, the number of healthier items in the vending machines increased to include more options and occupy more slots (24 additional slots per vending machine). With regard to the beverage vending machines, no changes were made for two reasons: firstly, the beverage vending machines were not owned by the mine site as they were owned and operated by a charitable organisation; secondly the vending machines could not accommodate water bottles, only canned beverages. With regard to refrigerated beverages, only full cream milk was available at the start of the study. By the end of the study, both reduced fat milk (95% fat free) and skim milk (99% fat free) were available as healthy alternatives to the full cream milk.

Table 4-14: Food and drink items in each of the six vending machines and refrigerators at the start (baseline) and end (final) of the study

VENDING MACHINE SNACKS	**Baseline slots (n)**	**Final slots (n)**
Less healthy items		
Chips/extruded snacks (>600 KJ/serve)	44	24
Chocolates	37	26
Confectionery	24	20
Healthier items		
Chips/extruded snacks (<600 KJ/serve)	24	36
Popcorn (<600 KJ/serve)	0	4
Confectionery (sugar free)	0	4
Muesli bars (<600 KJ/serve)	0	4
VENDING MACHINE BEVERAGES		
Less healthy items		
Sugary soft drinks	24	24
Healthier items		
Diet soft drinks	16	16
REFRIGERATED BEVERAGES	**Baseline number of packets per refrigerator (n)**	**Final number of packets per refrigerator (n)**
Less healthy items		
Full cream milk (1 Litre)	24	24
Healthier items		
Lite (95% fat free) milk (1 Litre)	0	12
Skim (99% fat free) milk (1 Litre)	0	12

4.4.5 Other measures

The Get Healthy NSW program referral was utilised by 4% of the overweight and obese workforce (n=5). Using the Australian Type 2 diabetes risk assessment tool (Department of Health 2013), 27.6% (n = 39) of participants were at low risk of developing type 2 diabetes, 48.3% (n = 68) of participants were at an intermediate risk and 24.1% (n = 34) were at high risk of developing type 2 diabetes. Blood pressure and blood glucose measurements carried out on the participants showed that 8% (n = 12) of participants had previously undiagnosed hypertension and 4% (n = 6) had previously undiagnosed diabetes. In all these cases participants were advised to seek further input from their General Practitioner. Of note is the enthusiasm with which these undiagnosed hypertension and diabetic participants engaged in the healthy lifestyle program with the aim to improve their overall health. Fifteen of these 18 participants were lost to follow up due to downsizing of the workforce hence no meaningful comparisons of the effect of the intervention program on them could be made.

4.5 Discussion

The results indicate that the majority of the workers at the mine site were either overweight or obese at the start of the study. Among study completers (n=83), 83.2% of participants were either overweight or obese (42.2% overweight and 41% obese) at baseline. After one year of the workplace health promotion program, 80.7% of participants were either overweight or obese (38.6% overweight and 42.1% obese). The BMI of participants showed a 2.5% increase in the normal BMI category as participants in the lower threshold of overweight shifted down from overweight to normal BMI. There was a 1.1% increase in the number of obese participants as participants in the higher threshold of overweight shifted up from the overweight to the obese category. These shifts resulted in a 2.5% decrease in the overall combined overweight and obesity rates. Access to workers' pre-employment and medical records were not made available to establish a weight gain pattern since commencement of work at the mine site. However, anecdotal evidence from 21% of the workers participating in the study (n=30) indicated that on average, workers tended to gain 5kg of weight each year for the first three years after starting work at the mine site. Subsequent self-reported weight gain for each additional year after the first three years was estimated at 500g-1kg per year on average. The results also indicated that while there was no significant weight loss over the study period among the participants, the workplace health promotion intervention was feasible and successful in at least maintaining the weight of the workers over the one year study period, the first time this had reportedly happened since the participants had commenced work at the mine site. Longer-term workplace health promotion programs of one year and above have demonstrated similar findings, in which successful maintenance of weight has been achieved (Dekkers et al. 2011, Goetzel et al. 2009, Goetzel et al. 2010, Kwak et al. 2010, Lemon et al. 2010 and Linde et al. 2012). However, none of these workplaces was as rigid as the one in this study, in which work tasks were highly prescribed and there was little time and opportunity for other activities. Hence, being able to maintain participants' weight was a significant achievement of the program, given the limitations of what was possible at the mine site (Appendix 4). A possible reason for the small reduction in overweight and obesity prevalence over the one year intervention period was the poor morale and stress of the workers in the face of significant downsizing of the workforce at the mine site. Another reason may be that obesity is complex and there are multiple related behaviours and determinants that mean that it is difficult to address this issue; as well as the long latency that can be expected between implementation of the intervention program and the behaviour change likely to be required to impact upon the weight status of the workers in this study as one year was not a long time to change BMI categories. Further research is required in a stable workforce in the mining industry to verify if the changes in overweight and obesity proportions could be higher than those found in this study as this would remove the confounding variables of significant participant attrition, poor morale and stress. In addition, those workers who were identified as having previously undiagnosed hypertension and diabetes participated more in adopting the healthy lifestyle. Such health reasons can be powerful motivators for workers to adopt healthy lifestyle and intervention programs at worksites and thus be incorporated into future research.

Increased consumption of core foods and decreased consumption of unhealthy foods was noted among study completers who had useable food diaries for analysis. There was a significant increase in fruit consumption by 0.8 serves ($P<0.05$) with the study participants approaching the Australian Dietary Guidelines and Australian Guide to Healthy Eating of two serves of fruit per day at the end of the study. An increase in vegetable consumption by 0.3 serves was also seen, though it must be noted that the recorded serves of vegetables were significantly higher than the national average consumption ($P<0.05$) suggesting over-reporting of consumption of vegetables. Overall, the consumption of fruit and vegetables increased by 1.1 serves per day. This is higher than the findings of Beresford et al. (2001) and Robroek et al. (2012) who reported increases of 0.5 serves and 1.0 serves respectively. A study by Sorensen et al. (1999) reported a higher combined increase of 2.8 serves per day of fruit and vegetables over an 18-month study period, which was much higher than this study. This magnitude of increase could possibly be explained by the addition of a family-based intervention component of their health promotion program, which was lacking in this study.

Over-reporting of meat and alternatives and discretionary foods were also likely as the reported intake was higher than the National average intake. However, it is possible that the intake of discretionary foods may reflect the actual intakes of the participants, as anecdotal evidence (n=30) suggested that buying fast foods was a common practice in this cohort of workers on their way home after a shift because it was quick and convenient. This explains the high contribution of discretionary foods to total energy intake in this cohort of workers when compared with the national average. Average daily consumption of bread and cereals, and milk and dairy products were comparable to the national average and did not change significantly at the end of the study.

Interventions targeting physical activity were very limited in this study and were restricted to providing education on physical activity and its importance as well as its relation to chronic diseases and a pedometer challenge. The education messages were kept short and instructional in nature as research has shown this to be the recommended approach to physical education messages (Heath et al. 2012). Work during the 8-hr and 12-hr shifts followed a rigid prescribed set of duties that had to be completed at every shift leaving no extra time to engage in any physical activity onsite. In addition, the transit time to and from the mine site, which could be as much as 4-hrs a day, added to the time unavailable for engaging in physical activity. Anecdotal evidence from workers indicated that during days off work, time was spent relaxing and engaging in minimal “extra” physical activity than those due to routine household duties. Most participants were able to achieve the recommended physical activity guidelines of 150 to 300 minutes per week of moderate intensity physical activity at follow up (which translated to 750–1000 Met minutes/week) or 75 to 150 minutes of vigorous physical activity (which translated to 562.5–1125 Met minutes/week) (Department of Health 2014). But this result must be interpreted with caution as the small number of participants who provided complete physical activity data resulted in significantly reduced power (5.6%) of the physical activity component of the intervention. In addition, the data were based on self-reported physical activity, which were likely to be overestimated, a phenomenon common in self-reported physical activity questionnaires (Brown et al. 2004, Sebastião et al. 2012, Dyrstad et al. 2014). Other possible reasons for the likely overestimation may be due to:

- Social inclusion response bias (Aadahl and Jorgensen 2003) by which the participants may feel a need to demonstrate some form of physical activity so as not to be seen as being different from their peers and mates.
- The fact that the work rosters allowed for days off that would end up spreading over two weeks. There was therefore a likely chance that workers may have reported more than a week's physical activity on the questionnaire.

Leisure time physical activity and physical activity associated with household activities remained the same over the study period. This may be due to the small sample size analysed for the physical activity domains but it may also be due to the lack of time to participate in these activities outside of work as workers on a 12-hr shift could spend up to 16 hours away from their home leaving 8 hours to eat, sleep and get ready for the next day. Heath et al. (2012) have shown that workplace physical activity interventions without a pedometer component has a small effect size (0.21) as compared to one where a pedometer is used in addition to information and education.

Some extent of physical activity intervention, apart from education, was achieved through the pedometer challenge. While this challenge was useful in engaging some participants, not all were able to take part in the challenge as the pedometers could not be worn due to performance of duties that were critical to running the mine site. The pedometer challenge was chosen as it has the highest effect size (0.68) for engaging participants in physical activity (Heath et al. 2012). It is also one of the physical activity interventions that can effectively utilise workplace social support systems such as similar working crews to facilitate engagement in physical activity (Health et al. 2012). The success of such a social support mechanism was clearly demonstrated among Crew C who seemed to have had a supporting influence on each other as all of them exceeded the step-count cut-off. On the other hand, the pedometer challenge used in this study had limited use during days at work due to the restricted area where participants could walk. It was mostly beneficial during days off work when participants were able to increase step counts by engaging in sport and other physical activities. The majority of participants in the pedometer challenge (n = 37) were able to attain greater than 7,500 steps per day categorising them as leading physically active lifestyles with 33 participants leading a low active lifestyle and 11 participants leading sedentary lifestyles. There is thus possibility for improvement especially among the low active lifestyle participants. This has the added health benefit of improved glucose tolerance and better weight management with possible weight loss over an extended period of time (Swartz et al. 2003, Musto et al. 2010). There was no significant change in the two domains of physical activity measured namely leisure time and household physical activities over the study period and no change in sedentary behaviour among male workers during workdays, as no meaningful active workplace physical activity intervention was feasible. However, it is important to note the reduced sedentary activity among female workers even though this was not statistically significant. This could be due to an increase in household tasks among women even though his too was not statistically significant but may indicate a trend towards this behaviour. This trend needs further exploration in a larger cohort of participants.

The findings of this study are similar to McEachen et al. (2011) and Robroek et al. (2012) who both reported no changes in physical activity following a longer term (>1-yr) intervention program. Shorter-term intervention programs, on the other hand, have demonstrated significantly increased step count (Puig-Ribera et al. 2008), but whether this translates to long-term sustainable changes in physical activity is not clear. Workplace physical activity programs that incorporate the use of pedometers have had mixed outcomes, with some studies showing demonstrated increases in physical activity (De Cocker et al. 2009, Hess et al. 2011), and other studies showing that the increase in physical activity is short-lived and not sustainable (Behrens et al. 2007, Speck et al. 2009). The variation in outcome from a workplace physical activity program that uses pedometers is further supported by a meta-analytic review of workplace physical activity interventions that used a pedometer, which summarised that workplace pedometer interventions have very low demonstrable effect on increasing physical activity at the workplace (Freak-Poli et al. 2013). Given that the mine site is a restricted workplace with little environmental access to fully engage in brisk walking and other forms of physical activity, it is understandable why the pedometer challenge in this study was most useful during days off work. Of important note is the prolonged sedentary activity among this cohort of workers which can predispose to the development of chronic health diseases such as diabetes and heart disease with a resulting increase in mortality. Ekelund et al (2016) report that at least 60-70 minutes of moderate intensity physical activity per day is required to counteract the increased risk of mortality from prolonged sitting times. Engaging in this level of moderate intensity physical activity requires time which these workers clearly do not have given they work 12 hour shifts. It is clear that more research in the domains of physical education and pedometer use with higher participant numbers in a similar cohort of workers is required to demonstrate the effectiveness of a physical activity intervention component of a workplace health promotion program.

An audit of the work environment at baseline showed that the mine site was not a health promoting environment, as there were no posters or information about healthy diet, only two posters about physical activity, only three water stations to cater for the entire staff, no healthier alternatives within vending machines and only full cream milk provided in refrigerators across the site. By the end of the intervention, the work environment audit was repeated and showed a worksite that promoted health and wellbeing by displaying a number of posters on healthy food, chronic diseases and the interplay between diet, physical activity and chronic diseases, and the introduction of healthier options in the refrigerators and vending machines. A review of the vending machines onsite led to introduction of healthier options and a 5-star healthy rating labelling system, both of which have been shown to increase healthy food choices (French et al. 2010, Lemon and Pratt 2010, Sutherland et al. 2010). While usage and consumption statistics of the vending machines were not available to monitor the effect of the vending machine intervention, anecdotal evidence from visual inspection of the vending machines by the work, health and safety team indicated that consumption of healthy options did increase during the study period. The vending machines that dispensed beverages could not be modified to include water bottles as these were run by external charity organisations. Instead, additional water bubblers were installed in close proximity to every vending machine that dispensed beverages. This contributed to an improvement in hydration status, as discussed in chapter five.

It is important to note that 12 participants (8%, 1 female, 11 males) in the study had high systolic and diastolic blood pressures at three separate instances, making them a previously undiagnosed hypertensive. This is in keeping with the Australian national statistics in which hypertension is the most commonly diagnosed and managed chronic disease condition, accounting for 8% of all general practitioner visits (AIHW 2014). Nonetheless, it is an important finding in the context of the mine site as a workplace setting, given that two of the most common causes of mortality in Australia are coronary heart disease and cerebrovascular accidents, both of which are precipitated by hypertension (AIHW 2014). Thus any heart attack or stroke while working heavy equipment may prove disastrous at the mine site. Six participants (4%, 2 females, 4 males) were previously undiagnosed diabetics. This is again not uncommon in the Australian population, in which for every four adults diagnosed with diabetes, there is one adult that remains undiagnosed (AIHW 2014). While being an undiagnosed diabetic does not have any immediate life-threatening outcome, it does increase the risk of developing coronary heart disease. In addition, undiagnosed diabetes can be a burden of disease for the employer, due to increased frequency of sickness absence from work (Dray-Spira et al. 2013).

4.6 Limitations

The major limitation in this part of the study was the large participant attrition towards the end of the study. This was due mainly to loss of a significant number of the workforce due to a restructuring of the mining company in the face of a sharp decline in the global commodities prices. As a result, a large number of participants was lost, with the secondary effect of poor morale across the entire worksite. This poor morale also contributed to the lack of enthusiasm in the intervention program towards the end of the study. This was reflected in the small number of study completers in the final data collection phase at the end of the study period and the poor quality of the 3-day food records, resulting in exclusion of a large number of food records due to implausible data and non-completion of physical activity questionnaire, resulting in reduced power of the physical activity analysis. As a result, analysis of key associations between the intervention components and outcome measures were limited with low power and not statistically significant, even though a trend towards improvement may have been present.

Another limitation identified was the restricted access to the vending machines' contents, as these were managed by an external organisation that donated the proceeds of the vending machine to charity. Hence, removal of unhealthy products was not allowed, however an understanding was reached, by which addition of healthier snack options was allowed along with unhealthy products. Tracking this proved to be difficult as data on purchases were restricted and not provided. Hence visual and verbal accounts of usage were the only options available to assess this part of the intervention.

A limitation with regards to the physical activity component of the intervention was the focus on getting physically active while omitting the importance of education to reduce sedentary behaviour. However while it is anticipated that an improvement in physical activity will counter the effects of sedentary behaviour, the topic of sedentary behaviour would have added more value to this part of the intervention program. The onsite gym facility was also restricted and used only to train emergency rescue personnel. Furthermore, management did not allow workers additional break time to engage in some form of onsite physical activity. Hence encouraging and facilitating physical activity onsite was not an intervention component that was viable at any time. As a result, the pedometer challenge was the only physical activity intervention component that was possible onsite and was thus encouraged. The small number of participants who provided complete physical activity data resulted in a reduced power (5.6%) of the physical activity component of the intervention. Hence results of physical activity changes must be interpreted with caution and more data on the different domains of physical activity with more participants in the mining industry is required to fully ascertain the effect of a physical activity intervention among workers in this workplace.

Alternating shift work among the workers by which some workers would have worked on a day shift during the baseline data collection phase and a night shift during the final data collection phase, may have affected their ability to adequately quantify and record food and fluid intakes. Thus participants may have had only a limited time to consume food and drinks and may have postponed recording their intakes till a later time. This potentially introduces recall bias.

4.7 Conclusion

The workplace health promotion intervention program was demonstrated to be feasible at this mine site and successful in at least maintaining the weight of the workers over the one-year study period. Based on participants' body mass index, there was a 2.5% decrease in the rates of overweight and obesity over the one-year study period, mostly due to threshold shifts from participants who were borderline overweight and obese. Consumption of fruit increased significantly, approaching recommendations in the Australian Guide to Healthy Eating and the Australian Dietary Guidelines. Key learning from this study was that simple education messages and environmental changes are too weak an intervention by themselves to make significant changes in behaviour. Management support is crucial to any workplace health promotion intervention and supplementation by a workplace policy may strengthen the interventions to make significant long-term sustainable changes in behaviour. Examples of management support in this workplace could include opening up access to the workplace gym as well as providing time for workers to utilise the gym. Management could also institute a free annual medical check for workers and their families. This has the added advantage of engaging the workers' families, a powerful motivator in itself. In addition to the annual free medical check, periodic quarterly visits by health professionals to engage workers in discussing various aspects of their health could reinforce the sustainability of the intervention program. An incentives program for workers who are able to participate in the healthy lifestyle program and achieve their stated target weight loss goals could also be considered by management. A definitive way for management to demonstrate its commitment to improving the health of its workforce is by implementing proactive workplace policies around food choices on site (e.g. including a policy about catering at meetings), physical activity (e.g. a policy on stand-sit workstations, walking meetings etc.), hydration and water consumption (e.g. a policy on hydration management plan), and general health and wellbeing. It is hoped that the learning from this part of the study could be used to further refine and improve the health promotion intervention program so as to actually achieve weight reduction in individual participants.

4.8 References

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CHAPTER 5 – FEASIBILITY AND EFFECTIVENESS OF THE INTERVENTION ON HYDRATION STATUS AMONG SURFACE MINE WORKERS

5.1 Introduction

Miners working in both temperate and tropical regions of Australia present to work dehydrated (Miller and Bates 2010, Biggs et al. 2011, Polkinghorne et al. 2013). During a work shift, it has been reported that only 50-60% of the fluid lost in sweat was able to be replaced, further increasing the risk of dehydration among miners who present to work hydrated (Sawka et al. 2001, Kalkowsky and Kampmann 2006). Dehydration has been associated with various health effects on the central nervous system and the musculoskeletal system, which may impair the worker's ability to perform optimally and increase the risk of accidents or injuries at the workplace. Dehydration is thus a valid concern to workers and their employers in the mining industry. This chapter looks at the prevailing hydration status of surface mine workers and explores the effect of the intervention program on hydration status.

5.2 Literature review

Hydration is the body's ability to manage total body water at different levels, that is, at the cellular level, tissue level, organ level and system level. Normal body water content status is termed 'euhydration' while a deficit in body water content status is termed 'hypohydration' or 'dehydration' (Parsons 2014). When the body is well hydrated, the body water content is distributed to all the cells. However, when the body is dehydrated, the cells lose water, thus resulting in a water deficit within the cells. Rehydrating with drinking water will eventually correct the cellular fluid deficit but this process is slow.

5.2.1 Body composition of water

The human body is composed primarily of water with 60% of the body weight in adult males and 50-55% of the body weight in adult females being water. This is the total body water (TBW). The TBW is divided between two compartments, the intracellular compartment, which makes up two-thirds of the TBW and extracellular compartment, which makes up the remaining one-third of the TBW. The extracellular compartment is further subdivided into the intravascular compartment (8% of extracellular compartment) and the interstitial compartment (25% of extracellular compartment) (Parsons 2014). The TBW is never static and is in a state of flux, always being balanced by the needs of the different tissues.

Different tissues and organs in the body have different water content. Apart from blood, muscle contains the greatest amount of water by volume of tissue. This is important as continued muscle contraction uses up water and glucose to produce the energy for contraction, thus predisposing to dehydration. Bone and fatty tissue contain the least amount of water by volume of tissue. Other tissues and their associated water content are presented in table 5-1.

Table 5-1: Water content of body tissues/organs for the average 75kg man

(Adapted from Parsons (Parsons 2014))

Tissue/organ	% of water by volume of tissue	% of Total Body Water	% of body weight
Muscle	76	55	43
Skin	72	22	18
Bone	22	5	15
Fatty tissue	10	2	12

5.2.2 Physiological regulation of body water

The body's ability to regulate TBW is dependent on the hypothalamus, the posterior pituitary gland, the heart and the kidneys (Hall and Guyton 2011). There are two primary stimuli that activate a cascade of physiological processes to maintain TBW balance. These are blood/plasma volume and plasma solute concentration. When the plasma volume is high, the plasma solute concentration is low due to a dilution effect and vice versa. Either or both of these stimuli are sufficient to initiate the cascade mechanism.

When the plasma volume is low, the baroreceptors located in the arterial walls detect the drop in blood pressure as a result of the low plasma volume. These baroreceptors then send signals to the hypothalamus to stimulate the posterior pituitary gland to release a hormone called antidiuretic hormone (ADH). This hormone acts on the distal tubules and collecting ducts of the kidneys making them more permeable to water thus increasing the amount of water that is reabsorbed by the kidney decreasing urine output. The reabsorption of water corrects the low plasma volume with a resultant normalisation of blood pressure (Hall and Guyton 2011, Parsons 2014).

When the plasma volume is high, the baroreceptors in the heart detect the increase in blood pressure as a result of the high plasma volume. This stimulates the heart muscle to produce atrial natriuretic polypeptide (ANP). This hormone is a powerful vasodilator that has end organ affects primarily on the kidneys. It increases the blood flow to the kidneys thereby increasing the amount of plasma being filtered by the kidney. This in turn results in large amounts of water and sodium being excreted in urine. This excretion of excess water corrects the high plasma volume with a resultant normalisation of blood pressure (Hall and Guyton 2011).

When plasma solute concentration is low, as can occur if too much water is consumed, the osmoreceptors in the brain detect this and signals the hypothalamus to slow or stop ADH release from the posterior pituitary gland. This restricts the permeability of the tubules in the kidneys and allows excessive water to be excreted by the kidneys while conserving sodium, resulting in normalisation of the plasma solute concentration (Hall and Guyton 2011, Parsons 2014).

When plasma solute concentration is high, the osmoreceptors in the brain detect this and initiate the thirst mechanism. At the same time, ADH is released from the posterior pituitary. The combined effect is an increase in body water through consumption and retention by the kidneys. This increases the plasma volume and dilutes the solutes, thus normalising solute concentration (Hall and Guyton 2011, Parsons 2014). The entire physiological cascade mechanisms are summarised in figure 5-1.

The total body water has an important influence in thermoregulation and performance of the body in hot environments. The total body water normally remains relatively constant as a result of the various buffering mechanisms within the body as illustrated above, however physical exertion and exposure to heat affects this water balance as the body water starts to flux in order to support thermoregulation (Sawka and Coyle 1999). Effective thermoregulation thus relies on total body water, especially on plasma to transfer heat from the core to the skin for heat dissipation. In addition, body water is also used in sweating, which cools the skin by convective and evaporative heat loss resulting in a return of cooled blood back to the core, thus lowering the core temperature.

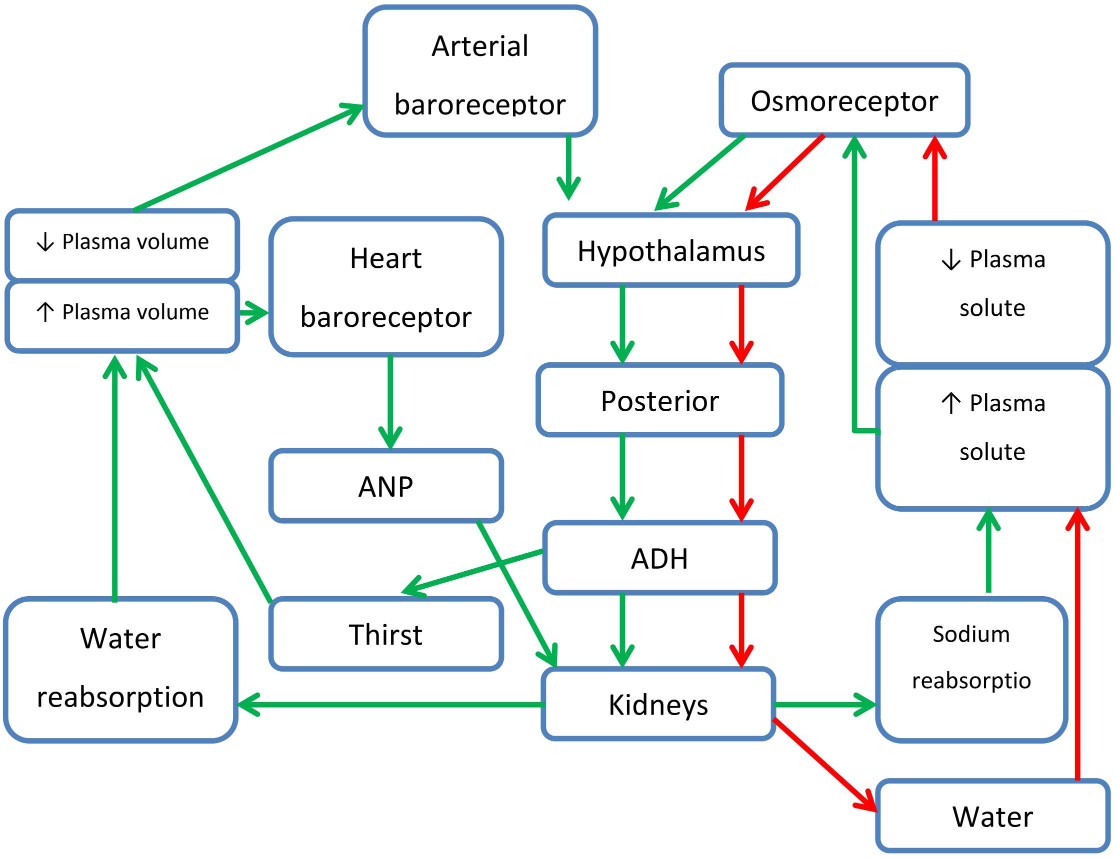


Figure 5-1: Schematic representation of the physiological mechanisms involved in regulation of water balance in the body. Red arrows – inhibitory pathways, Green arrows – excitatory pathway (adapted from (Parsons 2014)).

5.2.3 Health effects of dehydration

Early effects of dehydration include light-headedness, dizziness, tiredness, irritability and headaches, all of which are a function of decreased blood flow and decreased oxygenation of the brain (Hall and Guyton 2011). The adverse health effects of dehydration include central nervous system dysfunction, such as depressed cognitive function, which may further predispose workers to lapses in concentration and judgement resulting in potentially disastrous events (Suhr et al. 2004, Austin et al. 2008, Suhr et al. 2010, Ganio et al. 2011). Studies have shown that dehydration at 2% of body weight resulted in impairment of visual motor tracking, short-term memory, attention deficits and decreased arithmetic competence (Gopinathan et al. 1988, Cian et al. 2001). Dehydration can affect physical performance through a number of mechanisms, including central nervous system depression, fatigue and cardiovascular strain (Murray 2007).

The effects of chronic dehydration on the kidneys has been demonstrated in several studies and summarised to conclude that development of kidney stones has been consistently associated with chronic dehydration (Armstrong 2012). The effects of dehydration on chronic diseases such as overweight, obesity, type 2 diabetes and certain cancers have been debated (Stookey et al. 1997, Jiang et al. 2008, Armstrong et al. 2012, Bai et al. 2014, Borys et al. 2014). There is insufficient evidence to conclusively associate hydration with prevention of chronic diseases especially overweight, obesity, bladder and colon cancers, yet some studies have indicated the potential benefit of staying hydrated with regard to weight management possibly due to feelings of fullness associated with drinking water (Stookey and Ge 1998, Dennis et al. 2008, Phelan et al. 2008, Stookey et al. 2008, Muckelbauer et al. 2013). Furthermore, there is evidence that dehydration predisposes workers to fatigue, heat stress and heat related illnesses which can be potentially fatal, especially when exposed to high environmental temperatures (Kenefick and Sawka 2007, Armstrong et al. 2010, Bates et al. 2010). This is further discussed in chapter six of this thesis.

Workers with pre-existing medical conditions and undiagnosed medical conditions, such as diabetes and heart disease, are at an even greater risk of adverse health effect from working in hot environments due to impaired thermoregulation (Rutkove et al. 2009, Sokolnicki et al. 2009, Gryglewska et al. 2010, Biggs et al. 2011, Armstrong et al. 2012, Jehn et al. 2014). It is therefore important to identify those workers with pre-existing diabetes or heart disease, and monitor them closely.

Studies have shown that more than half of workers in the mining industry presenting to work are dehydrated at the start of their shift (Brake and Bates 2003, Bates and Schneider 2008, Polkinghorne et al. 2013). This is a cause for concern, especially for those workers in the mining industry who work in hot environments as they are at an increased risk of adverse health effects. This further reinforces the importance of hydration of workers prior to commencing work in hot environments.

5.2.4 Assessing hydration status

A 3% body weight loss in water is the cut-off criteria for defining significant dehydration, as at this level of dehydration the body induces physiological changes such as increased heart rate and decreased sweating sensitivity, thus further reducing the body's ability to cope with heat stress (Casa et al. 2000). The 3% body weight loss in water is now often used as the maximum dehydration limit in most industries that expose workers to hot environments (Hanson 2000, ISO7933 2004). Ways of assessing hydration status include simple methods such as urine specific gravity and colorimetric tests to more complex methods such as dilution technique, blood sample analysis for plasma osmolality and plasma volume and urine osmolality (Armstrong 2005).

5.2.4.1 Plasma osmolality

Plasma osmolality has been used for assessing total body water, however this method does not accurately represent total body water gain or loss during exposure to hot environments (Armstrong et al. 1998, Armstrong 2007). This is because the body's buffer mechanisms help to maintain the plasma volume by shifting water out of cells and into the plasma. Moreover, this method of assessing hydration status is invasive and impractical for use as an everyday test among workers.

5.2.4.2 Urine osmolality

Urine osmolality has been suggested as a possible gold standard for hydration assessment and monitoring (Shirreffs 2003). Urine osmolality is more sensitive at detecting changes in hydration status faster than plasma osmolality and is therefore a more sensitive indicator. However, it is still impractical and expensive for use in everyday testing among workers.

5.2.4.3 Direct urine specific gravity (USG) instrumentation

The urine specific gravity is less sensitive than the plasma or urine osmolality in representing total body water and hydration status, but it has been shown to be a reliable and important indicator of the body's *absolute* hydration status (Brake and Bates 2003, Popkin et al. 2010, Montazer et al. 2013). The USG is non-invasive and quick and cheap to conduct, making it practical for use as an everyday testing method to assess and monitor hydration status of workers. Anecdotal evidence suggests that some workplaces have introduced USG testing as a standard protocol for hydration assessment and monitoring. A limiting value of the USG is used as an indicator of hydration status. This is outlined in table 5-2.

A number of direct reading instruments have been developed for testing urine specific gravity. The instruments could either be dipped in a sample of urine and the USG read directly or a few drops of urine is placed on the reading chamber and the USG then read off the instrument. The underlying principle behind urine specific gravity measurement is that the instrument actually measures the refractive index or ratio of the velocity of light in air to the velocity of light in the urine sample and is dependent upon the number and weight of the dissolved particles (Armstrong et al. 1994, Casa et al. 2000).

Table 5-2: Index of hydration status (adapted from (Armstrong et al. 1994, Casa et al. 2000, Oppliger et al. 2005, Armstrong et al. 2010)).

Hydration level	**Hydration status category**	**Body weight loss (%)**	**Urine Specific Gravity**
Good	Hydrated	< 1 - 2	1.001 - 1.015
Fair		2 - 3	1.016 - 1.020
Poor	Dehydrated	3 - 5	1.021 - 1.025
Very poor			1.026 - 1.030
Clinical dehydration		>5	> 1.031

5.2.4.4 Colorimetric tests

Colorimetric tests for hydration status are based on reaction of urinary metabolites with reagents triggering a colour change. The change in colour is then read off a colour chart to indicate the hydration level or the USG. Many are in the form of urinary dipsticks. The USG tested this way correlates with urine osmolality (Simerville et al. 2005). There are however certain confounding variables to the use of the urine dipsticks that must be taken into account, these including vitamin intakes, medications and even pre-existing medical conditions, such as diabetes or renal failure. These variables tend to render the dipstick tests inaccurate due to the increased urinary metabolites as well as changes to urine colour. Despite these limitations, the dipstick test for hydration is simple to do, cheap and practical for use in workplaces.

In summary, assessing and monitoring hydration status at workplaces is best accomplished using either the direct reading of USG instruments, or the dipsticks, or both, as these methods are non-invasive, simple, cheap and practical for everyday use.

5.2.5 Promoting hydration at work

There are very limited studies that have exclusively focused on health promotion interventions at worksites with water/fluid consumption as a key focus area. Beverage consumption has been shown to be the predominant contributor to fluid intake rather than water consumption alone (Mears and Shirreffs 2015). A number of individual and environmental factors have been known to influence workers' decisions about food and fluid consumption in the workplace. For example, the presence of vending machines at worksites has been associated with an increased consumption of sugar-sweetened beverages in favour of water consumption (Davy et al. 2014). While other beverages and not only water, contribute water content to the body, certain fluids when consumed in excess may have a diuretic effect. Examples of such fluids include tea, coffee, soft drinks, energy drinks and alcohol (Shirreffs and Maughan 1997, Armstrong 2002). However, with regard to coffee, research has disputed its diuretic effects, especially as tolerance develops (Armstrong et al. 2005, Armstrong et al. 2007), but this debate is far from over (Zhang et al. 2014). Clearly more focused workplace interventions are required to promote water consumption specifically at workplaces so as to ensure that workers remain hydrated throughout their shift.

5.2.6 Summary

Maintaining optimal hydration status is important for workers in the mining industry especially for overweight or obese workers who may be dehydrated and working in hot humid environments. There is a real threat to this group's health and wellbeing since such workers are at an increased risk of developing heat related illness, which may be potentially fatal. It was therefore a crucial part of this study to assess hydration status of surface mine workers and to develop and test a simple workplace intervention to promote water and other fluid consumption. A detailed methodology of this process is outlined below in section 5.3.

5.3 Methodology

5.3.1 Design

Three formal monitoring periods were selected for this part of the study. The first was a baseline monitoring conducted in January-February 2013, depicting the peak summer period. The second was a mid-point monitoring conducted six months into the study, depicting the winter period, and the third was a follow-up monitoring conducted one year later in January-March 2014, again depicting the peak summer period.

5.3.2 Participants

Of the 157 participants who enrolled in the study, 141 took part in hydration measurements, and 83 took part at all three time points (baseline, midpoint and final). All observations were conducted prior to shift commencement during the day and night shifts.

5.3.3 Measures – instruments and procedures

5.3.3.1 Questionnaire

The same questionnaire that was previously described in chapter four was used to collect information on hydration practices and fluid consumption (Appendix 5). Specifically, sections three and seven of the questionnaire were for this part of the study. Section three of the questionnaire collected information on hydration practices and behaviours, while section seven collected information on fluids and the frequency of different fluids consumed. This fluid frequency questionnaire was based on a validated tool (Hedrick et al. 2010) and is further discussed in chapter seven. The questionnaire was administered to all participants by the primary researcher as previously outlined in chapter four.

5.3.3.2 Hydration status assessment

The hydration status was assessed by measuring the USG using an ATAGO digital handheld "PEN" refractometer (PEN-URINE S.G.). The refractometer was calibrated at the beginning of each day of testing by testing a sample of demineralised water and zeroing the refractometer. Both pre- and post-shift USG were tested in all participants. The pre-shift USG was measured prior to participants commencing their shift. Post-shift urine specific gravity measurements were not considered useful as a previous study by the researcher showed that pre-shift hydration status largely determines the post-shift hydration status (Polkinghorne et al. 2013). USG testing was done immediately in front of the participants and the samples discarded. This assured the participants that only USG was being tested and also provided immediate feedback to the participants of their hydration status. The USG was converted to hydration status with reference to table 5-2 (Armstrong et al. 1994, Casa et al. 2000). The limiting values were adapted to simplify categorisation of hydration level into two groups: hydrated and dehydrated. A feedback sheet showing hydration status and matching USG was given to each participant (Appendix 12).

5.3.4 Measures – intervention

As part of the study, the health promotion intervention program also focused on drinking fluids and staying hydrated. Specific aspects of the intervention program that focused on staying hydrated are discussed below in sections 5.3.4.1 to 5.3.4.5.

5.3.4.1 Immediate feedback and advice

Immediate feedback was provided to all participants during USG testing. Part of this feedback included showing them a representative urine colour chart that also indicated their hydration status. Feedback on improving hydration status was then provided verbally to all participants. Information given included optimal amounts of water to consume in a day (3-4 litres per day (Hall and Guyton 2011)) and prior to starting their shift (at least one litre), tips on staying hydrated throughout their shift (drinking at least one cup (250ml) of water every 15 minutes (Miller and Bates 2010)) and avoiding diuretic fluids, such as soft drinks and energy drinks.

5.3.4.2 Periodic voluntary hydration testing

To promote a greater awareness of hydration status, all participants were informed that they could voluntarily undergo hydration testing at any time during their shift, including when selected to undergo drug and alcohol testing.

5.3.4.3 Review of urine colour charts

All toilet facilities at the mine site had urine colour charts posted to guide workers in knowing their hydration status through the colour of their urine. Initially these standard charts were found to be poorly representative of hydration status and were thus reviewed to provide a better representation of hydration status

(Appendix 13). The old urine colour charts were then replaced with the new charts in all toilets. The new charts were also posted to general notice boards along with information and education posters targeting hydration.

5.3.4.4 Information and education

A three-month information and education program centred on hydration was implemented in two parts in the summer of 2013-2014. In November 2013, the first information and education topic was "Hydration and its importance" (Appendix 14). This topic focused on introducing the basics of hydration, including the amount of water to consume during normal work and when working in hot environments, recognising signs of dehydration and knowing what fluids can have a diuretic effect. In addition, data was provided from the baseline hydration testing to reinforce the importance of hydration. Finally, practical recommendations were provided for the workers such as drinking a litre of water prior to starting the shift, refraining from drinking soft drinks, energy drinks, alcohol or coffee for 12-24 hours before starting the shift, among others.

The second information and education topic delivered in December 2013 was "Hydration and heat stress" (Appendix 15). This topic focused on introducing heat stress and linking hydration with heat stress. It also highlighted the importance of recognising dehydration early and provided practical recommendations for drinking water, reporting signs of dehydration and clothing and sunscreen use when working in a hot environment.

The third information and education topic delivered in January 2014 was "Hydration and fluid guidelines" (Appendix 16). This topic built on the previous two topics, consolidating the information on hydration and the various fluids that are available to hydrate. Specifically, this topic focused on the advantages and disadvantages of the different fluids for hydration. In addition, the approximate composition of commonly consumed beverages was provided to illustrate their energy content, the sugar content (carbohydrate) and the caffeine content. This provided the workers with an avenue to make an informed choice about beverage types consumed. Furthermore, fluid consumption guidelines for work in hot environments were specified and strategies to stay hydrated pre-shift, during the shift and post-shift, were provided.

5.3.4.5 Provision of drink machines around the site

A number of water bubblers were installed around the site, especially in areas with high worker traffic, such as the crib rooms and meeting rooms, where shift handovers were conducted. Water bubblers and drink vending machines operated side by side. However, the products in the vending machines were labelled to inform the workers about healthier and less healthy choices. This aspect of the intervention program has been discussed in chapter four.

5.3.5 Data processing and analysis

Only those participants who took part in hydration measurements at all three time points of the study were included in data analyses. All data were entered into the statistical software, IBM SPSS version 21. Mean and standard deviations are provided as summary indices for all data. The cut-off point for USG was set at 1.020 in keeping with literature (Armstrong et al. 1994, Casa, Armstrong et al. 2000, Oppliger et al. 2005, Armstrong et al. 2010). Statistical significance was set at a P-value of < 0.05.

Repeated measures analysis of variance (ANOVA) and independent samples t-tests were used to evaluate the differences between exposure groups (based on job location and pre- and post-intervention) and at each time point. Paired samples t-test was used to evaluate the differences in pre-shift USG between baseline and midpoint, midpoint and final and baseline and final test points. Correlation analysis was used to evaluate the relationship between risk factors such as age, body mass index, duration of exposure, hydration behaviours and practices, and hydration status.

5.4 Results

The general demographics of participants in the hydration measurements at the three time points are presented in table 5-3. The average age of participants was 39 years, with a range of 20-60 years. Males constituted 78% of this population (n=65) while females constituted 22% (n=18). The average body mass index was 29.4 kg/m^2.

Table 5-3: Demography of participants in the hydration testing at all three test points (n = 83).

	Mean (± SD)	*Range*
Age (yrs)	39 (± 11)	20 - 60
Weight (kg)*	92.3 (±17.2)	58.6 - 134.8
Height (m)	1.77 (± 0.08)	1.51 - 1.96
BMI (kg/m^2)*	29.4 (± 4.6)	21.1 - 42.1

*First test point (baseline) measures used

With regard to hydration status, table 5-4 presents the pre-shift USG and the hydration status over the three time points of the study. There was a statistically significant decrease in the USG as well as a statistically significant improvement in hydration status ($P < 0.001$). This was reflected only among the male workers ($P < 0.001$) and not the female workers ($P = 0.117$). No statistically significant relationship was found with regard to day or night shift ($P = 0.098$), although workers presenting to the night shift were generally dehydrated compared to the day shift. Figure 5-2 presents the trend of pre-shift USG over the entire study period.

Table 5-4: Pre-shift Urine Specific Gravity (USG) and hydration status of all participants at the three test points (n = 83).

	1st test point (baseline)	**2nd test point (midpoint)**	**3rd test point (final)**	**P - value**
USG				
Mean ± SD	1.020 (± 0.007)	1.017 (± 0.007)	1.015 (± 0.007)	< 0.001*
Range	1.003 - 1.032	1.003 - 1.032	1.002 - 1.028	
Hydration status n (%)				
Hydrated	33 (47.5)	56 (67.3)	62 (75.3)	<0.001†
Dehydrated	50 (52.5)	27 (32.7)	21 (24.7)	

* Repeated measures ANOVA, †Chi-square statistic

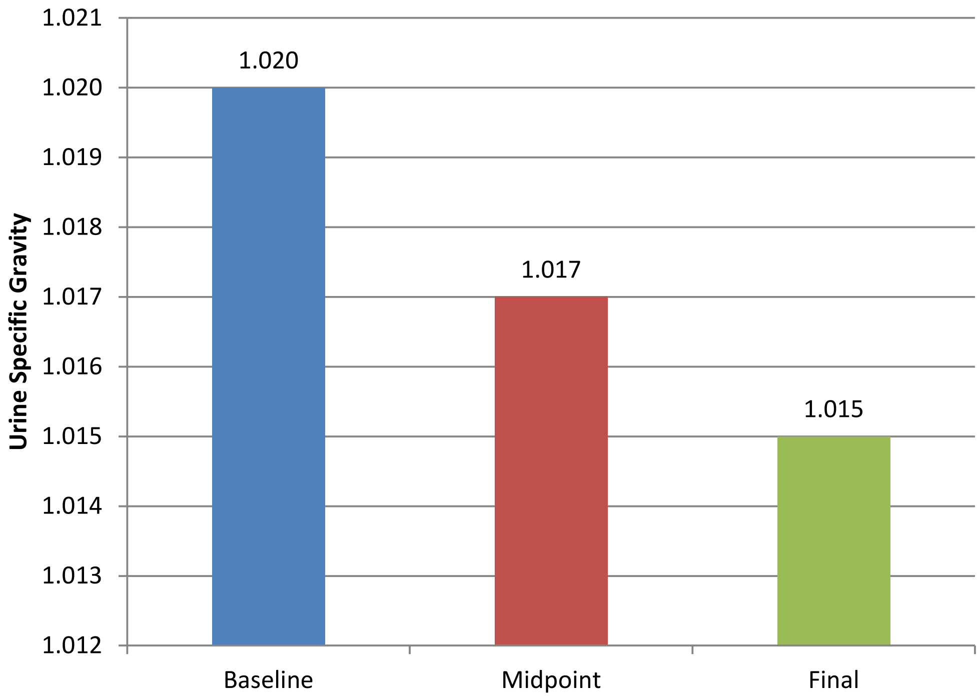


Figure 5-2: Average pre-shift Urine Specific Gravity trend over the entire study period (n = 83).

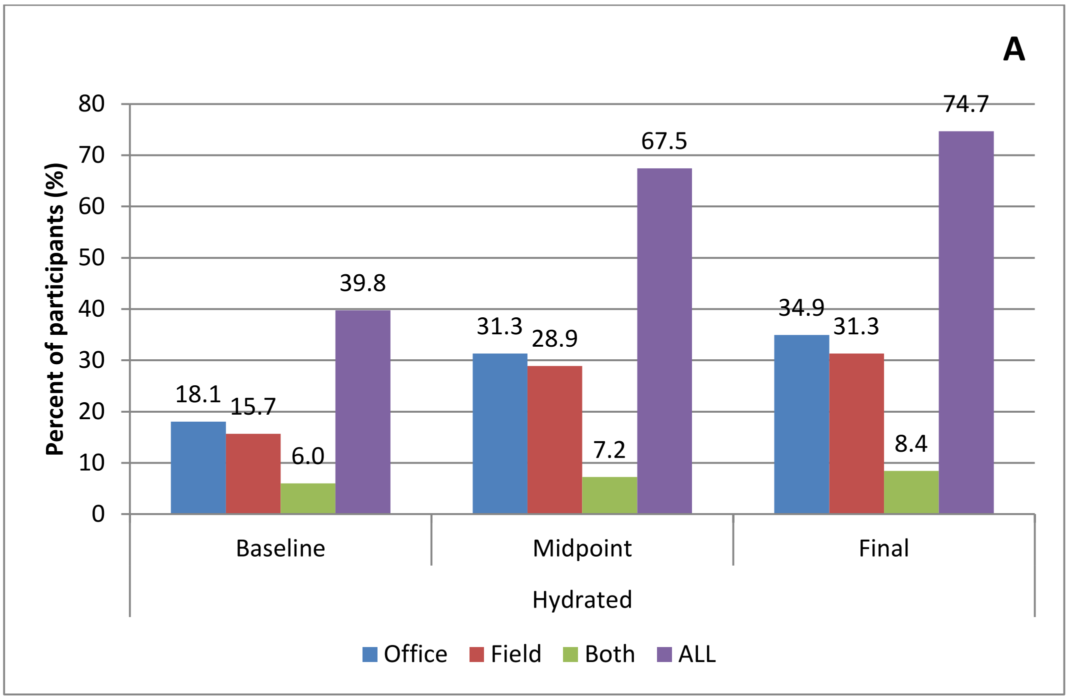
There was a statistically significant difference in the hydration status of field (predominantly outdoor) and office (predominantly in an air conditioned office) workers ($P < 0.05$). This is summarised in table 5-5. The proportion of workers who started their shift dehydrated was 72.6% at the start of the study. This improved to 30.5% of workers starting their shift dehydrated at the end of the study, a 58% improvement compared to the start of the study. Figure 5-3 (A and B) presents a breakdown of the trend of hydration status of participants based on their job location, that is, field, office or both, at the mine site across the three testing points.

Table 5-5: Hydration status of participants by job location over the three test points (n = 83)

Job location	Hydration status	1st test point (baseline)	2nd test point (midpoint)	3rd test point (final)	P - value
Field*†	Hydrated	13	24	26	< 0.05
	Dehydrated	29	18	16	
Office*†	Hydrated	15	26	29	< 0.05
	Dehydrated	16	5	2	
Both	Hydrated	5	6	7	0.70
	Dehydrated	5	4	3	

* Statistically different from baseline to midpoint

† Statistically different from baseline to final



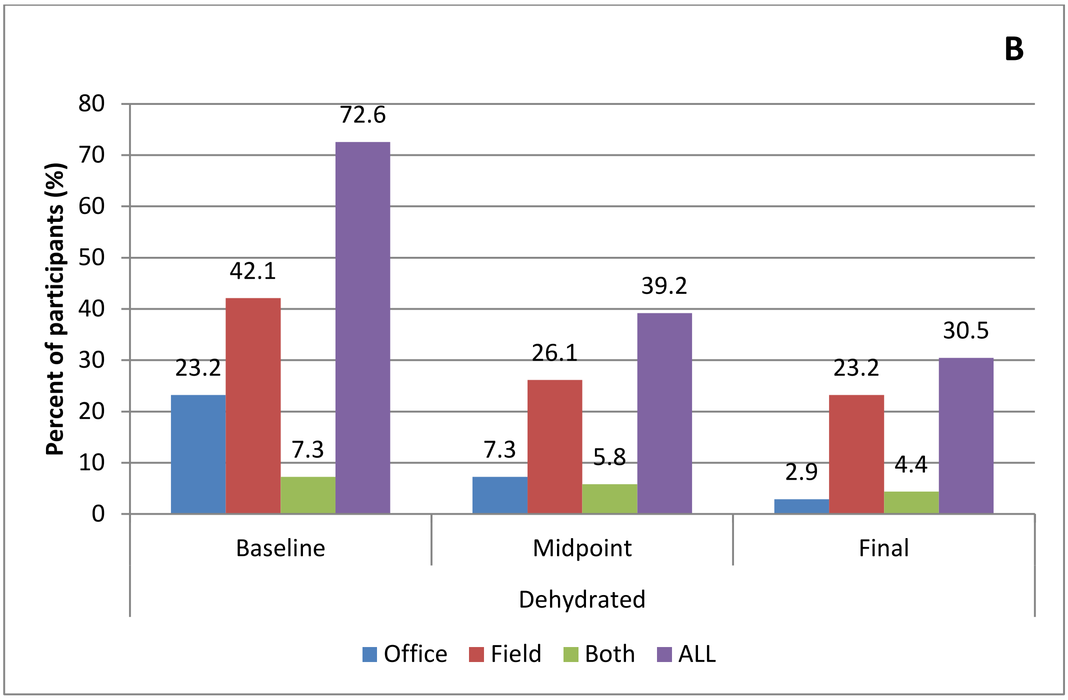


Figure 5-3: Hydration (A) and Dehydration (B) trends across categories of workers (n=83).

A significant 72% of workers predominantly consumed water at work, with other beverages supplementing water consumption. The majority consumed between 500mL and 2000mL of water during a shift. A snapshot of the prevalent hydration practices is presented in table 5-6.

Table 5-6: Prevalence of hydration practices and perceptions at work

Fluids predominantly consumed at work	***n (%)***
Water	76 (72.4)
Tea/Coffee	19 (18.0)
Soft drink	9 (8.6)
Sports drink	1 (1.0)
Water consumed per shift (1 cup = 250mL)	***n (%)***
< 2 cups	20 (20.8)
2 - 4 cups	32 (33.3)
5 - 8 cups	32 (33.3)
9 - 12 cups	10 (10.4)
> 12 cups	2 (2.2)
Perceived adequate water consumption at work	***n (%)***
Strongly agree	3 (2.9)
Agree	42 (40.3)
Disagree	53 (51.0)
Strongly disagree	6 (5.8)

Workers perception of their drinking habits was the only significant factor that correlated with hydration status. Table 5-7 summarises the correlation analysis of hydration status with possible risk factors. Figure 5-4 presents the trend of self-reported beverage consumption during the study period.

Table 5-7: Correlation of hydration status with potential risk factors

Risk factor	**Spearman's correlation (rho)**	**P - value**
Age	0.165	0.103
Gender	0.097	0.335
BMI	-0.008	0.940
Education level	0.017	0.874
Smoking status	0.100	0.321
Physical activity	-0.048	0.636
Perception of adequate water consumption	-0.355	< 0.001
Work site (field, office, both)	-0.146	0.148
Shift (day, night)	-0.167	0.098

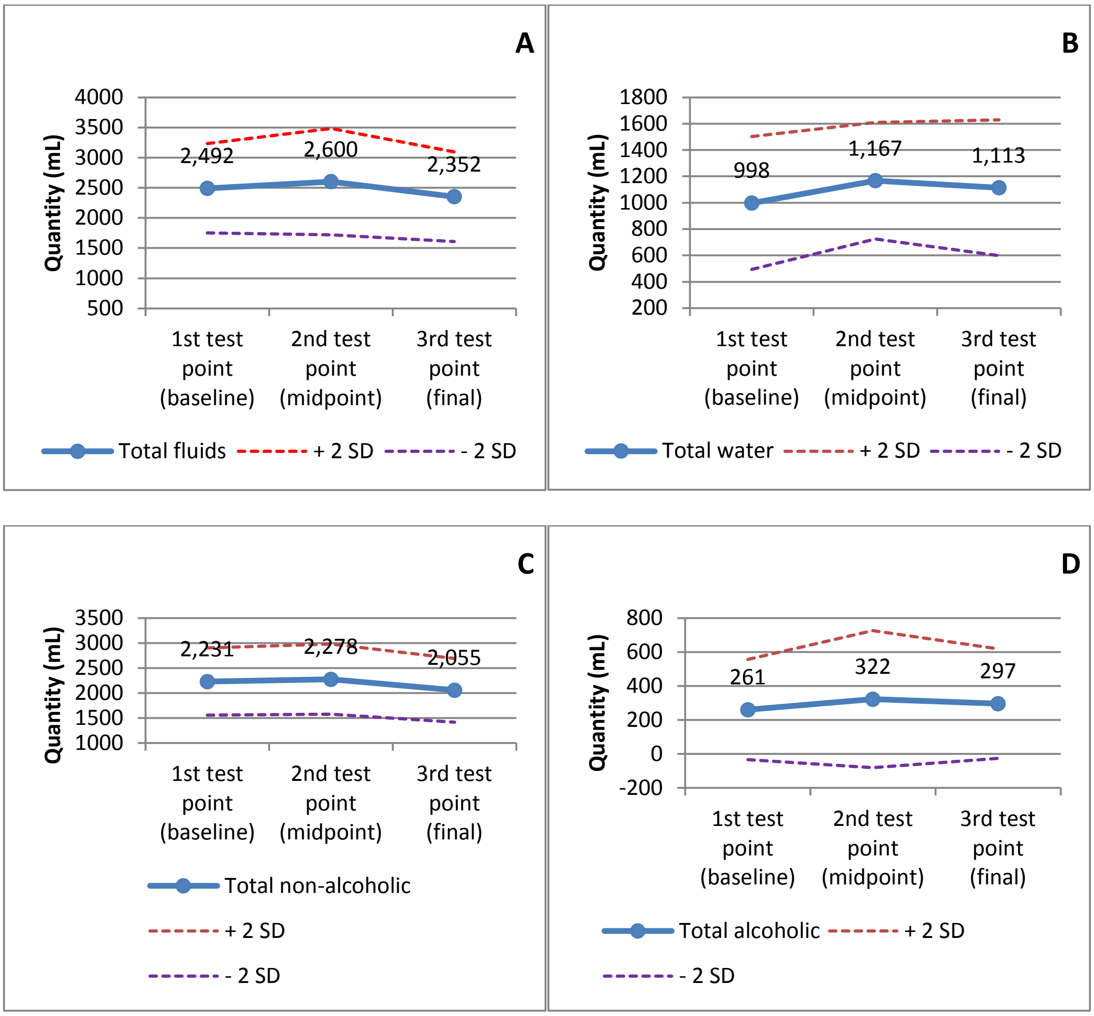


Figure 5-4: Average daily fluid consumption recorded using the Fluid Frequency Questionnaire for Total fluids (A), Total water (B), Total non-alcoholic beverages (C) and Total alcoholic beverages (D).

5.5 Discussion

The primary aim of this part of the study was to assess the hydration status of workers in a surface mine in a temperate region of Australia. To the author's knowledge, no other study on dehydration has been conducted on workers in surface mines in temperate climates of Australia. The secondary aim, if dehydration was determined to be a problem, was to develop and implement a workplace health promotion intervention to promote water and other fluid (milk and low calorie drinks) consumption and decrease unhealthy fluid consumption (alcohol and sugary drinks). The results indicate that the workers were dehydrated prior to commencing their shift, which puts those working in the heat at an increased risk of developing heat related illness. A simple workplace intervention program to promote water and other fluid consumption was thus implemented.

This study showed that just over 70% of workers reported to work dehydrated. This finding is higher than that found in a previous study on hydration status in underground mines in a temperate region of Australia, where 58% of workers started their shift dehydrated (Polkinghorne et al. 2013). Comparative studies done in surface mines located in a tropical region of Australia showed that between 65% and 90% of workers started their shift dehydrated (Carter and Muller 2007, Miller and Bates 2007, Peiffer and Abbiss 2013, Hunt et al. 2014). Studies of hydration status in underground mines located in tropical climates showed that up to 70% were starting their shift dehydrated (Brake 2001, Brake and Bates 2003). It is evident that the severity of dehydration is not restricted to surface mine workers in tropical climates.

This study showed that only 500mL-2000mL of water was being consumed during a shift. This is consistent with the findings of the study of hydration done with underground workers in temperate Australia (Polkinghorne et al. 2013). Consumption of 2000mL-4000mL is the daily water requirement of the body and thus serves only as maintenance of hydration levels during a shift (Hall and Guyton 2011). Pre-shift hydration status has been indicated to be possibly the primary determinant of post-shift hydration, and by proxy, the mid-shift hydration (Gopaldasani et al. 2012, Polkinghorne et al. 2013). The reason for this is that an average of 4000mL-5000mL of water, and possibly more, is required to rehydrate from a dehydrated status, depending on the level of dehydration. It is therefore important to focus on workers hydrating themselves sufficiently prior to commencing their shift, as it becomes easier to maintain hydration during the shift by consuming normal amounts of water during the shift. It is important to note that additional amounts of water will still be required for those working in the heat, as more water is lost during the process of sweating. Nonetheless such workers will be better protected against heat related illnesses than if they were dehydrated.

Workers in this study showed good insight with regard to their perception of drinking enough water at work. As many as 51% of workers stated that they did not think they consumed enough water at work and this correlated very highly with dehydration status (Table 5-6 and 5-7). This is an important finding in this study, as a lack of perception or a misguided perception is more difficult to correct through an intervention program. Several studies have highlighted the importance of participants' knowledge and perception as key factors in the uptake of health intervention programs (Chinn et al. 2006, Ishii et al. 2009, Jacobs et al. 2010, Choe et al. 2012, Blake et al. 2013, Harada et al. 2014).

Following the health intervention program that focused on improving pre-shift hydration, significant improvements in pre-shift hydration status was noticed at the 6-month mark (2nd test point) and the 12-month mark (3rd test point). This was evident across both field and office workers (Table 5-5 and Figure 5-3).

Several studies on health promotion at workplaces have shown that short-term intervention programs, usually of six months or less, have greater success than long-term intervention programs, that is, twelve months and above (Anderson et al. 2009, Milani and Lavie 2009, Olson et al. 2009, Groeneveld et al. 2011, Lassen et al. 2011, Strijk et al. 2012, Bevis et al. 2014). The reason for this is that long-term health promotion programs target risk factors that are associated with chronic diseases such as overweight and obesity, which take a longer time to show demonstrable changes. Risk factors like overweight and obesity are usually multifaceted and involve the interplay of genetics, food environment at home and psychosocial aspects, thus making these risk factors difficult to control and maintain over a long period of time. A simpler risk factor such as hydration status, which is dependent on consumption of water supplemented by other beverages, shows more promise for long-term success and sustainability. This is reflected in this study as consumption of water increased over the study period (Figure 5-4). It is important to note that the dip in consumption of total fluids towards the end of the study may be explained by underreporting fluids consumed, given that there was an improvement in hydration status at the end of the study. Another reason could be the morale of the workforce at this pivotal time as the mine was going through a period of structural change, including employee redundancies.

5.6 Limitations

The first limitation in this study is the use of the fluid frequency questionnaire to collect information on water and beverage consumption. While a validation of this questionnaire showed it to be a good marker for tracking fluid intake trends progressively (chapter seven), overestimation of beverage intake is a possibility. The second limitation was the number of dropouts due to the loss of a large number of the workforce towards the end of the study. In addition, the morale of the rest of the workers in the study was low, as many lost their colleagues and mates. This would have limited the sustainability of the intervention program for the whole study and this was reflected in the slight dip in total fluid and water consumption, and a slight increase in total average alcohol consumption from the start of the study.

5.7 Conclusion

A majority of surface mine workers in a temperate climate were dehydrated at the commencement of their shift. Implementation of an intervention program that included behavioural and environmental changes resulted in an improvement of the hydration status over the duration of the study period. Water was the predominant fluid of choice at the workplace. This was supplemented with tea, coffee, soft drinks and energy drinks. Overall the consumption of water and other supplement beverages increased over the study period sufficiently to improve the pre-shift hydration status at the end of the study period. The success of this simple intervention program can be sustained over a long term and can be applicable to other surface mine sites.

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CHAPTER 6 – HEAT STRESS AND HEAT STRAIN AMONG SURFACE MINE WORKERS

6.1 Introduction

Workers in the mining industry, in both surface and underground mines, are often exposed to high levels of occupation-related heat stress. This can occur when they are working in hot, humid environments in underground mines or out in the open, exposed to solar radiation in surface mines, especially when these mines are located in the tropics. Heat is often generated by nearby machinery being used in the mining process and is often exacerbated by the high ambient temperatures of the climatic zones in which the mining operation is located. These environmental factors, coupled with physiological factors such as metabolic demands, dehydration and poor general health status, among other physiological factors have the potential to cause heat strain among workers in these environments. The end result is heat-related illnesses. This chapter characterises the thermal environment at a surface mine, determines the potential for heat-related stressors and evaluates the potential heat strain on high-risk workers in this environment.

6.2 Literature review

Humans are homeotherms, that is, they are warm-blooded and thus regulate their core body temperature within a very narrow range (36.1°C to 37.2°C) (Parsons 2014). All enzymatic and biochemical reactions including organ function, muscular contractions and propagation of nerve impulses within the human body are temperature dependent. Shifts in core body temperatures can therefore affect the ability of body organs and systems to function effectively. For instance, elevation of the core body temperature above the upper limit of normal (hyperthermia) may initiate denaturing and breakdown of proteins, including DNA and RNA (Streffer 1982). Above 40°C core body temperature this denaturing may be irreversible, leading to permanent damage to organs and systems. Furthermore, a causal relationship exists between hyperthermia and decreased maximal oxygen uptake by tissues, which may attenuate physical effort and dampen an individual's metabolic output. This is perceived as fatigue (Wingo and Cureton 2006). The body's response to any changes or deviations from the normal core body temperature constitutes the process of thermoregulation. The physiological thermoregulatory mechanisms that attempt to compensate increases in core body temperature and prevent development of heat related illnesses can all be summarised mathematically, using the laws of thermodynamics, in the heat balance equation.

6.2.1 Heat balance equation

The heat balance equation is underpinned by the 1st and 2nd laws of thermodynamics. The 1st law of thermodynamics states that energy can neither be created nor destroyed but simply changes from one state to another. The 2nd law of thermodynamics states that energy tends to spontaneously flow from regions of higher concentration to regions of lower concentration. Based on these two laws of thermodynamics, for the human body to maintain the core body temperature within a narrow range of normality, there must be a heat (energy) balance that exists between the internal body environment and the external environment (Parsons 2014). In other words, a balance must exist between heat generation in the body (metabolic heat production), heat transfer and heat storage. This is all summarised in the heat balance equation as follows:

$$\mathbf{M - W = E \pm R \pm C \pm K \pm S}$$

where:

M = rate of metabolic heat production

W = external work performed by the body

K = conductive heat loss or gain

C = convective heat loss or gain

R = radiant heat loss or gain

E = evaporative heat loss

S = heat gained or lost by the body

All of the above units are in *Watts per Metre Squared (W/m^2)*

When the body is in a state of thermoregulatory balance, the value of *S* is approximately zero. When the body is not dissipating residual heat or when the external environment is causing the body to heat up further, then the value of *S* will be positive (i.e. the body is storing heat), and vice versa. A positive *S* will result in hyperthermia unless the heat balance is restored and the accumulated heat energy is dissipated. This balance is achieved by the physiological process of thermoregulation.

6.2.2 Thermoregulation

Thermoregulation is the body's ability to self-regulate its core temperature within the normal range. This process relies on a number of complex interactions between the various systems of the body. The main systems responsible for thermoregulation are the central nervous system (CNS), the peripheral nervous system (PNS) and the cardiovascular system (CVS). The acute physiological response to thermal shifts in the environment include shunting of blood from the core to the periphery (skin) and sweating at thermal triggers, while the chronic physiological response includes decreased blood viscosity and early sweating at non-thermal triggers (Kondo et al. 2010). Secondary physiological responses also aid in the thermoregulatory process and include piloerection, water conservation by the kidneys and sensation of thirst. Apart from the physiological processes that operate in thermoregulation, humans have developed behavioural responses to augment and optimise the physiological thermoregulatory processes. These behavioural responses include undressing, fanning, seeking shade/shelter and pacing themselves while working (Parsons 2014). While some of these behavioural responses are learned progressively; others such as self-pacing are a response to subtle physiological triggers such as the onset of fatigue (Ekkekakis and Lind 2006, Wingo and Cureton 2006).

While all the above physiological and behavioural processes are involved in thermoregulation, these processes are not infallible. A limit is eventually reached when these processes can no longer buffer or compensate the rise in core body temperature from heat stress, and the heat strain builds up to eventually overwhelm this thermoregulatory system, resulting in heat-related illnesses.

6.2.3 Heat-related illnesses

Ordinarily, humans exposed to heat from endogenous or exogenous sources have no significant health consequence if they are able to compensate for the heat stress and negate its deleterious impact. Heat-related illnesses arise when the compensatory mechanism described above is unable to prevent a rise in core body temperature (Donoghue 2004, Parsons 2014). The spectrum of heat-related illnesses that may develop as a consequence may include:

- Prickly heat or heat rash – this is a transient debilitating condition that arises when the skin remains wet due to continued sweating in excess of evaporation. The water, salt and debris that remain on the skin may cause blockage and inflammation of the sweat glands leading to this condition (Donoghue and Sinclair 2000).
- Heat cramps – these are painful muscular spasms of the major muscles of the arms, legs or abdomen. They occur due to excessive loss of sodium salts through sweating (Stofan et al. 2005, Bergeron 2007, Parsons 2014).
- Heat syncope – this is a sudden loss of consciousness due to an abrupt decrease in blood pressure as a result of blood shunting from the core to the extremities in response to a rapid increase in environmental temperature. This

is normally seen in dehydrated and unacclimatised workers. It is mediated by the autonomic nervous system (Carrillo et al. 2013).

- Heat exhaustion – this occurs due to loss of muscular output as a result of a combination of dehydration and deficient oxygen and nutrient supply to the muscles, following circulatory insufficiency as blood flow has been redirected to the skin to cool the body and decrease core body temperature (Donoghue and Sinclair 2000, Wingo and Cureton 2006).
- Heat stroke – this is the end stage of complete thermoregulatory failure. It is a life-threatening condition as core body temperature rises to dangerous levels (in excess of 41°C), leading to irreparable damage to tissues and organs (Holman and Schneider 1989, Bazille et al. 2005). This condition requires urgent medical intervention.

Between 2012 and 2013, 20 cases of heat-related illnesses and deaths were recorded in the United States for those working in outdoor environments (Arbury et al. 2014). There is therefore a real threat to people working outdoors in surface mines in Australia. There are other adverse health consequences of hyperthermia that do not strictly fall into the category of heat-related illness. Confusion and cognitive degradation have been shown to occur in workers when the core body temperature reaches 38.3°C (Pisacane et al. 2007). This in turn impairs a worker's ability to recognise the severity of a threat and act accordingly, thus increasing the risk of serious harm, and possibly a fatal outcome (Hancock 1986, Xiang et al. 2014). Men may develop infertility if exposed to frequent episodes of hyperthermia while hyperthermia in women during pregnancy has been found to be teratogenic, especially if the core body temperature exceeds 39°C in the first trimester of pregnancy (McMurray and Katz 1990). There are some intrinsic factors that can limit the efficiency of the body's heat dissipation mechanisms, such as pre-existing medical conditions.

6.2.4 Pre-existing medical conditions

Pre-existing medical conditions such as diabetes can interfere with blood circulation to the periphery (skin) as a result of diabetic peripheral neuropathy, thus decreasing the efficiency of evaporative heat loss (Scott et al. 1987, Rutkove et al. 2009, Sokolnicki et al. 2009). Hypertension is another pre-existing medical condition that interferes with thermoregulation as a result of altered response of peripheral blood vessels to heat (impaired vasodilatation) (Gryglewska et al. 2010, Jehn et al. 2014). Use of certain medications and stimulants may also affect the body's thermoregulatory process by directly affecting the peripheral blood vessels or by elevating the metabolic rate (Brown and Kiyatkin 2004, Levine et al. 2012). Examples of such medications and stimulants include blood pressure medications such as beta-blockers e.g. atenolol and propranolol, central nervous stimulants such as amphetamines, antidepressants such as tricyclic antidepressants e.g. amitriptyline, and recreational drugs such as cocaine and methylenedioxy-methamphetamine (MDMA or Ecstasy).

The general fitness of the worker is equally important as overweight and obese workers have impaired thermoregulatory mechanisms because the excess body fat acts as a thermal insulator and also increases resistance to blood flow through fatty tissue (Anderson 1999, Savastano et al. 2009). This places overweight and obese workers at a greater risk of heat stress, heat strain and heat-related illness. A study showed that up to 91% of workers in the mining industry are overweight or obese (Polkinghorne et al. 2013). Hence there is a need to investigate the extent to which overweight and obesity actually influences the risk of working in hot environments. Two other factors that fall under general fitness of the worker are the ability to acclimatise to the hot working environment and the hydration status of the worker.

6.2.5 Acclimatisation

Heat acclimatisation is a complex process that involves a series of physiological adaptations by the body, which occur after multiple exposure of a worker to hot working environments (Parsons 2014). Acclimatisation has been described as being a major factor in a worker's ability to cope with heat stressors within the work environment (Logan and Bernard 1999, Dang and Dowell 2014, Parsons 2014). The physiological adaptations in heat acclimatisation include increased blood volume, increased sweat rate and decreased electrolyte loss in sweat and urine. The cumulative effect of these physiological adaptations results in a more efficient sweating mechanism that is triggered earlier by exertion in a hot environment rather than a rise in core body temperature (Charkoudian 2010, Kondo et al. 2010). Thus, workers who are not acclimatised to working in hot environments will be at an increased risk of heat strain and heat-related illness than workers who are acclimatised to working in such environments. The length of time taken to acclimatise varies due to differing physiologies of each worker and can range from seven to 21 days (Parsons 2014). However, it is important to note that the variations in thermoregulatory capacity have been found to have a stronger association with hydration status than acclimatisation (Montain and Coyle 1992, Sawka et al. 1992). Even acclimatisation depends on the hydration status of workers to a large extent given that the end result of acclimatisation is increased sweat rate, which would be limited in dehydration.

6.2.6 Hydration status

Hydration status has been discussed previously in chapter five. Staying hydrated is crucial to working in hot environments as it enables efficient maintenance of core body temperature within normal limits. Core temperature is regulated by the hypothalamus from where adjustments are made in response to inputs from thermoreceptors in the skin, muscle and central nervous system (Parsons 2014). These adjustments are the physiological responses to hot environments described above in the section on thermoregulation. These physiological responses are highly dependent on total body water to function effectively, such that dehydration or hypohydration will result in reduced heat strain tolerance and thus inability to tolerate as high an increase in core body temperature as when hydrated (Sawka et al. 2001a, Sawka et al. 2001b). This is further illustrated in figure 6-1. It is important to note that the capacity of hydration to protect workers is finite, as over-hydration from excessive consumption of water can result in dangerous electrolyte disturbances (Armstrong et al. 2007). Research has shown that heat exhaustion and heat cramps are strongly correlated with dehydration (Chan et al. 2013).

Furthermore, dehydrated persons exhibit disproportionate increases in their core body temperature and heart rate on exposure to heat stress when compared with hydrated persons (Cheung and McLellan 1998, Carter et al. 2005). Hence the risk of hyperthermia and consequent heat-related illness can be decreased by being well hydrated prior to exposure to hot environments and also by maintaining optimum hydration levels during exposure. This is not the case for workers in the mining industry, as a large number of them start work dehydrated.

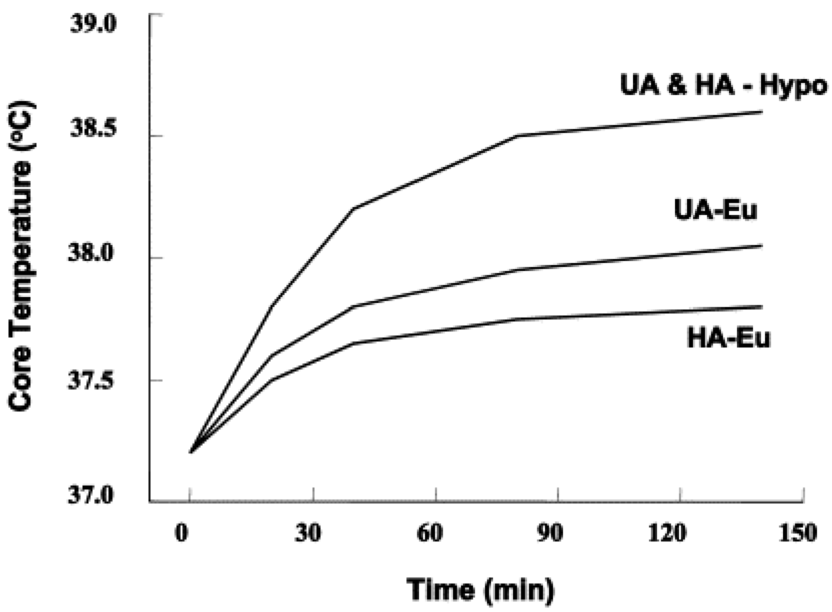

Figure 6-1: Core temperature changes during exercise-heat stress in heat acclimatised (HA), unacclimatised (UA), normal hydrated (euhydrated (Eu)) and hypohydrated (Hypo) persons (Sawka et al. 2001).

Although hydration status is not a measure of heat strain, the state of dehydration can result in high heat strain, resulting in increased risk of heat-related illness. Thus the maintenance of optimal hydration levels is critical in preventing heat strain, as well as supporting other bodily functions. Therefore, assessing and monitoring hydration status is important for people working in hot environments. Assessment of hydration status must be done in conjunction with assessment of heat stress and heat strain to create a complete hot environment work profile that includes both the worker and the environment.

6.2.7 Heat stress and heat strain

The combined effect of the external thermal environment and internal metabolic heat production is the thermal (heat) stress on the body, while the physiological responses to thermal stress by the body is the thermal (heat) strain (Tillman 2006). Exposure to heat stressors that contribute to heat strain result in symptoms ranging from headaches, sweating, exhaustion and impairment of cognition, through to frank thermoregulatory failure and even death (Parsons 2014). This usually results from gradual failure of the body's thermoregulatory processes, leading to the development of heat-related illnesses.

6.2.7.1 Assessment of heat stress

Heat stress assessment requires consideration of several key factors. These include air temperature (both wet bulb and dry bulb temperatures), radiant temperature, humidity, air velocity and the insulation factor of the type of clothing worn (Parsons 2014). These six factors affect the human response to heat. In order to protect a worker from heat stress and the risk of heat related illness, heat stress indices have been developed, many of which take all six factors into consideration. These indices can be categorised into rational and empirical indices.

1. Rational indices

Rational indices, also known as theoretical indices, are measurements based on physiological parameters of the human body in response to a hot environment. These parameters include sweating, core body temperature, heart rate and metabolic work. Many are modelled on the heat balance equation. Common rational indices in use in the mining industry include the Predicted Heat Strain and the Thermal Work Limit.

A) Predicted Heat Strain

The predicted heat strain (PHS) was developed to improve the analytical method of assessing hot environments based on the required sweat rate index (Malchaire et al. 2001). The PHS predicts minute by minute sweat rate and rectal temperature (a surrogate for core body temperature). Many significant changes were made to the PHS to include the effects of forced convection, body movements and exercise, acclimatisation, maximum skin wettedness for efficient evaporation of sweat, maximum sweat rate, maximum dehydration and water loss and maximum permissible rectal temperature (Malchaire et al. 2001). Individual factors can thus be modified to determine which conditions can be adjusted to enable a safe working environment. The PHS therefore encourages the introduction of sustainable higher level controls (such as substitution and engineering controls) over the predominantly administrative controls used in the other common rational index used, the thermal work limit. A fundamental assumption of the PHS is that acclimatised workers are able to sweat more efficiently and abundantly, thus resulting in a lower heat storage (lower core body temperature) and lower cardiovascular constraint (lower heart rate). This assumption may be limiting as workers have varying hydration levels. In fact, up to 58% of workers in the mining industry are dehydrated, putting them at an increased risk of heat strain (Polkinghorne et al. 2013).

The PHS was validated through a series of laboratory and field experiments involving stable and dynamic conditions with high and low radiation, humidity and air velocity. It is important to note that experiments to develop the PHS model were done on male subjects and cannot therefore be generalised to females working in hot environments. In the mining industry, this is not a weakness of the PHS as most people working in hot humid environments generally tend to be males. The PHS is based on a complex set of algorithms making it difficult to use without computerised software. This is one of the major limiting factors that has prevented widespread uptake of the PHS despite being an International Standard (ISO7933 2004). Other limitations to the PHS include the assessment of rapidly changing environments, short exposures and the use of fully encapsulated protective suits all of which are outside the scope of the PHS index.

B) Thermal Work Limit

The thermal work limit (TWL) is defined as the limiting or maximum sustainable metabolic rate that an euhydrated, acclimatised individual can maintain in a given thermal environment within safe limits of both deep body core temperature and sweat rate (Brake and Bates 2002). The TWL estimates the work rate that can be maintained in a given environment in which the core body temperature should be less than 38.2°C and the sweat rate less than 1.2 kg/h. It is gaining increasing popularity within Australia and the Middle East (Miller and Bates 2007, Bates and Schneider 2008). The basis for this index is that for any given thermal environment and any given combination of environmental and clothing parameters, there is a maximum rate at which heat can be dissipated from the body. The index makes use of the wet bulb, dry bulb and globe temperatures and the air velocity to calculate the index. The calculated index is then compared to primarily administrative interventions as outlined in table 6-1 below.

The TWL makes a number of important assumptions that workers are physically fit, not affected by any thermoregulatory limitations and able to self-pace their work. These assumptions are not valid for workers in the mining industry, as over half the workers are already dehydrated, overweight or obese, thus limiting their thermoregulatory capacity, and self-pacing is virtually non-existent as workers must work to a specified quota every shift (Brake and Bates 2003, Bates and Schneider 2008, Savastano et al. 2009, Polkinghorne et al. 2013). Furthermore, the TWL does not take into account the clothing ensemble worn by the workers as the original algorithm for the TWL used a clothing insulation factor of 0.35, equivalent to a worker wearing tee-shirt and shorts. The clothing insulation factor has subsequently been revised in a number of proprietary algorithms but the modifications have not been made available nor supported by any published research. Instrument manufacturers that have incorporated the modified algorithms have stated neither what version of the TWL is being used, nor what clothing insulation factor is being used. This has resulted in different instruments producing different values of the TWL for a given thermal environment.

Table 6-1: TWL working zones and recommended management interventions

(Source: www.pointhealth.com.au)

TWL (W/m^2)	Working Zone	Interventions (controls)
> 140	Unrestricted	No limits on self-paced work for educated, hydrated, acclimatised workers
115-140	Buffer	Buffer zone exists to identify situations in which environmental conditions may be limiting to work • Any practicable intervention to reduce heat stress should be implemented e.g. provide shade, improve ventilation etc. • Working alone to be avoided if possible • Unacclimatised workers not to work in this zone • Fluid intake of ≥1 litre per hour required • Work-rest cycling or rotation required
< 115	Withdrawal	Work limited to essential maintenance or rescue operations • No person to work alone • No unacclimatised person to work • Documentation required authorising work in hostile thermal conditions for specific purpose • Specific induction required emphasising hydration and identifying signs of heat strain • Apply 20 minutes work and 40 minutes rest schedule • Dehydration testing recommended at end of shift • Personal water bottle (2 litre capacity) must be on the job at all times

Further research has been done with the TWL using a clothing insulation factor of 0.6, equivalent to a worker wearing shirt and trousers, which correlated well with physiological parameters measured in a given thermal environment (Chan et al. 2013). To date there has been no independent validation of the TWL apart from validation by the creators of the index due to unavailability of the algorithms used.

2. Empirical indices

Empirical indices are those indices that have been developed by assessing the influence of varying environmental conditions on the human body's physiological response in a group of people under controlled test conditions. Common empirical indices in use in the mining industry include the effective temperature and the wet bulb globe temperature.

A) Effective temperature

The effective temperature (ET) was initially developed as a thermal comfort scale by Houghton and Yagloglou in 1923 (Houghton and Yagloglou 1923). It essentially combines the effects of air temperature, humidity and air velocity into a single index used for comparisons (Parsons 2014). Two separate charts for the ET were developed, one for persons naked to the waist – the basic ET, and one for normally clothed people – the normal ET. A fundamental flaw of the ET was that it overestimated the effects of humidity at low temperatures and underestimated them at high temperatures. In an attempt to correct this flaw, the dry bulb temperature was replaced with globe temperature, which resulted in the corrected ET. The ET scales do not adequately allow for the adverse effect of low air velocity when conditions are very humid (McArdle et al. 1947). A small allowance is made for clothing but no other personal factors (such as hydration status, weight and metabolic rate) have been taken into account. In addition, the ET is misleading when used to predict physiological effects at levels of environmental temperatures at which heat collapse may be expected, that is above 32.2°C effective temperature (Ellis et al. 1972). The ET is widely used in the mining industry in the United Kingdom and Europe (Kalkowsky and Kampmann 2006). In Australia, the ET is required under the Queensland Coal Mining Safety & Health Regulation, with a stipulated prohibition of work at an ET > 29.4°C (Queensland 2001).

B) Wet bulb globe temperature

The wet bulb globe temperature (WBGT) was developed in 1957 specifically for use by the United States military to reduce their heat casualties during training (Yaglou and Minard 1957). This is the most commonly used index of heat stress worldwide and was also adopted as an International Standard (ISO7243 1989). The index combines the air temperature, humidity, air velocity and radiant heat into a single number for comparison. Two versions of the index exist, one for outdoors and the other for indoors. The calculated WBGT is then compared with screening criteria provided by the American Conference of Governmental Industrial Hygienist Threshold Limiting Values (ACGIH-TLV) to determine exposure times and work-rest regimes (ACGIH 2014). It is important to note that the screening criteria are based on the assumption that the workers are fit, acclimatised, fully clothed, have access to adequate drinking water and are able to function without exceeding a core temperature of 38°C. The WBGT does not take into account humidity or the hydration level of workers. This limits the WBGT as it does not adequately reflect the additional strain workers experience when evaporation of sweat is restricted by high humidity or low air velocity (Budd 2008). Furthermore, the WBGT has been shown to be excessively conservative and unsuitable for use in environments with high ambient temperatures, as it may lead to production loss due to frequent work stoppage (Miller and Bates 2007, Budd 2008).

6.2.7.2 Assessment of heat strain

While assessment of heat stress using the heat stress indices provides guidelines to manage those working in hot environments, assessment of actual heat strain through physiological monitoring is required when the heat stress indices cannot ensure the safety of the exposed worker. This often occurs when the heat stress indices indicate periods of work no greater than 30 minutes in a given hot environment or the use of fully encapsulated personal protective equipment (PPE), which is not factored into any heat stress index, as it does not allow air or water vapour movement, or a combination of both.

Physiological monitoring includes parameters such as core body temperature, heart rate, sweat loss and urine specific gravity, all of which strongly correlate with heat strain (ISO9886 2004). The most commonly used physiological monitoring parameters include the core body temperature, the heart rate and the urine specific gravity. The urine specific gravity has been discussed in chapter five.

A) <u>Core body temperature</u>

Following the guidelines of the International Standards, the core body temperature of any person working in a hot environment must not exceed 38°C (ISO7933 2004). Various methods have been proposed to measure the core body temperature, and include oesophageal temperature, rectal temperature, intra-abdominal (core) temperature, oral temperature, tympanic temperature, auditory canal temperature and urine temperature (ISO9886 2004).

The tympanic and oesophageal temperatures react more quickly to changes in exertion as the tissue has a lower thermodynamic inertia compared to intra-abdominal temperature (Gagnon et al. 2010). The auditory canal temperature appears to be more favoured as an acceptable compromise between precision of estimation and practicality due to its simplicity, acceptability, cost effectiveness and ease of use (ISO9886 2004, Huggins et al. 2012). A comparison of auditory canal temperature and rectal temperature showed that the auditory canal temperature underestimates the rectal temperature by an average of 0.7°C (Huggins et al. 2012). Recently, ingestible telemetry pills have begun to gain significant favour as the method is more efficacious and has been validated to represent an individual's true core body temperature (Byrne and Lim 2007, Casa et al. 2007, Ruddock et al. 2014). It nonetheless is more expensive to use and prone to electromagnetic and radiofrequency interference that may result in inaccurate results (Byrne and Lim 2007).

B) <u>Heart rate</u>

For each °C rise in core body temperature, the heart rate increases, on average, by 33 beats per minute (bpm) (ISO9886 2004). Three heart rate limits have been proposed as a measure of heat strain. These are:

- ISO 9886 – Heart Rate Limit calculated as "185-0.65*(worker's age)". This heart rate limit then becomes the upper limit for sustained output while working in a hot environment.
- Heart rate recovery – First proposed in 1963, the heart rate recovery assesses the physiological strain on the heart when working in hot environments (Maxfield and Brouha 1963). The heart rate of a seated worker is measured and recorded in the last 30 seconds of the first, second and third minutes. These measures are designated P1, P2 and P3 respectively. The interpretation of the heart rate recovery is as follows:
    - The physiological stress is acceptable if P3 < 90 bpm or P3 ≥ 90 bpm but with a P1 minus P3 ≥ 10 bpm.
    - The physiological stress of the work is too high to allow sufficient recovery for the subject if P3 ≥ 90 bpm and P1 minus P3 < 10 bpm.
- The ACGIH guidelines for limiting heat strain – These include:
    - A sustained heart rate in excess of "180-worker's age in years" for workers assessed with normal cardiac performance.
    - Recovery heart rate at one minute after a peak work effort greater than 120 bpm.

The core temperature, the heart rate, or both may be used in the assessment of heat strain depending on the resources available.

6.2.8 Summary

In summary, the process of thermoregulation is controlled centrally by the hypothalamus with sensory inputs from thermoreceptors in the body. Physiological compensations are made in response to a hot environment to limit heat storage by the body, thus limiting any rise in core body temperature. A failure of these compensatory mechanisms leads to dangerous elevations of core body temperature. This may result in heat-related illness ranging from heat rash to the potentially fatal heat stroke. Pre-existing medical conditions such as high blood pressure and diabetes can limit the ability of the body to physiologically compensate for increases in core body temperature, predisposing such persons to a higher risk of heat-related illness. Other factors such as body fat may impair heat dissipation, as the fat acts as a thermal insulator for the body, trapping the heat. Acclimatisation is one way to *train* the body to adapt to working in hot environments. This normally takes between seven and 21 days to happen. A key factor in a person's ability to work in hot environments is their hydration status, which has been discussed previously in chapter five. Heat stress indices have been developed to provide a guide for workers in hot environments. It is important to understand the limitations of the different heat stress indices prior to their application. Heat strain assessment may be required when a heat stress index cannot protect a worker. Heat strain assessments can be done by measuring the core body temperature, the heart rate, or both.

For overweight or obese workers who are dehydrated and working in hot humid environments, there appears to be a real threat to their health and wellbeing as such workers are at an increased risk of developing heat-related illness, which may be potentially fatal. It was therefore a crucial part of this study to assess heat stress, heat strain and hydration status among high-risk workers at the study site, that is, workers who were exposed to hot environments. A detailed methodology of this process is outlined below.

6.3 Methodology

6.3.1 Design

Three formal monitoring periods were selected for this part of the study. The first was a baseline monitoring conducted in January 2013 depicting the peak summer period. The second was a mid-point monitoring conducted in August 2013 depicting winter period. The third was a follow-up monitoring conducted one year later in January 2014, again depicting the peak summer period.

6.3.2 Participants

Participants for the heat stress study were selected as a subset from the entire study population based on the shift that was working during the testing days. All observations were conducted during the day shift. The workers targeted for the heat stress study were those at high risk for developing heat-related illness. As most people who worked at the mine were either in air-conditioned vehicle cabins or offices, only those whose work required them to be exposed to a hot environment were selected. These workers were thus grouped into similar exposure groups (SEGs). These included shot firers and processing personnel only. Drillers were not identified as an at-risk group as they were always in an air-conditioned cabin in the drilling machine. Maintenance workers were not identified as an at-risk group as they all worked in ventilated sheds under shade. Shot firers were responsible for assembling, positioning and detonating explosives at the mine site to dislodge rock or soil. As such they were required to work out in the sun throughout their shift. Processing personnel were responsible for inspecting, measuring and recording various parameters around the crushers, grinding mills, settling tanks and agitation tanks, all of which are located outdoors, requiring processing personnel to work in the sun throughout their shift. Characteristics and activities performed by each SEG are summarised in Appendix 21.

Of the 152 participants who enrolled in the study, 13 were identified as employees directly exposed to working in a hot environment and therefore at high risk of developing heat-related illness. Other workers who were exposed to working in the same hot environment but who were not part of the overall study, were approached to participate in this aspect of the study, but all declined to participate.

6.3.3 Measures – instruments and procedures

6.3.3.1 Questionnaire

A questionnaire comprised of four sections was developed (Appendix 17).

- **Section 1** collected demographic information from participants including age, gender and job. Other parts of the first section included date, shift, measured weight, measured height and USG.
- **Section 2** collected information on frequency of heat-illness symptoms experienced over the previous twelve months.
- **Section 3** collected information on the working environment, and included information pertinent for assessing heat stress such as type of clothing worn, parts of the body used mostly during work, number of breaks taken and number of hours working in the sun.
- **Section 4** collected information on hydration and included questions on accessibility to drinking water, frequency of drinks, quantity of water drunk, other fluids drunk apart from water and frequency of urination.

The questionnaire was administered to all participants by the primary researcher who also measured the weight, height and pre-shift USG prior to participants commencing their shift, and post-shift USG after the end of the shift. Participants completed all other sections of the questionnaire, which was handed back to the researcher at the end of the shift.

6.3.3.2 Environmental monitoring

Environmental parameters such as the wet bulb temperature, dry bulb temperature, globe temperature, humidity and air velocity were all measured using three different instruments – the QUEST Temp 36 (S/N: TKG050022), the CALOR Heat Stress Monitor (S/N: 1026998) and the KESTREL 4400 Heat Stress Meter (S/N:

664553). All three instruments were used within their specified operating ranges. Instruments were mounted on a tripod at waist height, approximately 1.2 meters from the ground. Monitoring locations were selected next to the working areas for all participants so as to take representative measurements of heat exposures. Measurements were taken periodically throughout the shift, starting at 6:00am and ending at 6:00pm.

A) QUEST Temp 36

The QUEST Temp 36 was used in compliance with the manufacturer's instructions. It was first checked to see if it was within its calibration date (see calibration certificate in Appendix 18). Following that, the instrument was tested with a dummy dongle that verified that the instrument was within its calibration range. During each measurement, the QUEST Temp 36 was left to equilibrate with the environment for a minimum of 10 minutes prior to data being collected and recorded.

B) CALOR Heat Stress Metre

The CALOR Heat Stress Metre was used in compliance with the manufacturer's instructions. It was first checked to see if it was within its calibration date (see calibration certificate in Appendix 19). The CALOR Heat Stress Metre collected static measurements after 2 minutes of equilibration with the environment. No prior checks or pre-calibration was required as long as the instrument was within the calibration date, and only the TWL was being used and not the alternative Heat Strain Model. However, on using the CALOR Heat Stress Meter on the first day and comparing it with the other two heat stress meters, it was discovered that the CALOR Heat Stress Meter readings were markedly different from the other two. The error in measurement with the CALOR instrument ranged from 0.6°C to 4.8°C. Based on this margin of error, it was decided that the CALOR instrument would be discontinued and all data from the CALOR instrument discarded. Upon further investigation, it was discovered that the sensor panel on the CALOR instrument had been damaged, resulting in the inaccuracies of measurement. The sensor panel could not be replaced in time to continue the study using the CALOR instrument.

C) KESTREL 4400 Heat Stress Meter

The KESTREL 4400 Heat Stress Meter was used in compliance with the manufacturer's instructions. It was set up on the tripod with a vane mount that made the instrument able to take omnidirectional air velocity readings averaged progressively. The KESTREL 4400 was left to equilibrate for a minimum of 10 minutes prior to data being collected and recorded.

6.3.3.3 Physiological monitoring

The physiological monitoring was developed with reference to ISO 9886:2004 – Ergonomics-Evaluation of thermal strain by physiological measurements. Variations from the ISO9886 were essential due to funding limitations and practicality of performing the assessments with minimal interference to normal operations.

The core body temperature was measured using the tympanic temperature as a surrogate. A Braun Thermoscan PRO 4000 was used to measure tympanic temperature using infrared reading of the tympanum, with the reading provided to the nearest 0.1°C. All participants were wearing hats with neck flaps covering their ears. This allowed the use of the tympanic temperature as a surrogate for the core temperature, as there was little effect of the external environment on the ear and auditory canal. Readings were done on the right and left tympanums, and averaged. The heart rate was measured, using the pulse rate as a surrogate, by physically counting the pulse rate on the radial artery of the right arm. This was done by the primary researcher, who is a trained health professional and competent to take these readings. Any abnormality in the rate or rhythm of the pulse was crosschecked by taking the pulse on the left arm as well.

6.3.3.4 Hydration status

The hydration status was assessed by measuring the USG as outlined in chapter five (Section 5.3.3.2).

6.3.4 Measures – intervention

As part of the study, the health promotion/intervention program also focused on heat stress awareness. Specific aspects of the intervention program that focused on heat stress were packaged together with hydrations status and have been discussed in chapter five (Section 5.3.4.4).

6.3.5 Data processing and analysis

All data were entered into the statistical software IBM SPSS version 21 for analysis. Mean and standard deviations were provided as summary indices for all data. Cut-off points for the core body temperature was 38°C in keeping with International Standards (ISO7933 2004). The cut-off point for USG was set at 1.020 in keeping with literature (Armstrong et al. 1994, Casa et al. 2000, Oppliger et al. 2005, Armstrong et al. 2010). Statistical significance was set at a P-value of < 0.05. The limits used for the heat stress indices were based on the International Standards for the PHS, the ACGIH for the WBGT, the Queensland legislation for the ET and the TWL guidelines (Queensland 2001, Bates and Miller 2002, ISO7933 2004, ACGIH 2014). Environmental data analysis for the PHS modelling was done using the software ergonomics of the thermal environment (ETE) produced by Rio Tinto Pty Ltd.

Independent samples t-test was used to evaluate the differences between each exposure group (shot firers and processing personnel) for body mass index, USG, heart rate, core body temperature and fluids consumed. Paired samples t-test was used to evaluate the differences between pre- and post-shift USG. Correlation analysis was used to evaluate the relationship between risk factors such as age, body mass index, duration of exposure, hydration status, heart rate, core body temperature and the heat stress indices and heat strain. Repeated measure analysis of variance was used to evaluate the differences in the physiological and environmental variables collected at the different time points during the shift.

6.4 Results

The general demographics of participants who took part in the heat stress study are presented in table 6-2. The average age of participants was 39 years with a range of 23 to 58 years. Most participants were male. One female shot firer was the only exception. The average body mass index was 30.3 kg/m^2. All participants were acclimatised to working in hot environments and had been doing so for over two years. None of the participants had any pre-existing medical conditions preventing them working in hot environments.

Table 6-2: Demography of participants in the heat stress study (n = 13).

	Mean (± SD)	*Range*
Age (yrs)	39 (± 12.0)	23 - 58
Weight (kg)	92.9 (± 12.5)	75.5 - 113.4
Height (m)	1.75 (± 0.07)	1.64 - 1.90
BMI (kg/m^2)	30.3 (± 3.5)	24.9 - 35.1

With regard to hydration status, table 6-3 presents the pre- and post-shift USG, while figure 6-2 presents the trend of hydration status over the entire shift. There was a statistically significant deterioration in the hydration status of the participants over the 12-hr shift ($P < 0.05$), with only one participant who was left hydrated at the end of the shift. Shot firers were the highest risk group, with 75% of them presenting to work dehydrated and all of them remaining dehydrated at the end of their shift.

Table 6-3: Pre- and post-shift Urine Specific Gravity (USG) and hydration status of participants (n = 13).

	Pre-shift	**Post-shift**	**P - value**
USG			
Mean ± SD	1.021 (± 0.005)	1.024 (± 0.003)	0.009*
Range	1.010 - 1.027	1.019 - 1.032	

* Statistically significant at P <0.05 using paired samples t-test

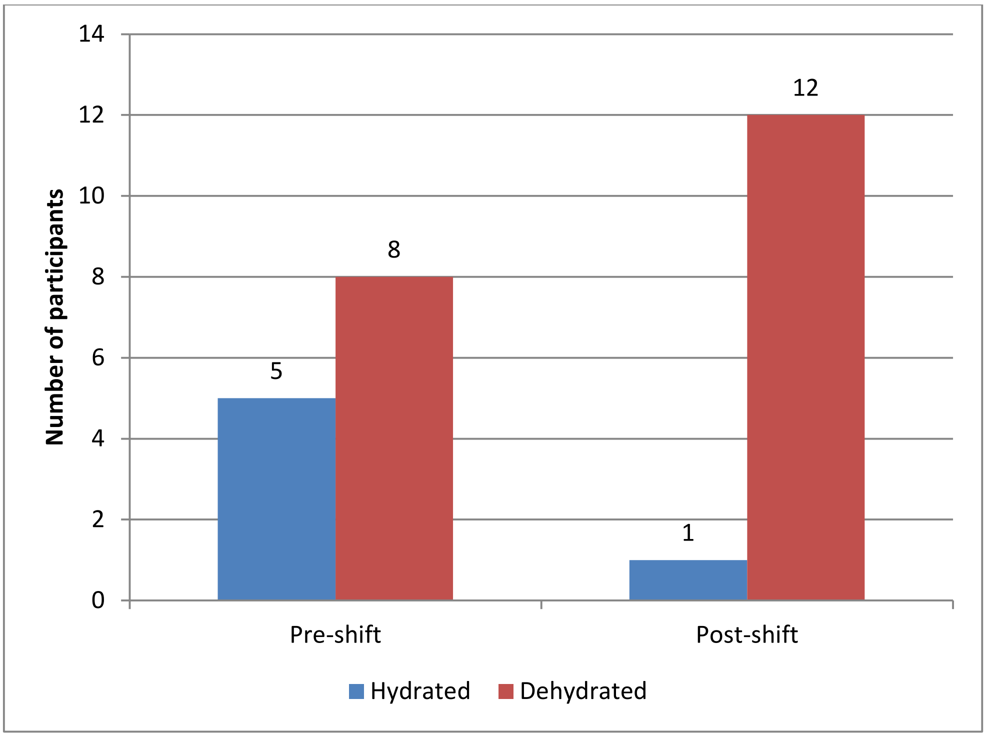

Figure 6-2: Hydration status pre- and post-shift (n = 13).

Tables 6-4A and 6-4B presents the distribution of heat strain symptoms among the participants during a 12-hour shift over the previous year. Headaches and fatigues were the most common symptoms of heat strain. More heat strain symptoms were experienced during the day shift than during the night shift and more heat strain symptoms were experienced by workers aged 55 to 59 years. The environmental data collected at the first (baseline), second (midpoint) and third (final) monitoring periods are presented in tables 6-5, 6-6 and 6-7 respectively. The heat stress indices are also displayed in the same tables for comparison with each other.

Table 6-4A: Heat strain symptoms among participants.

SYMPTOM	n (%)	Frequency	Shift
Rash on skin	2 (15.4)	More than once	Day only
Muscle cramp	2 (15.4)	More than once	Day only
Headache	9 (69.2)	More than once	Day and night
Weakness	3 (23.1)	More than once	Day only
Fatigue	6 (46.2)	More than once	Day and night
Dizziness	2 (15.4)	More than once	Day only
Clammy/moist skin	1 (7.7)	More than once	Day only
Irritability	1 (7.7)	More than once	Day and night
Hot dry skin	2 (15.4)	More than once	Day only
High body temperature	2 (15.4)	More than once	Day only
Low coordination	1 (7.7)	More than once	Day only

Table 6-5B: Heat strain symptoms by age group.

AGE GROUP	No. of Symptoms	Frequency	Shift
25 – 29	5	More than once	Day only
30 – 34	5	More than once	Day only
35 – 39	3	More than once	Day only
40 – 44	2	More than once	Day only
45 – 49	0	More than once	Day only
50 – 54	0	More than once	Day only
55 – 59	16	More than once	Day only

Table 6-6: Environmental monitoring data and heat stress indices for the first (baseline) monitoring period

CREW	DATE	TIME	WB (°C)	DB (°C)	GT (°C)	AV (m/s)	RH (%)	WBGT (°C)	TWL	ET	PHS	Predicted water loss from PHS
Processing	30/01/2013*	09.00	14.4	23.7	30.1	1.5	34	18.5	333	22.0	Rectal temp of 38°C not exceeded	8.2L over 12-hr shift
		10.00	18.4	25.2	43.5	1.1	52	24.1	215	27.5		
		11.30	16.9	27.1	42.0	1.3	34	23.0	240	26.8		
		13.00	18.1	30.2	44.8	2.4	29	27.0	222	27.5		
		15.00	17.1	31.4	41.6	3.0	21	23.4	256	26.2		
Shot firer		14.05	20.3	34.1	46.7	1.9	27	27.0	201	28.8	Rectal temp of 38°C not exceeded	10.4L over 12-hr shift
Processing	31/01/2013*	09.00	15.8	22.7	34.9	1.5	48	20.3	291	24.1	Rectal temp of 38°C not exceeded	8.0L over 12-hr shift
		10.00	16.3	27.1	38.1	1.6	31	21.7	275	25.4		
		13.00	19.6	33.9	44.7	2.1	25	26.1	222	28		
		16.00	16.7	37.2	45.0	1.1	9	24.4	230	27.3		
Processing	01/02/2014*	09.00	14.7	18.3	25.4	2.1	68	17.2	365	19	Rectal temp of 38°C not exceeded	6.6L over 12-hr shift
		10.00	17.3	22.4	37.4	1.1	60	21.8	259	25.6		
		14.00	17.2	25.5	32.8	3.0	43	21.2	320	25.5		
Shot firer		12.00	17.8	26.9	38.7	6.1	40	22.9	276	25.0	Rectal temp of 38°C not exceeded	7.7L over 12-hr shift

WB - Wet bulb temperature, DB - Dry bulb temperature, GT - Globe temperature, AV - Air velocity, RH - Relative humidity, ET - Effective temperature, PHS - Predictive Heat Strain (Phase 1 - 390 minutes work, Phase 2 - 45 minutes lunch break, Phase 3 - 270 minutes work)

* Overcast for most of the day

Table 6-7: Environmental monitoring data and heat stress indices for the second (midpoint) monitoring period

CREW	DATE	TIME	WB (°C)	DB (°C)	GT (°C)	AV (m/s)	RH (%)	WBGT (°C)	TWL	ET	PHS	Predicted water loss from PHS
Processing	05/09/2013	10.30	15.5	19.3	28.8	2.1	60	18.5	338	21.0	Rectal temp of 38°C not exceeded	5.2L over 12-hr shift
		12.30	16.2	26.8	35.5	3.0	36	21.1	304	24.2		
		14.30	16.5	26.7	30.6	0.8	31	20.6	298	24.9		
		16.30	16.1	25.0	27.8	0.9	37	19.8	310	21.3		
Processing	06/09/2013	08.30	14.7	18.6	27.4	2.8	68	17.2	358	19.6	Rectal temp of 38°C not exceeded	4.8L over 12-hr shift
		11.30	16.9	22.6	29.1	2.5	52	19.9	341	21.2		
		14.30	18.1	26.2	36.8	3.1	30	23.5	267	25.0		
		16.30	16.7	26.7	30.1	3.1	29	19.8	320	21.5		
Processing	10/09/2013	13.00	14.6	20.1	30.4	2.8	36	19.1	319	21.3	Rectal temp of 38°C not exceeded	4.5L over 12-hr shift
		15.30	14.5	21.3	26.6	1.2	39	16.5	320	20.1		
Shot firer		14.30	17.2	22.9	40.0	0.8	26	24.9	236	26.9	Rectal temp of 38°C not exceeded	7.6L over 12-hr shift
		16.30	18.4	24.7	35.6	0.8	33	23.7	274	25.9		

WB - Wet bulb temperature, DB - Dry bulb temperature, GT - Globe temperature, AV - Air velocity, RH - Relative humidity, ET - Effective temperature, PHS - Predictive Heat Strain (Phase 1 - 390 minutes work, Phase 2 - 45 minutes lunch break, Phase 3 - 270 minutes work)

Table 6-8: Environmental monitoring data and heat stress indices for the third (final) monitoring period

CREW	**DATE**	**TIME**	**WB (°C)**	**DB (°C)**	**GT (°C)**	**AV (m/s)**	**RH (%)**	**WBGT (°C)**	**TWL**	**ET**	**PHS**	**Predicted water loss from PHS**
Processing	14/01/2014	08.30	22.2	28.7	42	1	57	26.8	204	24	Rectal temp of 38°C exceeded at 121 minutes following lunch break	8.9L over 12-hr shift
		10.30	23.9	33.4	46.6	1.1	45	29.3	169	26.7		
		13.30	24.9	37.2	56.1	1.2	36	32.4	<115	28.3		
		15.30	22.6	37.1	47.9	4.2	28	29.1	179	26		
		17.30	26.4	41.7	58.4	3.8	30	34.3	<115	29.6		
Processing	15/01/2014	08.30	21	28.3	40.2	0.5	52	25.6	201	24	Rectal temp of 38°C not exceeded	9.9L over 12-hr shift
		11.30	22.8	37.5	53.9	0.9	27	30.5	121	27.5		
		14.00	22.8	39.7	53.1	1	22	30.6	134	28.2		
		17.00	23.5	41.2	53.6	5	21	31.3	<115	28.1		
Shot firer		10.30	23.5	34.9	49.3	1.1	38	29.8	154	29.5	Rectal temp of 38°C exceeded at 35 minutes following lunch break	12.7L over 12-hr shift
		14.15	24.8	42.5	59.1	0.1	23	33.4	<115	32.5		
		15.30	25.4	44.9	60.6	0.6	20	34.4	<115	30.7		
Processing	16/01/2014	08.45	21.3	31.5	38.9	2	40	25.8	255	24.3	Rectal temp of 38°C not exceeded	8.6L over 12-hr shift
		11.00	23	36.6	48.3	1.9	31	29.4	175	26.9		
		13.00	23.2	39.9	51.8	1.7	23	30.6	145	28.4		
		15.00	23.9	41.9	56	1.5	21	32.1	<115	29		
Shot firer		09.00	26.2	36	51	0.8	46	32.1	<115	29.2	Rectal temp of 38°C exceeded at 66 minutes into the shift	12.9L over 12-hr shift
		10.45	24.5	37.6	51.1	1	34	31.1	135	28.2		
		15.30	25.4	44.1	59.6	0.8	21	34.1	<115	30.2		

WB - Wet bulb temperature, DB - Dry bulb temperature, GT - Globe temperature, AV - Air velocity, RH - Relative humidity, ET - Effective temperature, PHS - Predictive Heat Strain (Phase 1 - 390 minutes work, Phase 2 - 45 minutes lunch break, Phase 3 - 270 minutes work)

The PHS model indicated that workers would generally exceed rectal (core) temperatures of 38°C after lunch break with at least 2.5 hours left to the end of their shift during summer months. The estimated minimum water required to maintain thermoregulation during this summer period was at least 8.6 litres over the 12-hour shift. Participants all agreed that the working conditions during testing in the summer months were *hot* (46.2%) to *very hot* (53.8%).

Each participant's measure of USG, fluids consumed during the shift, average number of heat strain symptoms experienced during a shift over the past one year, maximum tympanic temperature and maximum pulse rate are presented in table 6-8. Consumption of very large amounts of fluids, in excess of five litres (over eight litres as predicted by the PHS) was required to maintain adequate hydration when working in hot environments. Three participants exceeded the ISO7933 standard's maximum core body temperature limit of 38°C while two participants exceeded the ACGIH guidelines for limiting heat strain as their pulse rates exceeded the recommended guidelines.

Correlation of the maximum recorded tympanic temperature and the maximum recorded pulse rate with potential risk factors are presented in tables 6-9 and 6-10. Pre-shift hydration status was strongly correlated with the maximum tympanic temperature ($P < 0.05$).

Table 6-9: Participants' measures of USG, fluids consumed, heat strain symptoms and physiological monitoring parameters

Participant	Age	Pre-shift USG	Post-shift USG	Quantity of fluids consumed during shift (mL)	No. of heat strain symptoms	Max. tympanic temperature (°C)	Max. pulse rate (bpm)
1	36	1.027	1.028	5000	1	37.5	88
2	34	1.020	1.024	5000	1	38.4	124
3	58	1.018	1.023	2000	1	38.0	132*
4	36	1.013	1.019	6000	2	36.9	96
5	43	1.024	1.023	1500	0	37.5	90
6	57	1.025	1.026	1250	8	37.4	128*
7	23	1.029	1.033	2000	4	38.2	136
8	55	1.022	1.025	2000	7	37.6	100
9	44	1.027	1.032	1500	0	37.8	96
10	28	1.010	1.022	2750	4	36.6	84
11	25	1.021	1.022	3000	0	36.8	80
12	41	1.015	1.022	3000	2	36.8	84
13	23	1.021	1.024	4000	1	36.8	138

* Exceeds the ACGIH guidelines for limiting heat strain (180-Age)

Table 6-10: Correlation of maximum tympanic temperature with potential risk factors

Risk factor	Spearman's correlation (rho)	P-value
BMI	0.085	0.783
Pre-shift hydration status	-0.693	0.009
Post-shift hydration status	0.158	0.606
Fluids consumed during shift	-0.156	0.611
Heat strain symptoms	0.300	0.319

Table 6-11: Correlation of maximum pulse rate with potential risk factors

Risk factor	Spearman's correlation (rho)	P-value
BMI	0.353	0.237
Pre-shift hydration status	-0.444	0.125
Post-shift hydration status	0.171	0.578
Fluids consumed during shift	-0.074	0.809
Heat strain symptoms	0.539	0.057

6.5 Discussion

The primary aim of this part of the study was to assess the thermal environment, determine the potential for heat-related stressors and evaluate the potential heat strain of high-risk workers, namely the shot firers and the processing personnel in a surface mine located in a temperate climate. Studies on heat stress and heat strain have been conducted on surface and underground mines in tropical climates (Miller and Bates 2007, Peiffer and Abbiss 2013, Xiang et al. 2014), but no studies have been conducted previously on surface mines in a temperate climate. The results of this study suggest that heat stress and heat strain were evident in high-risk surface mine workers, even in mine sites located in temperate climates, especially during the summer months.

The average age of participants was 39 years reflecting the fact that a predominantly middle-aged workforce participated in this part of the study. The average BMI of participants was 30.3, thus categorising these participants as predominantly overweight or obese. The BMI has some limitations for workers with high muscle mass, but direct observations of participants did not indicate that this was the case.

The USG measurements showed that participants predominantly started their shift in a dehydrated state and remained dehydrated at the end of their shift ($P < 0.05$). Only 5 of the 13 participants started their shift in a hydrated state. At the end of the shift, all participants except one were dehydrated, with two participants being clinically dehydrated (USG > 1.030). The only participant who remained hydrated at the end of the shift (Participant 4) started his shift in a hydrated state and reportedly consumed 6000 mL of fluid, comprised mainly of water, which was sufficient to keep him hydrated till the end of the shift, though he was close to borderline dehydration. It is clear that employees working in hot environments need to consume sufficient amounts of water and fluids to be able to stay hydrated throughout their shift. Using the PHS model, it was estimated that up to 8600 mL of fluids was required to maintain thermoregulatory balance while working in hot environments in this mine site. The quantity of fluids required to be consumed also depended on the pre-shift hydration status. For example, while Participant 10 had the best pre-shift hydration status, he reportedly consumed only 2750 mL of fluids during the 12-hour shift, which was insufficient to keep him hydrated over the entire shift. Participant 2, who had consumed 5000 mL of fluids, was not able to maintain his pre-shift hydrated status, as he was borderline hydrated at the start of his shift. This relationship of pre-shift hydration status, fluids consumed during the shift and post-shift hydration status is evident among the 13 participants (Table 6-8), however no statistically significant association between the three variables was demonstrated, possibly due to the small sample size in the study.

The pattern of pre-shift dehydration among high-risk employees working in hot environments in this study is consistent with other studies done in mine sites in tropical environments (Carter and Muller 2007, Miller and Bates 2007, Peiffer and Abbiss 2013) and thus affirms that mine location climate plays no part in the hydration practices of mine workers. Hence an intervention program targeting these hydration practices can be utilised to improve the pre-shift hydration status of mine workers. Such an intervention was trialled in this study and has been discussed in chapter five.

Environmental monitoring at the first (baseline) monitoring period did not show any risk to working in hot environment on the days tested. This was most likely due to those testing days being overcast for most of the shift and thus negating the contribution of solar radiation to the hot environment. Under such overcast conditions, there was no restriction to working outside. The PHS model predicted that an estimated average fluid consumption of 8.2 litres over the 12-hour shift would be sufficient to maintain thermoregulatory balance in these overcast conditions. The second (midpoint) monitoring period showed that working in winter and spring time did not restrict any work outside and the PHS model predicted that an estimated average fluid consumption of 5.5 litres over the 12-hour shift would be sufficient to maintain thermoregulatory balance. The different estimates of average fluid consumption between an overcast summer day and a winter or spring day can be attributed to the higher globe temperatures in the summer days, which would still cause fluid loss through sweating during thermoregulation. The third (final) monitoring period was a true indication of the working conditions during a peak summer period without any cloud cover. Several restrictions to work were indicated by the TWL and the PHS especially following lunch break, that is, during peak sun exposure between the hours of 1.30pm and 4.30pm (Table 6-7). The estimated average fluid consumption during these working conditions was 10.6 litres over the 12-hour shift, that is, an average of about 900 mL per hour or an estimated one (250 mL) cup of fluid every 15 minutes.

Heat strain symptoms were experienced by 10 out of the 13 participants in this study. It is interesting to note that the highest number of heat strain symptoms was experienced by the older workers aged 55 to 59 years, which affirms that age influences the thermoregulatory capacity of the body, with older workers less able to effectively adapt to the work environment. Incidentally, the maximum pulse rates that exceeded the ACGIH guidelines were noted in the two oldest participants in this study, with one of them reaching the critical core temperature of 38°C. Due to the small sample size of this study, it is difficult to extrapolate any further than the observations noted. These observations are consistent with research showing that older adults are less able to efficiently maintain thermoregulation (Austin et al. 2008, Dang and Dowell 2014, Jehn et al. 2014, Parsons 2014).

During physiological monitoring of the participants during the third (final) monitoring period, only three participants exceeded the core temperature of 38°C. One of the three participants also exceeded the maximum pulse rate guidance provided by the ACGIH. Correlating potential risk factors such as BMI, pre- and post-shift USG, fluids consumed during the shift and heat strain symptoms, with the maximum tympanic temperature and the maximum pulse rate showed that only the pre-shift hydration status was statistically significantly correlated with maximum tympanic temperature. This indicated that the pre-shift hydration status was the most crucial determining risk factor for people working in hot environments and who could potentially suffer a heat-related illness if they were dehydrated at the start of their shift.

6.6 Limitations

The first limitation in this aspect of the study is the small sample size. This prevented analysis of key associations between risk factors such as body mass index and hydration status, and heat stress, heat strain and physiological parameters of core body temperature and heart rate. Therefore, observations recorded in this study cannot be generalised to any extent without further data. The second limitation is the use of the tympanic membrane temperature as a surrogate for core body temperature. Research has documented that there is up to 0.7°C difference between the recorded tympanic membrane temperature and the core body temperature (Huggins et al. 2012). This has a direct bearing on the data used in this study as no correction factor was applied to approximate the tympanic membrane temperature to core body temperature. This was not possible, as the actual core temperature of a representative sample of participants would have been required to calculate the exact correction factor to be applied to the tympanic temperature, and this was beyond the scope of this study. The third limitation of this study is that intermittent measurements of the core body temperature and heart rate were done. A continuous measurement of these physiological parameters may have highlighted specific tasks and times of the day when participants may have been at an increased risk of heat strain. This data could have been used in designing a more effective heat stress management plan.

6.7 Conclusion

The single most important finding of this study was that workers were starting their shift in a dehydrated state, which predisposed them to reaching a critical core body temperature of 38°C sooner than hydrated workers. This finding was strongly correlated, though further studies with a larger sample size are required to verify this finding. No other risk factor correlated with the core body temperature or the pulse rate. This may also be due to the limited sample size in this study. Working in hot environments requires optimal thermoregulation by the body to prevent the onset of heat-related illnesses. Factors that interfere with this process include pre-existing medical conditions such as diabetes and heart disease, lack of acclimatisation and poor hydration status. Using the heat stress indices and monitoring the core body temperature and the heart rate can help predict potentially detrimental work condition thus preventing any heat-related illnesses.

6.8 References

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CHAPTER 7– RELATIVE VALIDITY OF THE FOOD AND FLUID FREQUENCY QUESTIONNAIRES

7.1 Introduction

With the ever increasing work demands and limited time available for employees to effectively participate in health research, existing tools to assess dietary intake such as food records (FR) and 24-hour recalls may be impractical as they can be burdensome, costly, and time and resource intensive (Hedrick et al. 2010, Flood et al. 2014). It is therefore important to find alternative tools that are practical, easily applicable and quick to administer. Short concise questions regarding food and beverage intake can be a useful assessment tool in this regard but they must reflect accurate assessment of dietary intake (Gwynn et al. 2011, Flood et al. 2014). This chapter explores the relative validity of a fruit and vegetable short food frequency questionnaire and a fluid frequency questionnaire that aimed to capture fruit and vegetable, and beverage intake of participants in this study, respectively, compared with a 3-day FR.

7.2 Literature review

Frequency questionnaires that estimate the frequency and quantity of foods (Food Frequency Questionnaire (FFQ)) and beverages (Beverage Intake Questionnaire (BEVQ) and Fluid Frequency Questionnaire) consumed are quantitative tools that use short questions (Mohammadifard et al. 2011). While they may appear convenient to use, they are fraught with potential sources of error due to their reliance on memory and thus should always be validated before widespread use (Carlsen et al. 2011, Mohammadifard et al. 2011). The validity of an assessment tool is the tool's ability to precisely and accurately approximate what it intends to measure (Masson et al. 2003). In order to assess the true validity of the Food and Fluid Frequency Questionnaires in this study, it would require highly accurate measurement of the food and fluid intakes of free-living individuals over several months and this is not feasible. Therefore, assessment of relative validity by comparing the Food and Fluid Frequency Questionnaire with an alternative dietary assessment method such as the 3-day FR, which has its own limitations (Byers 2001), is a feasible way to estimate accuracy.

While accuracy is compromised in FFQs, the ability to rank individuals along the distribution of intake into, for example, low, medium and high intake groups, helps assess relative risk and odds ratio of a disease or condition in relation to dietary intake (Masson et al. 2003). Food Frequency Questionnaires therefore have merit in nutritional research especially when studying the link between lifestyle-related chronic illnesses and poor dietary intakes (Barclay et al. 2008). Many FFQs that use short questions to estimate the frequency and amount of foods such as fruit and vegetables, and beverages consumed have been relatively validated by comparing them with self-reported FR, 24-hour recalls or weighted food records (Barclay et al. 2008, Ambrosini et al. 2011, Barbieri et al. 2013). There is however, limited validation of tools exclusively used to estimate fluid and beverage consumption

(Hedrick et al. 2010). The only exclusive tool that the author could find that estimated fluid and beverage consumption was the BEVQ (Hedrick et al. 2010).

The BEVQ is a 19-item questionnaire developed to estimate mean daily intakes of water, sugar-sweetened beverages (soft drinks, energy drinks and juices), alcohol and other beverages (tea and coffee) and overall total beverage intake (Hedrick et al. 2010). The questionnaire is essentially an FFQ that measures “How often” and “How much each time” a beverage was consumed over the past month. The total beverage consumed per day for each beverage can then be calculated by multiplying the frequency by the quantity consumed. This questionnaire has been validated in healthy adults, as compared with a 4-day food intake record and has been shown to be a reliable estimate of habitual beverage consumption (Hedrick et al. 2010).

The BEVQ was further reduced to a 15-item questionnaire to make the questionnaire more usable among adults with lower literacy levels and to improve the administration time of the questionnaire (Hedrick et al. 2012). The main differences between the 19-item and the 15-item BEVQ is the removal of three categories of beverages that did not contribute significantly to overall energy consumption (vegetable juice, mixed alcoholic drinks and meal replacement drinks), while beer and light beer were grouped together into one beverage category. The revised questionnaire was revalidated, and had acceptable validity and reliability when compared with the original 19-item BEVQ (Hedrick et al. 2012).

Rapid assessment of fluid and beverage consumption as a correlate of hydration status is useful in mitigating the effects of heat stress and heat-related illness by providing workers with information on adequacy of fluid consumption. In addition to dehydration, being overweight or obese exacerbates the effects of heat stress and heat-related illness, as the excess body fat acts as a thermal insulator trapping heat within the body (Savastano et al. 2009). Hence, adequate water consumption and good dietary habits are indispensably essential in these workers, as well as nutritional assessment tools that can effectively and accurately measure their regular intake of foods and fluids. Given the acute nature of dehydration and how easily it can be corrected, it is more useful to have a rapid assessment tool for fluid consumption. The paucity of fluid/beverage frequency questionnaires and their validation stifles research into this area. Most validated FFQs do incorporate some questions that estimate certain fluids and beverages as part of an overall nutritional assessment but these essentially tend to cover alcohol and soft drinks for adults and milk, soft drink and fruit juices for children (Ambrosini et al. 2011, Flood et al. 2014, Sam et al. 2014). Moreover, these FFQs take time to administer and are thus not suitable for rapid assessment of fluid and beverage consumption in a population that is pressed for time, such as the workers in this study. The BEVQ is thus a quick method to assess usual fluid intake in these workers. A Fluid Frequency Questionnaire based on the 15-item BEVQ was developed and validated to measure fluid/beverage intake among this study cohort.

The short FFQ on fruit and vegetable consumption has been used in state health monitoring (NSW Health 2012) and has previously been validated in young children (Flood et al. 2014). The fruit and vegetable questions from this short FFQ were used without any modification. However validation in adults was required and this was undertaken in this study cohort.

The aim was to determine the relative validity of short questions related to fruit and vegetable consumption, and fluid/beverage consumption, compared with a 3-day FR, as well as the applicability of the questionnaire to the men and women working in the mining industry.

7.3 Methodology

7.3.1 Design

The BEVQ was used as the template to develop the fluid frequency questionnaire, as this was the only tool that had been exclusively designed to estimate fluid/beverage intake. Further inspiration in the development of the questionnaire was taken from a validation study of short FFQ (fluid/beverage consumption questions only) for assessing dietary habits of two-to-five year-old children that was being finalised at the time of the study (Flood et al. 2014). To further simplify the questionnaire and to aid in rapid administration, the quantity section of the original BEVQ was removed and a single “Amount” column created by standardising each beverage quantity using Australian metrics, such as cup (250mL), can (375mL), bottle (600mL), bottle (500mL for iced tea only), stubbie/schooner (375mL), wine glass (150mL) and nip/shot (30mL). This meant that only frequencies needed to be ticked in the questionnaire. The total amount consumed for each beverage was then calculated by multiplying the standard amount for each beverage category by the frequency. The fruit and vegetable questions of the short FFQ from the study of Flood et al. (2014) were used without any further development or modification. The total amount of fruit and vegetables consumed was calculated in serves per day, as stated by participants, or as serves per week divided by seven days to obtain the amount in serves per day.

7.3.2 Participants

Participants included men and women recruited into the overall study and who completed the fruit and vegetable FFQ, the Fluid Frequency Questionnaire and the FR at the baseline or the final data collection process. As this part of the study assessed the validity of the fruit and vegetable FFQ and the Fluid Frequency Questionnaire, duplicate entries (entries were one year apart) were also analysed provided an FR was also completed by the participant at each time point. Forty-six participants completed the short FFQ on fruit and vegetable consumption, the Fluid Frequency Questionnaire and the 3-day FR. Of these 46 participants, eight participants had data that was considered implausible, as their recorded energy intake from their FR was below their calculated BMR and were thus excluded from the final analysis. One participant did not provide his age, which was required to calculate his BMR using the Schofield equation, and was thus also excluded from the final analysis. A total of 37 participants remained. The mean age of these 37 participants was 44 years (range 22-64 years) and the mean BMI was 29 kg/m^2

(range 22-39 kg/m^2). Anthropometric measures such as the weight, height and body mass index were taken, as described in section 4.3.3.2 above. All participants' fruit and vegetable FFQ, the Fluid Frequency Questionnaires and FRs were de-identified and coded to ensure anonymity.

7.3.3 Food and Fluid Frequency Questionnaire

There were two FFQ short questions on fruit and vegetables that were used from the validation study of Flood et al. (2014) in children. The Fluid Frequency Questionnaire was developed into a 21-item short questions survey that estimated beverage intake among the miners. Beverage categories were expanded to get a more detailed fluid consumption profile by including common beverages consumed in Australia such as flavoured milk, iced tea and cordial. Beers were not grouped together like the BEVQ and were separated into full strength, mid-strength and light beer (Appendix 11). All data from the fruit and vegetable FFQ, and the Fluid Frequency Questionnaire were collated and intake was averaged per day.

7.3.4 3-day Food Records

A 3-day FR was used as the reference comparison method for validating the fruit and vegetable FFQ and the Fluid Frequency Questionnaire. The FR contained detailed instructions on recording everything the participants consumed (both food and beverages) on two weekdays and one weekend day. The FR also included a sample recording for one day (Appendix 6). All data from the FR were entered into the FoodWorks Nutrition Software Version 7 (Xyris Software (Australia) Pty Ltd) using the AUSNUT 2007 database (Food Standards Australia and New Zealand) to collate information on the average energy and nutrient intake (including fluid) of each participant for the three days that were recorded. A Microsoft Excel 2010 database was created and used to document all nutrition decisions regarding the FR if food items in the FoodWorks software did not directly correlate with an item recorded by participants. This decision tool was then used throughout the data entry process for all similar FR entries into the FoodWorks software (Appendix 20). This ensured consistency throughout the data entry process. The completed FoodWorks data was then exported into Microsoft Access 2010 for Windows, from which serves of fruit and vegetables, and millilitres of fluids could be calculated for comparison with the fruit and vegetable FFQ and the Fluid Frequency Questionnaire.

7.3.5 Statistical analysis

The FoodWorks software was used to analyse the Basal Metabolic Rate (BMR) of participants using the Schofield equation factoring in the participants' age, weight, height and gender (Schofield 1985). Average daily intakes of fruit, vegetables and fluids were obtained from the fruit and vegetable FFQ, the Fluid Frequency Questionnaire and the FR. For simplicity in analysis, the 21 beverages in the Fluid Frequency Questionnaire were grouped into four categories: Water, Alcoholic beverages, Non-alcoholic beverages and Total Fluids. Further data analysis was performed using the IBM Statistical Package for the Social Sciences (IBM SPSS) version 19.0 for Windows. Common statistical tests used to validate FFQs and other nutritional assessment tools were identified and used. A brief description of these statistical tests follows.

7.3.5.1 Paired sample t-test

The paired sample t-test was used to compare mean intakes of fruit, vegetables and fluids between the fruit and vegetable FFQ, the Fluid Frequency Questionnaire and the FR. This was one of the methods used to validate the fruit and vegetable FFQ and the BEVQ when intakes were compared across the fruit and vegetable FFQ and the BEVQ with the FR (Hedrick et al. 2010, Flood et al. 2014). While the paired sample t-test is the simplest comparison between the fruit and vegetable FFQ, the Fluid Frequency Questionnaire and the FR, the distribution was not normal and thus non-parametric tests, such as the Spearman rank correlation, was also appropriately used (Johansson 2006).

7.3.5.2 Spearman rank correlation

The Spearman rank correlation was used to assess the magnitude and direction of the relationship between the fruit and vegetable FFQ, the Fluid Frequency Questionnaire data and the FR data. This is one of the preferred approaches to statistically assess the relative validity, especially as data are continuous (Masson et al. 2003). However, the Spearman rank correlation assesses the spatial relationship with only one aspect of the agreement that relates to ranking (Johansson 2006). It does not provide any meaningful information on the agreement between the two assessment tools, especially with regard to bias (Bland and Altman 1986). It is therefore more appropriate to use the Spearman correlation in conjunction with the Bland-Altman method (Cade et al. 2004, Flood et al. 2004).

7.3.5.3 Bland-Altman analysis

The Bland-Altman analysis measures only the level of agreement between the fruit and vegetable FFQ, the Fluid Frequency Questionnaire and the FR and makes no assumptions of which is the better method (Bland and Altman 1986), though it would be customary to assume the more detailed dietary assessment method is more likely to be accurate than the short FFQ (Cade et al. 2004). The analysis involves plotting the difference against the mean of both pairs of observations on a scatter plot. A regression line is then fitted to show the dependency between the fruit and vegetable FFQ, the Fluid Frequency Questionnaire and the FR. For perfect agreement between the two methods (i.e. equal variability with no systematic bias), the correlation of the differences would equal zero (i.e. as mean intake increases the two methods do not differ in their results). The β coefficient for the regression equation (Difference = $\alpha + \beta x$) with 95% CI was used to assess the degree to which the fruit and vegetable FFQ and the Fluid Frequency Questionnaire may have under- or over-estimated intake compared with the FR (i.e. measuring the non-significant linear trend). The limits of agreement (LoA) represent the limits in which 95% of the differences between the two methods are expected to lie in a particular population (Bland and Altman 1986). These are calculated as follows:

$$Upper\ LoA = d + (2 \times S_{diff})$$

$$Lower\ LoA = d - (2 \times S_{diff})$$

where d = Mean of Difference and S_{diff} = Standard deviation of the difference

However, of important note is how these 'Mean of Difference' and 'limits of agreement' describe the study population, and this is obtained by estimating the 95% confidence intervals of these statistics (Carkeet 2015). These were calculated using the following formula:

For 95% Confidence Interval of Mean of Difference (d):

$$d \pm t_{0.975,\, n-1} (S_{diff} / \sqrt{n})$$

For 95% Confidence Interval of limits of agreement (LoA):

$$Upper\ LoA \pm t_{0.975,\, n-1} \sqrt{2.92} (S_{diff} / \sqrt{n})$$

$$Lower\ LoA \pm t_{0.975,\, n-1} \sqrt{2.92} (S_{diff} / \sqrt{n})$$

Rather than relying on set cut-points, agreement between the two methods is left open to interpretation by the investigator on which is the better method (Carkeet 2015). If the difference between the two methods is not of significant or clinical importance then these two methods may be used interchangeably to measure the same quantity (Carkeet 2015).

7.4 Results

7.4.1 Validity of the short Fruit and Vegetable questions of the FFQ

Table 7-1 shows the mean and median intakes for both fruit and vegetables for the FFQ and the 3-day average from the FR with paired t-test and Spearman's rank correlation coefficients. The paired t-test showed that there was a significant difference in mean intake of vegetables between the two assessment methods. Vegetable intake had a moderate negative significant correlation (-0.508, $P<0.001$) between the FFQ and the FR while fruit intake had a non-significant correlation. This would suggest that vegetable intake in the FFQ was underestimated or more likely that the vegetable consumption in the FR was over-reported as shown in figure 7-1 above. This is confirmed in the Bland-Altman plots (Figure 7-1B). With regard to vegetable consumption, the FFQ could potentially overestimate by up to two serves while grossly underestimating it by seven serves. With regard to fruit consumption, there is poorer agreement between the FFQ and the FR, as the serves of fruit increases (Figure 7-1A). The FFQ could potentially overestimate by three serves and underestimate it by two serves.

Table 7-1: Comparison of mean and median fruit and vegetables intakes, mean difference and Spearman's rank correlation between the FFQ and the FR (N = 37)

	Food Frequency Questionnaire		3-day Food Record		Mean Difference	Standard Error of Mean	Paired t-test	Spearman's rank correlation
	Mean	**Median**	**Mean**	**Median**				
Fruit (serves/day)	1.8	1.5	1.4	1.0	0.4	0.2	P = 0.060	0.265
Vegetables (serves/day)	1.8	2.0	4.4	4.0	-2.6	0.4	P < 0.001	-0.508*

*P<0.001

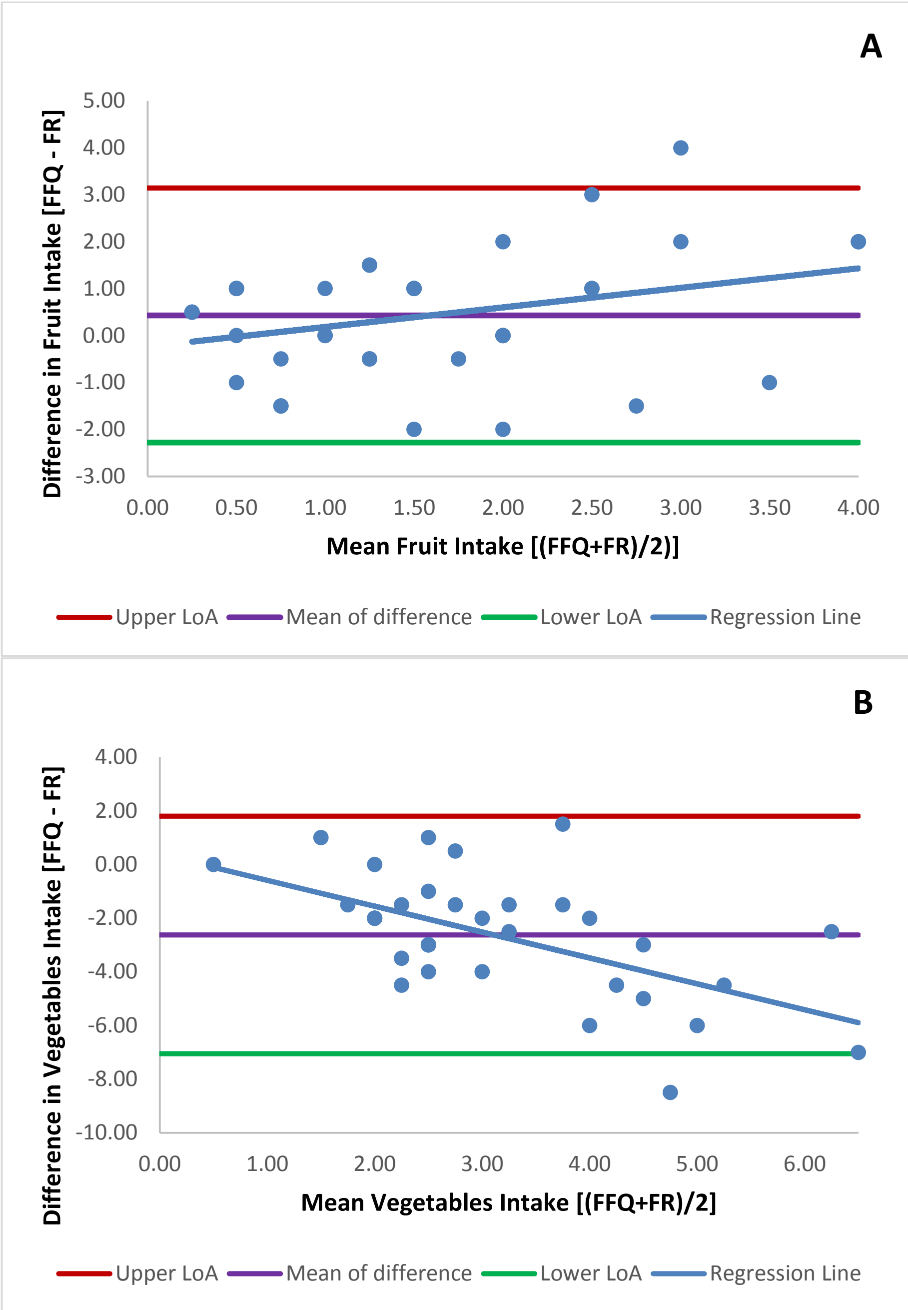

Figure 7-1: Bland Altman plot assessing the validity of the Food Frequency Questionnaire (FFQ) and the 3-day FR. **(A)** Fruit intake (N = 37). Plot shows the Mean of difference 0.4 serves (CI: 0.0, 0.8), Upper level of agreement (LoA) 3.1 serves (CI: 2.4, 3.9), Lower level of agreement (LoA) -2.3 serves (CI: -3.0, -1.5) and the Regression line (equation: y = -0.233 + 0.417x). **(B)** Vegetables intake (N = 37). Plot shows the Mean of difference -2.6 serves (CI: -1.9, -3.4), Upper level of agreement (LoA) 1.8 serves (CI: 0.5, 3.1), Lower level of agreement (LoA) -7.0 serves (CI: -8.3, -6.0) and the Regression line (equation: y = 0.378 - 0.965x).

7.4.2 Validity of the Fluid Frequency Questionnaire

Table 7-2 shows the mean and median intakes across all beverages grouped into water, alcoholic, non-alcoholic and total fluids for the Fluid Frequency Questionnaire and the average of the 3-day FR. The table also reports the calculated t-test and the Spearman's rank correlation coefficients. According to the paired t-test, there was no significant difference in the mean intake of fluids (mL/day) for all beverages ($P > 0.05$) between the two assessment methods. Estimates of fluid intakes were higher for the Fluid Frequency Questionnaire for alcoholic, non-alcoholic and total fluids than for the 3-day FR but lower for water in the Fluid Frequency Questionnaire than the 3-day FR (but not significant). In addition, Alcoholic showed the least variance between the two methods based on the mean difference between the Fluid Frequency Questionnaire and the FR (a difference of 106 mL). Among the beverage categories, only water and alcoholic showed significant correlation between methods (0.441 and 0.590 respectively), while total fluids and non-alcoholic beverages showed a non-significant weak correlation (0.111 and 0.218 respectively) between the Fluid Frequency Questionnaire and 3-day FR data. Hence water and alcoholic both showed *moderate correlation* while total fluids and non-alcoholic beverages showed *weak correlations* between the two methods (Dancey and Reidy 2007).

Furthermore, the Fluid Frequency Questionnaire underestimated water consumption by up to 1,994 mL per day and overestimated it by up to 1,612 mL per day in 95% of the study population. With regard to alcohol consumption, the Fluid

Frequency Questionnaire underestimated consumption by 830 mL per day and overestimated consumption by 1,042 mL per day. With regard to non-alcoholic beverages, the Fluid Frequency Questionnaire underestimated consumption by 1,909 mL per day and overestimated consumption by 2,214 mL per day. And with regard to total fluids consumption, the Fluid Frequency Questionnaire underestimated consumption by 2,065 mL per day and overestimated consumption by 2,582 mL per day.

The Bland Altman plots generally showed a tendency towards poor agreement between the Fluid Frequency Questionnaire and the 3-day FR for all beverage categories, except non-alcoholic beverages, and total fluid intake (Figures 7-2 to 7-5). In general, larger β coefficients are indicative of poorer agreement with increasing level of intakes. With regard to non-alcoholic and total fluid intake, the β coefficients (-0.101 and 0.012) indicates no significant bias between the two methods with increasing intakes; while for water intake, the β coefficient obtained from the regression line (-0.418 and significant 95% CI (-0.940, -0.137) around the β coefficient) indicate a statistically significant bias between the two methods of measurement ($P<0.001$) with increasing intake of water (Figure 7-2). The same observations cannot be made for alcoholic intake due to the positively skewed data, as many participants did not consume alcoholic beverages. This was true even after log transformation of the raw data (Figure 7-4).

Table 7-2: Comparison of mean and median fluid intakes between the Fluid Frequency Questionnaire and the 3-day Food Record (N = 37)

Beverage category (mL/day)	**Fluid Frequency Questionnaire**		**3-day Food Record**		**Mean Difference**	**Standard Error of Mean**	**Paired t-test**	**Spearman's rank correlation**
	Mean	**Median**	**Mean**	**Median**				
Water	825.30	500.00	1016.00	800.00	-190.70	148.20	P = 0.322	0.441**
Non-Alcoholic	2143.41	1974.00	1990.97	1792.00	152.44	169.44	P = 0.374	0.218
Alcoholic	382.48	246.14	276.54	0	105.94	76.93	P = 0.177	0.590***
Total Fluids	2525.88	2387.00	2267.51	2117.00	258.37	190.97	P = 0.185	0.111

*P < 0.05 **P < 0.01 ***P < 0.001

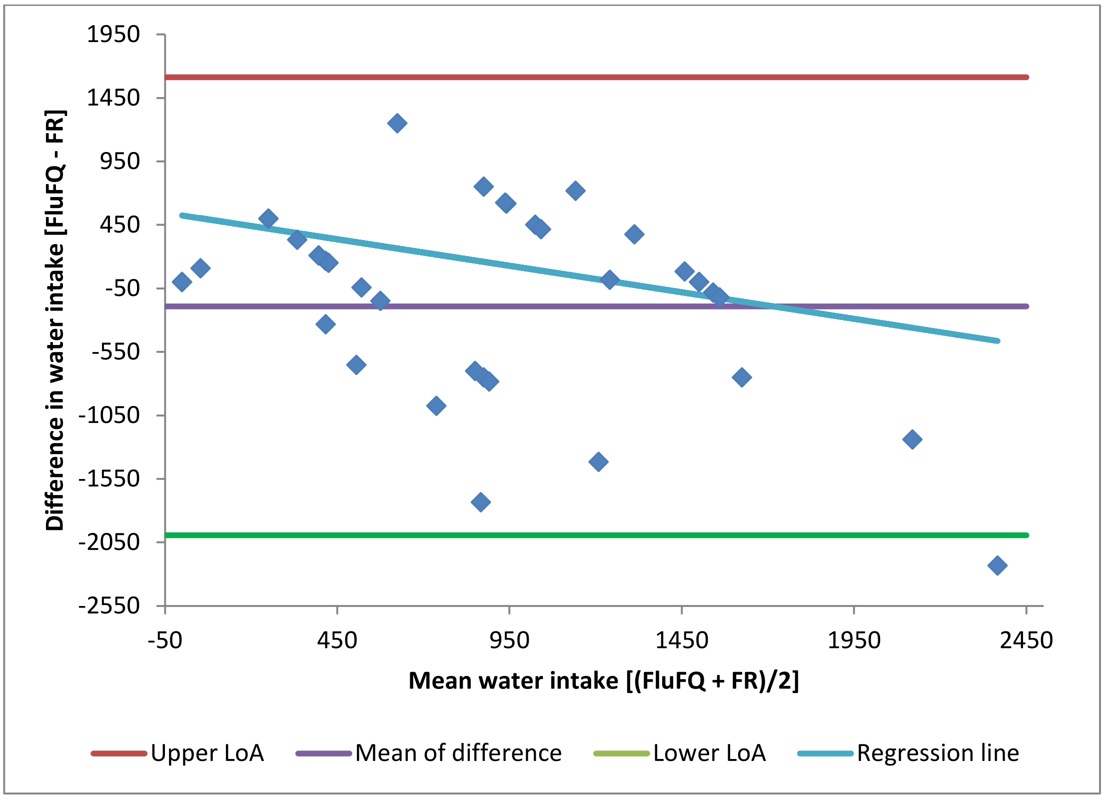

Figure 7-2: Bland Altman plot assessing the validity of the Fluid Frequency Questionnaire (FluFQ) and the 3-day FR for **Water** intake (N = 37). Plot shows the Mean of difference -190.70 mL (CI: -490.22, 108.82), Upper level of agreement (LoA) 1612.25 mL (CI: 1100.44, 2124.06), Lower level of agreement (LoA) -1993.65 mL (CI: -2505.46, -1481.84) and the Regression line (equation: y = 525.4 – 0.418x (CI for regression line -0.940, -0.137)).

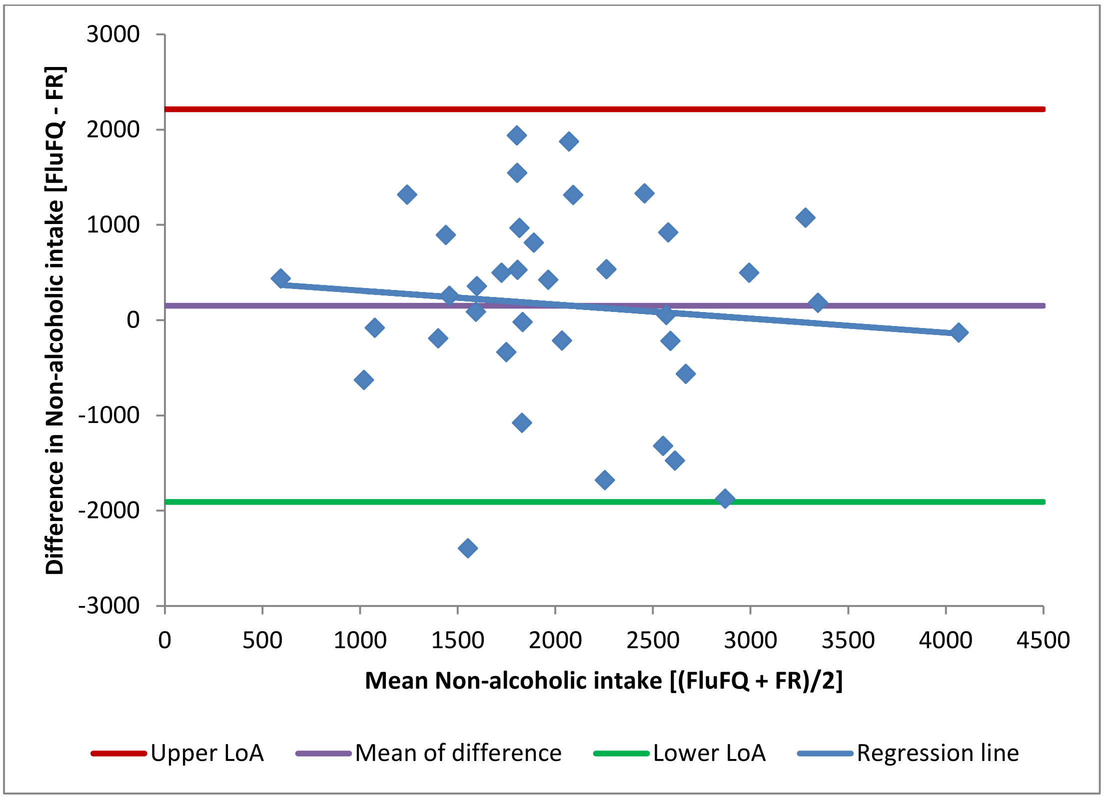

Figure 7-3: Bland Altman plot assessing the validity of the Fluid Frequency Questionnaire (FluFQ) and the 3-day FR for **Non-alcoholic** beverage intake (N = 37). Plot shows the Mean of difference 152.43 mL (CI: -190, 494.87), Upper level of agreement (LoA) 2213.74 mL (CI: 1628.59, 2798.89), Lower level of agreement (LoA) -1908.87 mL (CI: -2494.02, -1323.72) and the Regression line (equation: y = 457.31 – 0.101x (CI for regression line -0.645, 0.350)).

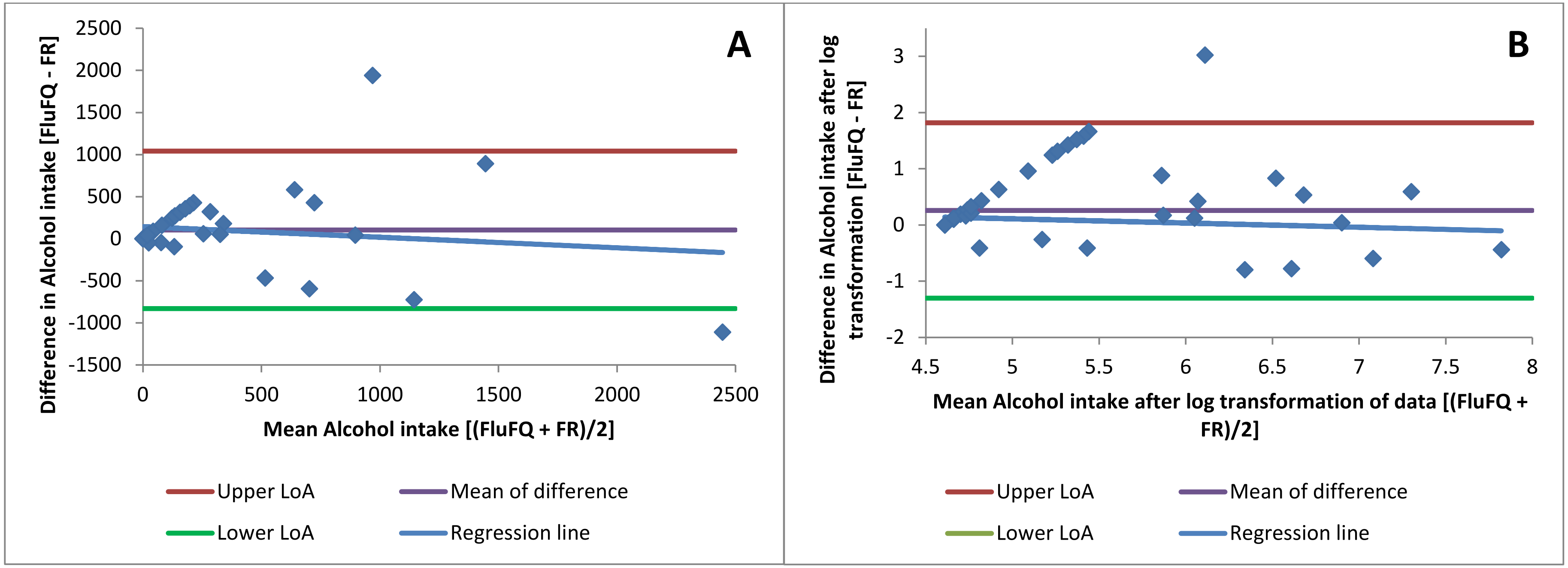

Figure 7-4: Bland Altman plot assessing the validity of the Fluid Frequency Questionnaire (FluFQ) and the 3-day FR for **Alcoholic** beverage intake (N = 37) using raw data **(A)** and log transformed data **(B)**. Plot **(A)** shows the Mean of difference 105.94 mL (CI: -49.54, 261.42), Upper level of agreement (LoA) 1041.86 mL (CI: 776.17, 1307.54), Lower level of agreement (LoA) -829.98 mL (CI: -1095.66, -564.30) and the Regression line (equation: y = 143.60 – 0.114x). Plot **(B)** shows the plots for log transformed data to show any relationship in the data more clearly.

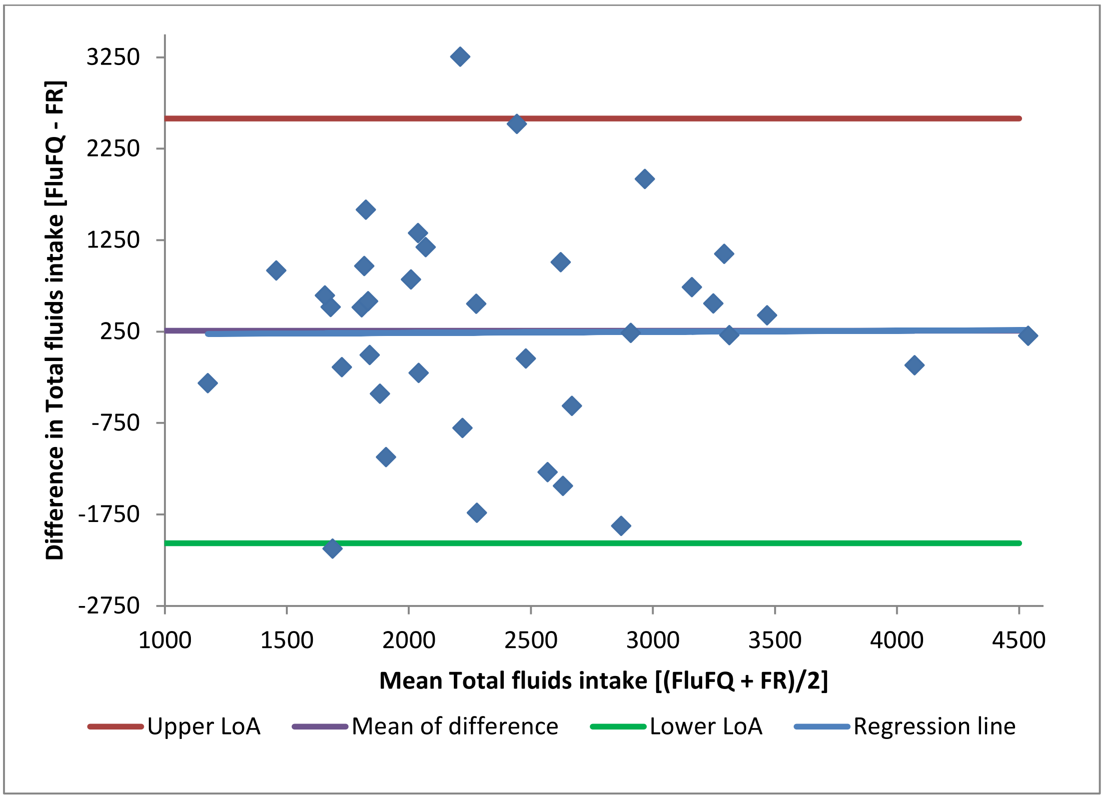

Figure 7-5: Bland Altman plot assessing the validity of the Fluid Frequency Questionnaire (FluFQ) and the 3-day FR for **Total fluid** intake (N = 37). Plot shows the Mean of difference 258.38 mL (CI: -127.57, 644.33), Upper level of agreement (LoA) 2581.62 mL (CI: 1922.11, 3241.13), Lower level of agreement (LoA) -2064.87 mL (CI: -2724.38, -1405.36) and the Regression line (equation: y = 211.876 + 0.012x (CI for regression line -0.520, 0.559)).

7.5 Discussion

There was a significant negative correlation for vegetables consumption between the FFQ and the FR (r= -0.508). This is due to the over-reporting of vegetables consumption in the FR and underreporting in the short FFQ by participants (Figure 4-4 and Table 7-1). This could possibly explain why the result in this study is different from a study conducted among Finnish adults that showed non-significant correlations for fruit and vegetables consumption between FFQ and FR (r = 0.53 and 0.44 respectively) (Paalanen et al. 2006). A study among Spanish adults also showed non-significant correlations for fruit and vegetables consumption between the FFQ and the FR (r = 0.57 and 0.70 respectively) (Fernández-Ballart et al. 2010). Another study by Flood et al. (2014) found significant correlations for both fruit and vegetables consumption between the FFQ and the FR (r = 0.52 and 0.55 respectively). However, it is important to note that the study of Flood et al. (2014) was conducted among two-to-five year-old preschool children from parent- and teacher-reported intake. The wide variability in correlation between FFQ and FR for different populations and different age groups suggests that both the FFQ and the FR varies by age, gender, population and possibly even subsets of population such as the workers in this study. In addition, the FFQ overestimation of fruits intake by up to three serves per day and the underestimation of vegetables intake by up to seven serves per day potentially could misclassify the participants as being compliant with the Australian Dietary Guidelines and the Australian Guide to Healthy Eating of two serves of fruit and five serves of vegetables per day (NHMRC 2013a and 2013b). This is comparable to the study of Hebden et al. (2013) who found that the FFQ underestimated by an average of 4.9 serves of fruit and vegetables per day in 95% of their sample. Therefore, use and interpretation of the FFQ data on fruit, and especially vegetable intake should be done with caution.

The methodology for measuring fluid intake in population studies remains controversial due to the paucity of research on standardised questionnaires that measure beverage intake, and also due to a lack of validation studies for existing questionnaires (Nissensohn, et al. 2015). This study investigated the relative validity of a quantitative Fluid Frequency Questionnaire compared with a 3-day FR in a sample of adults working in the mining industry. A range of beverages, categorised into four major consumption groups, was assessed. There were no significant differences in the mean consumption of beverages between the two measurement methods, suggesting that the Fluid Frequency Questionnaire can be used to quantify mean beverage consumption overall. Water and Alcohol consumption were significantly correlated ($r = 0.44$ ($P < 0.01$) and $r = 0.59$ ($P < 0.001$) respectively) but were not well represented in terms of absolute quantity of intake as indicated by the LoA. The correlation coefficient reported in this study for water consumption is well below the $r = 0.69$ reported in an earlier validity study of the Beverage Frequency Questionnaire (BEVQ) (Hedrick et al. 2010). However, it is higher than the correlation coefficient of $r = 0.35$ reported in a study that utilised the same questioning methodology for water intake in their questionnaire i.e. restricting quantity to standard cups (Flood et al. 2014).

When comparing the reported fluid intakes between the two methods, the Fluid Frequency Questionnaire has a higher reported intake than the 3-day FR for all categories except water. This is likely due to the upper limit set for water consumption in the Fluid Frequency Questionnaire. For instance, the highest level of water intake that could be recorded in the Fluid Frequency Questionnaire is "6+ cups" which translates to 1.5 litres (6 x 250 mL cup) of water per day. Some participants were recording water intakes far in excess of this amount in their 3-day FR, which would limit the ability of the Fluid Frequency Questionnaire to accurately assess water consumption. This was not a problem in the BEVQ as this measurement tool did not restrict its beverage quantity intakes to a single cup, but rather had 2.5 cups as its highest intake each time (Hedrick et al. 2010).

With regard to alcoholic beverages intake, the data was positively skewed as many participants reported zero alcoholic beverages consumption on the days that they recorded their 3-day FR when compared to the Fluid Frequency Questionnaire. This is similar to a study done by Hebden et al. (2013) and presents some difficulty when analysing such data. In such a case, the Fluid Frequency Questionnaire may be a more accurate estimate of alcoholic beverages consumption than the 3-day FR. Using log transformation to show any linear trends did not reveal any useful information. This may be due to the fact that participants completed their 3-day FR on days when "occasional drinkers" did not consume any alcoholic beverages. It is therefore difficult to draw any meaningful conclusions regarding alcoholic beverages intake between the two measurement methods.

As an overall fluid intake assessment tool, the reported total fluid intake in the Fluid Frequency Questionnaire has a high level of agreement with that reported in the 3-day FR. This is most likely to be a group level effect and thus conclusions at the individual level cannot be made with any certainty. Another possible reason for this may be that participants had been previously advised about their blood pressure levels, their blood glucose levels and their hydration status prior to completing the Fluid Frequency Questionnaire and the 3-day FR, which may have prompted an overestimation of fluids consumed in their Fluid Frequency Questionnaire and an increased intake when recording their 3-day FR. Nonetheless, the Fluid Frequency Questionnaire appears to be a useful tool to study progressive trends in fluid intake in a population group such as workers in the mining industry, particularly with regard to planning an intervention.

Staying hydrated through adequate water consumption among workers in the mining industry has workplace health implications, particularly for those working in hot, humid environments (Polkinghorne et al. 2013). Having a validated tool that can be quickly administered on site can be useful for Workplace Health and Safety professionals in assessing habitual fluid consumption patterns among workers, particularly with respect to intervention programs designed to improve hydration status.

7.6 Limitations

A number of limitations are present in this study. For relative validity testing, the 3-day FR was used as the reference standard, which has its own limitations and sources of error (Carlsen et al. 2011). The exclusion criteria for implausible FR entries did not account for an activity factor that should be used depending on the physical activity of the miners, hence only the BMR was used as a cut-off point. There were two reasons for this: first, there was a large discrepancy between the self-reported physical activity levels from the questionnaire and the physical activity level onsite suggesting over-reporting, and second, using the lowest physical activity level of 1.4 (sedentary) excluded 80% of participants' food records due to underreporting across the sample for the FR thus considerably reducing the sample size. Thus participants whose total energy intake (derived from the FR entries) fell below their calculated BMR (from the Schofield equation) were excluded from the final data analysis. Underreporting intakes is a phenomenon not uncommon among overweight and obese participants (Bandini et al. 1990). Participants also over-reported consumption of vegetables which skewed the validation statistics when comparing the FFQ with the FR. Participants in this study worked both day and night shifts, which would have affected their ability to adequately quantify and record their intakes as the different shift times would dictate their intake patterns. Due to the work demands placed on workers in the mining industry, participants may only have time to quickly eat and drink in the short breaks thus postponing the FR entries until they had more time. This would potentially introduce a recall bias, especially if they didn't remember to record it until the following day. Lastly it is quite possible that the Fluid Frequency Questionnaire underestimated certain beverage categories; particularly water, by creating an upper ceiling limit on quantity in the response categories (6+ cups per day).

7.7 Conclusion

The fruit and vegetables short questions of the FFQ should be used and interpreted with caution in a mining cohort, given the over-reporting of vegetables in the FR. The Fluid Frequency Questionnaire, on the other hand is a practical, easily applicable and quick to administer tool to measure fluid intake in the workplace. It may also be a useful tool for researchers assessing fluid intake in large populations and for assessing changes in fluid intake patterns following an intervention. This study on the relative validity of the Fluid Frequency Questionnaire shows that there is a tendency towards poor agreement with the 3-day FR for all beverage categories, *except* non-alcoholic beverages and total fluid intake. The Fluid Frequency Questionnaire may thus be used to assess overall fluid consumption, and progressively track changes in selected patterns of fluid consumption, particularly as a result of an intervention program focusing on fluid intake. With further refinement of the Fluid Frequency Questionnaire, such as removing a ceiling limit on water consumption, it may be possible to assess water consumption and thus indirectly assess hydration status of workers. This would however require further validation after refinement of the tool. Interpretation of the results of this validity study must be with caution, given the limitations of this study. More validation studies are required to assess questionnaires designed to estimate beverage consumption only so as to get closer to developing a standardised and validated tool for measuring beverage consumption.

7.8 References

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CHAPTER 8 – CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

The aim of this research was to demonstrate the feasibility of a workplace health promotion intervention program in the mining industry using an open cut mine as the study site. The results of this research have shown that it is feasible to introduce a workplace health promotion program that can be applied to the mining industry, albeit with some modifications depending on the type of mine site, the number of shifts, the number of hours in a shift, resources available and most importantly, interest from the management to run such a program. Major findings from this research are as follows:

- The prevalence of overweight and obesity among workers in the mining industry was very high (83%), even higher than the national average for Australia (62.8%) at the time this research was conducted in 2013 (ABS 2013).
- The majority of workers started their shift dehydrated (70%) thus predisposing themselves to developing heat-related illness from heat stress and heat strain if they were exposed to hot, humid work environments.
- A combination of individual behavioural and environmental changes enabled workers to maintain their weight over the study period and significantly improve their pre-shift hydration status.

8.2 Conclusion

The workplace health promotion intervention program was demonstrated to be feasible at this mine site and achieved the following effects:

- Maintained the weight of participants over the one-year study period with threshold shifts in BMI among the borderline overweight and obese participants, which resulted in a non-significant 2.5% decrease in overweight and obesity rates, half of the 5% that this research aimed for,
- Improved the hydration status of workers by 58% from baseline, 43% more than the 15% improvement that this research aimed for,
- Increased the consumption of fruit from 1.1 serves per day to 1.9 serves per day, nearly meeting the Australian Dietary Guidelines and the Australian Guide to Healthy Eating of 2.0 serves per day,
- Increased water consumption, and decreased non-alcoholic (tea, coffee, cordial, sports and energy drinks, and fruit juice) and alcoholic beverages consumption both of which contribute to a diuretic effect, thus worsening hydration status,
- Demonstrated that pre-shift hydration status is one of the crucial determinants of coping with heat stress while working in hot, humid environments.

8.3 Limitations

Specific limitations have been discussed in Chapters four to seven. The limitations stated here are a summary of those limitations and include the following:

- Large participant attrition towards the end of the study as a result of loss of a significant number of the workforce during a climate of declining commodity prices and restructuring of the mining company to remain profitable. This resulted in low morale and a reduced number of participants' engagement with the health promotion intervention program. This limited the power of the study and subsequent difficulty with interpreting results.
- Restricted access to snack and beverage vending machines such that less-healthy food and drinks could not be eliminated in favour of healthier options.
- Restricted work environment and time for the participants to engage in any meaningful physical activity onsite, thereby limiting physical activity interventions.
- Small number of participants who were at risk of heat stress and heat-related illness, limiting generalisation of findings regarding the association between hydration status, BMI and core body temperature.
- Using an exclusion criterion for FR that did not account for a physical activity factor as a result of misreporting of dietary data by the participants. This

may have skewed the validation statistics when comparing the FR with short questions from the Food and Fluid Frequency Questionnaires.

- Given the limited validity of the short fruit and vegetable questions, results from the short FFQ should be interpreted with caution.

8.4 Recommendations

Based on the findings of this aspect of the study, the following recommendations are made with respect to future workplace health promotion programs in the mining industry:

8.4.1 Nutrition

- Information about the benefits of good nutrition and consumption of core foods, and especially fruit and vegetables, should be communicated periodically to all workers.
- Researchers should undertake a review of onsite snack and beverages vending machines with a view to replacing unhealthy snacks and beverages with healthier options, and should consider adopting interpretative labelling systems (such as the 5-star rating system) for labelling snacks and beverages.

8.4.2 Physical activity

- Physical activity should be encouraged at the workplace through walking/exercise debriefs, walking/exercise handovers and walking/exercise meetings whenever possible. The aim would be to strive for 60 minutes of moderate intensity physical activity per day to counteract the detrimental effects of prolonged sitting on workers' long term health. One way of achieving this would be to hold gym meetings where participants are engaged in moderate intensity physical activity while having a meeting at the same time.

- Allow workers to have access to the onsite gym to engage in some form of physical activity during their spare time.
- Introduce sitting/standing workstations for all office staff to decrease prolonged sitting which contributes to sedentary activity.

8.4.3 Dehydration and heat stress

Based on the findings of this aspect of the study, recommendations were made to the mine site in the form of a heat stress management plan. The same recommendations are applicable to all mine sites for employees working in hot environments. These recommendations included the following:

1. Information about the benefits of hydration, starting work hydrated and sources of healthy fluids should be communicated to workers. Daily reinforcement of this during hot days may be required.
2. Pre-shift hydration testing using the urine specific gravity (USG) should be considered for high-risk workers (shot firers and processing workers) and appropriate measures taken to ensure a fair hydration (pre-hydration with water) prior to starting the shift.

3. During hot days, steps should be taken to limit the exposure of high-risk workers such as shot firers and processing workers. This could be achieved by the following options:

   For Shot firers –

   - Limit time on the ground in the open pit and spend more time in air conditioned cabins of vehicles in the open pit.
   - Rotate with other work groups in the open pit, if possible and appropriate.
   - Stop work especially on hot days when the risk of heat stress is elevated as indicated by the PHS predicting early onset of core body temperature elevation to 38°C prior to the end of the shift or a TWL less than 115.
   - Consider shade options while performing work in the open pit. This shade option could be engineered onto the vehicle to be easily deployed.
   - Ensure hydration by drinking fluids that are carried in the 20L water containers at the back of the vehicles.
   - Consider clothing and PPE options e.g. cooling suits and cooling towels worn around the neck.

   For Processing workers –

   - There are some processing jobs that can be done under cover. Hence consider rotating jobs half way through the shift with processing jobs under cover.

- Consider tasks which can be performed during cooler periods of the day such as early mornings or late evenings.
- Stop work especially on hot days when the risk of heat stress is elevated as indicated by the PHS predicting early onset of core body temperature elevation to 38°C prior to the end of the shift or a TWL less than 115.
- Consider shade options in certain areas of the buildings
- Consider clothing and PPE options e.g. cooling suits, use of camel backs and cooling towels worn around the neck.

4. Water should be freely available to all employees undertaking work in hot conditions. This may be supplemented with 7g/100ml of carbohydrate containing fluid and/or electrolyte-containing fluids for work that exceeds four hours in hot conditions, to provide energy and replace lost electrolytes (DiCorleto et al. 2013).
5. New employees starting work in the hotter months of the year need to undergo a period of heat acclimatisation prior to starting in the pit.

8.4.4 Policy

- Implementing a healthy workplace policy by the management to demonstrate corporate commitment to workers' health. Such policies could include:
    a. Policy on health eating, especially for worksites that provide food for workers such as FIFO worksites to ensure availability of health food.

b. Policy on physical activity to encourage this at the workplace. This can include sit/stand workstations, walking lunch among others.
c. Policy on social and emotional wellbeing, especially to manage the morale of the workforce.
d. Monitoring the trend of workers' weight using the pre-employment weight, as the baseline would enable better planning of health programs at the workplace, thus keeping workers in an optimal state of health.

8.4.5 Department of Health – Healthy Workers Initiative

- The Australian Government Department of Health's Healthy Workers initiative program is encouraged to approach the mining industry through key industry bodies such as the NSW Mine Safety Advisory Council (MSAC), Queensland Coal Mining Safety and Health Advisory Committee (CMSHAC), Queensland Mining Safety and Health Advisory Committee (MSHAC) and Western Australia's Mining Industry Advisory Committee (MIAC) in an effort to promote the health of employees not just from exposures to workplace hazards but also the general health of employees.

8.5 Contributions to the scientific community

To date there has been a paucity of research literature on workplace health promotion programs in the mining industry. This research has made significant contributions to the scientific community by demonstrating the feasibility and effectiveness of a workplace health promotion program in the mining industry among a cohort of workers who are difficult to access. In addition, the methodological difficulties outlined in this study are characteristic of any mining operation and serve as a guide to future studies involving health promotion programs in the mining industry. An important point to note is that this research was conducted in a non-unionised mine site, which is a rarity in the mining industry in Australia. For unionised mine sites, the unions are key stakeholders and must be willing to accept and engage with the health promotion program for any measure of success.

In a challenging environment in which the workers' time is of the utmost importance, the use of a valid quick tool for collecting information on fruit, vegetables and fluids consumed is paramount. This study has validated a fruit and vegetable FFQ and a fluid assessment tool with mixed results. Future research is required to refine this tool and revalidate it in an attempt to gather more accurate data on workers' fruit, vegetable and fluid consumption.

While evidence suggests that overweight and obese workers may be at an even higher risk of heat stress and strain due to increased adiposity, which acts as a thermal insulator (Savastano et al. 2009), this research did not find any such association. This may likely be due to the small sample size of workers exposed to high ambient temperatures at work coupled with these workers being acclimatised to working in hot, humid environments. More research with a larger sample size is required to clearly demonstrate any association between overweight and obese workers compared to workers who are not overweight and obese, and risk of heat stress and strain. This study did however find a strong correlation between the pre-shift hydration status of workers and the time taken for the core body temperature to increase to critical levels. Given the inadequate amount of fluids workers consume while at work, any workers starting their shift in a dehydrated state will remain dehydrated, or even have a worse hydration status at the end of their shift, predisposing them to heat-related illness. It is therefore important to enlighten workers on the need and importance of staying hydrated at all times

8.6 References

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Appendix 1 – Ethics approval

APPROVAL after review
In reply please quote: HE13/014
Further Enquiries Phone: 4221 3386

26 February 2013

A/Professor Vicki Flood
School of Health Sciences
University of Wollongong

Dear A/Professor Flood

Thank you for your letter responding to the HREC review letter. I am pleased to advise that the Human Research Ethics application referred to below has been **approved.**

Ethics Number:	HE13/014
Project Title:	Supporting healthy lifestyles in the mining industry – a focus on nutrition, physical activity and hydration
Name of Researchers:	A/Professor Vicki Flood, Dr Brian Davies, Mr Ken Bermingham, Mrs Jane Whitelaw, Dr Vinodkumar Gopaldasani
Approval Date:	26 February 2013
Expiry Date:	25 February 2014

The University of Wollongong/ISLHD Health and Medical HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research. The HREC has reviewed the research proposal for compliance with the National Statement and approval of this project is conditional upon your continuing compliance with this document.

A condition of approval by the HREC is the submission of a progress report annually and a final report on completion of your project. The progress report

template is available at
http://www.uow.edu.au/research/rso/ethics/UOW009385.html. This report must be completed, signed by the appropriate Head of School and returned to the Research Services Office prior to the expiry date.

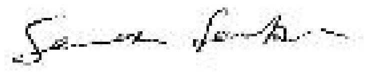
As evidence of continuing compliance, the Human Research Ethics Committee also requires that researchers immediately report:

- proposed changes to the protocol including changes to investigators involved
- serious or unexpected adverse effects on participants
- unforseen events that might affect continued ethical acceptability of the project.

Please note that approvals are granted for a twelve-month period. Further extension will be considered on receipt of a progress report prior to expiry date.

If you have any queries regarding the HREC review process, please contact the Ethics Unit on phone 4221 3386 or email rso-ethics@uow.edu.au.

Yours sincerely



Associate Professor Sarah Ferber
Chair, UOW & ISLHD Health and Medical
Human Research Ethics Committee

Appendix 2 – Participant information sheet

Title: Supporting healthy lifestyles in the mining industry – a focus on nutrition, physical activity and hydration

Project Information & Objectives

Healthy nutrition, physical activity and staying hydrated can all contribute to staying healthy and fit for work and recreation. The study aims to develop, implement and evaluate a healthy lifestyle intervention among employees of Cowal Gold Mine.

Investigators

- *Assoc. Prof. Vicki Flood* *(02) 4221 3947* *vflood@uow.edu.au*
- *Dr Brian Davies* *0407287406* *b.davies07@bigpond.com*
- *Dr Vinod Gopaldasani* *(02) 4221 3463* *vg915@uowmail.edu.au*
- *Jane Whitelaw* *(02) 4221 5232* *jwhitela@uow.edu.au*

What do I have to do?

If you agree to participate in this study you will be provided with information and advice regarding the health benefits of good nutrition, physical activity and good hydration and will be asked to answer some questions about your food and drink intake, physical activity at home and at work and your work environment. You will also be asked to keep a record of your food intake for 3 days in a week (2 weekdays and 1 weekend day). You will be asked to consent to have your height measured (using a stadiometer), be weighed (using a digital weighing scale) and to supply a urine sample (to be tested ONLY for hydration level using a digital optical refractometer) before and after the shift to determine the amount of fluid loss during the shift. You will also have your blood pressure and blood sugar levels measured. The blood pressure will be measured using a digital machine, with a cuff placed around your upper arm while your blood sugar levels will be measured using a glucometer, which requires a pin prick blood sample.

The study will run for 12 to 15 months, with regular measurements every 3-4 months. The regular measurements would include a questionnaire, weight, urine sample for hydration level testing, blood pressure and blood glucose levels.

Intervention component of the study

The intervention will include three main components:

1. Information and training sessions on healthy nutrition, physical activity and staying hydrated. Tools used include PowerPoint presentations, E-bulletin boards, noticeboards as well as regular follow-ups

2. Provision of water stations with palatable water, provision of accessories to facilitate water consumption, review of vending machines and snacks provided during meetings if possible to provide healthier food options, putting up notices and signs encouraging healthy eating, physical activity and staying hydrated

3. Review of guidelines, including discussions with management, which may facilitate the development of new guidelines/policies related to healthy nutrition, staying hydrated, physical activity and managing heat stress

Possible risks, inconveniences and discomforts
The only inconvenience we foresee involves the time taken to complete the questionnaire and to keep a record of your food intake. The only discomfort that we can foresee involves the finger prick test for blood glucose level.

Potential benefits
You will receive a copy of your hydration results with an explanation of what they mean. You will also receive feedback on your physical activity levels and nutrition in relation to the Australian guidelines for physical activity and healthy eating. Your health may benefit from this study through healthy nutrition, increased physical activity and improved hydration. Your workplace may benefit through a health promotion program that sustains and improves the overall health of its employees and this can be applied to other similar workplaces. If you have any concerns about your health please discuss them with your General Practitioner.

Participation is voluntary and you can withdraw at any time
Your participation is completely voluntary and participating or refusing to participate will not affect your relationship with your employer. You have a right to withdraw your consent to participate and/or data from the study at any stage.

Use of research data
Data from this research may be published in a peer reviewed journal article or presented at conferences. Data will also be used for Dr Gopaldasani's PhD thesis. In any reports, conference presentations or other publications resulting from this study, you will not be able to be identified. Group data will be shared with Cowal Gold in the form of presentations or reports. However, individual data will not be provided and you will remain completely anonymous.

Confidentiality
All information provided will be coded to ensure confidentiality. All your data will be confidential and stored in a locked filing cabinet in a secure place at the University of Wollongong. All digital information will be password protected. All identifying

information will be removed after data collection. Upon completion of this study, all data collected will be retained in a secure place in a locked filing cabinet at the School of Health Sciences, University of Wollongong for at least five years so as to comply with the University of Wollongong Code Of Practice – Research.

Enquiries

This study has been approved by the University of Wollongong/ Illawarra Shoalhaven Local Health District Human Research Ethics Committee. For any concerns or complaints regarding the conduct of this research, please contact:

- *UOW Ethics Office* *(02) 4221 4457* *rso-ethics@uow.edu.au*

Thank you for supporting this research

Appendix 3 – Participant consent form

Title: Supporting healthy lifestyles in the mining industry – a focus on nutrition, physical activity and hydration

Please read the following statements and sign below:

1. I have been given the information sheet explaining the study and all questions I have asked have been answered to my satisfaction
2. I have been advised of the potential risks and inconveniences upon participating in this research which includes a finger-prick blood sugar test
3. I understand that the research involves the following procedures:
    a. Receiving information and advice about healthy nutrition, sufficient physical activity and maintaining good hydration levels;
    b. Answering paper-based questionnaires at the start of the study and every 3-4 months thereafter till the end of the study;
    c. Keeping a 3-day food record (2 weekdays and 1 weekend day) at the beginning and at the end of the study;
    d. Having my weight, urine specific gravity, blood pressure and blood sugar levels measured at the start of the study and every 3-4 months thereafter till the end of the study;
    e. Having my height measured at the start of the study.
4. I agree to participate in the study and understand that I may withdraw at any time, taking my data with me.
5. I agree that the research data gathered for the study may be published provided that I cannot be identified as a participant.

Name of participant..

Signature of participant...

Date......../......./..........

Please sign and return this form to the Project Officer. You will be returned a copy of this form to keep for your records.
The principal investigator of this study is Dr Vinod Gopaldasani, a PhD student of the University of Wollongong, who is supervised by A/Prof. Vicki Flood and Dr Brian Davies.

- *Assoc. Prof. Vicki Flood (02) 4221 3947 vflood@uow.edu.au*
- *Dr Brian Davies 0407287406 b.davies07@bigpond.com*
- *Dr Vinod Gopaldasani (02) 4221 3463 vg915@uowmail.edu.au*
- *UOW Ethics Office (02) 4221 4457 rso-ethics@uow.edu.au*

Appendix 4 – Proposed intervention list

INDIVIDUAL			
	Details	**Cost implications**	**Feasibility**
1. Dietary advice / management	Participants interested in dietary advice for weight loss can be linked to the NSW Get Healthy Information and Coaching Service. This is a free personalised one-on-one confidential phone service that helps make lifestyle changes in relation to healthy eating, being physically active and achieving and maintaining a healthy weight.	Free. Program runs for 6 months.	Yes.
2. Information and education	Periodic (3 monthly) seminars or programs to inform and educate workers on healthy eating, physical activity, heat stress and staying hydrated. Avenues to implement include Emails, TV screens on transport buses, posters, health messages before the start of meetings etc.	Negligible. Can be part of the OHS team activities. Support provided by UOW research team.	Yes.
3. Hydration – staying hydrated	Information and education (see above) Provision of water bottles (See above) with quantity consumed to be recorded at the end of the shift.	Free samples of water bottles to be provided for trial run.	Yes for information and education. No for water bottles as supplier was unable to provide bottles for use.

4. Physical activity	Participation in offsite sporting activities. Incorporated into information and education seminars Use of pedometers with target goals to be met.	Low to moderate cost of pedometers. Free – Pedometers will be trialled as part of the intervention.	Yes.
	ENVIRONMENT		
	Details	**Cost implications**	**Feasibility**
Nutrition			
1. Provision of fruit & vegetables	Provision of F & V in common areas, pantry, during meetings, possibly on desks of workers	Moderate	No. Cost intensive for long term sustainability.
2. Provision of healthy alternatives to existing food products	Reduced fat milk to completely replace full cream milk, optional skim milk, completely replacing sweet pastries, cakes and biscuits with fruit/vegetables at meetings	Minimal	No. Replacement of existing food products not possible. However, healthy options can be placed side-by-side with existing products.
Physical activity			
1. Onsite gym use	Make onsite gym use available to interested participants. Should be advertised and encouraged to ensure participation.	None	No. Reserved for training of rescue personnel. No time allocation possible for use of facilities.

2. Offsite sporting activities supported by Barrick	Examples include touch footy, basketball etc. Need to make it competitive and fun e.g. have a league consisting of Crews A, B, C, D, office workers, with points allocation for wins and draws and possibly a prize at the end of the season.	Depends on program. Estimated moderate but returns far outweigh cost in terms of improved workers' morale, company image and translating to a healthier workforce.	No. Financial implications may not be supported by management due to consolidation of mining industry with regard to cost saving.
3. Stand at work	Situations in which this could be encouraged include standing while answering the phone, computer prompts with lockout screens telling participants to stand for 5-10mins, standing workstations if practicable.	None. Cost will be high if standing workstations are considered.	No. Financial implications may not be supported by management due to consolidation of mining industry with regard to cost saving.
Smoking cessation			
1. Must be supported by policy or guideline	Encourage a smoke- free workplace by eliminating smoking zones. Penalties/warnings for smoking at the workplace. Must be supported by policy or will fail completely.	None.	No. Too difficult to implement for fear of pushback from workers.
Hydration			
1. Provision of more drink machines around the site	Survey showed that more water bubblers are required around the site to encourage more water intake.	Low to moderate.	Yes.

2. Provision of water bottles	Specialised 2L water bottles with electronic tracker of amounts consumed can be trialled. Quantity consumed at the end of the shift to be recorded in mL.	Free samples (20-30) to be provided (See attached picture).	No. Supplier was unable to provide bottles for use.
Heat stress			
1. Monitoring and evaluation	Heat stress monitoring and evaluation to include measures of WB, DB, GT, air speed and clothing worn. Use of heat stress indices to determine risk followed by appropriate risk management. Detailed in the heat management policy.	Low.	Yes.
Monitoring strategies			
			Feasibility
1. Workers compensation claims, frequency and cost			No. Corporate sensitive information.
2. Sickness absence cost			No. Corporate sensitive information.
3. Lost Time Injury Frequency Rate (LTIFR)			No. Corporate sensitive information.
4. Absenteeism/absence rate/turnover and grievance rates			No. Corporate sensitive information.

5. Productivity – measured in terms of rates and cost			No. Corporate sensitive information.
6. Physical measures – weight, BMI, blood pressure, blood glucose			Yes.

Appendix 5 – Questionnaire for participants

CODE NO:________

TODAY'S DATE: ______________ SHIFT (DAY/NIGHT): ______________

WHAT IS YOUR USUAL JOB?: ________________________

MEASURED HEIGHT (m): ___________m

MEASURED WEIGHT (kg): ___________kg

MEASURED URINE SPECIFIC GRAVITY: ___________

MEASURED BLOOD PRESSURE: _________mmHg

MEASURED BLOOD GLUCOSE: _________mg/dl

I would like to ask you a few questions about yourself. Please remember that all data is confidential. All data will be de-identified before being used in the study.

Q1. AGE (yrs): _______yrs

Q2. GENDER (Circle one): M F

Q3. SUBURB OF HOME ADDRESS: ____

Q4. What is the level of the highest qualification you have completed?

☐1 Completed primary school ☐2 Completed years 7 to 9 ☐3 School certificate or Intermediate or Year 10 or 4th Form ☐4 Higher School Certificate or Leaving or Year 12 or 6th Form ☐5 TAFE Certificate or diploma ☐6 University, College of Advanced Education or some other tertiary degree or higher ☐7 Other_________________________________

Q5. In the last week, how many hours did you work? ________hrs

Q6. I am wearing the following clothes today: (Tick all that apply)

Briefs	☐1	Short sleeves shirt	☐5	Overalls	☐9	Boots	☐13
Sleeveless shirt	☐2	Long sleeves shirt	☐6	Belt	☐10		
T-shirt	☐3	Shorts	☐7	Socks (regular)	☐11		
Full sleeves shirt	☐4	Trousers	☐8	Thick long socks	☐12		

Q7. What part of your body do you use most during the course of your work? (Tick all that apply)

☐1 Hand/wrist/fingers ☐2 Upper arm ☐3 Shoulder ☐4 Back

☐5 Torso ☐6 Lower limbs ☐7 Ankles/foot

Q8. Have you ever experienced any work-related injuries?

☐1 Yes ☐2 No (Skip to Q10)

Q9. Provide a brief description of the type of work related injury you sustained

____

____

SMOKING[1]

Q10. Which of the following best describes your smoking status?

☐1 Smoke daily ☐2 Smoke occasionally ☐3 Do not smoke now but used to

☐4 Have tried it a few times but never smoked regularly ☐5 Never smoked

HYDRATION[2]

Q11. What do you drink most at work?

☐1 Water ☐2 Sports drink ☐3 Soft drink ☐4 Energy drink

☐5 Other_________

Q12. I drink enough at work

☐1 Strongly Agree ☐2 Agree ☐3 Disagree ☐4 Strongly Disagree

Q13. How many cups of soft drink, cordials or sports drink such as lemonade or Gatorade do you usually drink in a day? (1 cup = 250ml, 1 can of soft drink = 1.5 cups, 1 x 500ml bottle of Gatorade = 2 cups)

☐1 ______cups per day ☐2 ______cups per week ☐3 Don't drink soft drink ☐4 Don't know

Q14. How many cups of fruit juice do you usually drink in a day? (1 cup = 250ml, a household cup, or a large popper)

☐1 ______cups per day ☐2 ______cups per week ☐3 Don't drink juice ☐4 Don't know

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[1] Adapted from NSW Population Health Survey 2011, accessed 20/10/2012, http://www0.health.nsw.gov.au/PublicHealth/surveys/hsa/resources/adult%2011_questions/t_7_ques_31_smoking.pdf

[2] Adapted from NSW Population Health Survey 2011, accessed 20/10/2012, http://www0.health.nsw.gov.au/PublicHealth/surveys/hsa/resources/adult%2011_questions/t_7_ques_23_nutrition.pdf and http://www0.health.nsw.gov.au/PublicHealth/surveys/hsa/resources/adult%2011_questions/t_7_ques_02_alcohol_cannabis.pdf

Q15. How many cups of water do you usually drink in a day? (1 cup = 250ml or a household tea cup, 1 average bottle of water = 1.5 cups)

☐1 ______cups per day ☐2 ______cups per week ☐3 Don't drink water ☐4 Don't know

Q16. What would help you drink more fluids at work?

____

____

Q17. How often do you usually drink alcohol?

☐1 ____number of days ☐2 Less than once a week ☐3 Don't drink alcohol

☐4 Don't know

HEALTH[3]

Q18. When did you last have your blood pressure measured by a medical practitioner?

☐1 0-3 months ago ☐2 4-6 months ago ☐3 7-12 months ago ☐4 13 months to 2 yrs ago

☐5 More than 2 yrs ago ☐6 Never measured (Go to **Q20.**) ☐7 Don't know

Q19. Have you ever been told by a doctor/hospital you have high blood pressure (hypertension)?

☐1 Yes ☐2 Yes, but only during pregnancy ☐3 Yes, but only temporarily ☐4 No

☐5 Don't know

Q20. When did you last have your cholesterol measured?

☐1 0-6 months ago ☐2 7-12 months ago ☐3 13 months to 2 yrs ago ☐4 More than 2 yrs ago ☐5 Never measured (Go to **Q22.**) ☐6 Don't know (Go to **Q22.**)

Q21. Have you ever been told by a doctor/hospital you have high cholesterol?

☐1 Yes ☐2 No ☐3 Borderline ☐4 Don't know

Q22. Have you ever been told by a doctor/hospital you have high blood glucose?

☐1 Yes ☐2 No (→ **Q28)** ☐3 Borderline (MALE → **Q28**) ☐4 Only during pregnancy (→ **Q28**) ☐5 Don't know (→ **Q28**)

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[3] Adapted from NSW Population Health Survey 2011, accessed 20/10/2012, http://www0.health.nsw.gov.au/PublicHealth/surveys/hsa/resources/adult%2011_questions/t_7_ques_06_cardiovascular_precursor.pdf and http://www0.health.nsw.gov.au/PublicHealth/surveys/hsa/resources/adult%2011_questions/t_7_ques_11_diabetes.pdf

Q23. Have you ever been told by a doctor/hospital you have diabetes?

☐1 Yes (FEMALE → **Q24**; MALE → **Q26)** ☐2 No ☐3 Only during pregnancy (→ **Q28)** ☐4 Don't know

Q24. Were you pregnant when you were told you had diabetes or high blood glucose?

☐1 Yes ☐2 No (→ **Q26**) ☐3 Don't know (→ **Q28**)

Q25. Have you ever had diabetes or high blood glucose apart from when you were pregnant?

☐1 Yes ☐2 No (→ **Q28**) ☐3 Don't know (→ **Q28**)

Q26. What type of diabetes were you told you had?

☐1 Type 1 ☐2 Type 2 ☐3 Gestational ☐4 Other (Specify___________)

☐5 Don't know

Q27. What are you doing to manage your diabetes/high blood glucose? (Tick all that apply)

☐1 Having insulin injections ☐2 On tablets ☐3 Following special diet ☐4 Losing weight

☐5 Exercising most days ☐6 Others (Specify_________) ☐7 Not doing anything

☐8 Don't know

PHYSICAL ACTIVITY[4]

Q28. In the last week, how many times have you walked continuously for at least 10 minutes for **recreation or exercise?** ________number of times (if 0, go to **Q30**)

Q29. What do you estimate was the total time you spent walking in this way in the last week? (in hours and minutes) _______hours________minutes

Q30. **Excluding gardening**, in the last week, how many times did you do any **vigorous household chores** which made you breathe harder or puff and pant? ______number of times (if 0 go to **Q32**)

Q31. What do you estimate was the total time you spent doing these vigorous household chores in the last week? (in hours and minutes) _______hours________minutes

Q32. In the last week, how many times did you do any **vigorous gardening or heavy work around the yard** which made you breathe harder or puff and pant? ______number of times (if 0 go to **Q34**)

[4] Adapted from NSW Population Health Survey 2011, accessed 20/10/2012, http://www0.health.nsw.gov.au/PublicHealth/surveys/hsa/resources/adult%2011_questions/t_7_ques_26_physical_activity.pdf

Q33. What do you estimate was the total time you spent doing this vigorous gardening or heavy work around the yard in the last week? (in hours and minutes)
_______hours________minutes

Q34. **This question excludes household chores or gardening.** In the last week, how many times did you do any vigorous physical activity that made you breathe harder or puff and pant? (For example football, tennis, netball, squash, athletics, cycling, jogging, keep-fit exercises and vigorous swimming) ______number of times (if 0 go to **Q36**)

Q35. What do you estimate was the total time you spent doing this vigorous physical activity in the last week? (in hours and minutes) _______hours________minutes

Q36. **This question excludes household chores or gardening.** In the last week, how many times did you do any other more moderate physical activity that you haven't already mentioned? (for example, lawn bowls, golf, tai chi, sailing, etc) ______number of times (if 0 go to **Q38**)

Q37. What do you estimate was the total time that you spent doing these activities in the last week? (in hours and minutes) _______hours________minutes

Q38. Regarding all the types of exercise you have already mentioned above, how many days in the last week did you exercise (0 days to 7 days)? _______days

Q39. How many of these days did you exercise for at least 30 minutes per day (0 days to 7 days)? _______days

Q40. How do you usually get to work?

☐1 Car (as driver) ☐2 Car (as passenger) ☐3 Bus ☐4 Motorbike ☐5 Truck ☐6 Other_________

Q41. When at work, which of the following best describes what you do on a typical work-day?

☐1 Mostly sitting ☐2 Mostly standing ☐3 Mostly walking ☐4 Mostly heavy labour

☐5 Don't know

Q42. How much time do you spend sitting at work on a typical workday?
_____hours _____min

Q43. Do you have a gym membership? ☐1 Yes ☐2 No (Skip to **Q45**)

Q44. In the last week, how many times have you gone to the gym to work out?
______no of times

Q45. Did you know that your employer provides a 50% gym membership subsidy?

☐1 Yes ☐2 No

NUTRITION[5]

Q46. How many serves of fruit do you usually eat each day? (1 serve = 1 medium piece or 2 small pieces of fruit or 1 cup of diced pieces)

☐ 1 _____serves per day ☐ 2 ______serves per week ☐ 3 Don't eat fruit ☐ 4 Don't know

Q47. How many serves of vegetables do you usually eat each day? (1 serve = half cup cooked or 1 cup of salad vegetables)

☐ 1 ___serves per day ☐ 2 ___serves per week ☐ 3 Don't eat vegetables ☐ 4 Don't know

[5] Adapted from the NSW Population Health Survey 2011, accessed 20/10/2012, http://www0.health.nsw.gov.au/PublicHealth/surveys/hsa/resources/adult%2010_questions/t_7_ques_23_nutrition.pdf

Appendix 6 – 3-day food record

GENERAL INSTRUCTIONS

NAME:____

- Please fill in this food intake record on **3 days, including 2 weekdays and 1 weekend day.**
- The days in which food intake is recorded do not need to be consecutive, but need to be within the same 1-week period.
- Directions for how to fill in the food record are at the top of each day. An example of one afternoon/evening is on the following page.

When you have completed your food record please return it to the researchers.

If you have any questions about the study or how you should complete the food record please call 02 4221 3947 or email vflood@uow.edu.au or vg915@uowmail.edu.au.

Instructions to completing the food record

- **Write down EVERYTHING that you eat and drink over one day from waking to going to sleep. This includes snacks, water, medications, vitamin and mineral supplements.**
- Use a new line for each food or drink.
- Record the location of where the food was consumed in the location column. For example work, home, shops, restaurants etc.
- Record the type of eating occasion in the appropriate column. *For example, breakfast, lunch, dinner, morning tea, afternoon tea, snacks.*
- **RECORD EACH FOOD INDIVIDUALLY**, *for example a tuna sandwich may include two slices of wholemeal bread, two teaspoons of margarine and 1 small can of tuna (canned in brine)*.
- Include the amounts in household measures or natural portion sizes. *For example: 2 slices of bread, ½ cup rice, ½ cup peas.* Please use the set of standard spoon and cup measures we have provided to assist recording this information.
- Always record cooking methods such as boiling, frying etc.
- Give a detailed description of the food or drink and include brand names where possible. *For example Arnott's Milk Arrowroot® biscuit, Pure Blonde Full Strength Beer, etc.*
- Don't forget to include any sauces, mayonnaise or gravies that are used. We are interested to find out about usual eating patterns, so please keep the food intake as usual.
- If you record a day that is not usual, please indicate in the box at the end of each food record day how it differs from usual. *(For example: I was at a party*)
- **IF IN DOUBT ABOUT ANY FOOD, ASK YOUR PARTNER FOR ASSISTANCE**

Example of one day

Date: 22/03/12			**Day: Thursday** **No √**	**Went to work today Yes ☐**
Location	**Time**	**Meal/eating occasion**	**Food / Drinks/ & Cooking method (where applicable)**	**Amount/size EATEN**
Home	7am	Breakfast	Whole milk (on cereal) Weet-bix White sugar Toast – white bread (Tip Top) Margarine (Meadow Lea) Honey White tea; Black tea with 1 tea bag Whole milk Sugar	1 cup 3 weetbix 1 tspn 2 slices 2 tspn 1 tblspn 1 cup tea 2 tblspn 1 tspn
Work	10am	Morning tea	Banana water	1 medium banana 1 bottle (600ml)
Work	12md	Lunch	2x Cheese and ham sandwiches White bread (Tip Top) Margarine (Meadow-lea) Cheese (Kraft) Ham water Red apple	 4 slices 4 teaspoon 2 slices 2 slices 1 cup 1 large apple
Work	3.00pm	Snack	Muesli bar, Uncle Toby's crunchy nut crumble Gatorade	2 bars 1 medium bottle (600ml)
Home	6.30pm	Dinner	1 Beef Fillet, grilled potato, peeled, steamed carrots, peeled, steamed Green peas, boiled from frozen Apple Juice (Just Juice) Ice cream (Dairy Farmer's vanilla) Chocolate sauce (Cottees) Beer, Tooheys extra dry	1 fillet, 250gm 1 average ½ cup ½ cup 1 medium glass (1 cup from measuring cup) 2 medium scoops 2 tablespoons 2 stubbies

Was intake unusual in any way? No ☐ Yes ☑

If yes, in what way? _______Anniversary dinner____________________

DAY 1 FOOD INTAKE RECORD (WEEKDAY)

- **Write down everything that you eat and drink over one day from waking to going to sleep. This includes snacks, water, medications, vitamin and mineral supplements.**
- Use a new line for each food or drink.
- Record the location of where the food was consumed in the location column. For example work, home, shops, restaurant, etc.
- Record the type of eating occasion in the appropriate column. For example, breakfast, lunch, dinner, morning tea, afternoon tea, snacks.
- Record each food individually, e.g. a tuna sandwich might be two slices of wholemeal bread, two teaspoons of margarine and half a cup of tuna (canned in brine).
- Include the amounts in household measures or natural portion sizes. For example: 2 slices of bread, ½ cup rice, ½ cup peas. Please use the set of standard spoon and cup measures to assist recording this information.
- Always record cooking methods such as boiling, frying etc.
- Give a detailed description of the food or drink and include brand names when possible. For example Arnott's Milk Arrowroot® biscuit, Pure Blonde Full Strength Beer, etc.
    - Don't forget to include any sauces, mayonnaise or gravies that are used. We are interested to find out about usual eating patterns, so please keep the food intake as usual.
    - If you record a day that is not usual, please indicate how it differs from the usual.

Date:	**Day:** **Went to work today: Yes ☐ No ☐**

Location	**Time**	**Meal/eating occasion**	**Food / Drinks/ & Cooking method (where applicable)**	**Amount/ size**

Was intake unusual in any way? No ☐ Yes ☐
If yes, in what way? ____

DAY 2 FOOD INTAKE RECORD (WEEKDAY)

- **Write down everything that you eat and drink over one day from waking to going to sleep. This includes snacks, water, medications, vitamin and mineral supplements.**
- Use a new line for each food or drink.
- Record the location of where the food was consumed in the location column. For example work, home, shops, restaurant, etc.
- Record the type of eating occasion in the appropriate column. For example, breakfast, lunch, dinner, morning tea, afternoon tea, snacks.
- Record each food individually, for example a tuna sandwich might be two slices of wholemeal bread, two teaspoons of margarine and 1 small can of tuna (canned in brine).
- Include the amounts in household measures or natural portion sizes. For example: 2 slices of bread, ½ cup rice, ½ cup peas. Please use the set of standard spoon and cup measures to assist recording this information.
- Always record cooking methods such as boiling, frying etc.
- Give a detailed description of the food or drink and include brand names when possible. For example Arnott's Milk Arrowroot® biscuit, Pure Blonde Full Strength Beer, etc.
  - Don't forget to include any sauces, mayonnaise or gravies that are used. We are interested to find out about usual eating patterns, so please keep the food intake as usual.
  - If you record a day that is not usual, please indicate how it differs from the usual.

Date:	**Day:** **Went to work today: Yes** ☐ **No** ☐

Location	**Time**	**Meal/eating occasion**	**Food / Drinks/ & Cooking method (where applicable)**	**Amount/ size**

Was intake unusual in any way? No ☐ Yes ☐

If yes, in what way? ____

DAY 3 FOOD INTAKE RECORD (WEEKEND DAY)

- **Write down everything that you eat and drink over one day from waking to going to sleep. This includes snacks, water, medications, vitamin and mineral supplements.**
- Use a new line for each food or drink.
- Record the location of where the food was consumed in the location column. For example work, home, shops, restaurants, etc.
- Record the type of eating occasion in the appropriate column. For example, breakfast, lunch, dinner, morning tea, afternoon tea, snacks
- Record each food individually, for example a tuna sandwich might be two slices of bread, two teaspoons of margarine and 1 small can of tuna (canned in brine).
- Include the amounts in household measures or natural portion sizes. For example: 2 slices of wholemeal bread, ½ cup rice, ½ cup peas. Please use the set of standard spoon and cup measures to assist recording this information.
- Always record cooking methods such as boiling, frying, etc.
- Give a detailed description of the food or drink and include brand names when possible. For example: Arnott's Milk Arrowroot® biscuit, Pure Blonde Full Strength Beer, etc.
  - Don't forget to include any sauces, mayonnaise or gravies that are used. We are interested to find out about usual eating patterns, so please keep the food intake as usual.
  - If you record a day that is not usual, please indicate how it differs from the usual.

Date:	**Day:** **Went to work today: Yes** ☐ **No** ☐

Location	**Time**	**Meal/eating occasion**	**Food / Drinks/ & Cooking method (where applicable)**	**Amount/ size**

Was intake unusual in any way? No ☐ Yes ☐

If yes, in what way? ____

Appendix 7 – Diet, nutrition, physical activity and chronic diseases information

Introduction
Your diet and physical activity habits are important factors in the promotion and maintenance of good health throughout your life. By following the guidelines for healthy eating outlined below, you help reduce your risk of chronic diseases such as heart disease, type-2 diabetes, overweight and obesity and some cancers.

Food intake goals for Australians
Most Australians don't eat enough of the foods that are known to promote good health, including fruit and vegetables and wholegrain breads and cereals. Other foods and drinks that should be central in your diet include reduced fat milk, yogurt and cheese, lean meats, poultry, fish, eggs and water.

Most Australians eat too much 'discretionary foods and drinks' such as meat pies, sausage rolls, fried hot chips, potato crisps, lollies and chocolates, soft drinks, cordial, energy drinks, sports drinks, wine, beer and spirits. Details of specific food intakes for preventing diet-related chronic diseases are listed in the attached brochure.

Recommendations for preventing diet-related chronic diseases
Tips to maintain a healthy weight.

1. Maintain your weight such that your BMI is in the range of 18.5 - 24.9 kg/m^2. You can calculate your BMI by dividing your weight in kg by the square of your height in metres.
2. Eat a healthy breakfast.
3. Have a diet that includes at least 2 serves of fruit and 5 serves of vegetables per day.
4. Eat slowly and savour every mouthful.
5. Stop eating before you feel full.
6. Don't eat meals while watching the TV.
7. Choose water as a drink. Only have soft drinks, cordial, fruit drinks, energy drinks and sports drinks occasionally (e.g. less than once per week).
8. Consumption of alcoholic beverages is not recommended; if consumed, do not exceed 2 standard drinks per day.

9. Maintain regular physical activity on most days of the week – 30 minutes per day of moderate-intensity activity.

There are four steps for better health for Australian adults. Together, steps 1-3 recommend the minimum amount of physical activity you need to do to enhance your health. They are not intended for high-level fitness, sports training or weight loss. To achieve best results, try to carry out all three steps and combine an active lifestyle with healthy eating. Step 4 is for those who are able, and wish, to achieve greater health and fitness benefits.

Step 1 – Think of movement as an opportunity, not an inconvenience.
Any form of movement of the body is seen as an opportunity for improving health, not as a time-wasting inconvenience.

Step 2- Be active every day in as many ways as you can.
Make a habit of walking or cycling instead of using the car, or do things yourself instead of using labour-saving machines.

Step 3 – Put together at least 30 minutes of moderate-intensity physical activity on most, preferably all, days.
You can accumulate your 30 minutes (or more) throughout the day by combining a few shorter sessions of activity of around 10 to 15 minutes each.

Step 4 – If you can, also enjoy some regular, vigorous activity for extra health and fitness.
This step does not replace Steps 1-3. Rather, it adds an extra level for those who are able, and wish, to achieve greater health and fitness benefits.

Types of physical activity include:

Sedentary activities – sitting, lying down
Light activities – standing, moving around the home or workplace
Moderate activities – brisk walking, gentle swimming, social tennis
Vigorous activities – jogging, aerobics, football, netball

<u>Tips to add variety in your meals</u>

1. Choose a variety of colours of fresh vegetables and fruit – green, orange, red, yellow, purple and white.
2. Use wholegrain cereals like wholemeal bread and brown rice.
3. Include meat-free meals each week e.g. eggs, beans and tofu.
4. Try new foods such as polenta, couscous or quinoa.

Tips to limit added sugars consumption

1. Keep to a minimum the amount of sugars, honey, sweetened sauces or syrups added to foods.
2. Gradually reduce the sugars you consume over several weeks.
3. Eat fruit instead of biscuits, cakes, muffins, chocolates or lollies.
4. Avoid sweetened drinks. Choose water instead.

Tips to eat less salt

Excess salt consumption increases your risk of hypertension and subsequent heart disease

1. Limit foods high in salt, such as processed meats, e.g. bacon, ham, corned beef and devon rolls.
2. Choose lower sodium options among similar foods, e.g. slightly salted butter. Use nutrition information panels on packaged foods to choose less sodium-containing food option.
3. Use pepper, fresh or dried herbs, to season food instead of using salt. If salt must be used, use it sparingly.
4. Gradually cut down your salt consumption over several weeks. Your taste buds are constantly regenerating. You'll have new ones in a few weeks and they won't know the difference when you cut down on salt!

Your guide to fats

There are different types of fats – saturated (bad) fat, unsaturated (good) fat. Saturated fat increases your risk of health diseases. Saturated fats should be replaced with unsaturated (mono or polyunsaturated) fats.

Foods containing saturated fats include: butter, cream, lard and dripping, coconut and palm kernel oils, biscuits, cakes, pastries and pies, processed meats, commercial burgers, pizzas and fried foods, potato chips and crisps, sausages, untrimmed meats and full-cream dairy products, especially cheese.

Foods containing unsaturated fats include: seeds, legumes/beans, avocado, oats, fish, lean meat, poultry and eggs.

Tips to eat less saturated fat

1. Eat fish and legumes/beans more often.
2. Cut down on dishes with cream, buttery or creamy sauces or fatty gravy.
3. Use reduced-fat yoghurt, lemon juice, herbs and small amounts of unsaturated oils for dressings.
4. Don't deep-fry foods. Instead sauté, stir-fry, grill, bake, steam, boil, microwave, poach or barbeque your foods.

5. Order a side salad or vegetables instead of hot chips.
6. Choose reduced or low-fat milk, yoghurt and cheese.

References

NHMRC 2013, "Australian Dietary Guidelines Summary", accessed 30/10/2013, http://www.nhmrc.gov.au/_files_nhmrc/publications/attachments/n55a_australian_dietary_guidelines_summary_131014.pdf

WHO 2003, "Diet, Nutrition and the prevention of chronic diseases", accessed 20/10/2013, http://whqlibdoc.who.int/trs/who_trs_916.pdf

Appendix 8 – Physical activity information

Introduction

- Physical activity is the leading preventable cause of disease.
- Only about 57% of adult Australians are engaged in sufficient physical activity for health.
- The proportion of inactive Australians is increasing.
- The rising number of overweight and obese adult Australians is strongly linked to an overall decline in energy expenditure through physical inactivity.
- Increasing your physical activity levels can significantly contribute to reductions in chronic diseases such as heart disease, diabetes and certain cancers.
- Physical activity helps boost self-esteem, improve self-image and improve quality of life.

Health benefits of physical activity

- Reduced risk of developing high blood pressure.
- Reduced risk of developing Type-2 diabetes.
- Reduced risk of developing colon cancer.
- Reduced risk of dying prematurely.
- Reduced risk of musculoskeletal injuries.
- Fewer slips, trips and falls.
- Maintenance of healthy weight.

National Physical Activity Guidelines

To achieve health benefits, a person should participate in 30 minutes of at least moderate-intensity physical activity on most days of the week. This translates to:

- the accumulation of at least **150 minutes** of activity over 1 week (30 minutes per day on at least 5 days of the week).
- the accumulation of at least **150 minutes** of activity and at least **5 sessions** of activity over 1 week.

What you can do to stay physically active

- Be active every day in as many ways as you can.
- Put together at least 30 minutes of moderate intensity physical activity (e.g. brisk walking, gentle swimming, social tennis or golf).
- If you can, also enjoy some regular vigorous exercise for extra health and fitness (e.g. jogging, football, netball).
- Think of movement as an opportunity, not an inconvenience.

Appendix 9 – Heart disease information

Introduction

- Heart disease is the most common form of cardiovascular disease.
- Presents in two forms – *Heart attack* and *Angina.*
- Heart attack is a life-threatening event that occurs when a blood vessel supplying the heart itself is suddenly blocked completely, damaging the heart.
- Angina is chest pain or discomfort that occurs when a blood vessel supplying the heart itself is partially blocked, so that your heart muscle doesn't get enough oxygen-rich blood.

Putting it in perspective

- In 2011, heart attacks claimed 9,811 lives (27 lives each day).
- Each year 55,000 Australians suffer a heart attack (1 heart attack every 10 minutes).
- About 380,000 Australians have had a heart attack at some time in their lives.
- Males are three times more likely to have a heart attack.

Risk factors

- High blood pressure
- High cholesterol
- Overweight and obesity
- Physical inactivity
- Low fruit and vegetable intake
- Excessive alcohol consumption (greater than 2 standard drinks (20g of alcohol) per day)
- Smoking

NOTE – NINE IN 10 ADULT AUSTRALIANS HAVE AT LEAST ONE RISK FACTOR AND ONE IN FOUR HAVE THREE OR MORE RISK FACTORS.

Recognising heart attack

It is important to note that warning signs of heart attack vary from person to person and may not always be sudden or severe:

- Pain, pressure, heaviness or tightness in your
    - Jaw

- Neck
- Shoulder(s) – spreads from chest to shoulder and upper arm.
- Chest – the most common symptom. Feels like a crushing sensation.
- Back – dull ache between shoulder blades
- Arm(s)

- Other symptoms to watch out for include:
  - Nausea
  - Dizziness
  - Cold sweat
  - Shortness of breath

Appendix 10 – Diabetes information

WHAT IS DIABETES?

Diabetes is a chronic condition that lasts a lifetime. Our bodies convert glucose from food into energy through the action of a hormone called **Insulin**. In diabetes, this hormone is either no longer produced or not produced in sufficient quantities by the body. This results in the body being unable to convert glucose to energy, resulting in high blood glucose seen in diabetes.

TYPES OF DIABETES

There are three types of diabetes:

- Type-1 Diabetes
- Type-2 Diabetes
- Gestational Diabetes

Type-1 Diabetes

In this type of diabetes, the pancreas, which is the organ responsible for producing insulin stops making insulin. This causes the body to burn fats for energy, with accumulation of dangerous chemical byproducts in the body, which can be potentially life-threatening.

This type of diabetes accounts for 10-15% of all cases of diabetes, and typically occurs in people under 30 years of age, but can occur at any age.

Symptoms of Type-1 Diabetes:

- Being excessively thirsty
- Passing large amounts of urine
- Feeling tired and lethargic all the time
- Always feeling hungry
- Unexplained weight loss

Type-2 Diabetes

The most common form of diabetes, affecting 85-90% of people with diabetes. Affects older adults mostly. Some insulin is produced but the amount is insufficient and does not work effectively to convert glucose to energy. There is a strong genetic predisposition for Type-2 diabetes.

Symptoms of Type-2 Diabetes:

- Being excessively thirsty

• Passing large amounts of urine
• Feeling tired and lethargic all the time
• Always feeling hungry
• Gradual weight gain

Gestational Diabetes

This is seen in pregnancy and is a reversible cause of diabetes once the pregnancy is over.

Management of Diabetes

There is currently no cure for diabetes.

Type-1 diabetes is managed by maintaining a healthy lifestyle, including healthy diet and exercise, regular blood glucose testing and regular insulin injections for life.

Type-2 diabetes can be managed initially through lifestyle modifications, including healthy diet and exercise, and as the disease progresses, through medications and insulin.

Gestational diabetes is simply managed by adopting a healthy diet plan and regular exercise. Some women with gestational diabetes will require insulin treatment.

How do I know if I have diabetes?

Start by filling out the attached "Australian Type-2 Diabetes Risk Assessment Tool". If you score 12 or more in the risk assessment tool, you may have undiagnosed type-2 diabetes. See your doctor and get a fasting blood glucose test done.

Tips to stay healthy

Healthy eating tips

- Eat 3 regular meals each day
- Have at least 2 medium pieces of fruit each day
- Have at least 5 serves of (1 serve = 1/2 cup cooked or 1 cup salad) vegetables each day
- Avoid deep-fried foods
- Use skim or low fat milk/milk products
- Minimize lollies, chocolates, biscuits and pastries
- Minimize processed snack foods e.g. crisps and chips
- Drink water for thirst

Regular physical activity tips

- At least 30 minutes of moderate intensity physical activity on most, preferably all days of the week. Can be done in short 10-15 minutes sessions.

- Moderate intensity is any activity that noticeably increases your breathing and heart rate.
- Aerobic exercise makes you breathe harder and increases your heart rate. Examples include brisk walking, cycling and swimming.
- Resistance exercise improves muscle strength. Examples include free weights.

Appendix 11 – Fluid frequency questionnaire

For each of the drinks listed, indicate **how often** you drank them **over the last month** with a √. Take into account the amount indicated, so for example, if you drink one cup (approximately 250ml) of milk per day (thinking about milk on cereals and used in tea/ coffee), tick '1 per day'; if you drink 2 cups, tick '2-3 per day'.

Drink Type	Amount	Number of times drank this amount over last month								
		Never	**1-3 per month**	**1 per week**	**2-4 per week**	**5-6 per week**	**1 per day**	**2-3 per day**	**4-6 per day**	**6+ per day**
Fruit juice	1 cup									
Soft drink	1x375 ml can									
Low calorie soft drink	1x375 ml can									
Cordial, made with water	1 cup									
Low calorie cordial, made with water	1 cup									
Sports drinks (e.g. Gatorade, Powerade)	1x600 ml bottle									
Energy drinks (e.g. V, Red Bull)	1x250 ml can									
Coffee	1 cup									
Tea	1 cup									
Iced tea	1x500 ml bottle									
Water	1 cup									
Flavoured milk	1 cup									
Regular milk	1 cup									
Reduced fat / skim milk	1 cup									
Full strength beer (heavy)	1 stubbie/schooner									
Mid strength beer	1 stubbie/schooner									
Light beer	1 stubbie/schooner									
White wine	1 wine glass									
Red wine	1 wine glass									
Spirits (e.g. whiskey, rum)	1 nip/shot									
Sherry or Port	½ wine glass									

Appendix 12 – Hydration feedback

Hydration Status Results

Staying hydrated is easy…

#	Urine Colour*	Urine Specific Gravity	Shift start	Shift end	Hydration level
1		1.001 – 1.005	☐	☐	Good
2		1.006 – 1.010	☐	☐	
3		1.011 – 1.015	☐	☐	
4		1.016 – 1.020	☐	☐	Fair
5		1.021 – 1.025	☐	☐	Poor
6		1.026 – 1.030	☐	☐	Very Poor
7		1.031 – 1.035	☐	☐	Clinical Dehydration
8		≥1.036	☐	☐	

Appendix 13 – Hydration status charts

Chart before intervention

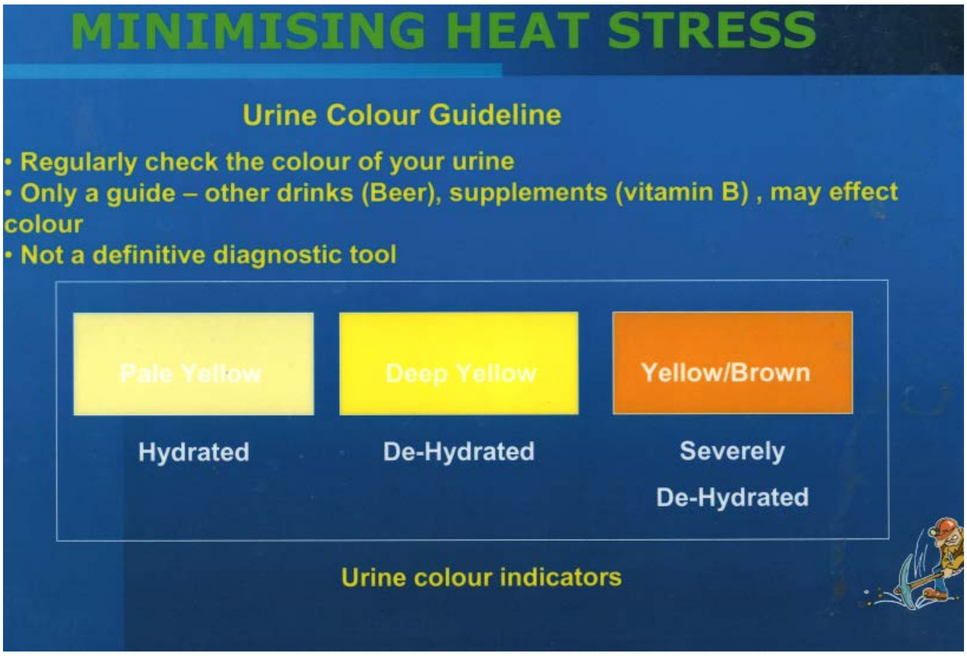


Chart after intervention

HOW HYDRATED ARE YOU?

Staying hydrated is easy…

#	Urine Colour	Urine Specific Gravity (USG)	Hydration level
1		1.001 – 1.005	Good
2		1.006 – 1.010	
3		1.011 – 1.015	
4		1.016 – 1.020	Fair
5		1.021 – 1.025	Poor
6		1.026 – 1.030	Very Poor
7		1.031 – 1.035	Clinical dehydration
8		≥1.036	

Appendix 14 – Hydration and its importance

Introduction

- Water is important for life. It is easy to overlook this in a busy work environment.
- Good hydration is essential for workers' health and safety.
- 2-3 litres of water needs to be consumed during a work shift in a normal environment.
- Working in **hot environments requires consumption of up to 5 litres of water per day** depending on how hydrated you start your shift.
- You cannot rely on thirst to know you need to drink water. When you feel thirsty you are already dehydrated.

Signs of dehydration

- Headaches, light-headedness, dizziness, irritability, tiredness all of which can decrease mental performance.
- Dry mouth, throat, eyes and skin.
- Urine volume will be reduced and will be darker than usual.
- Good hydration prevents headaches and bad breath and improves concentration, mental/physical performance and helps maintain a healthy body weight.

Did you know?

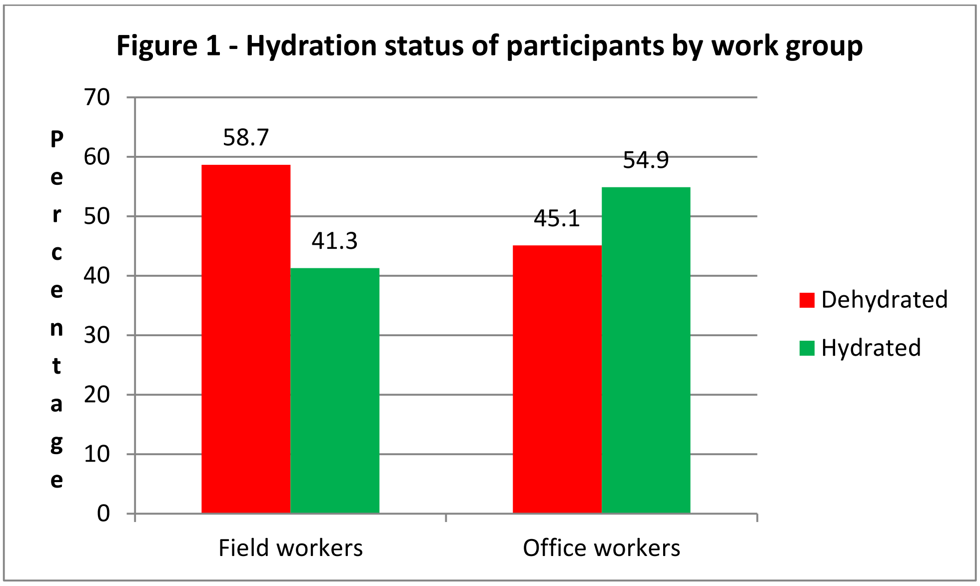
Drinks containing ***Caffeine*** such as *Coffee, Cola based soft drink, Energy drink and Sports drink* and ***Alcohol*** can have a dehydrating effect on the body. These drinks are therefore not as helpful for rehydration.

What to do?

- **DRINK WATER**. Water is the best quencher for thirst and rehydrates faster than any other liquid.
- Drinking water mixed with additives such as flavouring agents or electrolytes should be considered as a supplement to drinking water and not a replacement.

Urine test results from initial survey of the ongoing healthy miner study at Barrick CGM

- At the start of the study, more than half of the 141 participants at CGM came to work dehydrated (74 out of 141 people).
- Outdoor/field workers had the greatest risk of arriving at work already at risk of dehydration (44 out of 75 people), although almost half of those who worked indoors (23 out of 51 people), or those working in a mix of indoors and outdoors tasks (7 out of 15 people) were also at risk.



Recommendations

Drinking water

1. Drink at least 1 litre of water **before** the start of your shift.
2. Try to refrain from drinking soft drinks, energy drinks, alcohol or coffee for 12-24 hrs before your shift.
3. Drink up to 1 cup of water every hour **during** your shift.
4. Drink as much water as you can at the end of your shift.
5. **Workers who come to work hydrated** need to consume 1½ - 3 Litres of water to stay hydrated.
6. **Workers who come to work dehydrated** need to consume 4 - 5 Litres of water to become hydrated by the end of their shift.

At work

1. If you are working outdoors on a hot summer's day, take a bottle of water with you and drink at least 1 cup every 15 minutes.

2. Report any feelings of headaches and dizziness to your supervisor immediately and start drinking water as soon as you are relieved to rest.
3. Remember to carry water with you at all times.
4. Keep hydrated during your shift (drink frequently).
5. Eat fruit during your break.
6. Use the urine colour charts located in all toilets / noticeboards to get an idea of your current hydration status and drink water to keep yourself within the "Good" or "Fair" hydration level.

Appendix 15 – Hydration and heat stress information

Introduction

- Heat stress of an individual can be created as a result of a number of factors such as excessive exposure to heat, increased workload & clothing which, individually or combined may lead to a number of heat-related illnesses.
- Heat stress related illnesses range from mild conditions like prickly heat to life-threatening conditions like heat stroke.
- Everyone is at risk of heat-related illnesses but certain people are at greater risk: obese people, unacclimatised and dehydrated outdoor workers and people with chronic diseases such as diabetes or heart failure, or patients on medications.
- Good hydration is essential for working in hot environments.
- 2-3 litres of water need to be consumed during a work shift in a normal environment.
- Working in **hot environments requires consumption of up to 5 litres of water per day** depending on how hydrated you start your shift.
- You **cannot** rely on thirst to know you need to drink water. **When you feel thirsty you are already dehydrated.**

Identifying heat stress related illness

- Heat rash – itchy and painful skin rash
- Heat cramps – painful muscle cramps affecting various parts of the body
- Heat syncope (fainting) – starts with light-headedness, dizziness and finally fainting
- Heat exhaustion – **most common in dehydrated persons.** Characterised by clammy moist skin, weakness or extreme fatigue, nausea, headache, low blood pressure and weak pulse. May be a lead-up to heat stroke.
- Heat stroke

Signs of dehydration

- Headaches, light-headedness, dizziness, irritability and tiredness, all of which can decrease mental performance
- Dry mouth, throat, eyes and skin
- Urine volume will be reduced and will be darker than usual.

- Good hydration prevents headaches and bad breath, improves concentration and mental/physical performance, and helps maintain a healthy body weight.

What to do?

- **DRINK WATER**. Staying hydrated reduces your risk of developing any heat stress related illness.

How hydrated are you?

- Use the urine charts provided to roughly check how hydrated you are before commencing work in the heat.
- Coming to work hydrated, especially during summer months, is the best way to start your day.
- Urine test results from initial survey of the ongoing healthy miner study at Barrick CGM showed that **outdoor/field workers had the greatest risk of arriving at work already at risk of dehydration,** putting them at a higher risk of heat stress related illness.

Recommendations

Drinking plenty of water

1. Drink water to the point where your urine is light-yellow colour.
2. Limit your consumption of soft drinks, energy drinks, alcohol or coffee, as these drinks provide unnecessary calories and may promote diuresis, (passing lots of urine) which can contribute to dehydration.
3. Drink up to 1 Litre of water for every hour you work outdoors in the heat.
4. Drink as much water as you can at the end of your shift.
5. **Workers who come to work hydrated** need to consume 1½-3 Litres of water to stay hydrated.
6. **Workers who come to work dehydrated** need to consume 4-5 Litres of water to become hydrated by the end of their shift.

During work

1. Report any feelings of headache and dizziness to your supervisor immediately, and start drinking water as soon as you can.
2. Remember to carry water with you at all times.

Other

1. Wear light under-clothing to help evaporation of sweat.
2. Use strong sunscreen, as sunburn limits the body's ability to cope with heat.

Appendix 16 – Hydration & fluid guidelines information

Introduction

- One of the best things you can do to help prevent heat-related illnesses is to stay well hydrated by drinking more fluids (e.g. water).
- Dehydration affects your physical performance (e.g. ability to carry out physical work), mental and cognitive functions (your ability to think properly) and also increases fatigue.
- You **cannot** rely on thirst to know you need to drink water. **When you feel thirsty you are already dehydrated.**

Fluids available for consumption

Drink type	Positives	Negatives
Water	• Plain water is one of the quickest fluids to be absorbed by the body • It is freely available and safe • It is the cheapest fluid available	• Does not contain energy
Electrolyte fluids e.g. sports drinks, Gatorade, Powerade	• Provide energy (calories) • Provide electrolytes • Taste good, so you are likely to drink more of it	• Excessive use (high calorie intake) may predispose to weight gain and electrolyte imbalance
Carbohydrate (energy) fluids e.g. fruit juice, Red Bull	• Provide energy (calories) • Taste good, so you are likely to drink more of it	• Slow absorption compared with water • Excessive use (high calorie intake) may predispose to weight gain
Caffeine and alcohol-containing fluids e.g. coffee, tea, Red Bull, beer	• Provide energy (calories)	• Can increase non-sweat body-fluid loss through diuresis (increased urine production) particularly when consumed at rest • Not recommended for fluid replacement • Excessive intake can result in nervousness, insomnia, stomach upset, tremors and palpitations (racing heart)
Carbonated fluids e.g. sodas and other fizzy drinks	• Provide energy and potassium • Diet drinks have no energy and is thus preferable to sugary carbonated beverages.	• Can cause belching • Increased risk of dental cavities with sugary carbonated beverages.

Fluid consumption guidelines

- **FOR WORK IN THE HEAT LASTING LESS THAN 90 MINUTES**
  - Fluid requirements can be met by drinking adequate amounts of **WATER** alone.
- **FOR WORK IN THE HEAT EXCEEDING 90 MINUTES BUT LESS THAN 240 MINUTES (4 hours)**
  - In addition to **WATER**, consideration should be given to the inclusion of **CARBOHYDRATE**-containing fluid of less than 7 g/100ml concentration (see column 2 in table 1 below).
- **FOR WORK IN THE HEAT EXCEEDING 240 MINTUES (4 hours)**
  - In addition to WATER and CARBOHYDRATE-containing fluid, ELECTROLYTE-containing fluid, which includes sodium (20-30 mmol/L) and trace potassium (5 mmol/L) should be included to replace those lost in sweat.

Table 1 - Approximate composition of different fluids

	Carbohydrate (g/100mL)	**Energy (KJ/100mL)**	**Sodium (mmol/L)**	**Potassium (mg/L)**	**Caffeine (mg/100mL)**
Aim for	**(4-7)**		**(10-25)**		
Water	0	0	0	0	0
Diet Pepsi	0	0	4.4	93.1	10.1
Pepsi Max	0	0	4.8	101.5	19.4
Coke Zero	0.1	1.4	4.8	124	9.5
Diet Coke	0.1	1.5	6.5	136	12.7
Percolated Coffee *	0	2	0.9	490	45.4
Espresso *	0	4	6.1	1150	212
Green Tea *	0	5	1.3	270	10.6
Black Tea *	0.3	6	1.3	370	17.8
Powerade Zero	0.1	6.8	22	0	0
Instant Coffee *	0.3	10	1.7	300	24.1
Decaf Coffee *	0.4	10	1.7	360	1
Mother sugar free	0.1	19	21	0	31.8
Hydralyte	1.6	23.2	45	20	0
Aqualyte	3.7	61	12	120	0
Gatorade	6	103	21	230	0
Fruit juice (Orange)	5.5	115	1.3	1500	0
Powerade Isotonic	7.3	129	12	141	0
Pepsi	11.7	175	4	25.4	10.7
Coca Cola (Regular)	11	180	5.98	0	9.6
Mother	10.1	190	21	0	32
Red Bull (Original)	11	192	37.5	0	32
Mountain Dew	13	200	7.4	16.9	15.2
Chocolate Drink *	10.7	227	39.6	790	2.1
Lucozade Sport Body Fuel Drink	6.4	298	20.5	90	0

***(unsweetened) (Source: www.nutritiondata.self.com & www.calorieking.com.au)**

What you can do to stay hydrated

- **Pre-shift** – Pre-hydrating yourself with fluids should be initiated at least 2 hours before starting your shift to enable fluid to be distributed evenly in your body and allow urine output to return toward normal levels.
- **During shift** – Each individual's ability to consume fluids differs. You should aim to consume at least 600 ml to 1 L of fluid every hour.
- **Post-shift** – If time permits during the shift, consumption of normal meals and beverages will restore the normal state of body water, provided you have been consistently drinking fluids during your shift. Otherwise, drinking at least 1.5 L of fluid after your shift should start the recovery process towards the normal state of body water.

Appendix 17 – Heat stress questionnaire

CODE NO:________

Kindly complete this questionnaire as well as you can. Please remember that all data are confidential. All data will be de-identified before being analysed.

TODAY'S DATE: _____________ SHIFT (DAY/NIGHT): _____________

WHAT JOB ARE YOU WORKING AT TODAY: ________________________

MEASURED URINE SPECIFIC GRAVITY: Pre-work ___________

Post-work __________

MEASURED HEIGHT: _______cm

MEASURED WEIGHT: _______kg

AGE (yrs): _______yrs

GENDER (Circle one): M F

HEAT ILLNESS SYMPTOMS

Have you experienced any of the following symptoms during your work outdoors in the past 12 months (Tick or Mark)?

	SYMPTOM		**HOW OFTEN**		**SHIFT**	
	Yes	No	Once	More than once	Day	Night
Red rash on skin						
Muscle cramp						
Headache						
Nausea						
Vomiting						
Weakness						
Fatigue						
Dizziness						
Fainting						
Clammy/moist skin						
Irritability						
Hot and dry skin						
High body temperature						
Confusion						
Irrational behaviour						
Low coordination						
Loss of consciousness						
Convulsions/seizures						

PLEASE TURN OVER

HYDRATION

Q1. Was drinking water freely accessible during your work outdoors? ☐ 1 Yes ☐ 2 No

Q2. How often did you drink water during your work outdoors? _______ Times

Q3. How many cups of water did you drink during your work outdoors? (1 cup = 250ml or a household tea cup, 1 average bottle of water = 1.5 cups) _______ cups

Q4. What other fluids did you consume during your work outdoors?

☐ 1 Tea/Coffee ☐ 2 Soft drinks e.g. Coke ☐ 3 Sports drink e.g. Gatorade

☐ 4 Energy drink e.g. Mother or V ☐ 5 Other ___________

Q5. How often did you urinate during your work outdoors? _______ Times

ENVIRONMENT

Q1. How would you describe the temperature of the outdoor work environment you worked in today?

☐ 1 Very hot ☐ 2 Hot ☐ 3 Warm ☐ 4 Neutral ☐ 5 Cool ☐ 6 Cold ☐ 7 Very cold

Q2. Did you feel that it was dry or humid? ☐ 1 Dry ☐ 2 Humid

Q3. In the last week, how many hours did you work out in the sun? ________hrs

Q4. I am wearing the following clothes today: (Tick all that apply)

Briefs ☐ 1	Short-sleeved shirt ☐ 5	Overalls ☐ 9	Boots ☐ 13
Sleeveless shirt ☐ 2	Long-sleeved shirt ☐ 6	Hard hat ☐ 10	Gloves ☐ 14
T-shirt ☐ 3	Shorts ☐ 7	Socks (regular) ☐ 11	Singlet ☐ 15
Eye protection ☐ 4	Trousers ☐ 8	Thick long socks ☐ 12	Belt ☐ 16
High-visibility vest ☐ 17	Reflective jacket ☐ 18	Waterproof jacket ☐ 19	

Q5. What part of your body did you use most during the course of your work today? (Tick all that apply)

☐ 1 Hand/wrist/fingers ☐ 2 Upper arm ☐ 3 Shoulder ☐ 4 Back

☐ 5 Torso ☐ 6 Lower limbs ☐ 7 Ankles/foot

Q6. How many breaks did you take during your work today?

☐ 1 1 ☐ 2 2 ☐ 3 3 ☐ 4 4 ☐ 5 5 or more

Q7. How long were you working out in the sun today? _______ hours

THANK YOU FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE

Appendix 18 – QuestTemp 36 calibration certificate

AirMet Scientific P/L
7-11 Ceylon Street
Nunawading
Victoria 3131, Australia
Tel: 61 3 8878 3300 Fax: 61 3 8878 3344

Calibration Certificate

This document hereby certifies that this instrument detailed has been calibrated to the parameters listed below.

Certificate Print Date: Friday, 31 May, 2013
Calibration Date: Friday, 31 May, 2013
Next Calibration Due: Sunday, 31 May, 2015

Call ID: 00133728

Arrow Job Code:

Customer: UNIVERSITY of WOLLONGONG **Type:** Heat Stress

Model: QT34 **Serial No:** TKG050022

Description: Heat Stress Monitor

Sensor under test	Actual Temperature °C	Instrument Reading Before	Instrument Reading After
Globe	36.0		36.0
Dry	36.0		36.0
Wet	36.0		36.1
Ear			

This monitor has been calibrated using a NATA traceable thermometer.

Completed by: *Kurt Avallone* **Signed:**

NOTE: Model incorrectly labelled as QT34.

Appendix 19 – CALOR calibration certificate

CALOR INSTRUMENTS PTY LTD

Calor Instruments Pty Ltd
A.B.N. 43 101 705 524

Certificate of Re-Calibration

37 Collingwood Street,
Osborne Park, Western Australia, 6017
P.O. Box 1475, Osborne Park Business Centre,
Western Australia. 6916

Tel: + 61 8 9244 3011
Fax: + 61 8 9244 2649
e-mail: sales@calor.com.au
www.calor.com.au

Company:	University of Wollongong	
Contact:	Jane Whitelaw	
Product Description:	**Heat Stress Monitor V2**	
Serial No:	Digital: **1025115**	Sensor: **1026998**
Firmware Version:	Updated to V2.07 (Manual on CD)	
Date of Calibration:	26/05/2013	**Certificate No: B30191**
Calibration Technician:	Mark Bradley	
Next Re-Calibration Due:	25/05/2014	

Please return your Calor Heat Stress Monitor by the above date for Re-Calibration.

Send to:

Calor Instruments
37 Collingwood Street
Osborne Park
Western Australia
6017

This Calor Heat Stress Monitor has been re-calibrated by Calor Instruments Pty Ltd to the original specifications

Calor Instruments Pty Ltd manufactures and calibrates the Calor Heat Stress Monitor. Calor Instruments Pty Ltd is NOT a NARTA certified laboratory

Appendix 20 – Food Diary decisions spreadsheet

Food Item	FoodWorks Name	Volume / Measure	Foodworks Volume	General Notes
1/2 cup milk & Nutrigrain (plate full)	KELLOGGS NUTRI-GRAIN (2 cups) + Milk,cow,fluid,regular fat (~3.5%) (70 mL)	Plate-full w/ 1/2 milk	0.5 cup milk + 2 cup Nutrigrain	
2-minute noodles	Soup,Asian style,w noodles,instant dry mix,cup style,reconstituted w water (75 g) + water, tap (1 cup)			
Apple	Apple,red skin,unpeeled,raw	1 apple	1 medium (6-8cm dia)	
Apple cider (alcoholic)	Cider,apple,non-alcoholic (no alcoholic option?? Should I put beer instead to make up calories from alcohol?)			
Bacon & Egg roll	Sandwich,white bread,tablespread,egg & bacon,toasted			
Bacon	Bacon,cooked,nfs (0.25 cooked, diced)			
Bacon Pieces	Bacon,breakfast rasher,fried,olive oil	2 pieces	2 rashers	

Baked rice, sugar, milk, egg, peas	Rice,white,boiled without added salt (0.15 cup) + Sugar,white,granulated/lump (0.15 cup)+ Milk,cow,fluid,regular fat (~3.5%) (0.15 cup) + Egg,chicken,whole,cooked,nfs + peas (0.15 cup) C158		
Banana	Banana,cavendish,peeled,raw	1 Average	1 Medium
Banana Bread - Banana, Flour, Sugar	Banana,cavendish,peeled,raw (0.5 medium) + Flour,wheat,white,plain (0.25 cup) + Sugar,brown (0.125 cup (packed)		
Banana Bread (from café)	Cake,banana,uniced,homemade (1 piece - 1/10 of loaf)		
Basmati rice	Rice,white,boiled with added salt		
Beans	Bean,green,fresh,boiled,drained		
Beef patties fried	Burger patty/rissole,beef,commercial,grilled/fried without oil/fat (2 pqtties)		
Beef rump	Beef,rump steak,lean,grilled		
Beef sausages	Sausage,beef,grilled	2	2 sausage (nfs)
Beef Stew (onion, carrot, potato, beef) 2.5 cup	Beef,stewed,nfs (1 cup) + Onion,mature,peeled,boiled/steamed,nfs (0.5 onion) + Carrot,mature,peeled,boiled,drained (0.5 cup) + Potato,boiled,drained,nfs (0.5 potato)		

Beef strips	Beef,stir-fry strips,lean,fried,ns oil		
Beer (coopers pale ale)	Beer,lager		
Beer VB	Beer,lager		
Beer XXXX gold	Beer,lager		
Beetroot salsa	Sauce,salsa,tomato-based		
Berri Orange & Guava juice	BERRI JUICE ORANGE MANGO		
Black tea (no sugar)	Tea,regular,no milk,brewed from leaf/teabags		
Block of Chocolate	CADBURY CHOCOLATE MILK FRESH (200 g)		
Boccocini	Cheese,mozzarella (1 ball = 1 tb?)		
Bottle of water	Water,bottled,non-sparkling		
Bread - white (Helgas)	HELGAS TRADITIONAL BREAD WHITE		
Bread	Bread,from white flour		
Bread crumbs	Bread,from white flour,toasted (0.5 cup cubes)		
Broccoli	Broccoli,fresh,boiled,drained	1 cup	1 cup (flowerets)
Broccolini	Broccoli,fresh,boiled,drained		
Brownie	Brownie,chocolate,with nuts,homemade		
Butter	Butter, salted		
Cake	Cake,homemade,nfs		
Calamari rings (Baked)	Squid/calamari,crumbed,frozen,baked		
Can Coke (1.5) & Jim Beam (80 mL)	Alcoholic soda,bourbon & cola based (650 ml)		

Cappacino	Coffee,from ground coffee beans,espresso style,no milk + Milk,cow,fluid,regular fat (~3.5%) (50 mL)	400 ml & 1 cup	60 mL (espresso) 340 mL (milk, regular fat) & 60 mL espresso , 190 mL milk
Carrots	Carrot,mature,peeled,boiled,drained	0.5 cup	0.5 cup (sliced fr fresh)
Cashews, multigrain and soy snack mix	Nut,cashew,raw (15 g) + Soya beans dried (15 g)		
Casserole,homemade,lamb & Begetable,in tomato based sauce	Lamb,casserole cut,semi-trimmed,stewed + Mixed vegetables,frozen,broccoli & carrot & corn,cooked	Sauce,pasta,tomato-based,commercial,heated	
Cauliflower	Cauliflower,boiled,drained		
Centrium Advance	Multivitamin & mineral,tablet,nfs (1 tablet = 1 dose on FoodWorks)		
Cheese	Cheese,nfs	Slices (pre-packed)	
Cheese sauce (Restaurant and home)	Sauce,cheese,made with butter & milk,home-prepared		
Chicken & cheese toasted sandwich	Bread,from white flour,toasted + Chicken,breast,lean,baked + Cheese,cheddar,processed		
Chicken & veg soup	Soup,chicken & vegetable,homemade,prepared w water		

Chicken & vegetables (medium)	Chicken,baked/roasted,nfs (150 g) + Mixed vegetables,frozen,boiled/microwaved,drained (1 cup)		
Chicken alfredo	Sauce,pasta,cream-based,added chicken		
Chicken alfredo with penne pasta	Sauce,pasta,cream-based,added chicken + Pasta,white wheat flour based,boiled from dry,no added salt		
Chicken fillet, grilled	Chicken,breast,lean,grilled/BBQ	2 fillets	2 medium breast
Chicken schnitzel	Chicken,breast,lean,crumbed,fried,olive oil		
Chicken stock	Stock,chicken,liquid,commercial	Small amount ?? = 0.25 cup?	
Chips	Crisp/chip,potato,flavoured	50 g	50 packet (50g)
Chips (restaurant)	Potato,chips,deep fried,salted,from take-away outlet		
Choc Bavarian Cheesecake	Cake,cheesecake,chocolate flavour,biscuit base,cream cheese topping		
Chocolate	CADBURY CHOCOLATE MILK FRESH (2 tsp)	2	2 tsp
Chocolate coated bullets	Licorice,milk chocolate-coated	2 handfuls	0.5 cup
Chocolate Marshmallow	Marshmallow,chocolate & coconut-coated (snowball)		
Chupa - chup	Sugar confectionery,hard varieties (1 piece)		

Coffee (Nescafe espresso)	Coffee,from ground coffee beans,espresso style,no milk		
Coffee Macona White No sugar	Coffee,from instant coffee powder,w full fat milk		
Coffee Nescafe 3 shots (1 cup)	Coffee,from instant coffee powder,no milk (180 mL) + Milk,cow,fluid,regular fat (~3.5%) (70 mL)		
Continental chicken curry pasta	Pasta in cream based sauce,dry mix (90 g) + Milk,cow,fluid,regular fat (~3.5%) (190 mL) + water (250 ml)		
Coon grated cheese	Cheese,cheddar,processed		
Coon tasty lite	Cheese,cheddar,processed,reduced fat (<10% fat)		
Cordial	Cordial,less than 25% fruit juice,recommended dilution		
Corn	Sweetcorn,frozen,boiled,drained		
Corn flakes	Breakfast cereal,flakes of corn,unfortified		
Cream (dessert)	Cream,regular thickened,35% fat	1 spoon	1 tbs
Crumbed cutlet	Lamb,frenched cutlet/rack,lean,grilled		
Cup of Cappacino	Coffee,from espresso coffee,regular fat milk,ice & sugar,iced coffee style (60 mL) + Milk,cow,fluid,regular fat (~3.5%) (50 mL)		

Cup of Coffee	Coffee,from instant coffee powder,w full fat milk			
Cup of Milo	Beverage,chocolate flavour,from base (Milo brand),w ns milk & water			
Cup of Tea	Tea,regular,no milk,brewed from leaf/teabags (1 mug)			If they haven't specified a volume - I have assumed one cup and have done roughly 1:3 ratio of milk to water
Cup of Tea (green)	BASKIN & ROBBINS DELUXE GREEN TEA (2 scoops) + Water,tap (250 ml)			
Cupcake	Cake,cupcake,iced,commercial			
Curry chicken (BBQ chicken, curry hot pot + veg)	CONTINENTAL CREAMY CHICKEN CURRY (30G) + Chicken,breast,lean,grilled/BBQ + vegetables			
Curry chicken packet	Chicken,curry,prepared w curry powder,onions & stock			
Decaf Coffee	Coffee,from instant coffee powder,w full fat milk,decaffeinated			
Deep fry chips	Potato,chips,deep fried,salted,from take-away outlet			
Dim Sim (baked)	Dim sim,meat & vegetable filling,microwaved			

Dragon Fruit	Fruit,fresh,nfs		
Drink wine & coke zero	Wine,red (425 mL) + Soft drink,cola flavour,intense sweetened (375 mL)	800 mL	(assumed can of coke zero) - 425 mL red wine + 375 can of coke zero
Drumstick ice cream	NESTLE DRUMSTICK VANILLA		
Egg noodle	Noodle,boiled,nfs		
Eggs	Egg,chicken,whole,cooked,nfs		
Fish oil capsule	Fish oil,capsule formulation,nfs (1 dosage unit)		
Freedom Foods gluten free muesli bar	Bar,muesli,breakfast,fruit/snack style,nfs		
Fruit bar	Bar,muesli,plain/with dried fruit		
Gingerbread men	Gingerbread,iced (2 biscuits)		
Grain bread	Bread,mixed grain,toasted	2 pieces	2 slices
Grapes	Grape,raw,nfs (6 grapes (seedless)		
Gravy	Gravy,commercial,prepared		
Grilled steak	Beef,t-bone steak,untrimmed,grilled	1 Large	250 g
Ham cheese, tomato toasted sandwich	Sandwich,white bread,tablespread,ham,cheese & tomato		
Ham sandwich	Bread,from white flour (2 slice)+ ham, leg, non-canned, lean (1 slice)		
Hamburger	Hamburger,plain (beef pattie w lettuce,tomato,onion,sauce),takeaway style		

Hawaiian Pizza	PIZZA HUT,PAN,HAWAIIAN,SLICE (93 G)		
Hearty Roast chicken cup soup (continental)	Soup,chicken & vegetable,instant dry mix,cup style	1 sachet	75 g
Herbal tea	Tea,herbal other than chamomile,no milk (1 mug)		
Homemade chutney	Chutney/pickle,fruit,intense sweetened	1 spoon	1 tbs
Homemade sukiyaki	She attached a recipe so I put them into FoodWorks (she had 1.5 cup and I put 375 g into FoodWorks)		
Honey soy chips	RED ROCK DELI CHIPS (FLAVOUR NOT REQUIRED)	1 handful	0.5 cup
Horlicks Malk Drink	Beverage base,malted milk powder,w added vitamins A,B1,B2 & D	1 mug	1 cup
Hot Chocolate	Beverage,drinking chocolate,from chocolate powder,w full fat milk		
Hungry Jacks Angry Burger	HUNGRY JACKS,BURGER,WHOPPER WITH CHEESE (294 G)		
Hungry Jacks Angry Onions	HUNGRY JACKS,ONION RINGS,REGULAR (94 G)		
Hungry Jacks coke	HUNGRY JACKS,SOFT DRINK,COKE,NO ICE,REGULAR (454 ML)		
Ice cream vanilla IGA signature	Ice cream,regular fat,vanilla & other non-chocolate flavours		

Iced coffee	Coffee,from espresso coffee,regular fat milk,ice & sugar,iced coffee style		
Indian curry with beef	Beef,curry,vindaloo,Indian restaurant style		
Jalapeno	Chilli (chili),green,raw		
Jam	Jam,plum,preserve		
Jim Beam & Cola Can	Alcoholic soda,bourbon & cola based		
Juice	Juice,orange,added vitamin C		
Just Right	KELLOGGS JUST RIGHT CEREAL		
Lamb	Lamb,cooked,nfs		
Lamb chop	Lamb,chump chop,lean,grilled		
Lean cuisine	LEAN CUISINE NZ HOKI MEAL (180G)		
Lean Cuisine lamb + Rosemary Hot Pot	Potato,peeled,boiled,mashed,nfs + Lamb,cooked,nfs + Carrot,mature,peeled,boiled,drained + Pea,green,frozen,boiled,drained		
Leg ham	Ham,leg,non-canned,lean		
Light yoghurt + blue berry	SKI D/LITE BERRY TWIST YOGHURT		
Low fat fruit & nut meusli	Muesli,homemade,untoasted,added nuts,seeds & dried fruit		
Macchiato coffee (1 cup)	Coffee,from espresso coffee,regular fat milk,ice & sugar,iced coffee style (60 mL) + Milk,cow,fluid,regular fat (~3.5%) (50 mL)	1 cup	60 mL (espresso) 50 mL (milk, regular fat

Manderin (Medium)	Mandarin,peeled,raw,nfs			
Margarine (black & gold)	BLACK & GOLD SPREAD MONOUNSAT			
Mashed Potato	Potato,peeled,boiled,mashed,ns milk & butter,nfs	1 cup	500 g	
Melting moment	GRIFFINS MELTING MOMENTS			
Milk	Milk,cow,fluid,regular fat (~3.5%)			
Milk (lite IGA signature)	WOOLWORTHS MILK LITE FRESH			
Milk (whole) Devondale	DEVONDALE FULL CREAM FRESH			
Mixed vegetables	Stir-fry,mixed vegetable (capsicum,carrot,snow pea,bok choy & onion),w rice & soy-based sauce,no oil			
Mongolian sauce	Sauce,black bean,Asian,commercial			
Mrs fields pasta salad	Pasta,salad,with vegetables			
Muesli	Muesli,homemade/commercial,bircher			
Muesli bar (Be natural - berry)	BE NATURAL ALMOND APRICOT BAR (40G)			Other options just contained nuts
Mushroom gravy	Sauce,mushroom			
Naan bread	Bread,naan,Indian restaurant style			
Nescafe Cappacino Sachet	Coffee,from ground coffee beans,espresso style,no milk (1 shot) + 200 ml water			
Nutrigrain & milk (medium)	KELLOGGS NUTRI-GRAIN (1 cup) + milk reg fat (1 cup)			

Nuts mixed	Nuts,mixed (peanut,cashew,hazelnut,brazil nut)		
Oil & butter	Oil,nfs (0.5 tsp) + Butter,salted (0.5 tsp)		
Omelette	Omelette,chicken egg,cooked with fat		
Orange	Orange,navel (all varieties),peeled,raw	1	1 medium
Orange & poppy seed dressing	Dressing,commercial,nfs (20 mL)		
Orange juice	Juice,orange,added vitamin C		
Orange juice (25% strength)	Fruit drink,25% orange juice		
Osso Buco (Large)	Veal,leg steak,untrimmed,stewed/casseroled + Carrot,mature,peeled,boiled,drained (0.5 cup) + Celery,stir-fried without oil (0.5 cup) + Potato,peeled,boiled,mashed,nfs (0.5 cup) + sprouts (0.5 cup) + gravy (0.5 cup)		
Oysters	Oyster,raw		
Packaged Fruit cake	Cake,fruit,rich style,uniced,commercial	2 small pieces	2 piece (1/10 of 19x7x6cm)
Palm sugar	sugar, brown		
Pasta - gluten free	Pasta,wholemeal wheat flour based,boiled from dry,no added salt		

Pasta - wholemeal	Pasta,wholemeal wheat flour based,boiled from dry,no added salt		
Pear	Pear,unpeeled,raw,nfs		
Peas	Pea,green,fresh,boiled,drained		
Pepsi max	Soft drink,cola flavour,intense sweetened		
Pie - mrs macs	Pie, meat	1 pie	210 g
Piece of Fish (Baked)	Fish,fillet,frozen,glazed & flavoured,baked	1 piece	1 Fillet
Piece of fish and chips	Fish,fillet,frozen,glazed & flavoured,baked(1 fillet), Potato,chips,homemade - fresh/frozen,fried,olive oil (50 g)		
Piece of Steak & Mushrooms	Beef,t-bone steak,untrimmed,grilled (400 g) + Mushroom,stir-fried,olive oil (100g)	Large	250 g steak & 100 g mushrooms
Pies (chicken + mexican)	Pie,chicken,baked		
Pizza, pepperoni, tomato base (at pub)	Pizza,pepperoni topping,tomato sauce,thick base,chain style		
Plain yoghurt	Yoghurt,natural,regular fat (~4%)	3 spoon	3 tbs
Porridge w/ milk no sugar	Porridge,rolled oats,made with full fat milk	1 bowl	2 cups
Potato (baked)	Potato,baked without oil,nfs		

Potato (boiled)	Potato,peeled,boiled,drained,nfs			Have put 1 cup of peas, carrots, pumpkin - put 0.66 of a cup in Foodworks for each vegetable
Potato/pumpkin mashed	Pumpkin,peeled,boiled,drained,nfs (1 cup mashed) + Potato,peeled,boiled,mashed,nfs (1 cup)			
Prawn - 5 medium	Prawn,school,flesh only,purchased cooked	5 medium	7 g	
Pro-active Margarine	FLORA PRO ACTIV MARG		He did not specify grams on the 2nd day (#7) so I put the same amount he noted on the first day (10g)	
Profiterole	Bun,no dried fruit,iced,with mock cream?			
Pumpkin	Pumpkin,butternut,peeled,boiled,drained	1 cup peas, carrots, pumpkin	0.66 cup pumpkin	
Pumpkin soup	Soup,pumpkin,homemade			
Raisin Bran (Kelloggs)	KELLOGGS SULTANA BRAN			
Red onion	Onion,mature,white skinned,peeled,raw			

Rice (Baked)	Rice,white,boiled without added salt			
Rice Crackers	Biscuit,savoury cracker,rice			
Rissole	Burger patty/rissole,beef,commercial,grilled/fried without oil/fat			
Roast carrot	Carrot,mature,peeled,baked without oil			
Roast lamb	Lamb,easy carve shoulder,untrimmed,baked/roasted			
Roast pumpkin	Pumpkin,peeled,baked without oil,nfs			
Rolled Oats	Oats,rolled,raw	1 serve		
Roses chocolates	Chocolate,dark,fondant/cream filled	2 pieces (nfs)		
Salad	Salad,caesar,no dressing			
Salad (cheese, carrot, lettuce, red onion, cucumber	Cheese,nfs (0.2 cup) + Carrot,mature,peeled,boiled,drained (0.2 cup)+ Lettuce,iceberg,raw 0.2 cup + Onion,mature,white skinned,peeled,raw (0.2 cup) + Cucumber,common,peeled,raw (0.2 cup)			

Salad roll - meat, tomato, cheese + lettuce	Bread roll,from white flour (1 roll lunch style), Meat,raw,nfs (80 g), Tomato,common,raw (2 slices), Cheese,nfs (1 slice pre-packed), Lettuce,iceberg,raw (0.5 shredded/chopped)			
Salad Sandwich (chicken, tomato, cheese, lettuce)	Bread,from white flour (2 slice) + Chicken,cooked,nfs (1 medium slice) + Tomato,common,raw + 1 slice cheese, nfs + Lettuce,iceberg,raw (1 large leaf)			
Salad wrap	Wrap,flat white bread w crumbed fried chicken,salad & mayonnaise,fast food style			
Salami	Salami,nfs			
Salt	Salt,table,non-iodised			
Sandwich - tuna/egg w/ 2 slices brown bread	Bread,brown,from white & wholemeal flour + Tuna,canned,nfs (1 small can) + Egg,chicken,whole,cooked,nfs (1 med)			
Sanitarium grain biscuit	Biscuit,savoury crispbread,white & wholemeal wheat flour w grains & seeds			
Satsuma	Fruit,fresh,nfs			
Sausage	Sausage,beef,grilled			

Sausages and vegetables	Sausage,beef,grilled + Mixed vegetables,frozen,boiled/microwaved,drained		
Schweppes lemonade can	Soft drink,lemonade,intense sweetened		
Scotch & coke	Alcoholic soda,bourbon & cola based		
Scotch Steak	Beef,fillet,scotch,lean,fried,olive oil		
Seafood Salad	Seafood,mixed,poached,w creamy dressing & lettuce	1 punnet	150 g?
Shallot	Shallot,peeled,boiled	1 teas	0.5 serve (2 shallot bulbs)
Singapore noodles	Chicken,stir fry,soy based sauce,hokkien noodle & mixed vegetables (1 serving)		
Small seeve mashed potato	Potato,peeled,boiled,mashed,nfs (1 small)		
Solo soft drink lemon	Soft drink,lemonade		
Soup (packet)	Soup,chicken noodle,instant dry mix,cup style		
Spaghetti bolognese - small	Spaghetti in meat sauce,canned		
Spices/coriander	Spice,mixed spice (cinnamon,nutmeg & cloves) + Coriander,fresh,leaves & stem		
Spiral pasta	Pasta,white wheat flour based,boiled from dry,no added salt		

Steamed veg - cauliflower carrots brocc (1 packet)	Mixed vegetables (broccoli,cauliflower,carrot),w white sauce			
Steamed veg - peas corn brocc beans (1 packet)	Pea,green,fresh,boiled,drained (75 g) + Sweetcorn,frozen,boiled,drained (75 g) + Broccoli,fresh,boiled,drained (75 g) +(Bean,green,fresh,boiled,drained (75g)			
Sugar	Sugar,white,granulated/lump			
Suimin Bacon Cup Noodles	Soup,chicken noodle,instant dry mix,cup style			
Sun Rice Thai Green curry	Chicken,curry,green,Thai restaurant style			
Taziki Dip	Dip,cucumber & yoghurt,Indian restaurant style			
Tea with 3 equal tabs & UHT milk	Tea,regular,no milk,brewed from leaf/teabags (150 ml) + FABULOUS FULL CREAM MILK UHT (100 ml)			
Tea, milk, Sweetener (2 cups)	Tea,regular,no milk,brewed from leaf/teabags (400 ml) + milk regular (100 ml) + Sweetener,powder,nfs (1 individual packet)			
Tinned peaches - one peach	Peach,canned in intense sweetened liquid,drained (75 g)			

Tinned apricots & cream	Apricot,canned in syrup,drained (150 g?) + Cream,regular thickened,35% fat (1 tb?)			
Tinned chopped tomatoes	Tomato,canned in tomato juice,nfs			
Toast - White bread (Helga's)	HELGAS CONTINENTAL TRADITIONAL WHITE BREAD TOASTED			
Toasted ham sandwich	Sandwich,white bread,tablespread,ham & cheese,toasted			
Tomato Relish	Relish, corn (only relish option)			
Trail bar (Be Natural)	BE NATURAL ALMOND APRICOT BAR (40G)			
Tub of lite yoghurt (strawberry)	PAULS FRUIT YOGHURT STRAWBERRY LITE			
Tubs of Yoghurt	Yoghurt,flavoured,nfs (2 Tub)			
Tuna (in tomato & onion)	Tuna,flavoured,canned in water,drained			
Tuna (sweet chilli)	Tuna,flavoured,canned in water,drained			
Tuna (w lime & pepper)	Tuna,flavoured,canned in water,drained			
Tuna sandwiches	Bread,from white flour (4 slice) + Tuna,canned,nfs (1 small can)			
Tuna with hot chilli	Tuna,flavoured,canned in water,drained			
Veal	Veal,cooked,nfs			
Water (everyone)	Water,tap	2 glasses	2 cups	

White Coffee No Sugar	Coffee,from instant coffee powder,w full fat milk			Where they have put weight range - have used highest number in FoodWorks e.g. 100-150 g uses 150 g
White Coffee Triple Shot (1 cup)	Coffee,from instant coffee powder,no milk (180 mL) + Milk,cow,fluid,regular fat (~3.5%) (70 mL)			
White tea	tea (200 ml) + milk, regular fat (50 ml)			
Wine	wine, nfs			
Wine Spritzer	Wine,nfs + Water,carbonated/soda	3/4 cup	0.75 cup (cooked)	
Mince/Vege/Pasta	Pasta,beef/vegetable filled,boiled,w tomato-based sauce			
Two fruits	Fruit,fresh,nfs	1 fruit		
Biltong	Beef jerky, all flavours			
Hot Cross Bun	Bun,with dried fruit,iced (finger bun)			
Mentos	Sugar confectionery,mint flavoured,hard & chewy			
Chicken loaf (Steggles)	Chicken,breast,lean,smoked			

MIXED DISHES	DECISIONS ON MIXED DISHES
Cheese and cracked pepper chicken with pasta	Mixed vegetables,frozen,boiled/microwaved,drained 10% + Chicken,breast,lean,baked 40% + Cheese,cheddar (mild,tasty & vintage styles) 10% + Pasta,wholemeal wheat flour based,boiled from dry,no added salt 40% Pepper,ground,black/white
Carbonara pasta	Pasta,white wheat flour-based,dry (regular pasta), Sauce,pasta,cream-based,added beef & ham
Commercial sandwiches, rolls, wraps and burgers	As per FSANZ sandwiches, rolls, burgers and wraps measures program
Pasta in cream based sauce	Pasta,white wheat flour based,boiled from dry,no added salt 60% + Sauce, nfs 40%
Pasta & sauce,tomato based	Pasta,white wheat flour based,boiled from dry,no added salt 60% + Sauce,pasta,tomato-based,commercial,heated 40%
Soup,pea & ham,homemade	Water 75% + Pea,green,fresh,cooked,no added fat 25% + Ham,leg,non-canned,lean 25%
Beef,casserole cut,untrimmed,stewed,no added fat	Beef,cooked,nfs 50% + Mixed vegetables,frozen,broccoli & carrot & corn,cooked 25% + Sauce, nfs 25%
Soup,meat & vegetable	Water 75% + Mixed vegetables,frozen,broccoli & carrot & corn,cooked 12.5% + Beef,cooked,nfs 12.5% OR Chicken 12.5%
Meatballs,beef,lean,served w tomato-based prepared sauce	Beef,mince,fried,ns oil,nfs 60% + Sauce,pasta,tomato-based,commercial,heated 40%
Thai Green Chicken Curry	Chicken,breast,lean,stir-fried 30% + Rice,white,boiled with added salt 40% + capsicum 5% + green beans 5% + coconut cream 20%
Lasagne beef/chicken	Pasta,white wheat flour based,boiled from dry,no added salt 25% + Sauce,pasta,tomato-based,commercial,heated 25% + Beef,cooked,nfs 40% OR Chicken 40% + Cheddar cheese 5% + onions 5%
Chicken enchiladas	Bread,flat (pita/lebanese),white 20% + chicken breast 40% + Onion 5% + Capsicum 5% + Sauce,pasta,tomato 20% + lentils 5% + cheese 5%

Pasta,beef/vegetable filled,boiled,w tomato-based sauce	Sauce,pasta,tomato-based,commercial,heated 25% + Beef,mince,fried,ns oil,nfs 20% + Mixed vegetables,frozen,broccoli & carrot & corn,cooked 20% + Pasta,white wheat flour based,boiled from dry,no added salt 35%
Pasta,cheese & vegetable filled,no sauce,fast food style	Mixed vegetables,frozen,broccoli & carrot & corn,cooked 35% + Pasta,white wheat flour based,boiled from dry,no added salt 55% + Cheese nfs 10%
Rice,fried,with mixed vegetables & chicken,ns oil	Mixed vegetables,frozen,broccoli & carrot & corn,cooked 25% + Chicken,breast,lean,stir-fried 25% + Rice,white,boiled without added salt 50%
Chicken,stir fry,soy based sauce,hokkien noodle & mixed vegetables	Mixed vegetables,frozen,broccoli & carrot & corn,cooked 25% + Chicken,breast,lean,stir-fried 25% + Pasta,white wheat flour based,boiled from dry,no added salt 50%
Pasta,salad,with vegetables	Pasta,white wheat flour based,boiled from dry,no added salt 75% + Mixed vegetables,frozen,broccoli & carrot & corn,cooked 25%
Fried rice,white, mixed vegetables	Mixed vegetables,frozen,broccoli & carrot & corn,cooked 35% + Rice,white,boiled without added salt 65%
Beef,curry,vindaloo,Indian restaurant style	Beef,cooked,nfs 80% + Onion, cooked nfs 5% + Garlic 1.5% + Ginger 1.5% + Spices assorted 1% + Oil,cooking nfs 1% + Water 10%
Beef teriyaki Noodles	Beef,cooked,nfs 40% + Noodle,boiled,nfs 50% + Mixed vegetables,frozen,broccoli & carrot & corn,cooked 8% + Oil,cooking 1% + Teriyaki sauce 1%
Pasta bolognese,Italian restaurant style	Sauce,pasta,tomato-based,commercial,heated 30% + Beef,mince,fried,ns oil,nfs 30% + Pasta,white wheat flour based,boiled from dry,no added salt 40%
Pasta in cream-based sauce,reconstituted from dry mix w milk & butter	Pasta,white wheat flour based,boiled from dry,no added salt 60% + Milk full cream 30% + Butter,salted 10%+ Dry mix 30g
Rissole,beef & vegetables,fried	Beef,mince,fried,ns oil,nfs 80% + Mixed vegetables,frozen,peas & corn,cooked 20%
Beef,stir fry,chow mein (beef & noodles),Chinese restaurant style	Beef,mince,fried,ns oil,nfs 70% + Onion,cooked 2% + Cabbage,cooked 2% + Celery,cooked 2% + Carrot,cooked 2% + Green beans,cooked 2% + Egg Noodle,boiled,nfs 20%
Sushi,chicken	Rice,white,boiled with added salt 70% + Chicken,breast,lean,fried,ns oil 25% + Cucumber 4.9% + Nori 0.1%

Appendix 21 – Characteristics and activities performed by each Similar Exposure Group (SEG)

SEG No.	SEG Name	Roster Pattern	Shift duration	Work location	Activity Description
SEG01	Shot firer	7 days on / 7 days off	12 hrs/day	Outside in direct sun	The Preparation and set-up of a blast area which includes: Demarcate the blast loading area by ensuring adequate barriers and/or bunting is correctly erected; Set up of signs, and flashing lights where appropriate; Dipping of holes and recording (where required) on drill/blast plan; Identify holes that require re-drilling, are damaged or contain water; Backfill holes where necessary Blast loading activities which include: Laying out of Explosive Accessories; Priming blast holes; Loading explosives into blast holes; Checking of product column rise to design; Stemming of blast holes; Clean-up of blast area; Tie in of blast pattern to Design; Security of the blast area; Reporting of lost accessories or incidents on the shot The preparation for the firing of shots including: Inspection of the tie in (walk the shot); The allocation of blast guard locations; Ensuring blast guards are trained and competent in their duties; Liaising with the others and blast guards prior to clearing the area; Ensure the clearance of all personnel and equipment from the blast exclusion zone The firing of explosives and post blast examination

SEG02	Processing personnel	4 days on / 4 days off	12 hrs/day	Outside in direct sun	Identifying and reporting potential hazards to eliminate risks; Use risk management systems to ensure a safe workplace; Undertake daily plant inspections and report faults; Use fixed and mobile plant equipment in accordance with procedures; Support the maintenance team in the completion of maintenance schedules and repair work.
SEG03	Drillers	4 days on / 4 days off	12 hrs/day	AC vehicle Cabin	Setup and operate drilling rig; Drill holes to explore for mineral deposits and also for setting up of explosive charges by short firers; Record drilling activity
SEG04	Maintenance personnel	4 days on / 4 days off	12 hrs/day	Under cover shed	Carry out scheduled maintenance of fixed plant and mobile plant; Carry out repairs on faulty plant and mobile equipment
SEG05	Office personnel	5 days / week	8 hrs/day	AC office	Various activities including administrative, geological mapping, health and safety, human relations among others.