HYDRATION STATUS OF HIGH PERFORMANCE NEW ZEALAND RUGBY UNION PLAYERS IN A MATCH CONTEXT

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ABSTRACT

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The changes in body mass and urinary specific gravity of 24 rugby union players in the New Zealand Super12 development championship, were measured during five actual matches. The climatic conditions measured were ambient temperature, relative humidity and wind speed. All subjects participating in this study regardless of playing time showed a loss in body mass after each game. Fluid was available from bottles during formal breaks in play and during the ten-minute break at half time. The mean percentage of drink breaks utilised was only 48%, however this varied between games. The average change in body mass, or fluid deficit, of participants playing 60 minutes of rugby or more was calculated to be 1.87% ± 0.19% (SEM), and the range was 0.10% to 4.61%. Urine analysis for specific gravity supported the fluid deficit data, as the average urine specific gravity for players participating in 60 minutes of rugby was 1.025 and therefore considered to be dehydrated.

Final hydration status is related to the length of time a player is on the field, however even reserve players showed a loss of body mass between the pre-match to the post-match weigh-in.

The level of fluid deficit varied between players and for positional groups between games. However, It was observed that some players were

consistently dehydrated to a high level. This indicates individual fluid ingestion strategies are required to meet the needs of each player in a team.

Given the limited opportunities to replace fluid losses during rugby union, there is potential for heat stress and related illnesses to occur, however serious illness is unlikely. Dehydration can also cause impairment of both physical and mental performance, a reduced exercise capacity and impairment in temperature regulation. Rugby union players in this study were dehydrated to a level where performance may have been impaired, although future research is required to determine the level of fluid deficit at which performance impairment occurs during a rugby union match.

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ABBREVIATIONS

ACSM: American College of Sports Medicine

ADH: Antidiuretic hormone

BD: Blues development

BD <60: Group of BD playing less than 60 minutes

BD> 60: Group of BD playing less than 60 minutes

BIA: Bioelectrical impendence

BM: Body mass

CES: Carbohydrate electrolyte solution

CRT: Choice reaction time

ΔBM: Change in body mass

CHO: Carbohydrate

GER: Gastric emptying rate

HRI: Heat related illness

IRB: International Rugby Board

MART: Maximal anaerobic running test

NZRU: New Zealand Rugby Union

ORS: Oral rehydrating solution

RDA: Recommended daily allowance

RDI: Recommended dietary intake

SD: Standard deviation

SEM: Standard error of the mean

Ucol: Urine colour

Uosm: Urine osmolality

Usg: Urine specific gravity

UV: Urinary value

Water is the best of all things
PINDAR (C. 522-C. 438 B.C.), Olympian Odes

1 INTRODUCTION

Both recreational and elite sportspeople explore ways to achieve their maximal potential, and nutrition can play a major role in improving performance. The science of sports nutrition investigates factors that may limit exercise performance in a variety of sports and attempts to reduce or eliminate this factor via nutrition. As nutritionists are becoming an integral part of the support staff affiliated with elite sports teams, nutritional practices conducive to optimal sporting performance are increasingly considered.

1.1.1 Fatigue, hypohydration and hyperthermia

Metabolic heat is produced during exercise; under warm to hot conditions heat may not be dissipated at the same rate as it is produced resulting in a rise in body core temperature. A very high core body temperature can limit exercise performance [1,2,3] and has the potential to be life threatening. Steps must be taken to limit the rise in body temperature and therefore minimise the risk of hyperthermia. Athletes are being advised to acclimatise to hot conditions, pre-cool if possible and ingest fluids during exercise when competing in hot or humid conditions.

Evaporation of sweat is the body's primary system for regulating temperature particularly when ambient temperatures exceed those of the skin and core. An increase in sweat rate reduces the total body water and if not replaced leads to poor hydration status. The body is then said to be **dehydrating**, meaning that a body water deficit is occurring [4]. When there is an existing body water deficit the body is in a state of **hypohydration** [4]. There is a progressive decline in physical and mental function throughout all levels of fluid deficiency that may begin at a loss of only 1.0% body mass during

competition [5]. Dehydration of 2-3% of body mass occurs frequently in individuals participating in high-intensity intermittent exercise [6]. Even though there have been many studies on the general topic of fluid ingestion and the positive effect it has on exercise performance [7,8,9] the exact mechanisms by which a negative fluid balance can reduce exercise performance are still not clear. Body water deficit does have a significant implication for both cardiovascular and thermoregulatory function.

1.1.2 Rugby Union

A rugby union (15's) team will have a maximum of 15 players on the field at any one time with seven reserves, who can be substituted on only once during a game. As this study was based on a 15's team, all practices, laws and regulations mentioned will relate to this form of the game

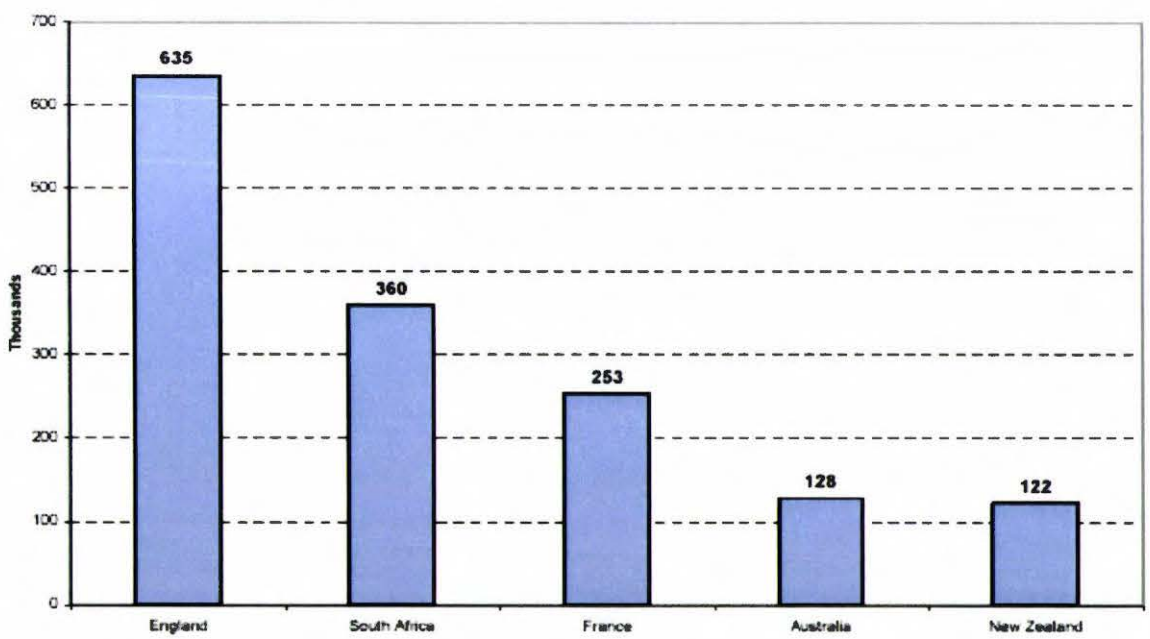
Rugby Union is a game similar to other football codes, in that it is a team sport involving intermittent high intensity sprints with periods of jogging and walking, and repeated physical contact. Players exhibit a wide range of anthropometrical attributes due to the positional requirements of the game. Endurance, speed, strength, power, co-ordination and agility are essential physical characteristics for success in this sport. To be effective players may also be required to reason, evaluate, formulate strategy, decision make, and anticipate opposition tactics instantly. Because of the prolonged duration and intermittent high intensity activity pattern of Rugby Union, intake of fluid and perhaps supplementation of carbohydrate (CHO) during training and competition are likely to be beneficial.

As team sports such as Rugby Union often involve international competition, matches can take place in hot locations and/or during summer or transitional months. Teams may have less than a week in the region prior to a match, and players from colder regions will not have time to acclimatise effectively to a hot environment.

Rugby is played internationally (figure 1-1) and in New Zealand rugby union is one of the top five sports on a population participation basis, and at 3.40% participation rate it is one of the highest rates globally [10]

While many professional teams keep their own statistics of individual players in regards to the change in body mass during a match, very few studies exist that investigate the hydration status of Rugby Union players. One South African group in 1981 [11] studied body temperature and change in body mass and found players to be 2.52% dehydrated when fluid was not ingested during play, another group in 1985 [12] found players to be 1.51% dehydrated after ingestion of 751ml (mean volume) of fluid during a match.

Figure 1-1. Rugby union player numbers (in thousands) of five top rugby playing nations[10]



Due to the lack of research and limitations of previous studies, there is still a need to establish the level and frequency of dehydration that is occurring in rugby union, and to bring this to the awareness of the individuals involved in the sport. Doing so may aid in the pursuit of increased exercise performance, and more importantly could reduce the risk of the potentially life-threatening consequences of hyperthermia and dehydration. In the U.K a newspaper reported that a 'super fit' 35 year old played a charity game of rugby, drank two pints of beer and then collapsed from dehydration and died shortly after [13]. Severe dehydration during sport can result in injury and death, and does so every year [14,15].

1.1.3 Study aims

This study was designed to determine the change in hydration status of rugby union players during seven games of the New Zealand Super 12 development championship, in a range of environmental conditions. A secondary aim was to determine any factors that may affect post-match hydration status of the players.

1.1.4 Study objectives

To complete these aims the following study objectives were determined:

- To measure the hydration status of each rugby player after each match by determination of the players change in body mass during the match and post-match specific gravity of the urine.
- To record drinking frequency for each of the 15 run-on players, by recording how many times they took a drink during a game.

- To record game variables such as environmental conditions (ambient temperature, relative humidity and wind speed), number of drink breaks and final score for each game.

- To calculate any statistical correlation, using Pearsons co-efficient equation, between environmental conditions and post-match hydration status.

- To calculate any statistical correlation, using Pearsons co-efficient equation, between game variables and post-match hydration status.

- To estimate the volume of fluid ingested in the 24-hr period prior to a match and determine if this was related to pre- and post-match hydration status determined by analysis of urinary specific gravity.

- To calculate any statistical correlation, using Pearsons coefficient equation, between environmental conditions and frequency of fluid intake of players during a match.

- To examine dietary intake of players in the 24 hours prior to a match, determined by the use of self-reported 24-hour food records.

2 LITERATURE REVIEW

2.1 SEARCH METHODS

A literature search was performed on two separate occasions using the following internet research databases; SPORTdiscus, Academic search elite, ISI Web of Science, and the Ovid databases. These were conducted in August 2002 and January 2004. Keywords searches included combinations of the following words; rugby, football, sport, exercise, intermittent exercise, thermoregulation, hydration, fluid balance, and fluid intake.

2.2 BACKGROUND

The positive effect sport nutrition has on exercise performance has been well documented over the last two decades [16]. Athletes must match energy intake with output, and meet nutrient requirements to provide this energy and aid repair and recovery from competition and training. Fluid ingestion is vital to replace body water loss due to sweating, and thus maintain fluid balance.

Burke and Deakin [16] provide a detailed account of the progress the science and practice of sports nutrition has made over the centuries. The interest in fluid and sport dates back at least to the 19th Century when Captain Barclay walked 1000 miles in 1000 hours, and stated that it was a personal rule that all liquids were avoided during long distance walking. In more modern times military personnel observed that the availability of water could decide the outcome of many major battles [17]. During World War II scientists studied the effects of physical exercise on soldiers in the desert, and were some of the first to recognise the importance of fluid replacement. It is believed that during the Six-Day war between Egypt and Israel, dehydration was the primary cause of death for thousands of troops [17]. A day in 1967 has

become well known due to advertising, an American college football team - the Florida Gators, won the Miami Orange Bowl playoffs after making an amazing comeback during the second half. During halftime they consumed a drink containing electrolytes and carbohydrates and attributed their success to this drink, soon to be released commercially as Gatorade [18].

Since the 1960's there has been wide-ranging research into the area of fluid replacement and the effect it has on exercise performance and sports medicine. This research has lead to the position statement of the American College of Sports Medicine (ACSM) [19] recommending athletes be '*well hydrated when beginning to exercise*', by drinking generous amounts of fluid in the 24 hours before an exercise session and 400 to 600 mL of fluid 2-3 hours before exercise. The ACSM states in regard to fluid ingestion during exercise, '*athletes should attempt to drink enough fluid to maintain fluid balance*'. The ASCM has established a guideline to achieve optimal hydration, and has set the volume at 150 to 350 mL of fluid consumed at 15- to 20-minute intervals, beginning at the start of exercise.

Rugby union players are only able to drink during formal breaks in play, the number of which varies in relation to an individual match. Players and trainers do not know when the breaks will be and the breaks are often short. The nature and regulations of many sports including Rugby Union, make drinking small amounts at regular intervals almost impossible. The fluid deficit that occurs under these circumstances is termed involuntary dehydration. However, even under conditions where access to fluids is not limited, researchers have found that unforced fluid intakes or drinking *ad libitum* during exercise often fails to replace all of the body water that is lost. This voluntary dehydration during physical exercise often replaces only about 50% of the fluid that is lost [20]. If an athlete does not replace this fluid a deficit will occur, meaning that exercise will often be performed in a state of

hypohydration. As dehydration is cumulative, this state of fluid deficit increases in the latter stages of prolonged exercise.

2.3 TEMPERATURE REGULATION AND FLUID HOMEOSTASIS

At rest the body maintains a constant internal environment to protect metabolic, biochemical, physical and cognitive function. Physical exercise and sport challenge the body's ability to maintain this environment within a range necessary to function optimally. Disturbance in homeostatic balances may include an increase or decrease in metabolites, such as electrolytes and lactic acid, a change in water balance, or an increase in tissue temperature. When homeostatic mechanisms are compromised during exercise, fatigue may be a result.

Fatigue has been defined as a process that changes the functional state, and possibly results in exhaustion and a termination of activity [21]. Physiological fatigue is the reduction in muscle capacity to generate force or power. Fatigue can act as a safety mechanism by inducing exhaustion and thus a reduction or cessation of exercise under conditions that may otherwise cause injury or even death. Physiological fatigue can occur centrally, in the central nervous system or motor outflow, and/or peripherally. It is unlikely fatigue is caused by any single mechanism, and an explanation of the complex processes can be found elsewhere [22]. Two processes which, when compromised, will result in the onset of fatigue, are cardiovascular function and thermoregulation. Water is essential for preserving blood volume and osmolality, and therefore plays a critical role in these processes. This role is described in more depth in the following sections.

Some increase in body temperature is observed during exercise without adverse effects, and metabolic heat production can have beneficial effects on

performance particularly by raising muscle temperature [23,24] and preventing muscle injury [25]. Studies have shown that sprint and anaerobic power performance can be improved during intermittent, high intensity exercise in a hot environment [23,26,27]. However when prolonged exercise is undertaken and body heat cannot be effectively dissipated, core temperature will continue to rise to a critical level. Sweating is the normal physiological response to a rise in body temperature, and regulates heat storage in the body by evaporative heat loss. If the sweat rate is high, substantial water and electrolytes can be lost from the body, resulting in a disruption of fluid and electrolyte balance if not replaced.

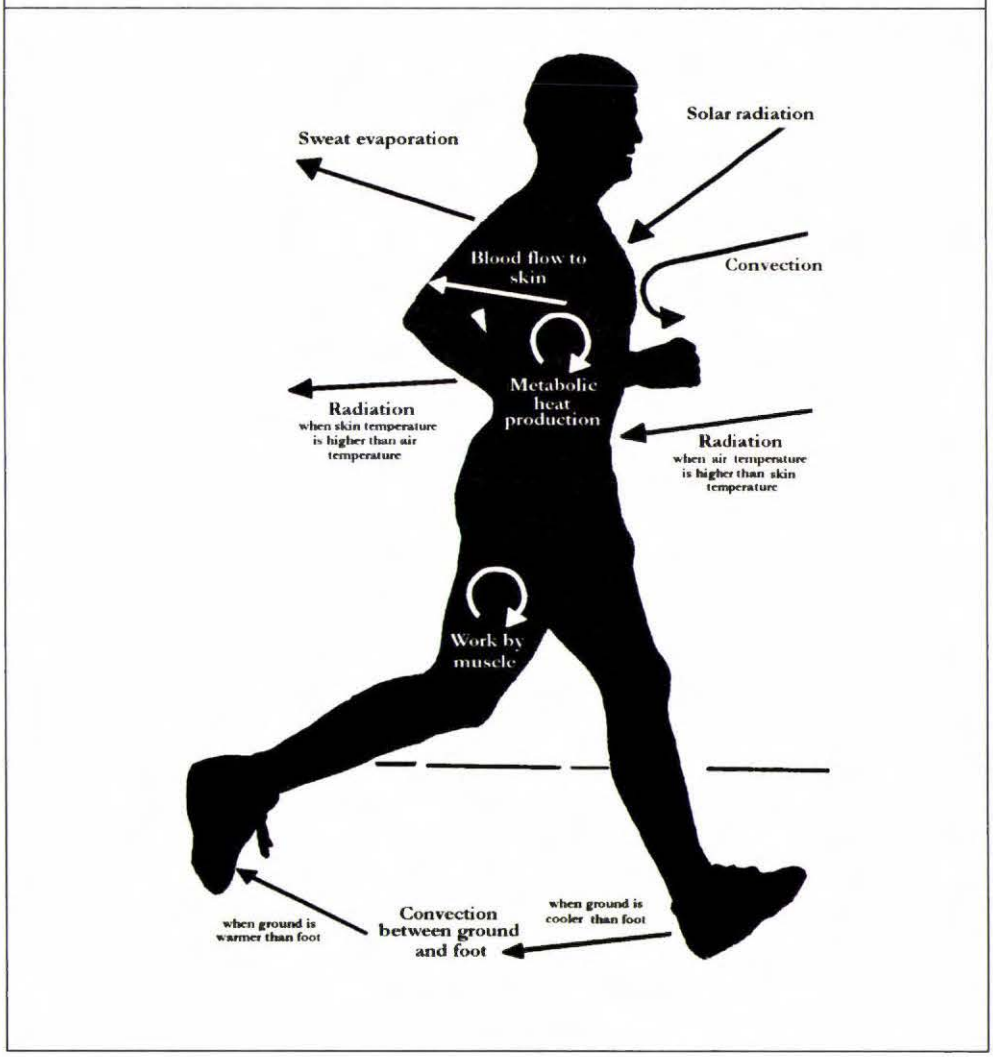
To appreciate the relationship between exercise performance and the rate of temperature increase and fluid and electrolyte loss, it is necessary to understand some of the regulatory processes involved with thermoregulation, fluid homeostasis and electrolyte flux.

2.3.1 Exercise and thermoregulation

The temperature of the skin is greatly influenced by the external environment and thus can vary greatly. In contrast the temperature of the deep internal tissues is maintained within a few degrees of the normal resting temperature (about 37.4°C). To maintain a stable core temperature, there must be a balance between heat gain and heat loss. Body heat can be gained from metabolic heat production and the environment. Heat from the body can be lost through conduction, convection radiation and evaporation (when ambient temperature is lower than core temperature) as illustrated in figure 2-1. Heat production is directly related to metabolic rate, at rest the metabolic rate of a 70kg male will be about 60W [28]. In a warm climate the rate of heat production can match and exceed the rate of heat loss. Physical exercise increases total body metabolism, by as much as 20 times that of the resting rate, to provide energy for skeletal muscle contractions. A marathon runner can attain a heat production rate of up to 1200W in a race, however the rise in

body temperature seldom exceeds the maximum range of 2-3°C [28]. This indicates the rate of heat loss has increased to match the rate of heat production.

Figure 2-1. Potential for heat production and dissipation during exercise. Adapted from Maughan and Nadel (2000) [28].



Heat dissipated by sweating occurs at a rate of approximately 2600kJ for each litre of water evaporated in moderate climates [28]. If the rate of evaporated sweat is 1.6 l/hr or 4160kJ/hr this equate to 1160J/s, or 1160W. At this sweat rate, which is well within normal sweat rate ranges during exercise [29], almost all of the metabolic heat load would be balanced by evaporative heat loss.

Hyperthermia during exercise is closely related to the intensity of the exercise performed [22,28,30], however environmental conditions, particularly during severe heat stress, will also influence body temperature. Heat can be dissipated or gained dependant on the external environment (figure 2-1).

Conduction depends on the type of environment, as thermal conductivity of air is low, while conductivity of water is high. Thermal conduction usually occurs through either water or a solid medium. Because of this it has limited value as a means of heat dissipation during exercise performed out of water, as only a small amount of surface area of the body is in touch with other surfaces during most types of exercise. Cooling by conduction can be achieved through ice or cool packs applied to the skin.

Convection and radiation are effective as means of cooling when the skin temperature is much higher than the ambient air temperature, and heat can move along this gradient. The same is true with heat dissipation via the blood as it moves along a temperature gradient from the core (high temperature) to the periphery of the body (relatively low temperature) as shown in figure 2-1. As the ambient temperature rises above about 35°C, the gradient between external and skin temperature is reversed and the body gains heat from the environment [28]. In conditions where the ambient temperature is above 20°C the majority of heat loss is achieved by the evaporation of sweat from the skin and accounts for as much as 98% of dissipated heat in hot environments [30,31]. Although efficiency of evaporative cooling is reduced when the air temperature is higher than body temperature. High relative

humidity of the atmosphere will also decrease the effectiveness of heat dissipation by this system, as fluid on the skin will not evaporate but rather drip off. The potential for heat loss by evaporation is high, but only if there is a plentiful supply of water on the surface of the skin, and this water is able to evaporate.

The ability of an athlete to compete in adverse conditions with only small increases in body temperature reflects the effectiveness of the thermoregulatory system during exercise. However, as ambient temperature and humidity rise, sweat rates will increase to compensate for the rise in external heat stress. Maintenance of core temperature is to the detriment of body water and electrolyte balance. The resulting hypohydration can itself impair exercise performance and present a health risk.

2.3.2 Body water and fluid balance

Water content of the human body at rest is usually in balance; water intake equals water output and a state of euhydration exists.

Evaporative heat loss will predominate as environmental heat stress rises. Table 2-1 illustrates the acceleration of water loss due to sweating as a consequence of exercise.

Table 2-1. Comparison of water loss from the body at rest in a cool environment and during prolonged exercise. 32

Source of Loss	Resting		Prolonged exercise	
	ML/hr	%	ML/hr	%
Skin	14.6	15.2%	15	1.1
Respiration	14.6	15.2%	100	7.5
Sweating	4.2	4.4%	1200	90.6%
Urine	58.3	60.8%	10	0.8%
Faeces	4.2	4.4%	0	0%
Total	**95.9**		**1325**	

Table 2-2. Distribution of water in the body.

Body Compartment	Percentage of total body water
Blood plasma	7.8%
Interstitial fluid (including lymph)	22%
Cartilage and connective tissue	8%
Contents of lumen of gastrointestinal tract	1.3%
Cerebrospinal fluid	0.5%
Bile	0.4%
Intracellular fluid	60%

Adapted from Brody (1999); 33

Water is the major component of body mass in the human, about 60% in males and 50% in females [34]. Muscle tissue is about 75% water; therefore an individuals' total body water depends upon their body composition.

About 5-10% of total body water is renewed every day [17]. In a 75kg sedentary male living in a temperate climate, body water content would be approximately 45kg and fluid turnover would be about 2-4 litres per day.

Water protects the cardiovascular system by maintaining plasma volume, it is essential for temperature regulation during exercise and in the heat, and is the medium for biochemical reactions within cells and tissues. Water is second only to oxygen in the necessity for the maintenance of life. Although a body can withstand a 40% reduction in body mass due to starvation, a loss of around 10% body mass due to dehydration can be fatal [4].

Water can be redistributed around the body and the presence of fluid in storage spaces can act as reservoirs when hypohydration is minimal [17]. About 60% of total body water in the adult is intracellular, the remainder being extracellular [33] as presented in table 2-2.

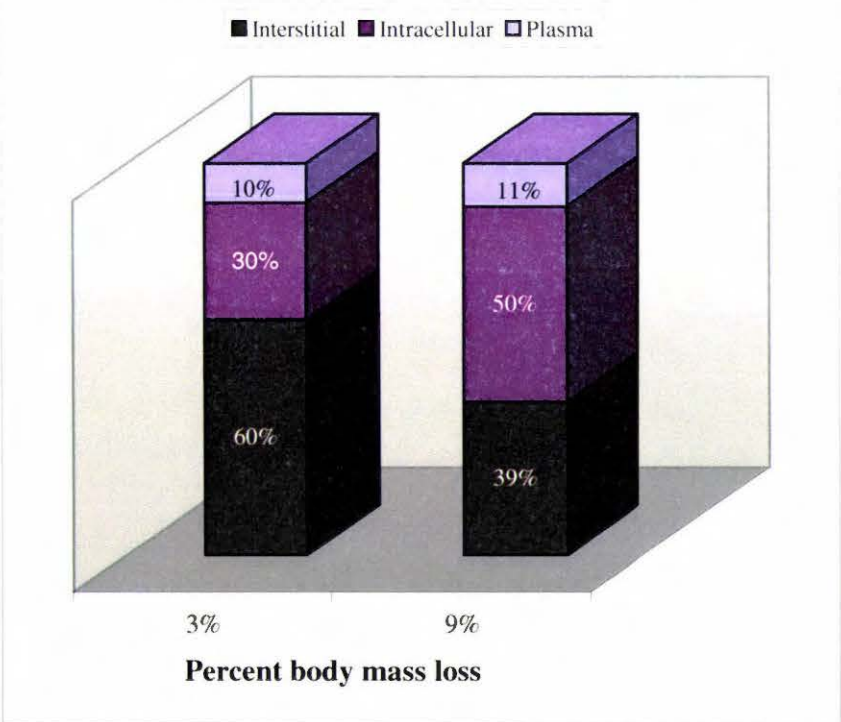
It is not surprising then, considering the important role water has in sustaining and facilitating the physiological functioning of the body, that hypohydration is associated with impaired physical and mental performance.

Water can be lost from the body through sweat, respiration, faeces, urine and insensible loss through the skin (table 2-1). Water gained in the body is predominantly from fluid ingestion in either food or beverages (approximately 90%) [28]. During exercise water is produced because of an increase in oxidative metabolism. As it is bound to the carbohydrate stored in the muscle (glycogen), water will be released once glycogen is released as a source of energy. This amount however has only a small impact on water balance when compared to the large losses due to sweating [17].

2.3.3 Fluid loss

The heat produced by the contraction of muscles during exercise or work will result in hyperthermia if not dissipated. Heat under these conditions is primarily dissipated from the body by evaporative cooling, or sweating. Even at low ambient temperatures high sweat rates are sometimes observed when energy output is high [28]. This indicates that dehydration is not only a problem when environmental conditions are hot and humid.

Figure 2-2. Partitioning of body water as reviewed by Sawka and Pandolf [17].



Fluid loss from sweat comes from both intracellular and extracellular compartments and ultimately results in cellular and systematic disturbances if not replaced. A small water deficit, for example after short-term sub-maximal exercise, or at the early stages of exercise is primarily due to a reduction of fluid in the extracellular spaces. As the volume of water lost increases a proportional increase in the percentage of fluid lost from the intracellular space occurs [17] as illustrated in figure 2-2. A three percent reduction in body mass is due to fluid loss predominantly from the interstitial compartment. At a reduction in body mass of nine percent, fluid losses are primarily from the intracellular compartment and secondly from the interstitial compartment [17].

The redistribution of water between these spaces is dependent on osmotic gradients. Alterations in solute concentrations cause water to flow between intracellular and extracellular compartments. Fluid loss while sweating is accompanied by a loss of electrolytes from the body, mainly sodium, potassium and chloride, and is predominantly from the extracellular space. There is much variability in sweat composition between individuals and between exercise sessions, depending on the rate of secretion, the state of fitness and acclimatisation [28]. However, sweat is always hypotonic in respect to other body fluids and muscle (table 2-3), so the net effect of prolonged sweating is an increase in the osmolality of plasma. During dehydration this plasma hyperosmolality mobilises fluid from the intracellular to the extracellular space to protect blood volume and therefore the cardiovascular system.

Table 2-3. Major electrolytes and the concentrations in plasma, sweat and muscle [4]

Electrolyte	Plasma mEq/L	Sweat mEq/L	Muscle mEq/L
Sodium (Na^+)	137-144	40-80	10
Chloride (Cl^-)	100-108	30-70	2
Calcium (Ca^{2+})	4.4-5.2	3-4	0-2
Potassium (K^+)	3.5-4.9	4-8	148
Magnesium (Mg^{2+})	1.5-2.1	1-4	30-40

2.3.4 Measurement of fluid loss

To understand fluid needs during exercise an athlete must know the magnitude of their sweat losses. Body water content can be measured in a laboratory by tracer methodology [35], and therefore losses after exercise can be measured and compared. To be of practical use fluid deficits need to be calculated in the field, as environmental conditions and exercise intensity will vary between sessions. The most widely used method of measuring fluid loss and sweat rates in the field is to weigh an individual pre- and post-exercise, subsequently measuring any change in weight [4,29,36]. Each kilogram of weight loss is approximately equal to one litre of fluid deficit. Accuracy of measurements is very important, as the amount of weight loss will often be under 2kg. A more detailed description of body mass measurement protocol is outlined in section 2.9.1.

In the field fluid loss is often estimated by measuring the change in body mass [36,37,38] and corrected for fluid and food intake and urinary and faecal loss. An example of a basic hydration self-testing program (with corrections only for FFI and urinary loss) can be found in appendix A. However this method does not differentiate between eccrine and non-eccrine fluid loss [39]. To precisely determine sweat loss, corrections must be made to the change in body mass for fluid and food intake (FFI), urinary and faecal loss (UFL), trapped sweat in clothing (TS), respiratory water loss (RWL) and metabolic weight loss (MWL) during the period between body mass measurements [39]. This equation is shown below where weight is W.

$$\text{Sweat loss} = (W_{\text{pre-ex}} - W_{\text{post-ex}}) + W_{\text{FFI}} - W_{\text{UFL}} - W_{\text{RWL}} - W_{\text{MWL}} + W_{\text{TS}}$$

Sweat rate can be calculated by dividing the total volume of sweat loss by the duration of exercise [36].

$$\text{Sweat rate (L/hr)} = \text{Sweat loss (Litres)/duration of exercise (hours)}$$

A study on prolonged running in women [39] showed that the most accurate field methods of determining sweat loss in women when respiratory water loss (RWL) and metabolic weight loss (MWL) could not be calculated were correcting change in body mass for; Fluid intake (FI), fluid intake and urinary loss (FI and UL), and fluid intake urinary loss and trapped sweat (FI, UL and TS). Correcting for fluid intake and urinary loss only was the most accurate equation. It appeared that not correcting for TS underestimated sweat loss by ~9%, however as not calculating for RWL and MWL overestimated sweat loss by ~16%, these two factors balance out to give an error of approximately 7%. However this was only true in warm conditions. In cool weather RWL and MWL was larger causing an overestimation of sweat loss of ~20%. This research concluded that there was a trend for all field methods to

overestimate sweat losses in cool weather when sweat rates were below 600 ml/hr and underestimate when sweat losses were above 800 ml/hr.

Individual sweat rates and fluid losses vary greatly [29] and are influenced by a number of factors, which include: body size and composition, gender, exercise intensity, type of exercise, environmental conditions, clothing and equipment, acclimatisation and individual metabolism and fitness.

Heat and humidity play a major role in sweat rate and water loss, as environmental conditions directly influence body temperature. Body temperature can rise directly through radiative heat from the external environment and by decreasing the heat gradient between skin temperature and external temperature, thus reducing sweat evaporative efficacy. Athletes competing in summer or events located in hot environments should be particularly aware of the need to monitor sweat losses. Other external conditions such as airflow may influence sweat rates, as the body is cooled and the temperature lowered by convection. Cyclists create their own airflow by moving at speed though the air, while athletes competing in a stadium can be sheltered from any cooling advantage created by a breeze.

The exercise type and intensity will contribute to heart rate and sweat rate. As the body works harder it produces more metabolic heat and the heart rate increases. While sweat rates may be lower during sub-maximal exercise, total sweat loss during competition will probably be greater in events of longer duration, as more time is spent exercising, and therefore sweating [29].

Minimal loose fitting clothing or breathable fabric helps promote heat loss, by not inhibiting the cooling process from sweat evaporation. Heavy clothing [40] and headgear could be detrimental to the cooling process, and dark coloured clothing can increase radiative heat gain [11,41].

Both increases in fitness and heat acclimatisation lead to improved sweating efficiency as a means of heat dissipation. That is, an individual becomes a better sweater, the sweating mechanism is activated sooner and more sweat is produced [17].

The environment also affects other types of water loss during exercise, dry air will increase the volume of transcutaneous and respiratory water loss. Dry cold air at high altitudes will further increase rates of water loss through respiration [28].

Losses must be monitored over a number of sessions in similar conditions for an athlete to gain information in relation to his or her sweat rates for given environments. When this is not possible, guidelines calculated from average values in specified conditions, and during varied exercise types and intensities can be utilised [29] (appendix B). When sweat rates have been measured or estimated, fluid intake strategies can be devised to keep water loss at a minimum.

2.3.5 Fluid intake and absorption

It has been suggested that matching fluid intake to sweat losses will result in fewer homeostatic disturbances and this will translate into optimal performance [42,43]. Much of the research presented in the literature has been conducted during hot conditions and shows performance is decreased when low levels of fluid are consumed [44,45]. However, it has been stated that these results and conclusions may not translate to thermoneutral environments [46,47]. There has been much research on fluid ingestion and how it relates to performance during a 1-hr cycling trial. There is no conclusive evidence that fluid ingestion during a 1-hr cycling trial improves performance, mainly due to conflicting results. These inconsistencies could be because of small subject numbers producing non-significant results and/or variances in experimental models, as different fluid types (CHO composition),

drinking regimes and environmental conditions are used. A more in depth look at these studies can be found in section 2.4.1.

During exercise the principal issue in maintaining fluid balance is matching fluid intake with fluid loss due to sweating. Thirst, however, does not appear to be an adequate mechanism to regulate this, and incomplete water replacement or voluntary dehydration occurs [5,48].

The dipsogenic urge or sensation of thirst is a complex neurophysiological drive. The desire to drink is influenced by numerous factors: the requirement for other nutrients, stimulants or a warm, cooling or calming effect and these may initiate the feeling perceived as thirst [48,49]. The drive to drink may not always be due to a physiological need for water intake but rather a social, habitual, cultural or ritualistic requirement [49]. Conversely, an individual may not respond to a physiological need to drink for the same reasons, thirst is ignored and dehydration can occur. The sensation involved with drinking inducement is dryness in the mouth or throat.

The physiological basis for the dipsogenic response are the same mechanisms as those involved in water and electrolyte reabsorption in the kidneys, and controlling blood pressure [28,48]. These are chemical and pressure centres which signal plasma hyperosmolality and hypovolaemia. Receptors in the thirst control centres in the hypothalamus and forebrain respond to osmotic pressure, volaemia and blood pressure, others respond to the fluid balance hormones that also regulate renal excretion (section 2.3.6).

While thirst acts as a guide to the need for fluid replacement under resting conditions [5], unfortunately it may not be an adequate indicator of fluid needs during exercise [20]. The drive to drink during exercise can be delayed until an individual is approximately 2% dehydrated [50] (2% body weight loss). In addition, the dipsogenic drive alone may not be able to fully replace fluid deficit, therefore the reliance upon thirst as a regulator for fluid balance

can result in some degree of dehydration [5]. Another inhibiting factor in regards to fluid balance is the rate fluid empties the stomach and is then absorbed by the intestine. Slow emptying after a large volume of fluid is ingested can cause distension of the stomach and gastrointestinal discomfort.

If the fluid ingestion rate matches sweat rate, the first limiting factor to fluid absorption, and thus the maintenance of fluid balance, is the rate of gastric emptying (GER). Typically gastric emptying during exercise occurs at a rate of about 600 ml/hr, without added ingestion [49,51], however there is much individual variance from this.

2.3.5.1 Gastric emptying of the stomach

Variance in GER can be due to differences in body size and fitness, the amount of water in the stomach, the volume of fluid ingested, the level of thermal strain [51], the level of exercise intensity [52], state of hydration [51], and formulation of the fluid ingested [53,54].

Once the stomach is emptied to about 30% of initial volume, GER decreases [55,56,57]. The implication for this in regards to exercise has lead to the previously mentioned position statement of the ACSM [19]. It is recommended that athletes be well hydrated prior to exercise, by drinking a fluid bolus of 400 to 600 mL 2 – 3 hours before and then topping up by drinking small amounts every 10 – 20 minutes. Ingestion of a fluid bolus is followed by a rapid gastric emptying phase, and drinking small amounts of fluid after ingestion of a fluid bolus maintains gastric volume and maximises the rate of gastric emptying to about 20 – 40ml/min (1.2 to 2.4 litres per hour if volume is maintained) depending on fluid composition [58]. Gastric emptying has been shown to be reduced when exercise intensity exceeds about 70 – 75% VO_{2max} [52]. Although a well controlled study on intermittent high-intensity exercise in two 15 minute intervals [59, showed that gastric emptying rates were reduced when VO_{2max} was below 65%, when compared to walking at 12 – 13% VO_{2max}. During intermittent cycling exercise at 74%

VO_{2max} gastrointestinal transit time was not different from rest and was not different when a concentrated glucose or flavoured dilute fluid was used [60]. Other studies have found that gastric emptying may be reduced during exercise at 75% VO_{2max} when water is ingested, but not when a glucose polymer [61] or carbohydrate-electrolyte [62] solution is ingested. At very high exercise intensity there is likely to be limitations to the availability of fluids, and any benefits of fluid ingestion at this stage will be minimal, as high intensity activity is seldom prolonged. However in one study investigating fluid ingestion during prolonged high intensity exercise [63], subjects were required to cycle at about 85% VO_{2max} for one hour. Subjects pedalled further (43.1 km) when no fluid was consumed compared to when 1.5L of flavoured water was ingested (42.3 km, $P<0.05$). This reduction in performance when fluid was ingested was ascribed to gastrointestinal discomfort. Brouns *et al* [52] have suggested that rates of fluid intakes higher than 800ml/hr can produce gastrointestinal discomfort during high intensity exercise. However, during a simulated basketball match [64] where players were participating in intermittent high intensity exercise mean fluid intakes were in excess of 1L/hr, and some players had a fluid intake rate of 1.5 to 1.8L/hr.

The composition, osmolality, energy content and volume of fluid ingested will contribute to the GER [53,65]. While historically research into dehydration and the effects of fluid replacement have used water as the fluid, more recently studies have been investigating the effect of carbohydrate-electrolyte drinks on dehydration and sports performance. The osmolality of a rehydration beverage is important as it will affect both GER and intestinal absorption, both processes which determine the rate of fluid and substrate delivery to the body. Hypotonic and isotonic drinks will promote fluid delivery to the cells, while strong hypertonic drinks will cause a net secretion of fluid from the cells into the intestine, thus increasing the potential for dehydration. While osmolality is an important factor affecting GER, energy content appears to have a greater influence [54,66].

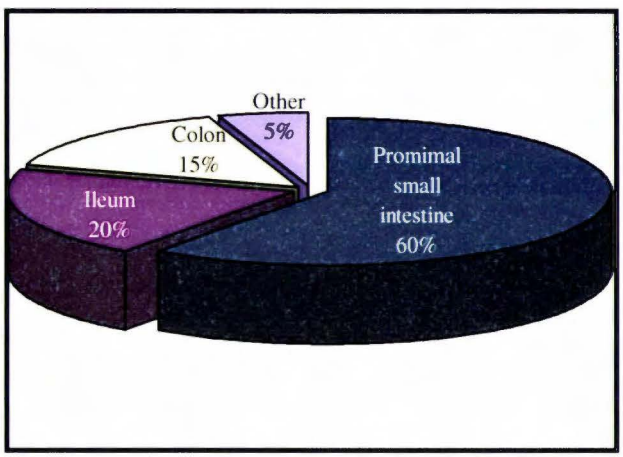
Substitution of maltodextrins (glucose polymers) for glucose monomers reduces the osmolality of a solution while maintaining carbohydrate and therefore energy content. This substitution can slightly increase the rate of gastric emptying, particularly at high energy densities [53,54]. Rehrer et al [67] showed that a maltodextrin – electrolyte solution with an osmolality of up to 336 mmol/kg did not significantly affect GER when compared to a maltodextrin solution without electrolytes, and therefore a lower osmolality. This study and others indicate that the energy density of a beverage may have more impact on GER than osmolality [54,66].

When drinking rates are high the stomach may become distended before the fluid deficit is restored. As little fluid is absorbed in the stomach, the second limiting factor is the rate of absorption in the small intestine.

2.3.5.2 Absorption in the small intestine

The distribution of fluid absorption in the proximal small intestine (duodenum and jejunum), ileum and colon, is shown in figure 2-3 with the greatest percentage (50-60%) of any given fluid load occurring in the duodenum and jejunum [68].

Figure 2-3. Distribution of fluid absorption percentages in the intestine of any given fluid load [68]



Fluid is taken up into the intestine along osmotic gradients between the luminal contents and the intracellular fluid of the cells making up the intestinal wall. Therefore it is essential any rehydration beverage is hypotonic to plasma (280 mmol) [68,49]. Glucose is absorbed actively and dependent on the luminal concentrations of glucose and sodium. If the concentration of CHO or electrolytes were high and therefore the fluid hypertonic, fluid would be secreted out of the cells and into the intestine, thus exacerbating dehydration. Many sports drinks have an osmolality close to that of body fluids, due to a high glucose content, however a hypotonic beverage would promote rehydration more effectively [69]. Carbohydrate concentration is often high in sports drinks to provide an energy substrate or improve flavour. Sodium is normally included in drinks in the form of sodium chloride [69] and is often added for a number of reasons, one of which is to replace sodium losses that can occur as a consequence of sweating, particularly during prolonged periods of exercise. Low sodium levels or hyponatraemia (low blood-sodium concentrations of less than 130 mmol/L) occurs when sodium is lost through sweating, and not replaced. Ingesting large amounts of fluid

without sodium during prolonged exercise has been observed to increase incidences of hyponatraemia [71]. Although plasma sodium levels probably remain within a normal range during most forms of intermittent exercise, it is been shown that the presence of sodium in a beverage may help hydration as it enhances the desire to drink, helps stimulate jejunal absorption of glucose and water and helps the body to retain fluid [70] (section 2.7.3). However moderate to high concentrations can make a drink unpalatable. Sodium supplementation in rehydration beverages is discussed further in section 2.7.3

At rest the maximal rate of water uptake by the small intestine is 1.0 to 2.3 l/hr [68]. While the rate of absorption in the small intestine during exercise is not currently known, Noakes has estimated it to be between 750-1000 ml/hr [71].

Noakes [71] has highlighted the dangers of hyperhydration, and hyponatraemia due to water intoxication during exercise. Recent research [72,73] investigates the possible need to re-evaluate fluid ingestion guidelines, so that hyponatraemia can be avoided during ultra distance sports. Furthermore, many studies have shown athletes cannot tolerate the high levels of fluid ingestion that is required to replace fluid loss [74,37].

2.3.5.3 Fluid intake

A wide range of factors has been reported to influence voluntary fluid intake; palatability, temperature, gastrointestinal distress [75], awareness of performance enhancement, carbonation [76], heat acclimatisation and availability of fluid [17]. Palatability can include factors such as flavour and mouthfeel. An enjoyable flavour and absence of aftertaste, or 'glugginess' in the mouth will increase fluid intake [48,77,78]. Intake is also increased when fluid is in the range of 15-20°C [79], and when athletes believe ingestion of a beverage will help to enhance their performance [75]. Heat acclimatisation has been shown to cause an increase in the volume of fluid ingested, primarily due to a shortened time until the first drink is taken, and an increase in the

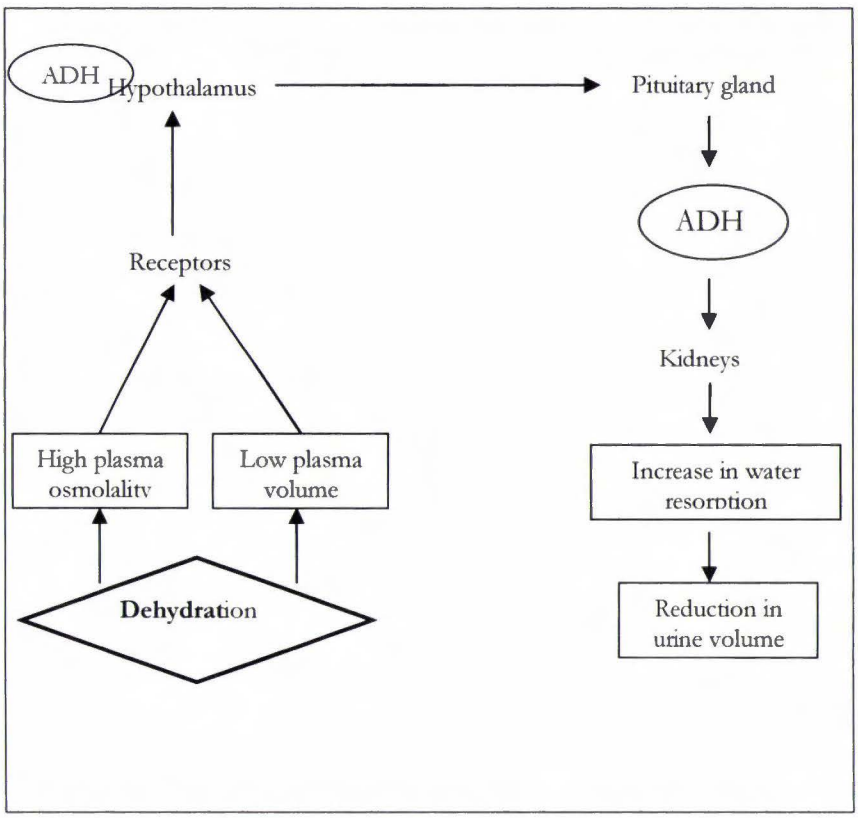
frequency of drinking [80,48]. Carbohydrate and electrolyte supplementation has been ascribed to having an ergogenic effect on exercise performance, the type and composition of fluid recommended for different physical activity is outlined in section 2.8.

Fluid ingestion acts by both reducing dehydration and maintaining the sweat response effectiveness, thus lessening the rate of heat storage in the body. Conservation of both fluid within the body and particularly the osmolality of plasma, predominantly by reabsorption of sodium, are regulated by the kidneys.

2.3.6 Fluid balance regulation in the kidneys

One of the primary functions of the kidneys is to filter out and excrete some of the waste products of metabolism. Approximately 150-200 litres of fluid is filtered through the glomeruli per day [81]. Essentially all of this is resorbed back into the body after filtering, as only 1% of filtered water appears in the urine. Another function of the kidneys is to regulate the balance of water and electrolytes in the body. Excess water is excreted, and in times of water and electrolyte deficiency these are conserved to aid the restoration of balance. Blood volume, plasma osmolality and plasma sodium concentration seem to be the primary factors regulated in this way.

Figure 2-4. The regulation of water resorption in the kidneys by antidiuretic hormone ADH .

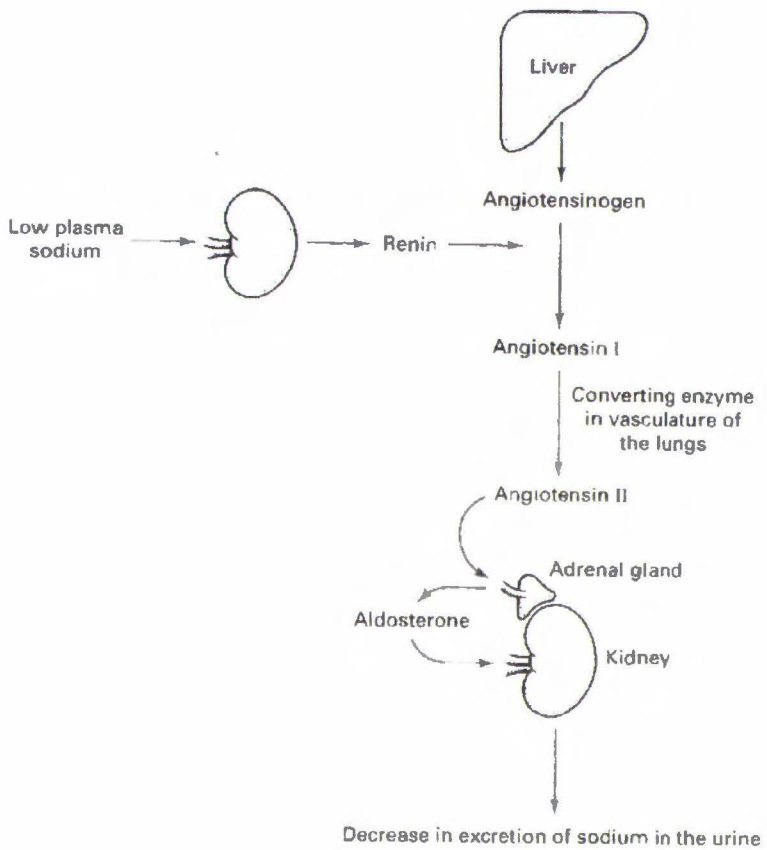


Anti-diuretic hormone (ADH) regulates the volume of urine produced by influencing water resorption (figure 2-4). High plasma osmolality and low blood volume activate receptors, which send signals to the hypothalamus for ADH to be synthesised, which in turn sends signals to the pituitary gland for release of ADH. ADH output is also stimulated by an increase in plasma angiotensin concentration [33]. The volume of water conserved by this regulatory system is relatively low when compared to water losses from sweating. The decrease in renal excretion of sodium due to decreased urine flow is probably a more important regulatory system in maintaining fluid balance as sodium salts account for more than 90% of the osmotic pressure in the extracellular fluid.

When the sodium concentration of the plasma falls, the kidneys respond by lowering urinary sodium and thereby conserving this nutrient. This occurs by a variation in the rate of sodium reabsorption by the renal tubules. When plasma sodium is low renin is synthesised and secreted into the bloodstream by cells in the walls of the arterioles entering the glomerulus. Renin then catalyses the cleavage of a peptide bond in the pro-hormone angiotensin (which is released by the liver). This cleavage creates angiotensin I which is converted to the biologically active form angiotensin II. Angiotensin II causes the adrenal gland to synthesise and secrete aldosterone, a steroid hormone. Aldosterone then travels the small distance to the kidneys through the bloodstream where it induces the tubule cell to increase its efficiency of reabsorption of sodium ions [33]. This pathway of sodium conservation by the kidneys is illustrated in figure 2-5.

Because sweat is hypotonic with respect to other body fluids, the effect of prolonged sweating is an increase in the sodium concentration and osmolality of plasma. Plasma hyperosmolality has been shown to reduce sweat rate and exacerbate the rise in core temperature during exercise by reducing blood flow to the skin and thus impairing the sweating response to high internal body temperature, independent from dehydration induced reduction in plasma volume [82]. Research indicates that plasma hyperosmolality may have a greater influence on evaporative cooling than volaemia [83]. These findings have lead to research into electrolyte supplementation in fluid replacement beverages.

Figure 2-5. Regulation of sodium levels. Low sodium plasma levels activate the mechanisms involved in sodium conservation in the kidneys. Renin increases angiotensin, which increases aldosterone [33].



2.3.7 Hypohydration and physiological function

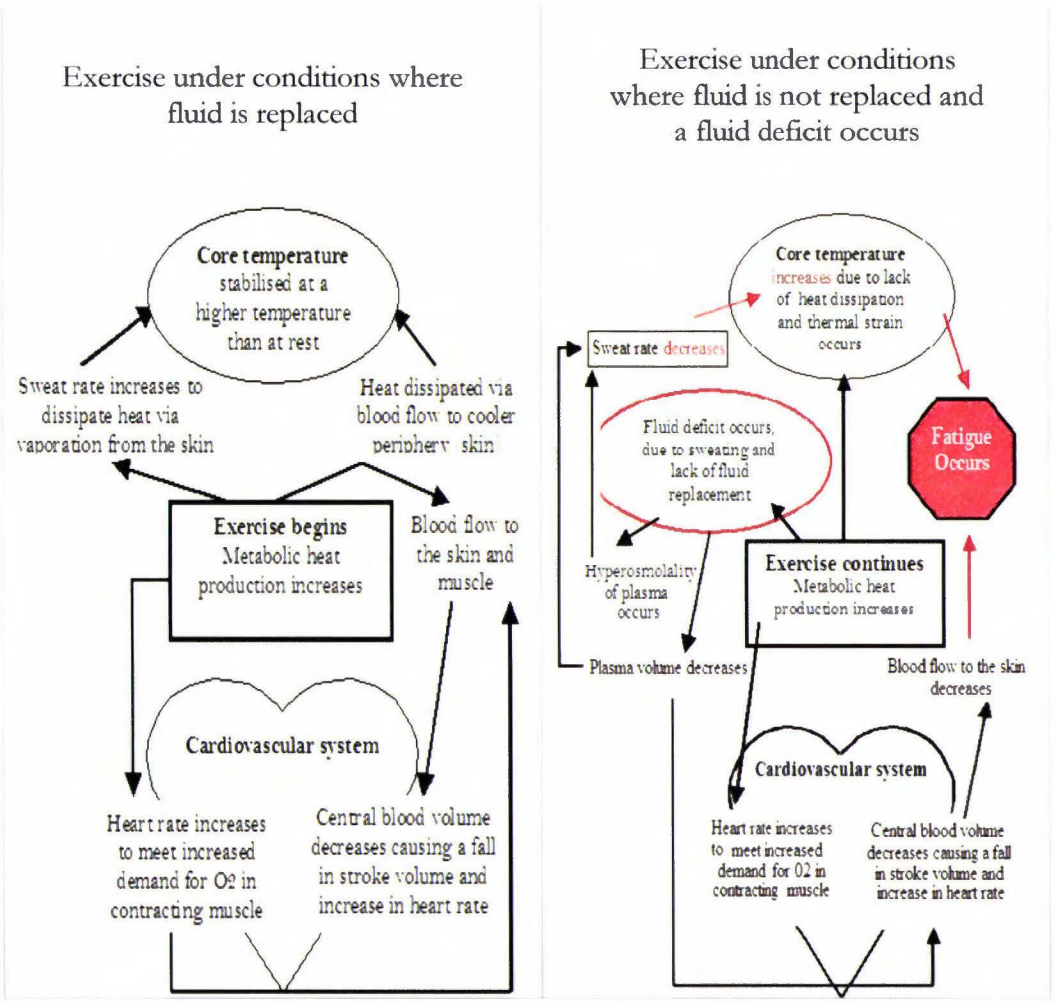
Past and current research has investigated the physiological responses of the body during when hypohydrated, and during dehydration, and findings indicate changes in the cardiovascular and thermoregulatory systems predominate. It has been shown that there is an increased cardiovascular and thermal strain when as little as 1.5 – 2% of body mass is lost as sweat [84].

Dehydration results in a reduction in plasma volume and as a consequence of this less blood is available to the exercising muscle and the skin. Hypovolaemia is associated with a reduced stroke volume resulting in cardiovascular strain, as the heart rate must increase to maintain normal blood flow. The reduction in central plasma volume and increase in peripheral blood low during exercise causes a reduction in venous return and as a consequence a reduction in cardiac output.

As illustrated in figure 2-6, body water deficit also causes an increase in thermal strain, the degree of which is determined by the level of hypohydration. As the body water deficit increases the body's ability to dissipate heat reduces. Cardiac output is also reduced and subsequently there is less blood flow to the skin resulting in a reduction in heat dissipation via this avenue. Sweat rate is also decreased as fluid deficit increases, causing a further exacerbation of thermal strain.

The underlying biochemical and physiological mechanisms involved in a decreased sports performance are not completely understood but the physiological changes described above are thought to contribute collectively in some way to exercise fatigue.

Figure 2-6. Physiological changes during exercise with and without fluid replacement.



2.4 EFFECTS OF DEHYDRATION AND HYPERTHERMIA ON PERFORMANCE

It appears hyperthermia and hypohydration both have a major role in onset of fatigue in warmer conditions, and can both be influenced by hydration practices. Depending on the climate the method of dissipating the heat produced while exercising will vary. In hotter climates there is a greater dependence on evaporative heat loss, and therefore on sweating. Environmental heat stress and metabolic heat produced by the body during exercise act to increase thermal strain. If fluid loss due to sweating is not replaced this leads to progressive dehydration and an elevated core temperature, which both exacerbates the onset of fatigue and a risk of heat related illnesses (HRI). Types of HRI, and their symptoms, signs and treatment are shown in table 2-4.

Table 2-4. Types, symptoms and treatment of heat related illnesses [85]

HRI	Symptom	Sign	Treatment
Heat oedema	None	Peripheral oedema	Rest, elevation of extremeties, acclimation
Heat cramps	Painful muscle cramps	Palpable muscular spasm	Stretch, ice massage, oral fluids
Heat syncope	Syncope	Loss of consciousness	Rest, supine with feet up, monitor vital signs
Heat exhaustion	Fatigue, inability to continue exercise, mild confusion, mauca, vomiting, syncope, 'chills' of head and neck	Hypotension, orthostasis, elevated core temperature (up to 40.5°C), syncope	ABC's, cool, rest, monitor temp/VS, oral fluids
Heat stroke	Pronounced mental status changes, fatigue, nausea, vomiting, syncope	Elevated core temp (> 40.5°C), hypotension, tachycardia, tachypnoea, syncope, possible cessation of sweating, coma, DIC, ARF	ABC's, cool urgently, call emergency services, monitor VS, IVF if available
ABC – airway, breathing, circulation; ARF = acute renal failure; DIC = disseminated intravascular coagulation; IVF = intravenous fluids; VS = vital signs			

Whilst there is extensive literature illustrating the role carbohydrate (CHO) metabolism has on an athletes' capacity to sustain prolonged endurance exercise, in warm environments the depletion of CHO stores is not always the limiting factor upon performance, as fatigue may occur while substantial CHO stores remain [28].

A primary challenge when exercising in the heat is to avoid dehydration. This can be achieved by matching fluid consumption to sweat loss. As discussed previously, the drive to drink during exercise may be delayed until an individual is approximately 2% dehydrated [50] (2% body weight loss), and *ad libitum* water intake results in an incomplete fluid replacement [20]. This indicates that unless forced drinking occurs some degree of dehydration will result.

2.4.1 Exercise performance and dehydration

The deleterious effects of dehydration can be seen in body water losses as low as 1% of body weight and are progressive throughout all levels of fluid deficiency [44,43,86]. Fluid deficits as low as 1.8% of body mass have been shown to significantly impair performance of high-intensity exercise [44,87]. Based on the changes to both the cardiovascular and thermoregulatory systems during dehydration, it can be assumed that exercise performance particularly endurance performance is impaired. Research has been conducted that shows a negative influence on aerobic activity performance during moderate to severe levels of dehydration. The extent of impairment appears to be related to the magnitude of fluid deficit.

2.4.1.1 Physical work capacity

Sawka and Pandolf reviewed the research [17] in relation to percentage dehydrated and the effect this has on exercise performance. Results indicate that physical work capacity during aerobic exercise in neutral climates

decreased when dehydrated even by levels as low as 1% and decreased further through larger fluid losses. Greater decreases in performance were incurred in hotter environments when compared to the same level of dehydration in a temperate environment, indicating additive effects of thermal strain and dehydration. Armstrong *et al* [86] reported a 3.3% increase in the time-recorded for a 1500 metre run at a body water deficit of 1.9%. While a 3% increase in time does not seem a significant amount over a distance of 1500 metres, a race of short duration, it could be the difference between winning and losing. In longer races, the increase in time, recorded due to even low levels of hypohydration (1.6% loss of BM) was found to be significant. Other researchers have observed even greater decrements in time to fatigue. At a level of 1.8% hypohydrated cyclists performing maximally had a 31% decrease in time to fatigue under hot conditions compared to those not hypohydrated [44]. The variances in performance decrement found in these studies are most likely due to the methods used to obtain a state of hypohydration in the subjects. The running trial utilised diuretics, while the cycling trial dehydrated subjects by exercising them at 70% $VO_{2\ max}$ prior to the high-intensity exercise session. The accumulated fatigue from the dehydrating period and the high-intensity bout in the cycling trial may have contributed to the large decrement in time to fatigue.

It has been observed that in thermoneutral environments fluid ingestion resulting in a reduced percentage body mass loss does not result in enhanced exercise performance during a 1-hr cycle trial [46,47]. It is possible that in the McConell trial [47] the level of participant hypohydration (1.9%) when fluid was not ingested was not a limiting factor on cycling speed. It is also likely that the very small number of subjects in each group (n = 3) would contribute to the lack of significant differences in physiological and performance results between the hydrated and hypohydrated groups. The trial conducted by Backx [46] was well designed and had a greater number of subjects, (n = 8) each completing four cycling time trials on four separate occasions under the

same environmental conditions. The participants were randomly selected to be in one of three groups at each trial, therefore each group has the potential to have 10 subject results, however this is not stated in the literature. These groups were divided into different drinking regimes, and consumed a bolus of 6 ml/kg^{-1} BM of fluid containing 6.4 g of CHO and 0.05 g sodium per 100 ml, followed by either 900ml (HF), 450ml (MF) or 120ml (LF) of fluid over the next 1-hr of cycling. Each group consumed the same amount of carbohydrate, independent of fluid volume. As there was no significant difference in performance between the three groups it was concluded that '*when a pre-exercise CHO bolus is consumed, there is no effect of subsequent consumption of different volumes of CHO beverages when trained cyclists undertake a 1-h performance task under thermoneutral conditions*'. The literature does not state the fluid deficit expressed as a percentage, but as the fluid deficit expressed as grams is available, the percentage can be estimated by using the mean preliminary body mass measurement of 77kg. The estimated percent of initial body mass loss in the three groups are HF 0.7%, MF 1.3% and LF 1.7%. As in the McConell study [47], it could be that a fluid deficit of 1.7% is not a limiting factor in a 1-hr cycling time trial performance. Conclusive evidence that fluid ingestion during a 1-hr cycling trial increases performance does not exist, mainly due to conflicting results in the literature. These inconsistent results are due to small subject numbers and variances in experimental models, as different fluid types (CHO composition), drinking regimes and environmental conditions are used.

2.4.1.2 Aerobic power

Similar to physical work capacity, declines in maximal aerobic power occur because of hypohydration, however these performance decrements are apparent only at higher levels of fluid deficit [17]. In temperate climates maximal aerobic power was not reduced until 3% or more body weight was lost due to dehydration [86], and when fluid deficits greater than 3% loss in body weight occurred greater reductions in aerobic power were seen [87]. As

with work capacity, reduction in maximal aerobic power occurred at lower levels of fluid deficit (2%) in hot environments.

2.4.1.3 Speed and sprint performance

Recent research in regards to the role fluid ingestion has on exercise performance indicates that total fluid replacement during a 1 hour self pacing cycling trial has no impact on distance covered nor on core temperature in moderate, warm and hot conditions [88] possibly due to the moderate levels of hypohydration of the subjects (< 2%). Alternatively during a sub-maximal intensity cycling trial [89] of longer duration (2 hours) rectal temperature and heart rates were elevated, and plasma volume decreased in dehydrated subjects during the last 60 minutes. Upon completion of the 2 hours, a sprint to exhaustion was conducted. The time to exhaustion was almost twice as long in the hydrated group (328 seconds) when compared to the hypohydrated group (171 seconds). A similar study [45], and one perhaps more relevant to the type of exercise undertaken during many team sports, had subjects performing 50 minutes of cycling at 80% VO_2 max, this was followed by a 'sprint to the finish' in which they completed a finite amount of work as fast as possible. Performance improved by 6% when fluid intake replaced 80% of fluid loses (1330ml) compared to when the volume of fluid ingested was low (200ml). These studies indicate that sprint performance is reduced when exercise induced hypohydration occurs.

While most research has been conducted observing cyclists during prolonged sub-maximal exercise or high-intensity exercise, it is expected that the effects of dehydration on intermittent high-intensity exercise will also result in reduced exercise performance.

2.4.1.4 Skills related to team sports

Many team sports involve intermittent periods of high intensity exercise. A trial on intermittent running, using a maximal anaerobic running test (MART) was conducted to determine if hypohydration would decrease performance

[90]. Eleven subjects performed 20 sprints with 100-second rest periods between the sprints. Time to complete the MART was significantly reduced in the hypohydrated group. However hypohydrated subjects were dehydrated prior to the trial by the use of sauna, which is not the case during team sport. Exercise induced hypohydration has been shown to have a detrimental effect on skilled motor performance in well-trained subjects in cricket [91]. The negative effect on performance observed in dehydrated cricketers has also been seen in soccer players. After an intermittent high-intensity shuttle running exercise for 90 minutes, trained soccer players were shown to have a 5% impaired performance in a skill test when fluid was withheld [92]. Differences between the fluid ingestion and fluid abstaining groups included higher mean heart rate, perceived exertion, serum aldosterone, osmolality, sodium and cortisol responses when fluid was withheld.

Alternatively, research on a simulated basketball game showed participants to have no significant reduction in capacity to perform physical tasks when dehydrated to fluid deficits of 2% body mass [64]. However, there did exist a trend towards an increased heart rate, reduced performance over a 30 second sprint and greater inaccuracy in goal shooting. The non-significant reduced goal shooting accuracy observed was calculated to have a possible 6-point deficit during a game, and thus could easily result in the difference between winning and losing. This trial had a balanced cross-over design, and simulated two basketball games for each participant, with a period of exercise lasting 40 minutes. While it was well designed it is likely the small number of subjects (n = 10) will have caused the changes in performance results to be non-significant. The participants began the trial euhydrated and the short duration of exercise will have resulted in players being dehydrated for a short period of time. The short time spent in a moderately dehydrated state may have contributed also to the lack of significant performance impairment. Although the decreases in 30-second sprint and goal-shooting performance were not

significant, this trial does indicate that fluid restriction during high intensity, moderate duration exercise may be detrimental to team sport performance.

2.4.1.5 Strength and power

The effect of dehydration on anaerobic power performance is less clear as most of the research has been conducted on athletes who reduce weight quickly in order to make it into a given weight class. These athletes primarily are involved in short-duration high-intensity explosive exercise, as seen in power lifters, wrestlers and gymnasts. There is little evidence to indicate hypohydration of varying levels adversely effects performance when the duration of exercise is less than 40 seconds. A study by Viitasalo and colleagues [93] showed a 7.8% reduction in strength, as measured by force production and vertical jumping height, when athletes were hypohydrated by 3.4% of body weight. In direct contrast a similar study [94] found that at a 3.8% loss of body weight due to hypohydration, subjects had no reduction in strength. However, many of the sports mentioned above have a longer duration than 40 seconds. In one study it was shown that wrestlers hypohydrating to 6% of body mass prior to a tournament displayed a significant reduction in power as the tournament progressed [95]. Much less is known about the effect of exercise-induced hypohydration on strength and power performance in sports consisting of high-intensity intermittent exercise as often executed in team sports. The study mentioned above involving basketball players [64], indicates a trend towards anaerobic performance being impaired with a moderate level of dehydration (1.9%).

2.4.1.6 Physical performance

While dehydration has long been ascribed as having a major role in reduced exercise performance, especially when performed in the heat, research is conflicting in relation to aerobic capacity, endurance, speed, intermittent sprint performance, strength and power and skill performance. It appears different thresholds of fluid deficit exist in relation to these separate measures

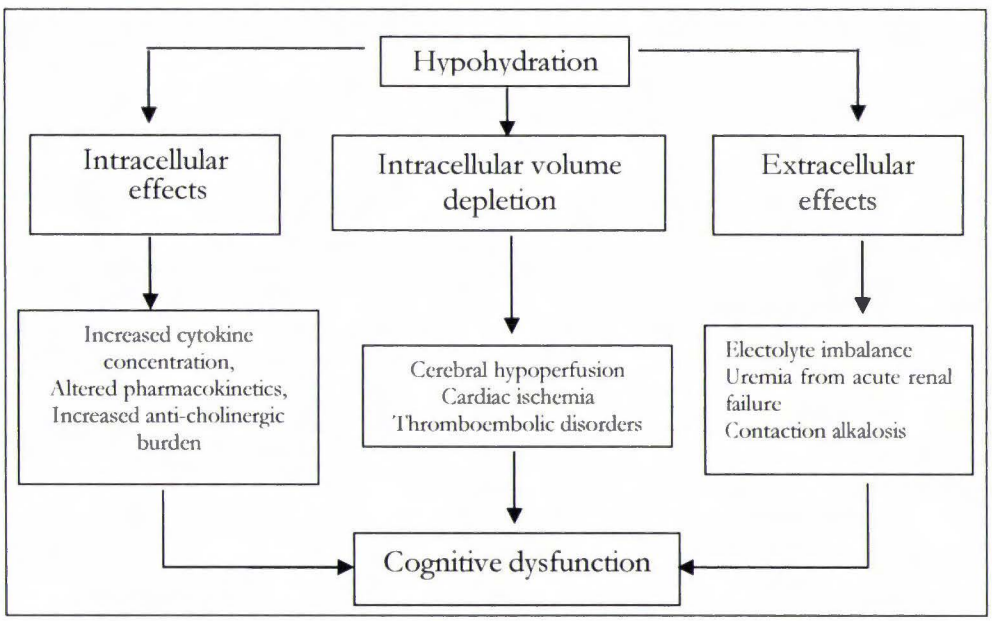
of exercise performance. Physical work capacity appears to be inversely related to the percentage dehydrated from as little as 1%, and environmental heat stress further exacerbates this impaired performance. In relation to maximal aerobic power, a critical water deficit of approximately 3% may exist [86]; this level could be lower when environmental heat stress is high. While performance in skill tests appear to be reduced when fluid is not ingested, critical levels cannot be established from the current literature, due to few well-designed controlled trials and a wide variety of experimental models. Often athletes are dehydrated using different methods, for example diuretics, sauna, or sweating due to exercise, and each of these methods may have an impact on the performance of the exercise to follow. While the results obtained from clinical trials may be significant and meaningful for that trial, translating results and conclusions into other forms of exercise, environmental conditions, methods of dehydration, duration of exercise and volumes and types of fluid ingested would not be accurate. However research suggests that even at moderate levels of hypohydration, in which athletes may not perceive thirst, performance in activities similar to that involved with team sports is likely to be impaired even in thermoneutral environments. No conclusive evidence exists indicating that dehydration adversely effects power and strength performance when periods of high-intensity exercise are dispersed among periods of prolonged sub-maximal exercise, but this is more due to the lack of research than conflicting results. The magnitude of performance impairment is related to the degree of exercise-induced hypohydration, and research has shown that even at low levels of dehydration performance is negatively affected, particularly in hot environments.

2.4.2 Cognitive function and hypohydration

When body mass deficits of as little as 1-2%, caused by fluid restriction occur, individuals have reported a decline in self-rated alertness and ability to concentrate [96]. Heat acclimatised subjects were reported to have significant and progressive reduction in cognitive function when hypohydrated at a fluid

loss of 2% of body mass and above [97]. The pathophysiology of this reduced cognitive function is illustrated in figure 2-7. Hypohydration at low levels has been shown to reduce mental performance as assessed by decision-making and reaction time tests [97]. Short- and long-term memory, visuospatial function, perceptive discrimination and reaction time have been shown to be impaired in hypohydrated subjects [98,99].

Figure 2-7. Pathophysiology of cognitive dysfunction in moderate and severe hypohydration [100].



The psychological effects of hypohydration were examined in a study involving subjects cycling at a low-intensity for 2.5 hours [101]. During a 3-hour recovery period fluid was either withheld or available. There was no significant difference in choice reaction time (CRT) tests conducted during the recovery period, in the two trials. But the lack of fluid during recovery had an effect on several sub-scales of a 'Perception of Mood' questionnaire.

There are difficulties when interpreting research on hypohydration, as the methods used to induce a water deficit usually include heat exposure, exercise or both. All of which will induce elevations of core temperature, which will in itself effect exercise performance. Therefore it is difficult to assess the individual contributions to reduced exercise performance of hyperthermia and hypohydration.

2.4.3 Hyperthermia and performance

The fluid deficit that occurs during exercise when fluid is not replaced, may cause an increase in the rate of heat storage [102]. For every litre of fluid lost from the body, core temperature can rise by 0.3°C, cardiac output can decline by 1L/min and heart rate can rise by 8 bpm [103]. Muscle tissue also exhibits increases in temperature, glycogen degradation and lactate levels [102,104].

The influence dehydration has on elevating core temperature has been questioned, particularly in relation to endurance activities [105]. However, it has been demonstrated that under both hot (34°C) [106] and moderate (21°C) [107] conditions, the rise in core temperature during exercise has been attenuated by ingestion of fluids. The percentage loss in body weight an individual is dehydrated by is strongly correlated to the rise in oesophageal temperature under hot conditions. One study indicated that with each 1% increase in dehydration, the oesophageal temperature rose by 0.21°C [108].

McDougal and colleagues [109] found that during hyperthermic conditions the tolerance to exercise was greatly reduced (45 mins) when compared to normothermic conditions (75 mins). Research undertaken by other parties has shown similar results [110]. The assumption that hyperthermia impairs exercise performance is based on studies observing increased exercise time to fatigue and reduced performance of endurance exercise when temperatures are cooler or when subjects are cooled during or prior to exercise [110,111,112]. A study investigating the effect of climatic heat stress on intermittent exercise performance [113] involved subjects performing two

trials in a counterbalanced design. It was found that anaerobic capacity, expressed as oxygen equivalents, was significantly reduced in the hot, humid trial when compared to the cool trial. Rectal temperature, skin temperature and weight loss were also significantly higher in the hot trial.

It has been observed that hyperhydrated individuals may not have different rates of sweating when compared to euhydrated ones, but sweating efficiency could be greater [114]. As the specific heat of water is higher than that of body tissue, it is possible that this higher tolerance to an elevated core temperature, and improved exercise performance is due to a greater capacity to store heat in well-hydrated individuals rather than superior heat dissipation. This hypothesis is supported by research from González-Alonso and colleagues [115] who concluded from their research on endurance athletes that hypohydrated individuals became exhausted at a lower core temperature when compared to euhydrated subjects. A review of the literature by Kay and Marino [116] indicates that fluid intake of a sufficient volume and a cool temperature may act as a heat sink, providing a mechanism for heat storage that attenuate rises in core temperature.

The theory of a critical core temperature limiting exercise performance and endurance has been supported in recent studies and appears to be approximately 40°C [3]. It has been observed that an elevated core temperature limits endurance performance in hot conditions and that time to exhaustion is inversely related to initial body temperature and directly related to the rate of heat storage [104].

High aerobic fitness, heat acclimatisation and pre-cooling can prolong the time to exhaustion during sub-maximal exercise in the heat as they result in a lower initial core temperature [117,118], lower heart rate [119], and an increase in the volume of fluid ingested. These have been shown also to increase the level of 'critical' core temperature [115].

There has been speculation that at a core temperature of about 40°C there may be a negative effect on the motor control centres of the brain [120]. This would result in impairment of motor coordination, reduction in motor drive and increased perception of effort, which typically occur in the latter stages of exercise in the heat [100]. A study investigating ambient temperature and the effect it has on psychomotor performance [121] produced interesting results. Researchers found that at 22°C CRT decreased gradually at about 217 W and then rapidly increased above the pre-exercise value. At 33°C psychomotor performance remained steady until 189 W when it increased rapidly. It was concluded that short-term exposure to dry heat diminishes CRT at rest but not during heavy exercise, and in fact CRT improved when exercising.

The underlying mechanisms involved with hyperthermic induced fatigue during exercise in the heat are not well understood, and ongoing research is attempting to ascertain the processes involved. Hypohydration appears to contribute to the advancement of fatigue during hyperthermia, therefore fluid ingestion prior to and during exercise may attenuate the rise in body temperature due to exercise and compounded by heat stress. Heat acclimatisation, physical fitness, fluid ingestion and pre-cooling may prolong the time to exhaustion during exercise, as they can prolong the time to reach a critical core temperature. This occurs by either beginning exercise with a lower initial core temperature, or increasing the capacity to store or disperse heat.

2.5 INTERMITTENT EXERCISE

Intermittent exercise is the type undertaken during most team sports. These include basketball, netball, cricket, hockey, softball and the football codes, soccer, American football, Australian rules, rugby league and rugby union. Individual sports such as tennis, badminton and surfing are also of the intermittent high-intensity type. However there are obvious difference

between these team sports, due to length of playing time, time between high intensity episodes, environmental conditions, clothing worn, positional variances, impact, strength, agility, speed, and the number of opportunities to drink during play. Burke and Hawley have reviewed fluid loss, hydration practices and guidelines for a variety of team sports [122]. The football codes are the most similar in nature, however vast differences still exist. For example, soccer does not involve the physical impact of rugby union and rugby league teams have fewer restrictions on fluid availability as trainers are allowed access to the players during play.

There is very little literature with regards to dehydration and the influence it has on exercise performance during intermittent short burst, high intensity exercise, for a prolonged length of time (> 60 minutes). Of the types of intermittent exercise mentioned, soccer is probably the most studied. It has been observed that fluid loss of soccer and basketball players can equal that of marathon runners [123], and that dehydration as a consequence of this type of prolonged submaximal exercise may reduce exercise performance.

2.6 RUGBY UNION

International rugby union matches consist of two forty minute halves with a maximum of 10 minutes break at half time. During the game normally three members of the support staff are able to access the field, this is usually the doctor, physiotherapist and trainer. While also attending to injuries, these staff members may pass water bottles to players. Usually fluid is passed to players in squeeze bottles with a choice of either a CHO-electrolyte drink or water, individual player bottles are rarely used. The three staff members are authorised to move onto the field during stoppages in play due to injury, or while a conversion is being kicked. Law 5.7 (g) as stated by the International Rugby Board (IRB) [124] reads '*When weather conditions are exceptionally hot and/or humid, the referee, at his discretion, will be permitted to allow one water break in*

each half. This water break should be no longer than one minute. Time lost should be added on at the end of each half. The water break should normally be taken after a score or when the ball is out of play near the half way line'.

2.6.1 Exercise physiology in a professional Rugby Union team

Rugby union forwards have a different body composition to backs [125], they are generally heavier, taller, (table 2-5) and have a greater percentage adipose tissue. They have also been shown to have a higher sweat rate [29] (appendix B).

Table 2-5. Average values for rugby union players [125], for body mass, height and somatotype.

	Body mass, kg	Height, cm	Somatotype* (1995-1999)		
			Endo	Meso	Ecto
Forwards 1975-1999	103.7	184	3.7	7.5	1.0
Backs 1975-1999	84.7	179	2.4	6.8	1.5
All Players 1975-1999	95.1	183	3.2	7.2	1.2

Deutsch and colleagues [126] analysed the physical demands of rugby union by dividing player positions into four groups, props and locks, back row forwards, inside backs and outside backs. Both forward groups (props &

* Somatotype is a body shape classification system. It breaks the body into three components; a measure of endomorphy, mesomorphy and ectomorphy. For an illustration and further description of this see appendix G. A more detailed description can be found in Carter and Honeyman Heath (1990)[197].

locks and back row forwards) spent more time in high exertion activities (85-95%HR_{max}) than backs. Outside backs spent the most time in low exertion activities <75%HR_{max}. Table 2-6 summarises this data showing the percentage of time spent in each exertion zone.

Table 2-6. Percentage of the four positional groups spent in three exertion zones, expressed as a percentage of HR_{max}.[126]

Position	High Exertion 85-95%HRmax	Moderate Exertion 75-84%HR_{max}	Low Exertion <75%HR_{max}
Props & Locks	58.4%	22.6%	5.8%
Back Row Forwards	56.2%	19.8%	5.6%
Inside Backs	40.5%	36.5%	no result
Outside Backs	33.9%	36.5%	20.1%

A later study by Doutreloux and colleagues [127] backs up the Deutsch research. This study investigated the heart rates (HR) of different positional groups during rugby union matches and found forwards had a high HR more often than backs.

Motion analysis data [126] showed that outside backs covered a greater total distance (5750 metres) than either props and locks (4400m) or back row forwards (4080m). Types of movements were classified as standing, walking, jogging, cruising, sprinting, utility, rucking/mauling and scrummaging. Total distance covered during walking, utility movements and sprinting is shown in table 2-7. The backs, particularly the outside backs, covered a far greater distance sprinting than the forwards. Forwards maintained a higher level of

exertion than backs, due to more constant motion involving fairly static high-intensity activities.

This study on elite colts (under-19) clearly illustrates that there is a difference between player positions in relation to motion and intensity of activity.

Table 2-7. Summary of distance covered for each position group, in each of three classifications of movement. [126]

Position	Walking	Utility Movements	Sprinting
Props & Locks	1000 m	106 m	72 m
Back Row Forwards	991 m	154 m	94 m
Inside Backs	1740 m	417 m	208 m
Outside Backs	1780 m	475 m	340 m

It was concluded from a study on aerobic exercise physiology in an elite union team [128], that backs had a higher peak oxygen uptake per kilogram than forwards, even though results were not significantly different in cardiopulmonary exercise test duration, anaerobic metabolism and time taken for a 3 km run. It was assumed in this study that the results were due to variations in body structure, backs being the shorter, lighter and having a lower percentage body fat of the two positional groups.

In rugby union forward players travel less distance, particularly while sprinting but spend a greater proportion of their time performing high-intensity activity than backs.

2.6.2 Previous research on Rugby Union players

Very few studies exist that investigate the hydration status in Rugby Union players. Goodman and colleagues [12] examined the effect of water intake on body core temperature during rugby matches in an observational study. They found that there was a mean fluid loss of 1.4 to 1.6 % of initial body mass over a range of climates. While it was not clear what the minimum body mass change was, the maximum was 2.9%. This study was testing the hypothesis developed from a previous study [11] that fluid ingestion during a match would decrease end core temperature. Results showed there were no significant correlations between water deficit expressed as a percentage and final rectal temperature, and the volume of fluid ingested per kg initial body mass and final rectal temperature.

Subjects participated in three matches being played in what was described as thermoneutral environments. However, while the range of ambient temperature was small, between 18 and 23°C and would be considered mild, relative humidity was not mild in all games. One match was played when humidity was 18% while the other two were approximately 80%. The impact of varying humidity on fluid deficit between the three games was not accounted for in this study. The range of wind speed was 0-3.5 m/s (0-13km/hr).

The amount of fluid ingested during the matches was between 200 ml and 1000 ml, with a mean of 751 ml over all three matches. The final rectal temperatures and final sweat losses were very similar between the 1985 study and the previous 1981 study. Body temperature was lower in the fluid intake trial by 0.24°C, and this decrease in mean temperature was in agreement with a previous study, showing a loss in fluid of 1 litre can cause a rise in core temperature of 0.3°C [103], however differences between the two mean rectal temperature were not significant. Results may have been non-significant due to small sample sizes (n = 11) or because the moderate volume of volume

ingested (mean 751ml) and inadequate replacement of fluid losses did not have a large effect on core temperature. Final water deficit, expressed as a percentage and therefore the level of dehydration, was significantly lower in the fluid study [12] (table 2-8).

Table 2-8. Comparison of rectal temp, sweat loss and water deficit (mean ± standard error of the mean) in the 1981 [11] and 1985 study [12].

	1981 study	**1985 study**
Final rectal temperature, °C	39.41 ± 0.14	39.17 ± 0.06
Final sweat loss, L	2.10 ± 0.18	2.05 ± 0.09
Final water deficit, %	2.52 ± 0.18	1.51 ± 0.10

The mean final rectal temperature in the fluid trial was (± standard error of the mean) 39.17 ± 0.06, and may be high enough to have impaired performance. The researchers state that with the exception of one player, rectal temperatures are higher in rugby players than marathon runners, at all levels of hypohydration. There was a large range of fluid intake rates, the minimum was calculated to be 150ml/hr and the maximum was 750ml/hr. It would be interesting to see the breakdown of mean fluid intakes over each game, to determine if the volume ingested was higher when humidity was high.

As rectal temperatures between the two studies did not significantly differ, it was concluded that in a thermoneutral environment, the ingestion of up to one litre of fluid has no significant beneficial effect on thermoregulation during rugby. However this conclusion is flawed due to the limitations and design of a study of this kind. Data collected from one group, cannot be

compared to data collected from another four years prior. The researchers, have stated the conditions were similar between the two studies, but unless the participants, rate of exertion, skill of the opposition and difficulty of the games were the same or similar, an accurate comparison cannot be made. The similar rectal temperatures between the data taken from the dehydrated group in 1981 and the hydrated group in 1985 could simply be explained by a higher rate of exertion during the games in 1985. The hydrated group in 1985 may have had a higher mean rectal temperature, or a higher rate of withdrawal from the games due to fatigue had they not ingested fluid. A well-designed study, where meaningful conclusions could be drawn, would have involved the same group of players, playing the same opposition in similar environmental conditions, with fluid ingested in one game and excluded in the other.

Nonetheless, these two studies do highlight that rugby union players are hyperthermic and many have a body water deficit above 2%. This body weight loss, and therefore level of dehydration can be reduced when fluid is ingested in moderate volumes.

Similar research into the hydration status of Rugby League players during spring [129], found that players were losing fluid in excess of 2% body weight during a match when fluid was available *ad libitum* prior to a match and during half time. Ingestion of fluid (mean was 810 ml) however kept the mean percentage dehydrated low at 1.21%. Individual players were dehydrated at the end of a match in excess of 2% even when fluid was consumed.

2.6.3 Heat related illnesses and weight changes

A study on weight change during American football training [130] highlights the difference between weight change averages in a group treated for heat related injuries (HRI) and a group of non-symptomatic players from the same team.

Table 2-9. Percentage body water loss in groups with heat related illnesses (HRI) and no heat related illnesses (HRI) [130].

	Body water deficit, %
Non- HRI group	1.83 %
HRI group	3.58 %

Both HRI and non-HRI groups showed significant difference between pre- and post-match weights. The group suffering from HRI had a much greater body water deficit than the group without illness (table 2-9). This study concluded that the relative weight loss contributing to HRI may be lower than previously suggested in the literature, and that steps be taken based on a threshold relative weight loss to prevent incidences of HRI.

2.7 HYDRATION GUIDELINES AND PRACTICES DURING EXERCISE

The guidelines prepared for nutritional requirements in relation to athletes and sportspeople are often based on studies involving solo sports. This is important to consider when hydration procedures are formed for players involved in any team sport. While the guidelines outlined below for fluid intake pre-, post- and during exercise can be a useful tool, the best strategy will be an individual one, based on sweat rates in different conditions and tolerance and limitations to fluid ingestion. Recommendations for fluid intakes aim to minimise total body water loss. Despite these guidelines voluntary dehydration is still common. There are some real and perceived issues in regards to fluid intake during exercise that may prevent an athlete from drinking. Ingestion of a large volume of fluid, particularly water, has

been associated with gastrointestinal discomfort and hyponatraemia and therefore these issues may limit fluid ingestion.

2.7.1 Pre-exercise hydration

Athletes should begin each match or event well hydrated, particularly under hot or humid conditions and when the event is prolonged. Individuals should ensure they have replaced the fluid loss since the last training or competitive session, and have consumed generous amounts of fluid in the 24 hours leading up to an event [19]. The ACSM also recommends pre-hydrating by ingesting 400 – 600 ml of fluid in the two to three hours preceding an event. This will ensure individuals begin exercise euhydrated, and will allow enough time for excess fluid to be excreted. The practice of maintaining a fluid bolus in the stomach will aid gastric emptying of any further fluid ingested, thus optimising fluid delivery and absorption during exercise.

2.7.1.1 Hyperhydration

As maintenance of fluid balance is crucial during exercise performed in the heat, there has been research in relation to hyperhydration (or increasing body water content above normal levels) before exercise, and the influence it has on hydration status. The theory is based on the observation that a decline in body water increases cardiovascular and heat strain during exercise by reducing blood volume and increasing blood osmolality. Studies into the influence of an expanded blood volume [131,132,133] have reported a reduced cardiovascular strain during exercise, but contrasting results in relation to heat dissipation and exercise performance. Research into attenuated plasma hyperosmolality [83,134] during exercise heat stress has shown improved heat dissipation but has not yet addressed exercise performance. A study on elite young soccer players showed that additional water intake (4.6 litres per day for a week compared to 2.7 litres per day for a week) in heat-acclimatised players increased body water reserves and improved temperature regulation during a soccer match [135]. Both before

and after the game players were required to perform seven repetitions of a soccer specific test. In both groups the time to perform these tests improved after the match, however there was no difference in performance time between the two groups.

Current research is investigating the effectiveness of glycerol as a potential hyperhydrating agent. Glycerol is a three-carbon alcohol, and as it provides the backbone to triglyceride molecules, is released during lipolysis. It is evenly distributed in all fluid compartments and exerts an osmotic pressure [136]. When glycerol is ingested with a large volume of fluid the osmotic pressure it exerts when rapidly absorbed, enhances retention of the fluid. It appears hyperhydration by ingestion of glycerol 2.5 hours before exercise may prevent hypovolaemia, and during a cycle test in warm condition this may reduce some signs of fatigue in relation to performance [137]. Glycerol may be of importance when taken with a fluid bolus before an event to maximise the retention of the fluid ingested. This may be useful when exercise will challenge fluid balance, either because of the climatic conditions, or when the opportunities to drink will be few. Recent research indicates some performance benefit may be obtained during endurance exercise when hyperhydration with glycerol occurs. Endurance time was shown to increase when participants were hyperhydrated with glycerol and water, compared to just water [138] and when subjects were hyperhydrated with a glycerol/carbohydrate sports drink compared to a carbohydrate sports drink [139]. However, in both these trials [138,139] no difference in heart rate, metabolic rate, sweat rate or core temperature was observed between the groups. Inconsistencies in the literature as reviewed extensively by Latzka and Sawka [140] can be mostly ascribed to different study methodologies, particularly timing of hyperhydration before exercise begins, and state of hydration in the control group.

2.7.2 Hydration during exercise

In the ACSM position statement it is recommended that athletes should look to consume '150 to 350 ml of fluid every 15 to 20 minutes' (450 to 1400 ml/hr) [19]. It is also stated by the ACSM that if an athlete cannot tolerate the quantities of fluid required to match fluid loss, then the 'maximal amounts tolerated should be ingested'. In the International Marathon Medical Directors Association (IMMDA) advisory statement [141] Noakes has interpreted this to mean that athletes should be encouraged to drink 'as much as possible' and has stated that this can lead to excessive fluid intake particularly in slower marathon runners. The recommendations of the IMMDA are that runners should aim to drink *ad libitum* between 400 to 800 ml per hour, with the higher rates during hot conditions particularly for the faster heavier runners and the lower rates in cooler conditions for the slower runners and walkers [141]. These recommendations are based on the actual rates of fluid intake during running races, which seldom exceed 500 ml per hour [142]. The conservative recommendations also take into consideration the rate of fluid ingestion of runners developing hyponatraemia, which can be as high as 1500 ml per hour [143,144].

Runners and walkers who take four or more hours to complete a marathon will have both lower rates of heat production and fluid loss rates, they will also be able to tolerate higher volumes of fluid and have time to ingest more fluid due to the less competitive nature of their race. Because of this they are advised by the IMMDA to not drink more than 800 ml per hour [141], as this could reach volumes of fluid in excess of three litres during the entire event. Noakes also states [141] that an *ad libitum* approach is more effective and safer than the higher maximum rates proposed by the ACSM [19] as long as fluid ingestion rates do not exceed 800 ml/hr. While this is a good recommendation for marathon runners, particularly those whom are not elite athletes, it may not be applicable for other sports where fluid intakes of over 1400 ml/hr (the maximum in the range recommended by the ACSM) have

been observed to have no detrimental effect on the athlete. High rates of fluid ingestion are not unheard of; in a review of voluntary fluid intake during team sports male basketball players had a mean fluid intake of over 1000 ml/hr with some individuals consuming 1.5 to 1.8 litres of fluid per hour [123].

Rates of dehydration can exceed 1800 ml/hr particularly in hot conditions [29]. Maintaining fluid balance under these conditions may be unachievable due to gastric emptying rates, detrimental to exercise performance because of gastrointestinal discomfort, and even unsafe particularly during endurance events [52,137,152,144]. The National Athletic Trainers Association (NATA) position statement [145] concludes that 'fluid replacement should approximate sweat and urine losses and at least maintain hydration at less than 2% body weight reduction'.

It is not advisable to provide absolute statements in regards to fluid recommendations, as individuals will have different hydration requirements, and will respond differently to fluid ingestion rates. However recommendations can provide a base for an individual to trial fluid ingestion strategies and therefore find the best fit for them. It may be important to practise this strategy during training sessions so that it becomes second nature, allowing an athlete to obtain higher rates of fluid ingestion when drinking *ad libitum*.

There seems to be a general consensus in the literature that dehydration should not exceed 2% of body mass loss during exercise in the heat [17,43,46,47]. However Noakes [141] does state that elite marathon runners often lose more than this with no adverse effects. During prolonged events such as a marathon athletes may lose mass through metabolic fuel utilisation and due to the release of water stored with the glycogen that is oxidised during exercise. It has been proposed that a 2 kg weight loss during a marathon may mean only 200 g of fluid was lost [146].

Exercise performance does not seem to be impaired when there is a fluid deficit less than 2% when exercise occurs for less than 90 minutes in a temperate environment. However, a fluid deficit of over 2% in similar conditions has been shown to impair performance [147]. Increased sweat rates when conditions are hot result in fluid deficits of less than 2% occurring within 60 minutes [148] and in these conditions exercise performance impairment has been seen at levels of 2% [45] and 1.8% [44] dehydrated. In events under 60 minutes large quantities of fluid will not be absorbed in a short time period, meaning there will be little or no significant benefit to exercise performance. Under these conditions training sessions should be utilised to form a fluid ingestion strategy suitable for the individual so that drinking *ad libitum*, will involve small amounts of fluid are consumed at regular intervals when possible.

It is advised that fluid ingestion recommendations be guidelines only and athletes should attempt to replace, without exceeding, any fluid loss that occurred during exercise. Drinking strategies can be developed and practised during training sessions to ensure gastrointestinal discomfort does not occur while optimising ingestion volumes. Drinking a fluid bolus an hour prior to exercise of 300 - 600 ml, and then topping this up before and during exercise by drinking small amounts (100 - 300 ml) every 10 to 15 minutes will increase gastric emptying rate and therefore reduce this limitation to the drinking rate. During endurance events the lower volumes stated above apply to slower athletes in mild conditions and the higher drinking rates apply to faster heavier runners, with rates not to exceed 800ml/hr. When sweat rates are high due to exercise intensity, hot conditions or other individual factors, maintaining fluid balance may not be possible. In this instance athletes should aim to keep fluid deficit below 2% in mild conditions where exercise lasts 90 minutes or more, and less than 1.8% when conditions are hot and exercise lasts more than 60 minutes. An athlete should never drink more fluid than has been lost during an event.

2.7.3 Post-exercise rehydration

An important part of recovery in an athlete is post-event hydration. In many cases [20,123] athletes do not consume enough fluid during exercise to balance fluid losses. When high levels of dehydration transpire, or the next exercise session is in the following 24 hours, rehydration strategies will be required to ensure fluid is replaced.

While water is a sufficient fluid replacement beverage for exercise with duration of one hour or less, a sports beverage with a CHO concentration of less than 8% will enhance the rate of rehydration [149]. The presence of CHO can improve palatability of a drink and therefore increase the volume of fluid ingested. CHO supplementation will also assist replacement of glycogen stores. Sodium will further enhance restoration of fluid balance [150]. Carbohydrate and sodium supplementation will be discussed further in section 2.8.

In a study investigating the impact of a high rate of carbohydrate-electrolyte solution (CES) ingestion on plasma volume [151], it was seen that when CES ingestion rate was high (120% of body water loss over 3 hours) a higher rate of plasma volume and fluid balance restoration was observed when compared to a low rate of CES ingestion (120% body water loss over 5 hours). This higher rate of fluid balance restoration occurred despite a temporary large urine output.

Glycerol when used in an oral rehydrating solution (ORS) after a first exercise session has been shown to improve time to exhaustion in a second exercise session, when compared to water [152]. There is very little research in relation to the use of glycerol as a component in ORS's, and it may have benefits enhancing the rehydration rate between exercise events when time is a factor.

2.7.4 Issues relating to drinking during exercise

If the fluid ingestion rate matches sweating rate, the first potential limitation to maintaining fluid balance during exercise is the rate of gastric emptying. Maintenance of fluid balance in the body is difficult if not impossible when sweat rates exceed 1.5 L/hr. An attempt to match high water losses with a high fluid intake could result in gastrointestinal bloating and discomfort [52, 144,153] a common complaint in long distance running. However, a recent study has suggested that gastrointestinal discomfort during endurance running may not be related to fluid or food intake but instead to metabolic disturbances [74]. The same study observed a higher incidence in 'mental status change' in runners who ingested a greater volume of fluid. This group reported dizziness, inability to concentrate and confusion, symptoms associated with hyponatraemia.

Hyponatraemia can develop either as a result of prolonged heavy sweating with a failure to replace sodium, or when excess water is retained in the body [37], often caused by excessive water intake. Although endurance athletes are more likely to suffer from dehydration than from overhydration, the latter is not uncommon. In fact some of the symptoms are very similar to heat exhaustion, fatigue, headache, apathy and nausea, and the individual may assume dehydration and increase fluid intake escalating the problem.

To date at least seven fatalities and more than 250 cases of hyponatraemic encephalopathy have been described in medical literature [72,73]. This has lead to the adoption of updated fluid ingestion guidelines by USA Track and Field [141] stating athletes should ingest between 400 ml and 800 ml of fluid per hour while exercising, and increase sodium intake. All reported cases of hyponatraemic encephalopathy have been either ultra triathlon or prolonged marathon events lasting in excess of eight hours. However, there has been a case of iatrogenic acute hyponatraemia in a football player due to administration of hypotonic fluids for muscle cramps [154].

2.8 HYDRATION BEVERAGES

Fatigue resulting from prolonged exercise is associated with hypoglycaemia [155], muscle glycogen depletion [156], metabolite depletion [157], metabolic depletion [148] and the effects of dehydration [103,158], one of which can be hyperthermia. Thus, the key objectives of sports fluid formulation should be to combat these physiological effects of exercise.

2.8.1 Carbohydrate supplementation

Prolonged exercise at 65-70% of maximum oxygen uptake depletes muscle and liver glycogen stores, with the rate of depletion having a direct effect on the time to exhaustion [159]. Exercise even under moderate conditions (20°C) has been shown to utilise muscle glycogen stores at a faster rate than in cooler conditions [104]. This leads to the hypothesis that during prolonged sub-maximal exercise in the heat CHO supplementation will improve exercise capacity and performance.

While the supplementation of CHO in fluid during prolonged exercise has been shown to have a positive effect on exercise performance [45,160,161,162,163] there are conflicting results in studies investigating the ergogenic effect of CHO during high-intensity intermittent exercise. Few studies have investigated the effect CHO ingestion on this type of exercise; those that have indicate there is no or little performance enhancement [164,165,166]. However, CHO ingestion was shown to have an ergogenic effect on intense exercise of one hour [167]. Conflicting findings make it impossible to draw any conclusions about the efficacy of carbohydrate ingestion in a hot or temperate environment in relation to intermittent exercise, and research is ongoing.

Increasing the palatability of a drink by adding CHO has been shown to increase the volume of fluid ingested, however moderate to high concentrations of CHO (> 8%) has been shown to limit gastric emptying and

intestinal absorption [168]. Preserving osmolality is critical to aid fluid replacement when formulating a sports drink. Therefore a need to balance CHO-electrolyte supplementation and hydration exists. The type of CHO utilised in sport drinks is not crucial, however there may be advantages in the use of sugars other than glucose, and there is extensive literature on the topic of CHO type [70].

While the role of CHO supplementation and the effect it has on high intensity intermittent exercise performance is still under contention, the increased palatability and potential for energy replacement of a drink containing CHO make it an attractive and popular ingredient in a sport beverage.

2.8.2 Electrolyte supplementation

Sodium is the major electrolyte lost during sweating, as there is a high concentration of sodium in the extracellular fluids of the body. Low sodium levels have been observed in athletes competing in ultradistance sports events [69,72].

Sodium increases the drive to drink by maintaining plasma osmolality, thereby increasing the amount of fluid consumed [169,170] and reducing the diuresis that can occur when only water is ingested [171,172]. It also aids the retainment of fluid [150] (section 2.7). Sodium supplementation may also prevent hyponatraemia in those individuals who are susceptible.

The improvements seen in fluid volume intakes when sodium is present in a rehydration beverage indicate a requirement for sodium to be ingested during some forms of exercise particularly when exercise is prolonged (longer than 1 hr) [19,148,157,173] and when large amounts of sodium is lost in sweat [148]. Ingestion of sodium as part of a sports drink may be useful in sports consisting of intermittent high-intensity prolonged exercise, particularly when high sweat rates occur. The ACSM states that inclusion of 0.5 to 0.7 g/litre

NaCl during exercise lasting more than 1 hour, may be beneficial [19] as it increases the drive to drink and palatability, thus increasing the volume of fluid ingested. Sodium can be introduced to the post exercise meal by addition of table salt or salty foods.

The optimum concentration and osmolality of a rehydration beverage will depend on the circumstances and sport. High CHO concentrations will delay gastric emptying, and thus reduce absorption of the fluid, however a higher concentration will deliver more CHO. Where the primary need is to supply an energy source during exercise, such as during prolonged activities and endurance events, increasing the sugar content of a drink will deliver more CHO to the cells in the intestinal wall. Figure 2.8 outlines primary concerns and types of hydration beverages suitable for different types of exercise. All athletes should begin exercise in a euhydrated state.

Figure 2-8. Hydration and beverage recommendations for various durations of exercise. Adapted from Maughan (2000) [70].

Non-endurance 0 – 30 minutes

Primary Concern: Minimal interference to exercise.

- Water is sufficient for drinking before and after single events
- Athletes in tournament situations and competing in multiple events need to rehydrate to avoid progressive dehydration over the event. This can be done with a beverage containing a low concentration of CHO (< 8% CHO) to replace energy substrate. Sodium in these events may be required when conditions are hot.

30 – 60 minutes

Primary Concern: Fluid intake and some need for CHO

- Water or CHO containing beverage (< 8% CHO)
- Aim to drink as much as comfortable and practical
- Drinking a bolus of fluid before the event and then topping up by sipping when able will maintain GER and fluid absorption.

Endurance 1 – 3 hours

Primary Concern: Fluid replacement and CHO provision

- CHO containing beverage (< 8%), particularly for longer duration
- If CHO can't be tolerated for entire event alternate with water
- Drinking a bolus of fluid before the event and then topping up by sipping when able will maintain GER
- Aim to consume 30 –60g CHO per hour
- Dilute CHO concentration for exercise in hot environments (4%) and higher (8%) for colder environments
- Inclusion of sodium chloride in beverage could be useful to promote fluid retention and maintain osmotic drive to drink. When conditions are hot and sweat rate is high, sodium will be required in longer duration events

Endurance > 3 hours

Primary Concern: Fluid and CHO and some attention to sodium losses

- Beverage containing CHO (< 8%) and sodium
- Drinking a bolus of fluid before the event and then topping up by sipping when able will maintain GER
- CHO can also be sourced from gels, cola drinks and fruit.
- Change flavours to prevent 'flavour fatigue'
- Aim to drink 30 –60g CHO per hour, however more may be required in the latter stages of an event.

2.9 HYDRATION TESTING OF ATHLETES

Hydration testing of athletes for practical purposes is conducted for two major reasons. In sports where weight classes exist, testing would be utilised to establish if an individual has hypohydrated to lower body weight and drop down a weight group. The second reason would be to monitor hydration status during competition and training for health and safety reasons, and to ensure a fluid deficit is not impairing sport performance.

Tracer methodology gives the best measure of total body water [174] however this is not practical in the field. The methods used in assessing hydration status in athletes include; monitoring body mass, urine analysis and blood analysis. These methods will be discussed further in the following sections.

Variance exists between individuals and between exercise sessions in relation to sweat rates, fluid consumption and fluid absorption. As discussed previously in section 2.3.3 individual sweat rates and fluid losses vary greatly [29] and are influenced by a number of factors. Appendix B highlights the variance of sweat rates in rugby union players during the same match, where the forwards had a much higher sweat rate (2.6 L/hr) when compared to the backs (1.6 L/hr). Differences in environmental conditions will influence sweat loss and fluid intake in the same individual between different exercise sessions. Fluid absorption also varies between individuals and exercise sessions as discussed in section 2.3.5. The fluid requirement of an individual can be determined by fairly simple means once hydration status in varying environmental conditions has been established. Where multiple exercise sessions occur in one day or a period of a few days, it is important to ensure fluid deficits at the end of one session have been replaced by the beginning of another. Hydration testing can assess this. Hydration status can be self-monitored by an athlete, or tested by a medical or support staff member.

Euhydration exists when an individual is in a 'normal' state, that is, neither over-hydrated nor hypohydrated. This normal state means that body weight is stabilised on a day-to-day basis, fluid is being excreted regularly via the urine, total body water is stable, as is extracellular and intracellular water, and there is no irregular blood chemistry. Hydration testing monitors either one or a combination of these factors.

2.9.1 Monitoring body mass

Body weight monitoring, as a means of measuring hydration status, is as simple as weighing on a professional quality scale both prior to – and directly upon completion of – exercise. The change in body mass (ΔBM) can be expressed either in kilograms, or as a percentage of the initial body mass measurement, also referred to as percentage dehydrated.

The scales used to measure body mass must be calibrated before every set of measurements to a known weight. Subjects must wipe off any accumulated sweat from the body and the same clothes should be worn in both pre- and post-exercise measurements, to ensure only body mass is included. Nude weight is preferable as clothing may contain sweat upon completion of exercise and therefore cause the post-exercise measurement to be overstated.

The ΔBM in kilograms is approximately equivalent to the volume of fluid loss in litres. Sweat rate can be calculated from this if the volume of water and food ingested, and volume of urine and faecal matter excreted, between the two weighing sessions is known. The relationship between ΔBM in kilograms and sweat loss is described in section 2.3.4.

If a standard weighing protocol is used, body weight monitoring is a simple and effective means of measuring hydration status. Athletes should aim to never exceed 1% dehydration by following a fluid ingestion plan. However, as suggested earlier this is impossible to maintain when sweat rates are very high. Weight lost during an exercise session should be regained within 24

hours [19], if extreme weight loss has occurred a state of euhydration may take longer to attain.

2.9.2 Urine analysis

Urine colour, urine osmolality and urine specific gravity are three indices that can be used to determine hydration status. Testing for urine colour and specific gravity are non-invasive, economical and can be conducted by the athletes themselves.

Under normal conditions urine volume is approximately 1.5-2.5 L/day, urine colour (Ucol) is a pale light yellow colour similar to straw, has an osmolality (Uosm) of < 500 mOsm/L and a specific gravity (Usg) of ≤ 1.020 [175]. Under conditions of progressive hypertonic dehydration, urine shows changes in these indices due to the water conservation mechanisms regulated by the kidneys. Several studies have shown that Ucol, Uosm and Usg correlate to body mass loss [176,177,178,179]. However, it has been shown that rapid ingestion of fluid previous to urine analysis may produce an incorrect reading of hydration status, as the body will excrete urine not absorbed by the body, even when a subject is not euhydrated [176]. Thus, urine may lag behind blood when showing dehydration.

The colour of urine can be measured with an eight-point likert scale [177]. This is a portable simple method that can be used by the athletes themselves, giving instant feedback to their hydration status. There is some degree of inaccuracy due to diet and interpretation using this method [175].

An osmometer or conductance meter measures Uosm. Studies have shown Uosm to increase in individuals with a fluid deficit of 1.9% of body mass to more than 900mosm/kg [178]. This technique requires a technician and there is a delay in feedback because of the resources involved. Research by Armstrong and colleagues [177] has indicated that urine specific gravity is strongly related to Uosm and can therefore be used as a more practical

alternative. Osmolality is a more exact measurement of urine concentration than specific gravity because of the dependence Usg has on the precise nature of molecules in the urine. However if glucose and protein are not present in the urine, Usg can make measurement of Uosm unnecessary.

Urine specific gravity is the density of urine when compared to water and measured in grams/ml, it is dependent on osmolality as well as concentration of urea, glucose and protein and needs to be adjusted for the presence of these. Usg is measured by refraction; this involves passing a beam of light through a urine sample and measuring the refraction of the beam. This method is accurate, but can be resource heavy and takes some time, so feedback to an athlete will be delayed. Popowski et al [176] found Usg as measured by refractometry to be significantly well correlated ($r = 0.68$, $P < 0.02$) with Usg as measured by reagent strips. Reagent strips can test Usg simply and portably, the strips are dipped in a small sample of urine and the colour patch is compared to the reagent strip colour chart. These strips measure the release of H^+ ions to estimate Usg to the nearest 0.005 between 1.000 (water) to 1.030 (dehydrated). A brochure for one type of reagent strip can be found in appendix E. The strips also test for protein and glucose in the urine, therefore if these particles are present Usg can be adjusted. Feedback is instant and simple training will ensure an athlete has the tools to test him- or herself. Subjective determination of the colour chart comparison is required and this could be a weakness when using this method.

In a well designed study investigating the relationship between plasma osmolality (Posm) Uosm and Usg in athletic male subjects during progressive dehydration [176] it was found that a moderate nonsignificant correlation existed between Posm and Usg ($r = 0.46$). However the urine indices lagged behind Posm during acute stages of dehydration. These results can be explained in part by the study protocol. Subjects were instructed to ingest fluid frequently prior to the trial to obtain a state of euhydration. Baseline

data was then obtained. Exercise induced progressive dehydration occurred to a loss of 1%, 3% and 5% of baseline body weight. While Posm increased as subjects were progressively dehydrated, Uosm and Usg did not increase at a 1% fluid deficit. It is likely that at the beginning of the protocol extracellular fluid osmolality was being regulated as opposed to extracellular volume. As the release of antidiuretic hormone (ADH) is inhibited when plasma osmolality is low, urine formation was being promoted rather than conserved. While urine may lag behind blood during acute changes in hydration status [176], testing protocols can be established to overcome this downfall. Subjects can be instructed not to change their drinking rate (abstain from drinking a large volume of fluid) before a urine test. Subjectivity can be minimised by having the same individual comparing reagent strips to colour charts when numerous urine samples are being analysed, or when different samples are taken over a period of time.

The level of accuracy and sensitivity required, the time requirements, the resources available and the expense of the method will determine the choice of method used to measure hydrations status. Urine indices appear to be more sensitive than plasma indices or BIA [175,177,178] however there may be a lag when large amounts of fluid are consumed [176]. Urine specific gravity analysis provides an instant feedback to an athlete of both pre- and post-exercise hydration status, and the ease, convenience and economy of Usg measurement makes it a very useful tool once testing protocol is established

2.9.3 Blood analysis

Hypertonic dehydration can be detected through the osmolality and sodium content of blood, particularly when dehydration greater than 3% has occurred [176,179]. Research has shown that in lower levels of hypohydration blood indices may not be effective as a means to determine hydration status [177]. In a study investigating hydration testing in mildly hypohydrated participants

using both urinary indices and blood indices [177], it was observed that there was no relationship between the two. As the participants were hypohydrated and this was only picked up in the urinary analysis it was concluded that these indices were more sensitive to mild hypohydration than blood indices. In contrast to these findings another study showed blood osmolality to be comparable to ΔBM, % even at low levels of hypohydration [176].

Isotonic and hypotonic hypohydration may be detected by measuring haematocrit and haemoglobin levels [179].

While blood indices may be an accurate measurement of hydration status at moderate to high levels of hypohydration, and perhaps at low levels, there are limitations on the use of blood analysis for hydration testing in the field, as it is invasive, resource intensive, and poses a risk of injury and infection to athletes.

2.9.4 Measurement of body water stores

Bioelectrical impedance analysis (BIA) involves a current of 50 kHz passing across the body, via electrodes placed on either the wrist or legs, while the resistance is measured. Equations based on the differing electrical properties of fat and lean mass are used to estimate fat free mass (FFM). Intracellular and total body water is estimated on the assumption that the subject is euhydrated. BIA equations are population specific and variations in diet, hydration, ethnicity and disease state affect the body's electrolyte balance and therefore the FFM estimate [175]. Errors in prediction are due to lack of precision in measurement of height and resistance, and the error in the prediction equation used. To lessen the error in measurement it is important to use standardised testing procedure [180]. This includes cleaning the skin with alcohol where the electrodes are to be attached, ensuring gel electrodes are placed in the proper position, minimising the time in a recumbent position, ensuring the angle of limbs is consistent, fasting by subjects for 4 hours prior to measurement, ensuring room temperature is consistent,

avoiding subjects exercising several hours prior to measurement and that the hydration status of subjects is the same, that is all subjects should be well hydrated at the time of measurement.

In theory BIA is easy to use, non-invasive transportable and once the unit is acquired, cost-efficient. In practicality athletes rarely meet the requirements for standardised BIA, they are likely to be dehydrated and have performed exercise prior to testing. They may have eaten within the four hours before measurement, and in the field it is difficult to maintain room temperature. These will all negatively affect the accuracy of measurements, making them meaningless. In addition appropriate equations for athletes must be used. In a sports team there may be different ethnicities, meaning different equations would be required. Testing hydration status of each individual in a sports team would be impractical due to time constraints, unless many BIA units and technicians are on hand. However this would lead to inaccuracy due to inconsistencies between procedures used by technicians. BIA techniques are considered to lack the precision and accuracy required for hydration monitoring [175], and because of this other techniques are recommended.

2.10 DIETARY ASSESSMENT

The importance of proper nutrition for athletic performance has been the subject of much research in the last 20 years. In order to maintain training regimes athletes must have an energy intake that equals their high energy expenditure. To maintain and promote good health, nutritional requirements or recommended daily allowances (RDA's) and recommended dietary intakes (RDI's) have been established for the general population. However nutritional requirements particularly the macronutrients (carbohydrate, fat and protein) may be much greater for athletes than the average person [181]. A recommended energy contribution of 55-60% carbohydrate, a maximum of 30% fat and 10-15% protein appears to be a sufficient dietary composition

for the majority of people [182], but there are concerns that this macronutrient balance may not meet an athletes specific requirement. This has lead to many studies examining the proper diet for athletes and the efficacy of increasing the proportion of protein, carbohydrate and even fat in the diet [181].

The daily requirements of at least some micronutrients in athletes are increased beyond normal levels. The reasons for this are increased excretion through sweating and possibly urine and faeces, and possible an increased free radical production during strenuous exercise, necessitating an increased intake of antioxidants [183,184]. However, many athletes have an increased food intake in relation to the general population and these higher nutrient requirements may be met by a higher food intake [181].

Before recommendations can be made it is useful to evaluate an athletes diet and assess nutritional status, the advantages and disadvantages of some commonly used dietary intake evaluation techniques are outlined in table 2-10.

2.10.1 Methods of dietary assessment

There are many data collection methods used when evaluating dietary intake, these include food frequency questionnaires, duplicate food collections, 24-hour diet recall, diet history recall, or a diet record or diary. The method used depends on the objective of the dietary assessment. The 'gold standard' for diet intake data collection is the weighed diet record for seven days and beyond [187]. An average daily food intake can be calculated from this information. In groups (n = 26) it was found that food records for a minimum of three days were necessary to obtain usual energy intake for the group, and an average of 27 days for an individual [185]. To estimate usual macronutrient intake the period of time becomes longer, up to 6 days for groups. Estimation of micronutrient intake takes longer still, and varies greatly between different micronutrients and even gender. It can take as long as 44 days to measure the usual dietary intake of vitamin A in females [185].

However, periods of longer than 3-4 days recording has been shown to decrease compliance, particularly when there is a requirement to weigh food [187]. Accuracy is reduced, records are incomplete and drop out rate is higher than when records are kept for fewer days [186].

Food frequency questionnaires involve a predetermined food list that can be standardised for research. This makes a well-designed questionnaire useful when attempting to obtain an overview of the dietary intake of a population or group, as it is a cost effective way to collect a large pool of data [187] Similar foods are often grouped together, and the questionnaire may have portion sizes included. Standard serve sizes in questionnaire may be smaller than those used by an athlete resulting in an underestimation of intake by the nutritionist/dietician. As it is a retrospective dietary evaluation method there is a frequency response option so individuals can report how often each food was eaten.

Table 2-10. Advantages and disadvantages of commonly used data collection methods for dietary assessment. Adapted from Deakin (2000) [187]

Advantages	Disadvantages
Food frequency questionnaires (FFQ)	
☑ Requires little time for respondent ☑ Quick and easy to administer. ☑ Cost effective. ☑ Good response rate ☑ Can be standardised for research	☒ Dependent on memory, as it measures past dietary intakes. ☒ Less accurate ☒ List of foods may miss some consumed by respondent ☒ Difficulty quantifying portion sizes. ☒ May over or underestimate due to portion sizes and cooking methods
Duplicated food collections	
☑ Accurate method	☒ Takes time. ☒ Is expensive to buy twice as much food. ☒ Food choice may be driven by ease of duplication. ☒ Can be under-reported [188]
24-hr diet recall	
☑ Requires little time for respondent ☑ Cost effective ☑ Good response rate	☒ Dependent on memory, as it measures past intakes ☒ Not representative of usual intake ☒ May underestimate energy intake
Food record/diary - weighed	
☑ Accurate volumes when weighing is reported correctly ☑ Accurate method, when repeated	☒ Time consuming ☒ Requires trained personnel ☒ Requires co-operative respondents ☒ Can led to a distortion of food choice ☒ Does not represent usual diet ☒ Underreporting may occur
Food record/diary - estimated	
☑ Provides insight into eating habits ☑ Fairly accurate when record lasts for 3-4 days ☑ Provides some detailed information	☒ Poor compliance after 4 days ☒ Does not represent usual diet ☒ May underestimate energy intake

The estimated diet record, using household measures appears to predominant as the method of choice [189]. However there are some limitations on evaluating intake this way. Self-recording food intake has been observed to change an individuals eating behaviour, primarily in relation to energy intake and snack food consumption, this can also occur when using the weighed diet record method, particularly if the individual is weighing their own food. Energy intake can be under-reported particularly in relation to overweight individuals [190]. Athletes also may unwittingly under-report consumption as they often ingest large quantities of food, and a 'medium' sized bowl, for example, may be larger in volume for them than for the general population [191].

Analysis of dietary intakes by the methods outlined above can only estimate usual, one off or average intake of nutrients and foods. To accurately assess nutritional status a combination of information is required. Nutritional status markers can be tested by clinical, anthropometric, dietary and biochemical assessment and measurements [192].

As dietary assessment only estimates food and nutrient intakes, techniques to evaluate these are chosen because they relate to the intended purpose of the assessment. To assess dietary intake the athlete should keep a food record or diary for a period that will ensure compliance, possibly up to 4 days. This should then be repeated at a later random date. Where possible the weighed method should be used, as estimations by household measures could result in under-reporting due to difference in perceived portion size. Underreporting may also occur in the weighed method, particularly in overweight individuals [190].

2.10.2 Nutritional requirements in athletes

As many athletes have an increased food intake in relation to the general population any higher nutrient requirements can usually be met by a larger food intake.

Carbohydrate is the predominant fuel source for prolonged moderate intensity or intermittent high intensity exercise [22]. As body CHO stores are limited, CHO intake by athletes before, during, after and in-between bouts of exercise increases the CHO availability in the short term [189].

Population dietary guidelines in westernised countries generally recommend CHO intake to provide 50 – 60% and protein to provide 10 –15% of total energy intake [182]. Increasing the percentage of CHO when large quantities of food are ingested could lead to a diet too bulky to consume, and thus providing CHO in excess of requirements for both glycogen storage and energy for training. Because of this, and due to the differences in body size of athletes, the requirements for CHO and protein are often expressed as grams per kg body mass per day (g/kg BM per day) [189]. The recommendations for strength athletes competing in moderate duration exercise with a moderate to heavy training regime is illustrated in table 2.11.

Table 2-11. Recommendations for strength athletes competing in moderate duration exercise.

Nutrient	Amount recommended
CHO	6 – 10 g/kg BM per day [193,194].
Protein	1.4 – 1.7 g/kg BM per day [195].

Athletes should be hydrated prior to competing or training, particularly when the event is prolonged, or where many events occur in a short space of time. Recommendations to achieve this include; an individual ensuring they have replaced the fluid loss since the last training or competitive session, and generous amounts of fluid should be consumed in the 24 hours leading up to an event [19]. It is also recommended by the ACSM that 400 – 600 ml of fluid be ingested in the two to three hours before prolonged exercise [19]. Fluid ingestion practices and recommendations prior to, during and after exercise are discussed in more depth in section 2.7.

3 METHODS

3.1 PARTICIPANTS

Thirty-three male rugby union players of the Blues Development 2003 squad were approached and asked to volunteer to be in this study. Out of the thirty-three approached twenty-four volunteered and fulfilled the inclusion criteria. Inclusion criteria were that players must either play in the first game of the season (match 1) and/or play in three or more of the following games for over 60 minutes. Recruitment was by the researcher through the Blues Rugby Union franchise based in Auckland, New Zealand. All participants were players for the Blues Development (BD) 2003 team and were in training for the Development championship at the time of recruitment. The development championship is a Super 12 'B' team competition, which acts as a reserve squad for the first grade and where young (over 18 years) up-and-coming players get game time and training. Many Super 12 development players will play in the first grade competition during the season, and more will play in the New Zealand National Provincial Championship (NPC) for their provincial rugby union later in the year. As development teams predominantly consist of young players, many have come from representing New Zealand in rugby union as a member of a colt team (under 18's and under 21's).

The BD players were semi-professional sportspeople returning to rugby union after a break of between three and five months, during this break any exercise undertaken was determined by the players themselves and is likely to have been highly variable. Rugby training as a team commenced two weeks prior to the first pre-season game.

During a training camp the researcher presented the outline and nature of the study to the players and explained the role they would have. At this point any questions the potential participants had were answered, and it was agreed between the researcher and the BD management that the first pre-season game would serve as a pilot.

All participants were fully informed of the demands associated with taking part in the study and their right to withdraw at any time. They were advised that a unique identifying number would be assigned to each of them to ensure no personal details would be published. The team management asked for the right to have access to information on each individual player. The participants were then given an information sheet and were asked to sign a consent form (appendix C) indicating their agreement to participate.

It was confirmed by the team medical staff that no player had a medical condition, or was on any medication that could potentially affect fluid balance or hydration status. There was no use of diuretics, as they are banned substances for these athletes.

3.2 ETHICS AND FUNDING

This project has been reviewed and approved by the Massey University Human Ethics Committee in February 2003, ALB Protocol MUAHEC 03/002.

The New Zealand Rugby Union (NZRU) provided funding for travel and accommodation for the researcher during the data collection period of this study.

3.3 EXPERIMENTAL DESIGN

This study was designed to obtain information on the changes in hydration status of rugby union players, during seven games in the Super 12 development season of 2003. The season began with a pre-season game on the 6th of February, and the first competitive game was on the 22nd of February. All preliminary measurements were obtained between the 4th and 15th February and collected by the author. An observational study was conducted over a period of 45 days during the NZ Super 12 Development teams championship 2003. The author also collected data obtained during the games. This competition was a round robin event consisting of five New Zealand rugby franchises. The participants played together as a team in a total of seven matches, the schedule is illustrated below in table 3-1.

Table 3-1. Blues Development 2003 Schedule

Game	*Venue*	*Kick-off time*	*Date*	*Opposition*	*Type of Match*
1	Waitemata	18:00	06-Feb-03	Hurricanes	Non competition
2	Hamilton	18:30	15-Feb-03	Chiefs	Non-competition
3	Waitemata	14:30	22-Feb-03	Hurricanes	Competition
4	Dunedin	12:00	01-Mar-03	Highlanders	Competition
5	North Harbour	17:30	08-Mar-03	Brumbies	Non-competition
6	Timaru	17:30	14-Mar-03	Crusaders	Competition
7	Whangarei	17:00	21-Mar-03	Chiefs	Competition

The format for data collection was established by consensus subsequently to game one, which was utilised as a pilot run, and adhered to throughout games two through to seven.

Players could drink freely from sports bottles provided by three members of the team management support staff during designated breaks in play. These bottles contained either water or a sports drink (Powerade, mountain fresh). Powerade contains carbohydrate (concentration of 8%) and electrolytes.

3.4 PROTOCOL

3.4.1 Baseline data

The author, a level one International Society for the Advancement of Kinanthropometry (ISAK) accredited anthropometrist performed Kinanthropometric assessment. A restricted profile (ISAK level one proforma) consisting of 17 measurements was conducted on each participant, taking approximately 15 - 20 minutes. A brief explanation of these standard anthropometrical measurements is given below. However, more detailed description of the methods undertaken can be found in the New Zealand Sport Guidelines for Athlete Assessment [196]. Measurements taken were used for calculating somatotype† [197] and as the subjects requested a tangible measure of body fat, percentage body fat was calculated from four skinfold sites‡. A formula driven calculation of fat percentage using various body measurements including skinfolds is considered to be flawed [196]. Sports

† Somatotype is a body shape classification system. For an illustration and further description of this see appendix G.

‡ Body fat was calculated using the Sloane -Weir regression equation for males ((Triceps sf + Subscapular sf + Supraspinale sf + Abdominal sf) x 0.153) + 5.783, where sf = skinfold. There is a great variance of fat percentage readings when using different regression equations on an individual; therefore the same equation should always be used for consistency. Different equations have been developed to take into account diversity in relation to gender, race and body type, and because of these differences comparing fat percentage calculated from regression equations between individuals is very difficult. Accurate methods of measuring body composition include DEXA, CT scan, MRI, underwater weighing and the BodPod.

and Exercise Science New Zealand recommends using the sum of skinfolds as a repeatable measure rather than any body fat regression equations. Body fat percentage as calculated for the purpose of this study was used as a type of index for body composition, as was somatotype.

Name and age were recorded and a unique individual identifier assigned to each subject. One measure of both body mass and stretch stature was taken, while two to three measurements of all skinfolds, girths and breadths were required and the median used.

3.4.2 Body mass (weight)

Body mass was measured in kilograms using calibrated digital scales (Salter model 918, Par Salter Housewares ltd, UK). Portable digital scales were placed on a hard level surface and calibrated to a 2 kg known mass, each day weighing occurred. Pre- and post–match body weights were measured while athletes were in minimal clothing and barefoot.

3.4.3 Stretch stature (height)

Stretch stature was measured in centimetres against a flat vertical surface. Height was measured in this way as the maximum vertical distance from the floor to the vertex of the head, with a Lufkin retractable metal tape (W606PM Coopertools NC USA).

3.4.4 Skinfolds (for body fat percentage and somatotype)

A Harpenden skinfold calliper was used (Holtain Ltd. Crymych, U.K) to take the skinfold readings. This instrument is designed to provide a constant pressure of 10.0 $g.mm^2$ at the calliper face irrespective of skin thickness. The dial was calibrated in 0.2mm increments and can be read to the nearest 0.1mm.

The following anatomical sites were identified and marked with a felt-tipped pen: acromiale, radiale, mid-acromiale-radiale horizontal line, tricep, bicep,

subscapulare, iliocristale ilioaxilla line, iliospinale, supraspinale, abdominal, mid thigh and mid calf. This facilitated measurement of skinfold thickness at the following sites: tricep, subscapular, bicep, iliac crest, supraspinale, abdominal, front thigh and medial calf, for the calculation of the % body fat and somatotype.

3.4.5 Girths (for somatotype)

A flexible steel Lufkin tape as mentioned previously was used to measure five girths, relaxed arm, flexed and tensed arm, waist, gluteal and calf. Care was taken to obtain the perimeter distance of the body part without depressing the natural contour of the segment. The relaxed arm measurement was taken at the landmark while the flexed-and-tensed girth was obtained at the site of greatest perimeter over the volitionally contracted bicep. The waist measurement was taken at the noticeable narrowing of the waist lying between the coastal border and the iliac crest. While the tape was around the waist the subject was required to talk to ensure they are not holding the breath. The gluteal (hip) girth is the perimeter at the level of greatest posterior protuberance while standing with the feet together. The maximum perimeter was also measured for the calf girth. This was acquired by manipulating the tape into a series of quick measurements to secure the largest value.

3.4.6 Bone breadths (for somatotype)

A Vernier bone calliper was used to measure two bone breadths, humerus and femur. This is defined as the distance between the medial and lateral epicondyles of the humerus or femur.

3.5 MATCH DATA

3.5.1 Subject measurements on match day

Individual measurements were taken from the run-on 15 players during a match, these were; pre- and post-match body mass, pre- and post-match urine samples and drinking frequencies. A schedule of events on match day is presented in appendix D. As this study was conducted in the field ΔBM was used as a proxy measure of sweat loss.

3.5.1.1 Body mass (weight)

Participants were weighed as described in section 3.4.2, two hours prior to a match, preceding transport to the rugby ground. They were barefoot and wearing the team training strip of t-shirt and shorts. Players would arrive to be weighed in a random order. Directly following a match the players would enter the changing room and be weighed in the same manner as above, however they were towel dried and the team shirt was removed due to sweat increasing the weight of a shirt. When compared (in the pilot study during game 1) the weight of a dry shirt was the same as the weight increase from dry shorts to wet shorts. Therefore, due to time constraints it was decided by the researcher to weigh the players post-match in shorts only as the difference in weight of clothing pre-match and therefore dry and post match, with wet shorts only was negligible. The time taken for the first to the last participant to be weighed was between 15 and 30 minutes.

Weight of food intake and bowel motions was not recorded between pre and post match weight due to resource restraints and compliance issues, and has been identified as a limitation in section 5.6.

3.5.1.2 Urine specific gravity

The players were provided with a urine collection pot labelled with their name 1 hour before departure to the rugby ground. At this point the players were informed that a valid urine sample must be taken midstream. The collection

pots once filled, were collected during the pre-match weighing session and placed in a cooler box. Urine was analysed for pH, glucose, ketones, protein and specific gravity (sg) prior to commencement of the game. This analysis was conducted between 30 to 60 minutes after the samples were collected. Analysis was performed by means of the Combur [10] Test®, (Roche Diagnostics Ltd, East Sussex, U.K) The Combur [10] Test® is a ten-patch reaction test strip for the semiquantitave analysis of urine including specific gravity, pH, protein, glucose and ketone bodies. A copy of the reaction strip information leaflet is included in appendix E

The urine was mixed thoroughly and tested at room temperature. The test strip was placed in the urine for approximately one second and the reaction colours of the test areas were compared with the colours on the label presented on the Combur [10] Test® container.

Identical procedures were repeated directly after a match to obtain post-match samples; these were collected within 1 hour upon completion of a game. If a participant could not urinate within this time a 'could not urinate' result was recorded. Analysis of the post-match samples were as above and occurred within 2 hours from the initial distribution of the collection pots.

3.5.1.3 Drinking frequency

Drinking frequency was measured as the number of times a player took a drink during the time he was on the field. The break numbers followed by the name of any players drinking during the break were recorded verbally into a Dictaphone. Data from the Dictaphone was later transcribed in order to count the number of drinks each player took during each half of the game, and the number of drink breaks available during the game. The sheet where this verbal data was transcribed to can be found in appendix F.

During the half time break of match six the total fluid, both water and sports drink, ingested by the whole team was calculated. This was achieved by

marking the starting level on the water and sports drink barrel and comparing this with the finishing level at the conclusion of half time.

3.5.2 Environmental measurements on match day

Data was collected on match day in relation to climatic conditions. Measurement of temperature (°C) and relative humidity (% RH) was recorded simultaneously using a digital whirling hygrometer (model HT-800, INS Instrumental Enterprise Co. ltd Taipei, Taiwan). The readings were taken from ground level on the rugby field upon commencement of both the first and second halves.

Wind speed was estimated in kilometres per hour, (km/hr) according to the Beaufort scale [198] at the beginning of the 1st and 2nd halves. The Beaufort scale estimates wind speed by observing the changes to the environment that occur as wind strength increases and is illustrated in appendix H. The approximated speed was then compared for reasonableness to the most recent weather report from the local radio station that day.

3.5.3 24-hr food record and analysis

Participants were asked to complete a 24-hour food record for the time period preceding game 4. Instructions on how to measure and estimate quantity of food and beverage items using household measurements and weights on packaging, were given both verbally and in writing by the researcher. The researcher was also available at the pre-match meal to answer any queries the players may have had in relation to the food records. Participants entered the date, time, quantity, type of food, brand of food and preparation method of everything they ingested. This book was collected during the pre-match weigh in for this game, and checked. An example can be found in appendix I.

The food records were analysed using the dietary analysis software FoodWorks® professional edition V2.0 [199] utilising the NZ food database

version W3.0, supplied by the New Zealand Institute of Crop and Food Research Ltd, Palmerston North. Food products consumed by an athlete and not present in the database were entered upon attainment of nutrient content from the product label or manufacturer.

The main objective for using 24 hr food records in this study was to assess the amount of fluid the players were consuming in the 24 hours prior to a match, and to relate the volume of fluid to the pre-match Urine Specific gravity reading.

3.6 DATA ANALYSIS

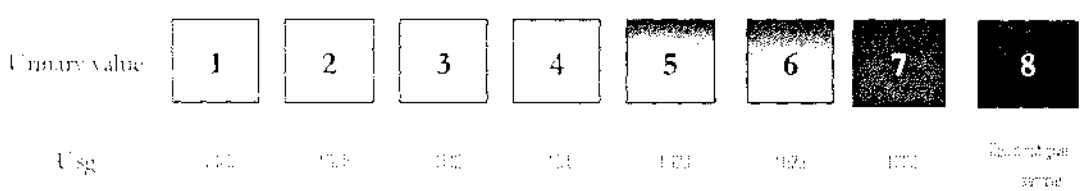
Measurements from games 1 and 5 were not used when analysing hydration status of participants playing more than 60 minutes of rugby (n = 14) due to lack of subjects fitting into this category. The reason for this being, that these matches were non-competitive games and there was no restriction on players numbers, so all fit team members were able to play. The data from match 1 only was used when analysing hydration status of participants playing under 60 minutes of rugby (n = 17).

Team members were divided into two groups for data analysis, dependent on their field position, and identical to the division present in a rugby union team. The Forward pack (FW) consisted of the Props (2), Hooker, Flankers (2), Locks (2) and Number 8, (jersey numbers 1 through 8 of the starting 15). The Backs (BK) consisted of the Halfback, 1st Five eighth, 2nd Five eighth, Centre, Wings (2) and Fullback (jersey numbers 9 through 15).

The change in body mass is calculated as the difference between the pre- and post-match weights (ΔBM, kg) and the percentage of weight change (ΔBM, %). For the purpose of this study a level of 1.8% dehydration at the end of a match has been set to determine hypohydration and the potential for exercise performance to be impaired.

Urine specific gravity (Usg) readings as presented on the Combur ^{9} Test®, ranges from 1.000 to 1.030. For the purpose of this study and to include the 'could not urinate' result, a simple scale from 1 through to 8 was used as illustrated in figure 3-1. Water has a specific gravity of 1.000 and a urinary value of 7 (equivalent to a Usg of 1.025) or above was considered to be hypohydrated which is consistent with past studies [177] and the National Athletic Trainers' Association (NATA) position statement.

Figure 3-1. Likert scale showing assigned Urinary Value (UV) to Urinary specific gravity (Usg) reading 200



The change in urinary value (ΔUV) was calculated as the difference between pre- and post-match urinary readings.

3.6.1 Data from National Provisional Championship (NPC) 2003 season

In order to establish if an observer bias was operating in the present study, pre- and post-match body mass measurements were obtained with permission from the North Harbour Rugby Football Union, North Harbour, New Zealand, for matches played during the NPC 2003 season. Approximately 30% of players in the Blues Development 2003 team played in this NPC team, and the trainer for both teams was the same.

3.7 STATISTICAL ANALYSIS

Results were calculated as the mean, standard deviation (SD), standard error of the mean (SEM) and range. Pre- and post-match data was analysed using Student's paired *t*-test to determine statistical differences. Results from the Forward Pack (FW) and the Backs (BK) were also analysed for statistical differences. Statistical significance was set as $P < 0.05$.

The correlations between several variables were investigated using the Pearson's product-moment correlation coefficient (r). Examples of variables are; change in body mass (ΔBM) vs post match urinary value, and environmental conditions vs hydration status indices. The results are presented as the mean $\pm$ standard error of the mean (SEM) unless otherwise stated.

4 RESULTS

4.1 SUBJECTS

The characteristics of the study group (n = 24) as measured prior to commencement of the season were (± SD): age (mean 22.8 ± 2.6 yr, range 19.3 – 28.8 yr), weight (mean 101.2 ± 14.8 kg, range 80.4 – 143.1 kg), height (mean 186.4 ± 7.4 cm, range 177.5 – 207.4 cm) and percentage fat mass (15.20 ± 2.87 %, range 11.26 – 20.15 %). The mean somatotype ratio for the entire team was 3.8 ± 1.2 : 6.7 ± 1.6 : 1.2 ± 1.0, as endomorphic : mesomorphic : ectomorphic respectively. This indicates the typical body type of the Blues development team 2003 was an endomorphic mesomorph. Table 4-1 displays the means of these results.

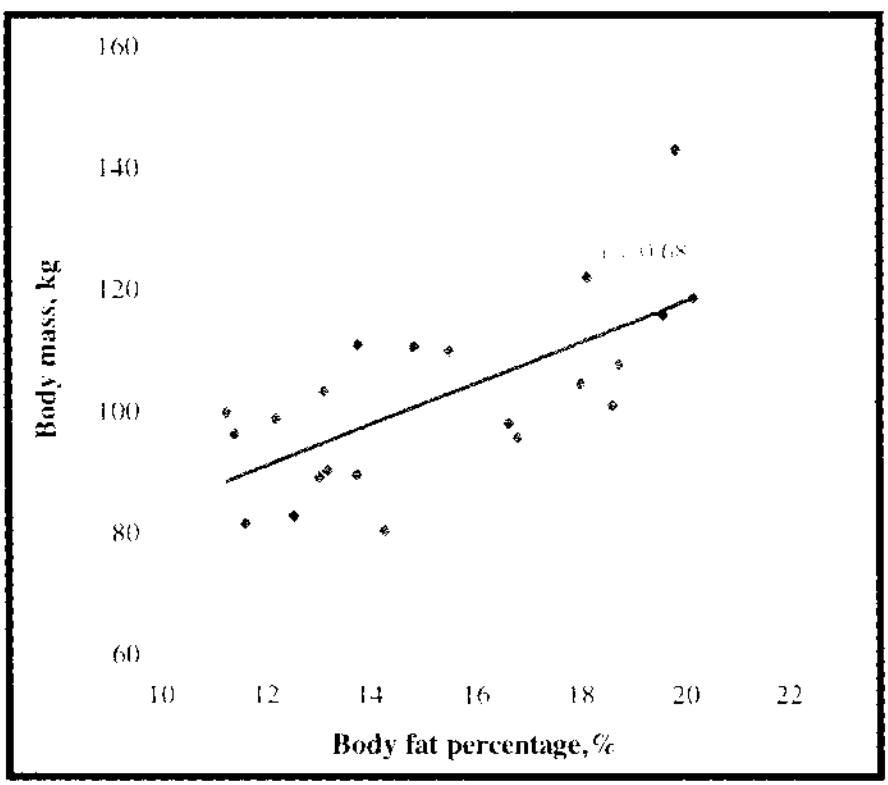
Table 4-1. Physical characteristics of the Blues Development team 2003, represented as mean values for body mass (BM), height, body fat and somatotype.

Group	BM, kg	Height, cm	Fat, %	Somatotype		
				Endo	Meso	Ecto
Forwards	110.7	189.5	16.24	4	7	1
Backs	90.0	182.7	13.98	3	6	1
Entire team	101.2	186.4	15.20	4	7	1

Endo = Endomorphic,
Meso = Mesomorphic,
Ecto = Ectomorphic.

There was a positive correlation as illustrated in figure 4-1, between body mass and percentage fat mass, r = 0.68.

Figure 4-1. Scatterplot of body mass and body fat percentage showing positive correlation between the two measurements.



Results for all players

Forwards had a greater mean body mass (FW 110.7 ± 3.5 kg), when compared with the backs (BK 90.0 ± 2.2 kg), P < 0.02. The mean height was also significantly different, with FW taller than BK, 189.2 ± 2.4 cm vs 182.7 ± 0.9 cm, P < 0.02, as was percentage body fat (FW 16.24 ± 0.87%, BK 13.98 ±

0.61%, P = 0.02). When compared, the means of somatotypes were shown to be similar between FW and BK groups (table 4-1), mean ages were also similar between these groups (Appendix J).

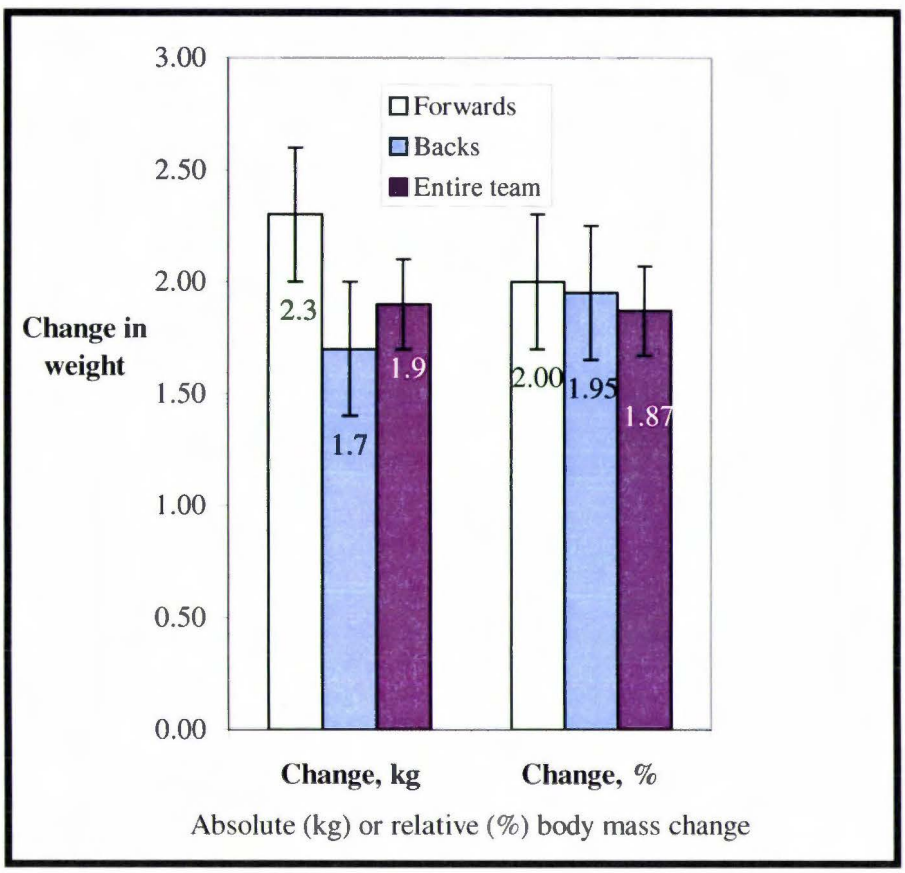
4.2 HYDRATION STATUS OF PLAYERS PARTICIPATING IN OVER 60 MINUTES OF RUGBY (BD > 60)

Hydration status was measured in the group BD>60 by calculating the change in body mass (ΔBM) and urinary value (UV). The change in BM is expressed in both kg and as a percentage of the initial BM. The UV was determined from the Usg readings from urine sampling, and table 3-2 illustrates how this was done.

4.2.1 Change in body mass (ΔBM)

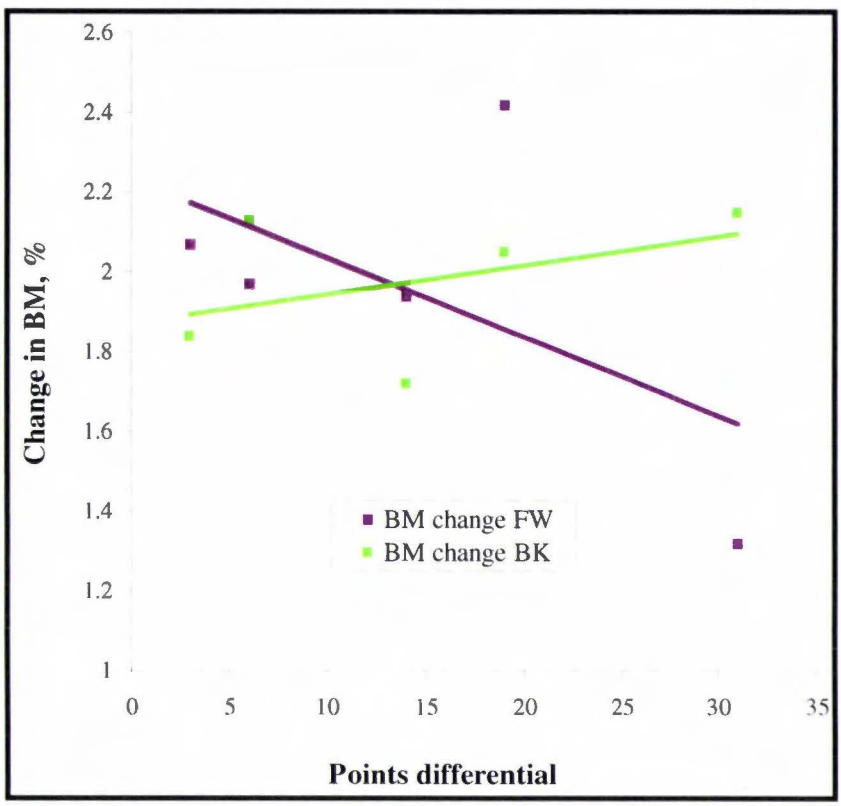
The mean ΔBM, kg and ΔBM, % for all participants over all games was 1.9 ± 0.2 kg and 1.87 ± 0.19% respectively, where n = 14. Pre- and post-match body mass measurements were significantly different when calculated over all games (P < 0.02), and each individual game (P < 0.02). The range in ΔBM, kg and ΔBM, %, encompassing all data collected on participants playing over 60 minutes of rugby was 0.1 kg to 5.2 kg and 0.10 % to 4.61%. There were no significant differences between forwards and backs for mean ΔBM, measured in either kg or %, over all games, (2.3 kg or 2.00%, and 1.8 kg or 1.95% respectively). Figure 4-2 shows the uniformity of this weight loss in the whole team and the two sub-groups. There was a difference in ΔBM, kg and mean ΔBM, % between FW and BK, however only game 3 showed this dissimilarity to be significant (game 3, FW 1.32 ± 0.06 %, BK 2.15 ± 0.33%, P = 0.04).

Figure 4-2. Bar chart of absolute and relative BM losses in subjects playing over 60 minutes of rugby (BD > 60) for all matches.



There are non-significant correlations between the positional group and game points differential (figure 4-3). An inverse relationship exists between the points differential and ΔBM, % in the FW group, r = -0.55. The opposite is true in the BK group, as ΔBM, % increases, the points differential increases, r = 0.42.

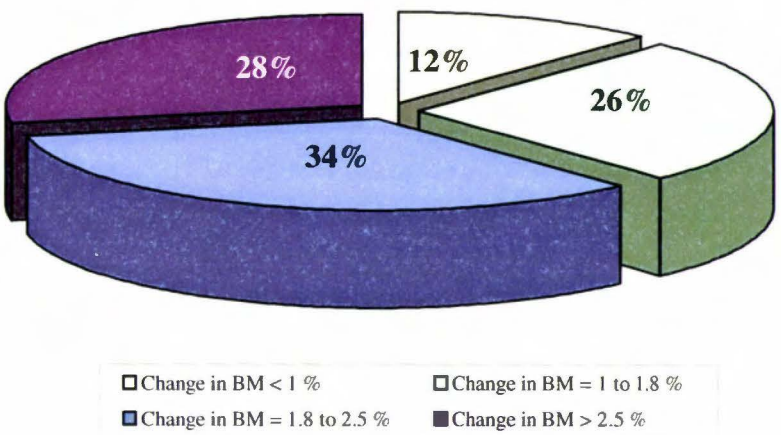
Figure 4-3. Relationship between change in BM of the positional groups (FW and BK) and game points differential.



Mean values for each match
FW = Forward group. BK = Back group

Sixty two percent of all ΔBM, % results were over 1.8% dehydrated, this distribution is illustrated in figure 4-4. Over one quarter (28%) of ΔBM results were over 2.5% dehydrated, and only 12% of all results were under 1% dehydrated. There was no correlation between % fat mass and ΔBM, %.

Figure 4-4. Distribution of overall ΔBM results, expressed as a percentage of pre-match weight lost.



4.2.2 Urinary value (UV)

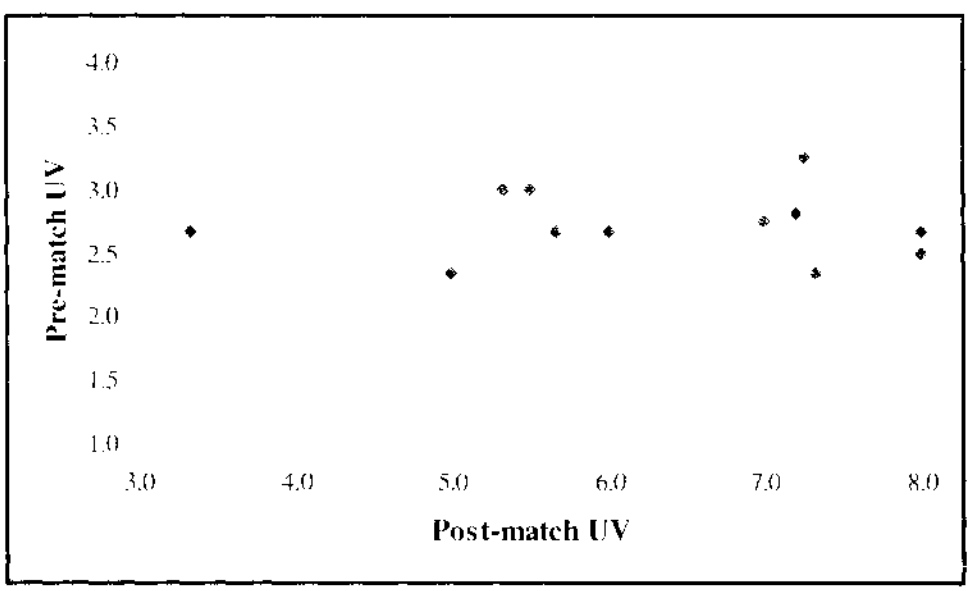
Urinary value is an assigned value to Usg and a 'could not urinate' result and can be expressed on a likert scale, as illustrated in figure 3-1.

The values for urinary indices (mean ± SD) over all games were: pre-match UV (mean 2.7 ± 0.27, median 2.7 and range 1 – 5), post-match UV (mean 6.3 ± 1.4, median 6.5 and range 3 – 8) and ΔUV (mean 3.6 ± 1.4, median 3.7 and range 0 – 6). There was a highly significant difference between pre- and post-match urinary value, $P < 0.02$.

Results for pre- and post-match UV and ΔUV were not significantly different between forwards and backs. There is a 95% confidence interval that a player will have a pre-match urinary result of 3 (Usg 1.010) or under.

There was a strong positive correlation between mean post-match UV and mean ΔUV over all games, (r = 0.98), and for each individual match (r = 0.91, 0.93, 0.89, 0.97 and 0.90 for games two, three, four, six and seven respectively).

Figure 4-5. Scatter Plot showing the lack of a relationship between Post-match UV and Pre-match UV.

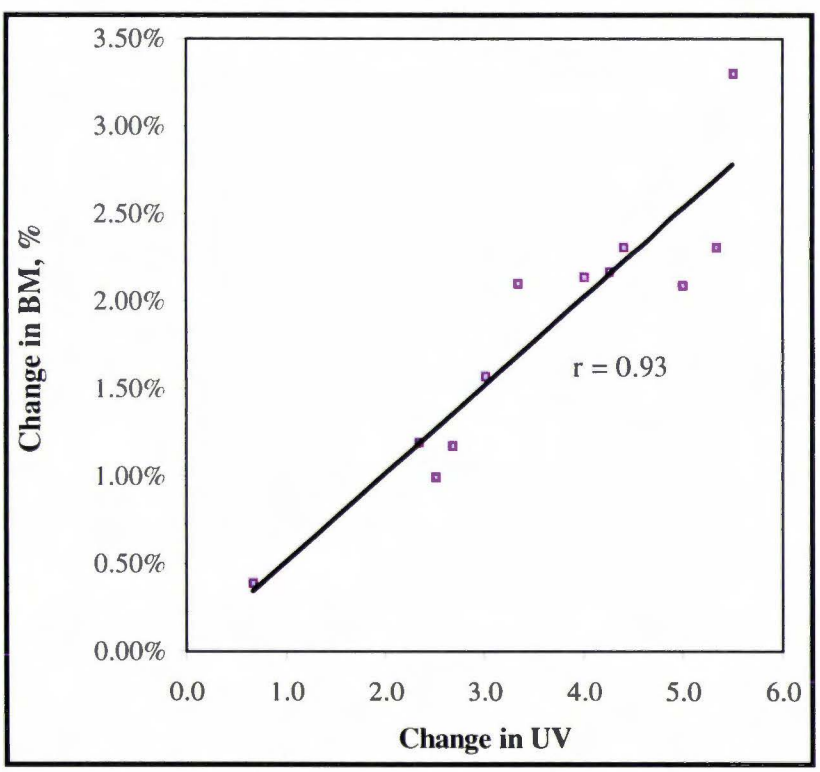


Each marker represents the mean value for one player, and is the average from all the games in which they played > 60 mins.

Post-match UV and ΔUV were not dependent on pre-match UV, this lack of a correlation (r < 0.001) is displayed in figure 4-5.

The mean value of ΔUV over all games increases as ΔBM escalates. This strong positive correlation is highly significant ($r = 0.93$, $P < 0.02$) and is represented in figure 4-6. Mean post-match UV also has a strong positive correlation with ΔBM, %, $r = 0.92$.

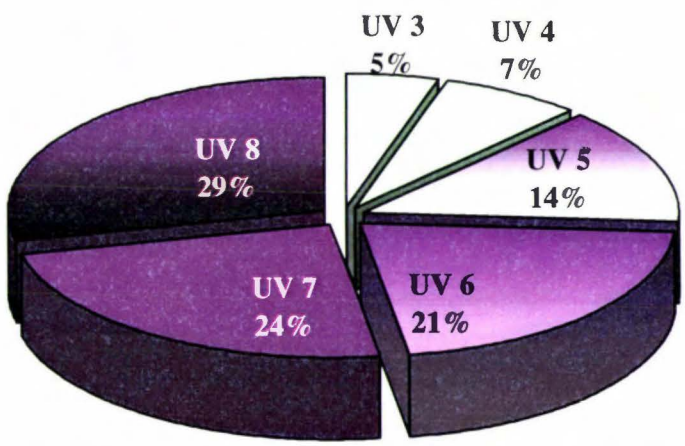
Figure 4-6. Scatterplot with linear trendline of weight change (decrease in % of pre-match weight) and change in urinary value, showing a strong positive correlation between the measurements.



Each marker represents the mean value for one player, and is the average from all the games in which they played > 60 mins.

As shown in figure 4-7, thirty two percent of all players (BD>60) over all games were not able to urinate post-match. Over half (53%) were dehydrated or very dehydrated (UV ≥ 7, Usg 1.030 or 'could not urinate') and almost three quarters (74%) were at least mildly dehydrated, (UV = 6, Usg ≥ 1.025 as illustrated on the likert scale in figure 3-1). The minimum post-match urinary value was 3, and thus euhydrated.

Figure 4-7. Distribution of overall post-match urinary values.

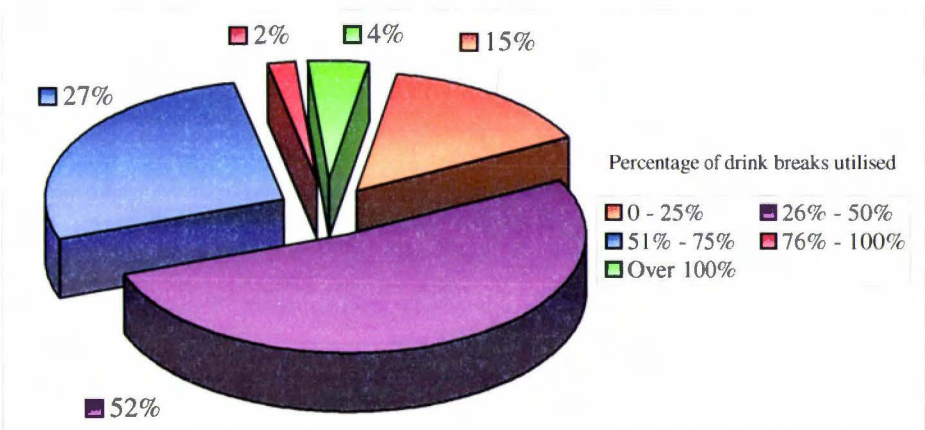


4.3 VOLUNTARY DRINKING FREQUENCY OF BD > 60

The mean (± SD), median and range for voluntary drinking frequencies (n = 14) excluding half time and over all games were, 4.2 ± 1.5, 3.5, and 0 to 13. Participants drank significantly more in the first half of a match with a mean

value from all matches of 2.6 ± 0.3, compared to a mean value 1.6 ± 0.2 in the second half, $P < 0.02$. Not all data from the individual matches produced a difference between first half and second half drinking rates, those that did were, match 2 ($P < 0.02$), match 3 ($P = 0.04$) and match 6 ($P < 0.02$). The mean number of drink breaks during a game (± SD), excluding half time was 10.8 ± 2.9, the range was 7 - 15. In all the data collected, less than half (48%) of the drink breaks available were utilised, two players drank more than once in some of the breaks during match 4. Figure 4-8 shows the mean distribution of drink breaks.

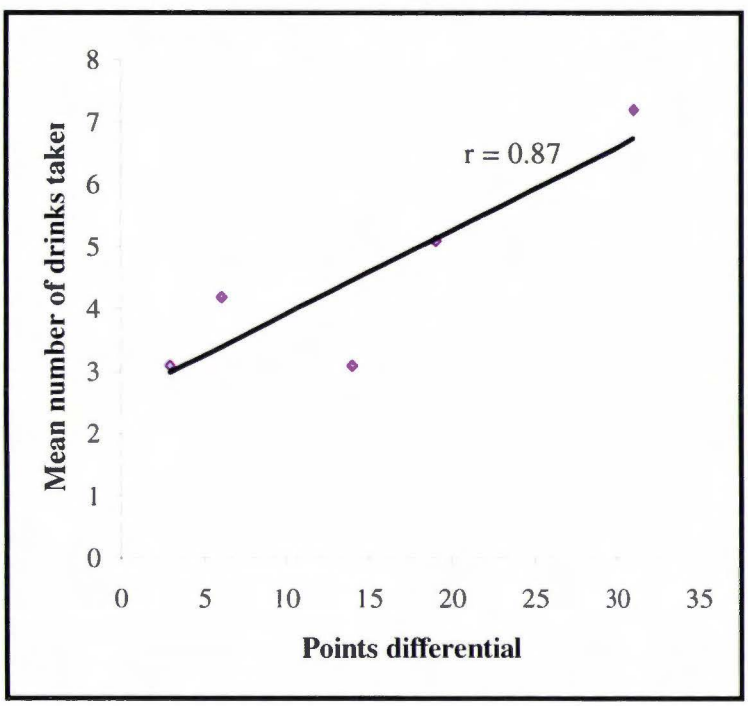
Figure 4-8. Distribution of drink breaks being utilised in all drinking frequency data collected



There were no statistically significant correlations between the mean frequency of drinking during a match and the date of a game, kickoff time, number of drink breaks available, or environmental conditions. However, there was a strong negative correlation ($r = -0.83$) between mean drinking frequency and wind speed, and a strong positive relationship between mean

drinking frequency and game point differential, r = 0.87. This non-significant relationship is illustrated in figure 4-9.

Figure 4-9. Correlation between drinking frequency (mean number of drinks taken and game point differential.



Drinking frequency did not appear to have a correlation with percentage body mass change, post-match urinary value or change in urinary value.

Drinking frequencies differed at times between FW and BK. The forwards had a significantly ($P < 0.5$) greater frequency of drinking than the backs in two out of the 5 games (games 3 and 7). The drinking frequency values over all games were: FW (mean 4.6 ± 0.7, median 4, range 0-13) and BK (mean 3.8 ± 0.4, median 3.3, range 1-10).

The total amount of fluid ingested during the half time break for game 6 was approximately 5280 ml or 352 ml per player (n = 22), the breakdown between water and powerade was; water 1760 ml or 117 ml per player, and powerade 3520 ml or 235 ml per player.

4.4 GAME STATISTICS

Kickoff times for the five rugby matches ranged from 12:00pm to 6:30pm. The ranges for temperature, humidity and wind speed were 16°C - 25°C, 36% - 63% and 2.5 km/hr - 27.5 km/hr, respectively. Every match was played on a fine or slightly overcast day with no presence of rain. This information along with venue, game result and number of drink breaks is presented in table 4-2.

Table 4-2. Game number, venue, date, kickoff time, result of game, number of drink breaks available and environmental conditions at the time of game for each match.

Game	Venue	Kick-off time	Date	Result	Temp °C	Humidity %	Wind Speed km/hr	Drink Breaks
2	Hamilton	18:30	15-Feb-03	31-28	23	38	17.5	11
3	Waitemata	14:30	22-Feb-03	18-49	22	36	2.5	15
4	Dunedin	12:00	01-Mar-03	19-13	25	58	27.5	7
6	Timaru	17:30	14-Mar-03	18-32	16	63	25	11
7	Whangarei	17:00	21-Mar-03	34-15	21	62	12.5	10

**All values for climatic conditions are averages of two readings, one taken at the commencement of the 1st half, and the other taken at commencement of the 2nd half.*
***Results show BD score first.*

Table 4-3. Individual game values grouped into forwards, backs and entire team (total), for body mass changes, hydration status and voluntary drinking rates

		GAMES				
		2	**3**	**4**	**6**	**7**
BODY MASS						
Mean ΔBM, %	*Total*	1.86 ± 0.21	1.88 ± 0.27	1.92 ± 0.25	1.69 ± 0.21	2.23 ± 0.39
	Forwards	2.07 ± 0.27	1.32 ± 0.06	1.97 ± 0.45	1.94 ± 0.19	2.42 ± 0.67
	Backs	1.84 ± 0.29	2.15 ± 0.33	2.13 ± 0.30	1.72 ± 0.37	2.05 ± 0.49
Range ΔBM, %		0.68 to 2.92	1.23 to 2.75	0.39 to 3.60	0.10 to 2.76	0.36 to 4.61
Percentage of players lost > 1.8%	*Total*	60%	50%	62%	55%	60%
	Forwards	67%	0%	50%	67%	60%
	Backs	50%	75%	71%	40%	60%
Percentage of players lost > 2.5%	*Total*	20%	33%	31%	9%	50%
	Forwards	33%	0%	33%	17%	60%
	Backs	0%	50%	29%	0%	40%
URINARY FLUID						
Mean post – match UV	*Total*	6.8 ± 0.5	6.7 ± 0.6	6.2 ± 0.5	6.0 ± 0.5	6.4 ± 0.4
	Forwards	7.0 ± 0.4	6.0 ± 1.0	5.8 ± 0.9	6.5 ± 0.6	6.8 ± 0.8
	Backs	6.5 ± 1.0	7.0 ± 0.7	6.4 ± 0.7	5.5 ± 0.9	6.2 ± 0.6
Range post - match UV		4 to 8	5 to 8	3 to 8	3 to 8	4 to 8
Percentage of players UV ≥ 7 post-match	*Total*	63%	67%	45%	38%	56%
	Forwards	75%	50%	25%	50%	50%
	Backs	50%	75%	57%	25%	60%
Mean ΔUV	*Total*	3.9 ± 0.5	4.3 ± 0.5	3.4 ± 0.6	3.1 ± 0.4	3.9 ± 0.5
	Forwards	4.0 ± 0.7	3.5 ± 0.5	3.3 ± 1.0	3.5 ± 0.6	3.8 ± 0.8
	Backs	4.7 ± 0.9	4.8 ± 0.6	4.0 ± 0.8	3.3 ± 0.6	4.0 ± 0.8
Range of ΔUV		1 to 6	3 to 6	0 to 6	1 to 5	1 to 6

		GAMES				
		2	3	4	6	7
DRINKING FREQUENCY						
Mean number of drinks taken	*Total*	3.1 ± 0.6	7.2 ± 1.8	4.2 ± 0.7	3.1 ± 0.3	5.1 ± 0.4
	Forwards	3.7 ± 1.0	12.0 ± 1.0	3.7 ± 1.2	3.2 ± 0.3	6.0 ± 0.3
	Backs	2.3 ± 0.5	4.8 ± 1.4	4.6 ± 1.0	3.0 ± 0.4	4.2 ± 0.4
Range		0 to 7	2 to 13	1 to 10	2 to 4	3 to 7
Percentage of breaks utilised	*Total*	28%	48%	60%	28%	51%
Percentage of players drinking in less than half of the breaks available	*Total*	90%	50%	46%	100%	30%
	Forwards	83%	0%	67%	100%	0%
	Backs	100%	75%	29%	100%	60%

Table 4-3 presents detailed data obtained from the individual games for participants playing over 60 minutes of rugby. Total values for the entire team (total), and separate groupings for forwards and backs, for hydration status and voluntary drinking rates are included.

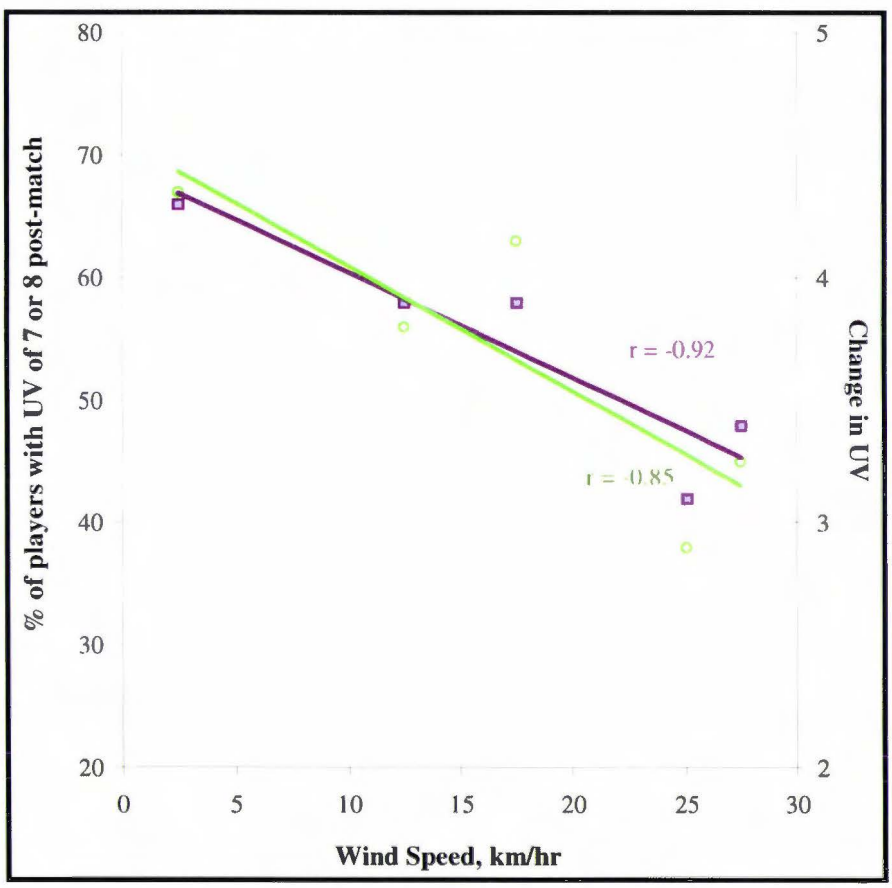
4.4.1 Hydration status

There was no statistical correlation between the date of a game nor time of kick-off and hydration status indicators such as ΔBM, post-match UV or ΔUV. No apparent correlation exists between games point differential and ΔBM, % or post-urinary value.

A positive correlation between temperature and hydration status indicates that as average temperature rose the mean of all the hydration status indices measured increased, ΔBM, % $r = 0.43$, post UV $r = 0.31$, ΔUV $r = 0.47$, however these results were not significant. Correlations between humidity and urinary values were also not significant but showed a strong negative relationship, (post UV $r = -0.92$, post UV ≥ 7 $r = -0.84$, ΔUV $r = -0.75$).

There was no apparent correlation between ΔBM and humidity. Wind speed was found to have negative correlations with urinary values, post UV r = -0.70, percentage of players with a post UV ≥ 7, r = -0.85 and ΔUV, r = -0.92 (figure 4-10), and a negative correlation with ΔBM, r = -0.34.

Figure 4-10. Correlations between wind speed and urinary values.

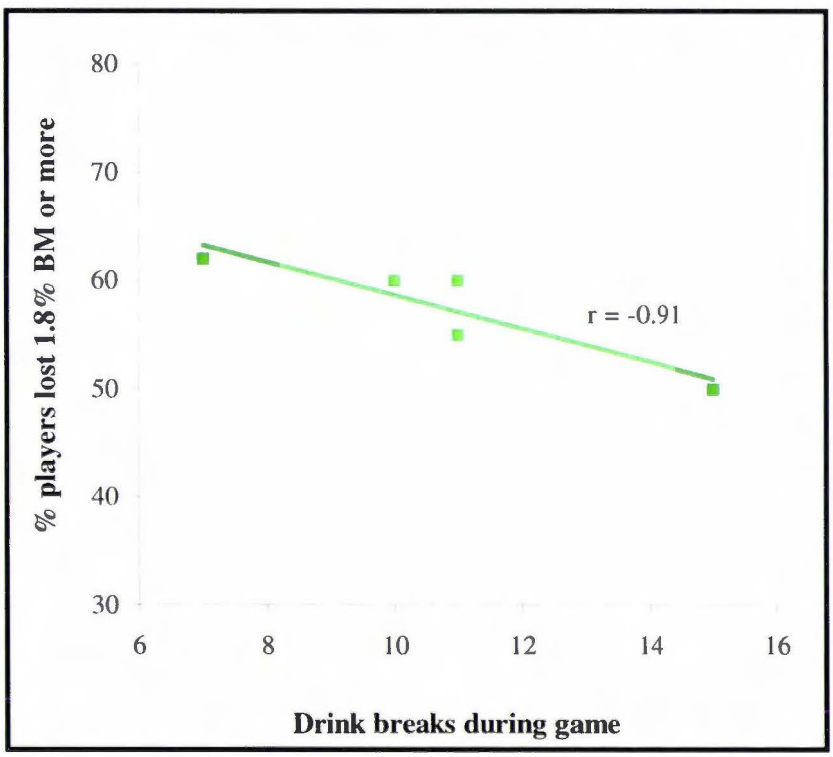


• *% players with a post UV of ≥ 7, & linear trendline —*

▫ *ΔUV, with a linear trendline —*

The number of drink breaks available has a strong negative correlation with the percentage of players losing over 1.8% body mass, r = -0.91 (figure 4-11), and a positive correlation with ΔUV, r = 0.63.

Figure 4-11. Correlation between the number of drink breaks available during a game and the percentage of players losing over 1.8% of BM .



4.5 DIETARY ASSESSMENT

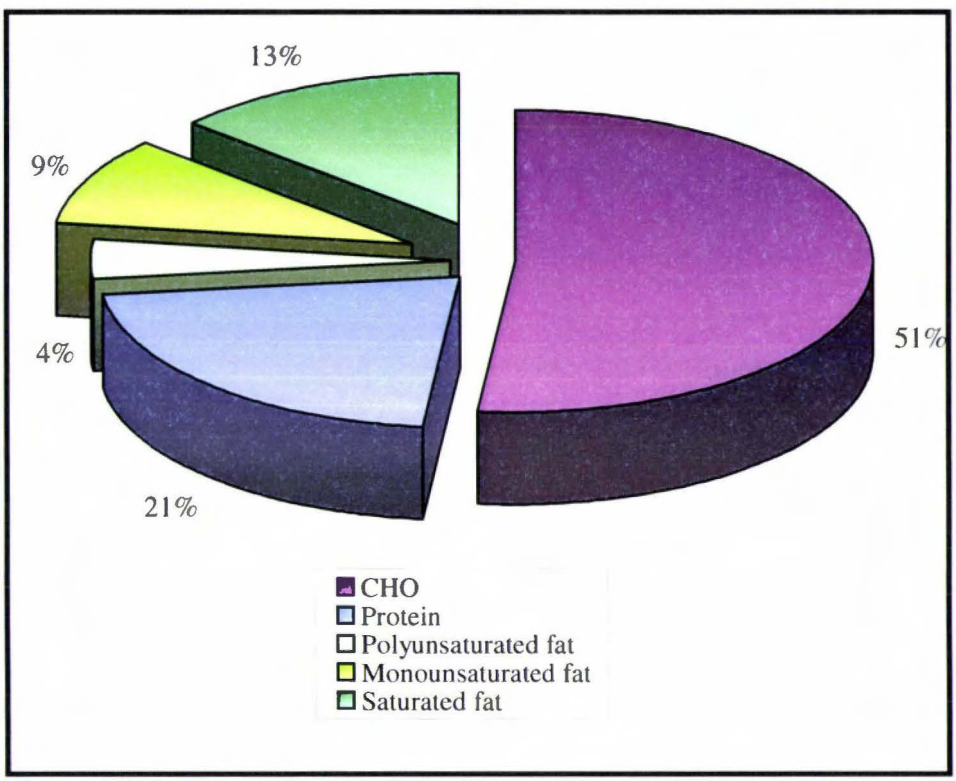
Eight subjects (30%) completed and returned the food record for the 24 hours preceding match four. The average daily energy, macronutrient and fluid intake for this period is presented in table 4-4. Fluid, Carbohydrate (CHO), protein and fat are presented as intake in grams and grams per kg body mass (g/kg BM). The mean energy intake for the 24 hours analysed was 19075 ± 1747 kJ, and the values for fluid intake were; mean (± SD) 4819 ± 1497 ml, and range 2032 – 6576 ml.

Table 4-4. Mean, median and range of macronutrient values for all players completing a self-reported 24-hour food record

	Energy	**Fluid**		**CHO**		**Protein**		**Fat**	
	kJ	ml	ml/kg BM	g	g/kg BM	g	g/kg BM	g	g/kg BM
Mean	19075	4819	51.8	588	6.3	245	2.6	140	1.5
Median	18800	5003	51.5	584	6.3	227	2.7	131	1.5
SD	1747	1497	16.9	98	1.3	52	0.5	29	0.3
Range	16726 - 21955	2032 - 6576	20.6 - 78.3	483 - 76	4.6 - 8.8	165 - 318	1.7 - 3.6	119 - 207	1.2 - 2.1

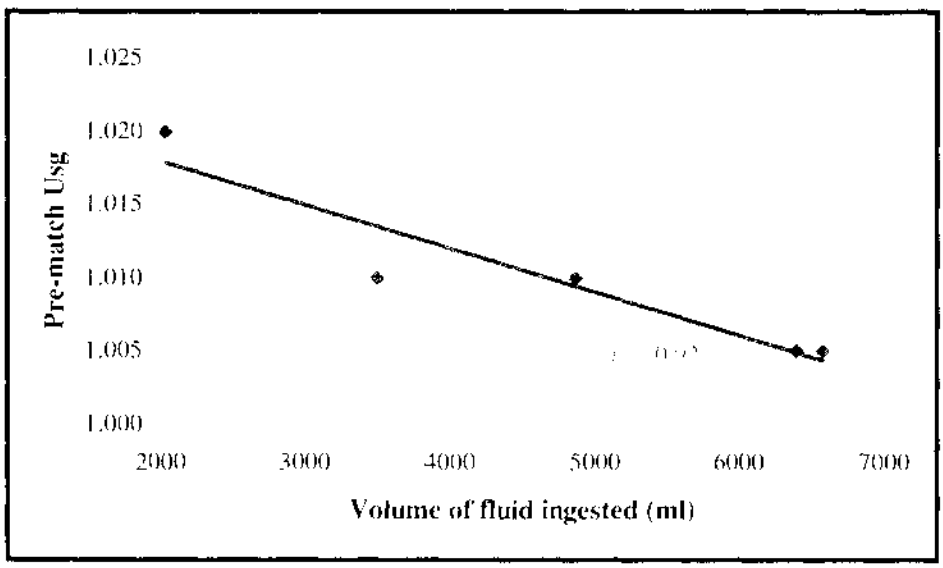
Figure 4-12 displays the distribution of carbohydrate, protein, polyunsaturated fat, mono-unsaturated fat and saturated fat to total mean energy for the 24 hr period. The mean intake of fat was 140 g and this is 26% of the total energy intake (polyunsaturated, monounsaturated and saturated fat). The mean intake of carbohydrate was 588 g and CHO contributed 51% of the energy intake. Protein contributed 21% of the energy intake, and 245 g of protein was ingested on average.

Figure 4-12. Distribution of energy percentage obtained from fat (polyunsaturated, monounsaturated and saturated), protein and carbohydrate in the 24-hour food records submitted by members of the Blues development team 2003.



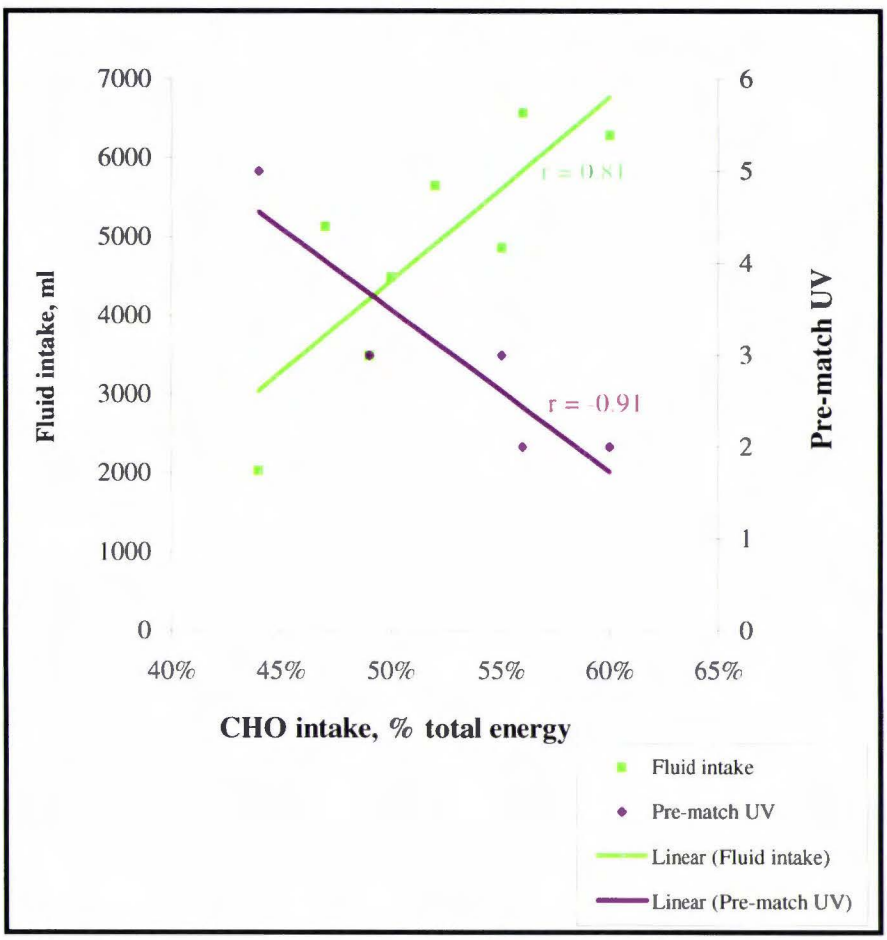
Six players out of the fifteen (40%) who were run on players for match 4, completed and returned food records. The quantity of fluid ingested in the twenty-four hours preceding game 4 was strongly and negatively correlated to the pre-match Usg and is illustrated in figure 4-13 (absolute fluid ingested in ml, r = -0.94 and relative volume of fluid ingested ml/kg body mass, r = -0.92).

Figure 4-13. Correlation between pre-match fluid intake and pre-match urine sample.



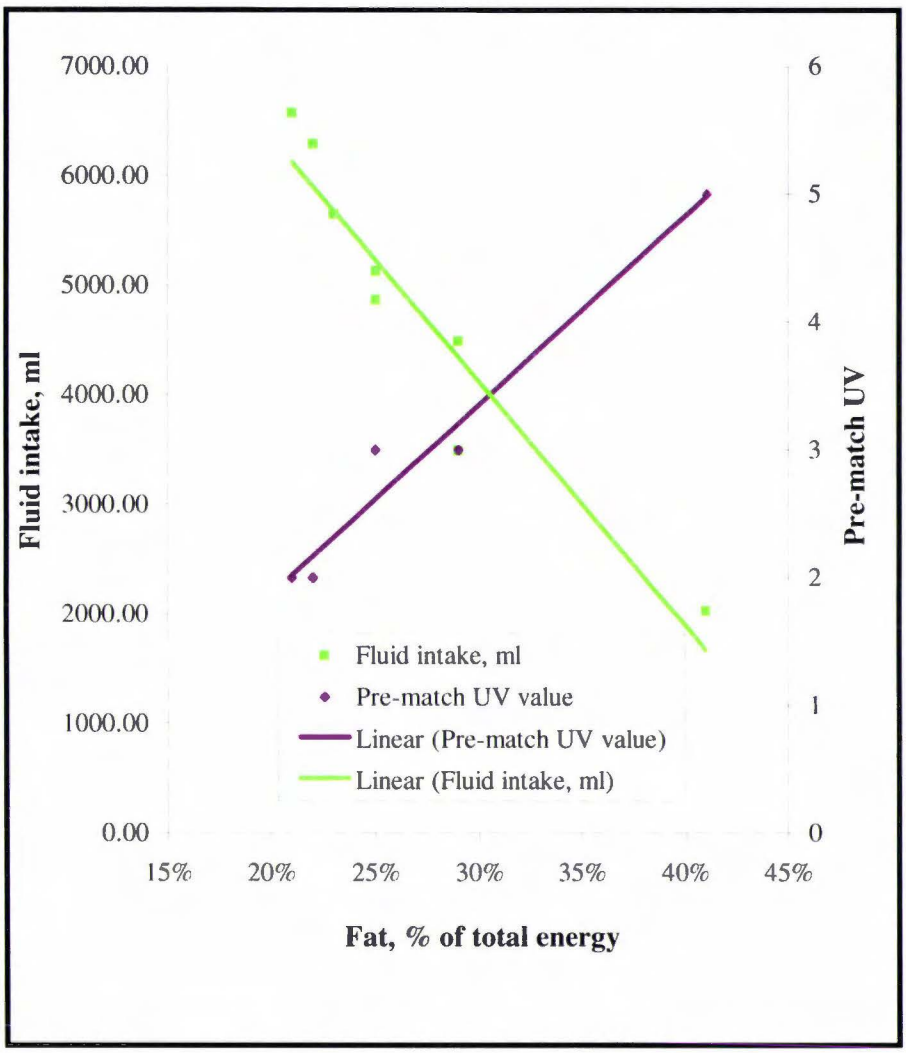
Furthermore, pre-match UV showed a strong negative correlation with carbohydrate ingested, measured in grams (r = - 0.82), g/kg body mass (r = - 0.80) and as a percentage of total energy intake (r = - 0.91), and CHO intake showed a strong positive correlation with fluid intake (CHO as a %, r = 0.81 and CHO in grams, r =0.83). The relationship that CHO has with both fluid and pre-match UV are illustrated in figure 4-14.

Figure 4-14. Scatter plot with linear trendline showing positive correlation between CHO intake and fluid intake (green) and negative correlation between CHO intake and pre-match UV (purple).



Fat intake measured in grams (r = 0.92), g/kg BM (r = 0.90) and as a percentage of total energy intake (r = 0.98) is strongly correlated with pre-match UV. Fat expressed as a percentage of energy intake and the volume of fluid ingested are strongly and negatively correlated, r = -0.96 (figure 4-15).

Figure 4-15. Scatter plot with linear trendline showing positive correlation between fat intake and fluid intake (green) and negative correlation between fat intake and pre-match UV (purple)



Results from the six completed 24-hr food records for match 4 show a trend ($r = 0.46$) for post-match UV to be lower when pre-match UV was low. And

as with pre-match UV, a negative correlation exists between post-match UV and fluid intake expressed in ml, r = -0.51 and as ml/kg BM, r = -0.75.

While these results are not significant, there is a trend that fluid intake in the 24-hr period preceding a match (both absolute volume r = -0.44 and relative volume r = -0.32) of fluid ingested is negatively correlated with the drinking frequency of a player during a match.

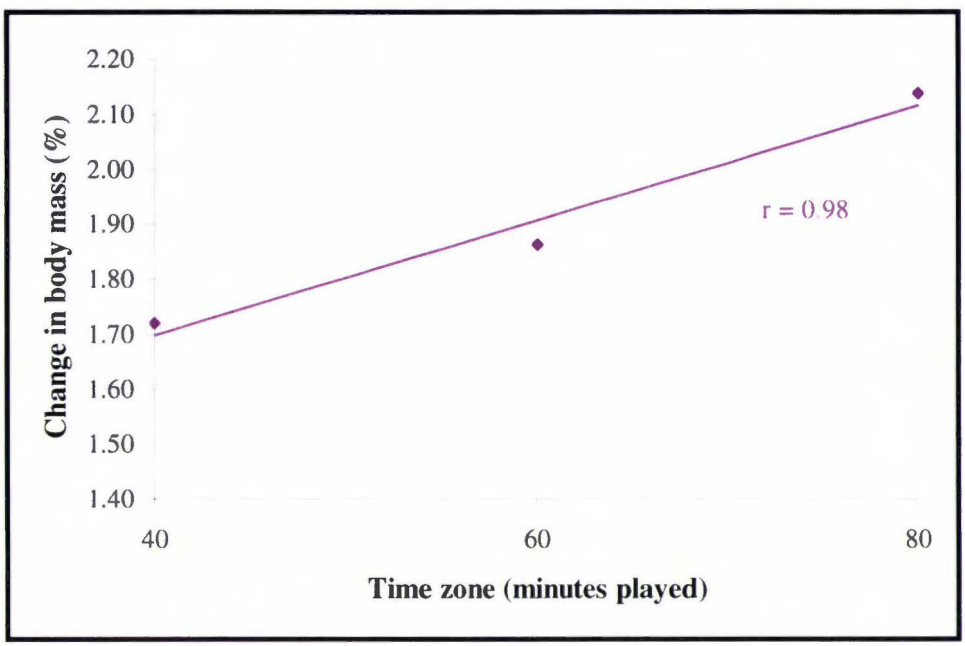
4.6 DURATION OF PLAYING TIME AND HYDRATION STATUS

The mean ΔBM, kg and ΔBM, % for all players in game 1, playing under 60 minutes of rugby (n = 17) was 1.8 ± 0.1 kg and 1.79 ± 0.13%. Pre- and post-match body mass mean values were 100.1 ± 3.6 kg and 98.3 ± 3.6 kg, this reduction in weight during the game was statistically highly significant, $P < 0.02$. The range in ΔBM was 0.86 % to 3.12 %.

The mean, median and range for pre-match UV were, 3.1 ± 0.3, 3 and 2 – 5. Post match values were 5.9 ± 0.3, 6 and 5 – 7. There is a significant difference between the mean values of these two measurements for all participants, $P < 0.02$, forwards, $P < 0.05$, and backs, $P < 0.02$. The change in BM had a positive correlation post-match UV, r = 0.74. There was no significant difference between backs and forwards in any of the hydration status markers in BD < 60.

There was a strong positive correlation, r = 0.98 between the amount of time the participant played (figure 4-16), when grouped into three time sectors (40, 60 and 80) and ΔBM, although the differences between these groups were not significant.

Figure 4-16. Correlation between change in body mass and minutes played. For players participating in a full half or more.

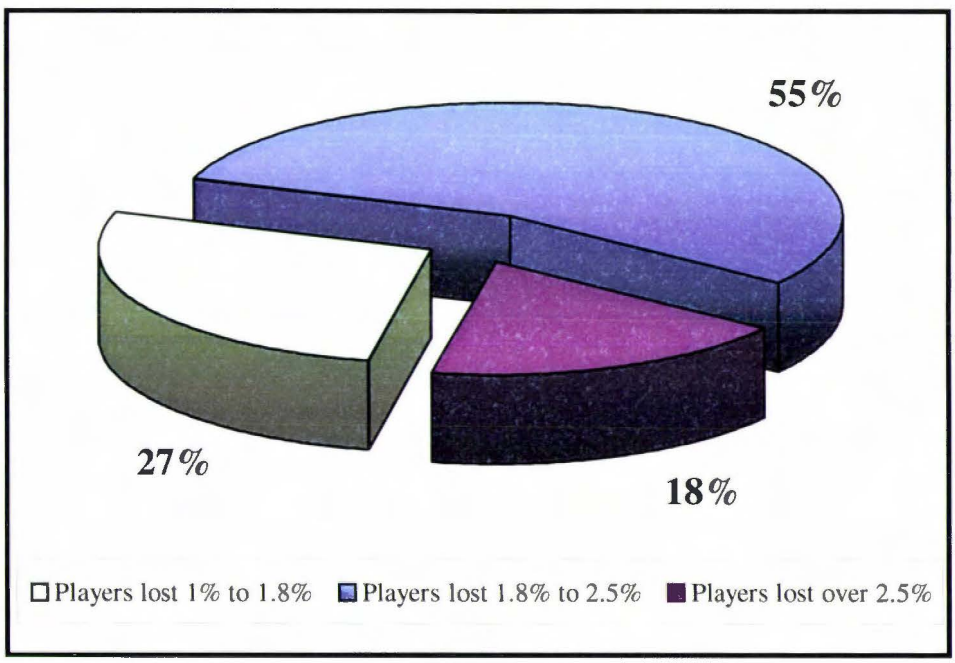


4.7 DATA FROM THE NATIONAL PROVISIONAL CHAMPIONSHIP (NPC) 2003 SEASON

Change in body mass data (n = 11) was obtained from the North Harbour Rugby Union upon completion of the NPC season in New Zealand. Analysis of this data demonstrated that the difference in body mass between pre- and post-match measurements was highly significant, $P < 0.02$, pre 113.0 ± 2.8 kg and post 110.6 ± 2.9 kg. The overall ΔBM, % was; mean 2.13 ± 0.26 % and range 1.07 % - 3.93 %. Figure 4-17 illustrates the distribution of ΔBM, %. Seventy three percent of players lost over 1.8% body mass.

The NPC 2003 team were significantly larger than the BD03 team, $P < 0.05$, however there was no statistical difference between the mean ΔBM, % calculated when the two teams were compared.

Figure 4-17. Distribution of ΔBM, % in the North Harbour NPC 2003 team



5 DISCUSSION

New Zealand male ruby union players were selected for this study from the Blues Super 12 Development Team of 2003. This ensured participants were as homogeneous as possible in regards to age, training, heat acclimatisation, level of fitness and knowledge of sport nutrition. Previous studies investigating the hydration status of rugby union players include research in South Africa on the effect of water deficit on body temperature in 1981 [11] and the effect of fluid ingestion on body temperature in 1985 [12]. The 1981 study found participants to be dehydrated to 2.52% of body mass while the 1985 study observed players were less dehydrated (1.51%) after a mean ingestion of 750 ml of water.

The present study was designed to investigate to what degree rugby union players are dehydrated when players are able to freely consume fluid during the designated drink breaks of a match. It was the intention also to investigate the role external conditions in relation to match day had in contributing to the hydration status of rugby players, and whether the elements of each individual match, such as number of drink breaks and intensity of the game, are also important factors influencing post-match hypohydration.

The body composition data is compared with past studies, and shows that the body composition of participants in this study are similar to data collected previously from rugby union players [125,126]. The factors influencing hydration status such as the game variables, player position and starting hydration status are discussed, along with those influencing drinking frequency. There is a brief section in regards to a pre-match nutritional analysis of the players, and this is followed by recommendations for improving the composition of the pre-match meal.

Due to the observational nature of this study, there were many limitations in relation to ensuring accuracy of the data collected. These are discussed in depth in relation to the impact they may have had on the results. There is a section including recommendations for future research on the subject of hydration status, fluid intake, dehydration and rugby performance and the dietary habits of rugby union players. Finally this chapter is concluded with the primary findings of this study along with recommendations in regards to fluid intake strategies and practices based on the present study.

5.1 BODY COMPOSITION

Rugby union players are generally heavier, taller and have a lower percentage body fat when compared to the general population [125]. The measurements of the BD 2003 team (table 5-1) were in agreement with this, and as in previous studies [125,128] backs were observed to be significantly lighter and shorter with a smaller lean body mass and a significantly lower percentage body fat than forwards (table 4-1). The difference in morphology between positions can be attributed to the differing skill and strength requirements of rugby [125]. Characteristics that have proven to be successful are selected for each rugby position, often at school age. All players must have some degree of all physical attributes important to the game of rugby, however forwards typically will predominantly require strength, power and stamina, thus will be bigger, while backs will primarily require speed, strength and agility. The physique of rugby union players has changed considerably over the last 100 years, with the trend moving to players being leaner and bigger [125]. Players in the present study were recruited after a break in the rugby union season, and had similar limited hours of rugby training before the measurements were taken. As this was not an elite team but instead development players from provincial and NZ colt teams, participants may have had a break from extensive training, and some may not have been at their peak fitness when the preliminary measurements were taken. Table 5-1 supports this theory as

mesomorphy is lower, and endomorphy higher in the BD2003 group when compared to the average value for rugby union players.

Table 5-1. Comparison of Blues Development 2003 players and average values for rugby union players 125 , for body mass, height and somatotype.

	Body mass, kg	Height, cm	Somatotype (1995-1999)		
			Endo	Meso	Ecto
Forwards 1975-1999	103.7	184	3.7	7.5	1.0
Backs 1975-1999	84.7	179	2.4	6.8	1.5
All Players 1975-1999	95.1	183	3.2	7.2	1.2
Forwards Blues Development	110.7	189.5	4.2	7.1	1.0
Backs Blues Development	90.0	182.7	3.3	6.2	1.4
All Players Blues Development	101.2	186.4	3.8	6.7	1.2

** Body mass and height values are averages from 1975-1999. Somatotypes are taken from the same review and are averages from 1995-1999.*

5.2 HYDRATION STATUS

It has been stated in the literature that the deleterious effects of dehydration can be seen as low as 1% in relation to physical work capacity during aerobic exercise in neutral climates [17,43], and that fluid deficits as low as 1.8% have been seen to impair performance during high-intensity intermittent exercise [44]. Conclusive evidence that fluid deficits less than 2% impair exercise performance is lacking, particularly for aerobic power, speed and skill, as the results from past studies are conflicting and sometimes inconclusive due to small sample sizes and varying methodology. According to past research, there is a high risk that an athletes performance may be impaired at and certainly beyond 1.8% dehydration, and a need to reduce this risk by ensuring fluid deficits are minimal or at least below this level. For that reason, and for the purpose of this study a lower limit for dehydration in relation to impairment of mental and physical performance was set at 1.8%.

During this study fifty ΔBM results for participants playing over 60 minutes of rugby were obtained over 5 games. All of these results (100%) showed a loss in body mass. The majority of athletes were dehydrated to a level where their match performance may have been impaired, as the mean level of post-match hypohydration over all games according to the change in body mass was 1.87%, and was higher than observed in a previous study (1.51%) on fluid deficits in rugby union players where the players consumed a mean of 750ml of fluid [12]. Prior research was conducted on rugby players where fluid was not consumed during matches [11] and those subjects were found to have a mean fluid deficit of 2.52%. Results from the present study where fluid was available to players during the formal breaks in play, showed a higher level of fluid deficit than that observed in a study on rugby league players (1.21%) [129]. In the rugby league study players were only able to ingest fluids *ad libitum* before the match and at half time, the mean amount of fluid ingested was 819 ml.

In the present study almost two thirds (62%) of ΔBM results were over 1.8% (figure 4-4), and over a quarter (28%) of results were over 2.5%. During the final match (game 7), 50% of players had a fluid deficit of 2.5% or over, the mean ΔBM was 2.23% and it was after this match that the largest fluid deficit during this study was observed (4.61%). While the subjects are consuming fluid, mean fluid deficits are very near those found in research on rugby union players where no fluid was consumed [11]. There is a very real possibility that a large proportion of players participating in a rugby match, perhaps up to half, are dehydrated to a level where performance is impaired. This is occurring in even thermoneutral environments. Such a large proportion of players not playing at their optimum would have an effect on the entire team performance and game result. A trial by Below *et al* [45] had subjects hypohydrated to a 1.9% reduction in body mass after performing 50 minutes of submaximal cycling. After the 50 minutes, cyclists were required to perform a 'sprint to the finish'. Sprint performance improved by 6% when fluid intake replaced 80% of fluid loses (1330ml) compared to when the volume of fluid ingested was low (200ml). This study is particularly relevant to team sports such as rugby union, where athletes perform submaximal exercise intermittent with high intensity activities [126]. A reduction in sprint performance of 6% when dehydrated below 2% may for example be the difference between scoring a try, or preventing an opposing try being scored.

Several studies have shown that Ucol, Uosm and Usg correlate to body mass loss when a subject is hypohydrated [176,177,178]. The current study is in agreement with this prior research, as the post-match urinary value (and therefore Usg) had a strong positive correlation with ΔBM. To preserve accuracy of results the subjects were asked to maintain their regular drinking patterns during this study and particularly not to drink excessive quantities of water before the pre-match urine sample was given. The post-match urine sample may have been underestimated as some subjects may have increased drinking rate after the match to eliminant their thirst. The risk of fluid not

been absorbed and instead the excess excreted in the urine was minimised by imposing a time cut-off of 1-hour post-match. Any urine samples returned after this time were not analysed but instead a 'could not urinate' result was recorded.

The mean post-match UV reading was 6.3 and equal to a urinary specific gravity of 1.025 (likert scale figure 3-1). Therefore the majority of players (figure 4-7) were 'mildly dehydrated' or worse, as 74% of all results were a 6 (Usg of 1.025) or above. A 'could not urinate' result was returned for 32% of all data. An inability to urinate within 60 minutes from conclusion of a rugby match is an indicator that a player is hypohydrated, however it is impossible to determine to what level this has occurred by urine analysis alone. As illustrated by the data in table 5-2, participant BD0308 could not urinate at the end of three of the matches. While his post-match UV's were identical (UV = 8) for these games, his calculated fluid deficits varied by 1.69% from the lowest (2.92%) to the greatest (4.61%). Urine specific gravity, when used as a hydration status indicator cannot determine the extent of fluid deficit when a subject is hypohydrated to and beyond the point where urine production ceases

Table 5-2. UV and ΔBM data collected from subject BD0308.

Match	*Post-match UV*	*ΔBM, %*
2	8	2.92 %
4	8	3.60 %
7	8	4.61 %

Urine specific gravity assessment as a replacement for urine osmolality is accurate if corrected for any protein and glucose present in the urine. Three post-match urine samples had some glucose recorded, possibly due to the consumption of high CHO gels at half time, and the urine results were not used.

5.2.1 Player position

There was no significant difference between ΔBM in the forwards and backs with the exception being game 3, and no obvious trend. For example, forwards had a greater fluid deficit in three of the games and the fluid deficit was greater in the backs for the remaining two. The primary reason will be due to the type of rugby being played, as this influences the intensity of exercise of each individual player. Open running rugby will result in backs taking a more active role, while a close low scoring game, with a great deal of scrums and mauls will mean forwards participate more than the outside backs. Tables 2-6 and 2-7 illustrate the differences between forwards and backs in the movement and distance covered during a rugby match [126].

Wet conditions also have a part in determining the type of rugby played, however it was not a factor in this study as all games were played in fine or slightly overcast conditions.

The opposition was different in every game, and this also will have a direct impact on the type of rugby and therefore the intensity of exercise evident for each individual and the two positional groupings. Figure 4-3 supports this, and shows that as the game points differential decreases, and the two teams are more evenly matched, forwards show an increase in mean ΔBM. The opposite is true for the backs, as the point differential increases, and possibly the rugby played was more open, ΔBM increases.

5.2.2 Pre-match hydration status

Ensuring euhydration upon commencement of exercise is an important factor when minimising dehydration and perhaps hyperthermia [19]. The ACSM recommends athletes be 'well hydrated when beginning to exercise', and states that this can be accomplished by drinking generous amounts of fluid in the 24 hours before an exercise session and 400 to 600 mL of fluid 2-3 hours before exercise. Ingestion of adequate fluid to ensure fluid balance prior to exercise may be difficult if the sports event begins in the morning or early afternoon. Drinking late at night and during the night may cause disruption of sleep patterns due to individuals waking with the need to urinate. Sports where multiple competitions occur in one or two days, such as during a rugby sevens tournament, will also challenge the maintenance of fluid balance. Recovery time is often short, making rehydration difficult.

Assessing hydration status prior to exercise can help an athlete form a fluid ingestion strategy to ensure they will be euhydrated before exercise commences. Monitoring hydration status by means of measuring the fluid deficit (ΔBM) relies upon both pre-exercise weight and post-exercise weight, and is an ineffective method when attempting to determine pre-exercise hydration status. Urine indices such as urine volume, colour, osmolality and specific gravity can inform an individual of hypohydration in time to rectify the fluid deficit.

The present study found the majority of participants to be euhydrated pre-exercise (mean: Usg 1.010, UV 2.7). Only one participant had a Usg of 1.020 (UV 5). There appears to be no correlation between pre-match UV and post-match UV, nor between pre-match UV and ΔBM, %. This result was unexpected, but could be due to the high rate of pre-match euhydration. It could be assumed that as long as a player is euhydrated at the time of kickoff (Usg of 1.015 or under) the exact pre-match Usg reading has no influence over the post-match Usg. In fact if the Usg is low, 1.000 – 1.005, it may be

that a player has ingested a large volume of fluid very quickly, and the result will be an increase in the volume of urine and need to urinate.

In a practical setting as discussed previously, Usg could be analysed a few hours prior to a rugby match, a player would have the results immediately and would be able to increase fluid ingestion in the lead up to a game if necessary. Urine analysis for specific gravity is therefore a valuable means of providing and athlete with instant feedback in relation to the effectiveness of their pre-competition hydration practices.

It is possible that the very high proportion of players with pre-match euhydration (98%) observed in this study could have been due to observer bias. While there was no instruction to the participants in regards to fluid balance maintenance, rugby players at this level have some knowledge of the importance of drinking fluid. As all participants were aware there was a study on hydration being conducted the presence of the researcher during the hours before a match may have influenced drinking habits by reminding them to ingest fluid. This bias is likely to be minimal however, as the team trainer had knowledge of sport nutrition and was very informed in regards to the importance of hydration in relation to sports performance. The trainer was observed during meals and meetings verbally reminding the players to drink plenty of fluid. It is likely that his impact on the rate of pre-match euhydration was far greater than any potential observer bias.

5.2.3 Game variables and environmental conditions

Environmental conditions such as radiative heat, ambient temperature, relative humidity and wind speed can influence the rate of heat production and storage in the body and therefore thermoregulation and fluid homeostasis. In agreement with previous studies [110,111,113], there is a positive correlation between ambient temperature and hydration status (ΔBM, % $r = 0.43$ and post-match UV $r = 0.41$). It is interesting that the correlations between humidity and hydration status measured by Usg were

negative, as this was not expected. This surprising result could be because the highest humidity reading (63%) was taken in game 6 when the ambient temperature was the coolest (16°C). It is probable that the low ambient temperature during this game had more of an impact on hydration status than a high-mild relative humidity. During the Super 12 NZ Development 2003 season, the humidity measurements for the Blues games were not extreme, and instead ranged between 36% and 63%.

As wind speed increased, the level of dehydration appeared to decrease. Wind flow will aid in cooling the body by convection, and this cooling effect will increase as wind speed increases, sweating efficiency will also increase in the presence of airflow across the skin. The cooling effect of airflow coupled with an improved evaporative cooling efficiency will decrease the sweat rate, as a consequence of a reduced rate of heat storage.

The games point differential is an indication of the intensity of the game as the higher it is, the less evenly matched the teams will be and the less likely the intensity of activity will be consistently high. However a decrease in point differential does not appear to increase the level of dehydration over the whole team. This may be due to a cancelling effect of the different positional groups. As mentioned previously as point differential increases the fluid deficit in backs increases and in forwards it decreases (figure 4-3). Indicating the intensity level of any single game will affect positional groups differently and this must be taken into consideration when developing fluid ingestion strategies.

5.3 DRINKING FREQUENCY

The hypohydration that occurs as a consequence of fluid intake restriction is termed involuntary dehydration and the body fluid deficit that occurs as a consequence of an individual not maintaining fluid balance even when water

is easily accessed is termed voluntary dehydration. Opportunities for drinking are restricted during a game of rugby union, so to a certain extent the dehydration observed was involuntary. However, the players on average are utilising less than half (48%) of the breaks available during a match to take a drink, meaning the fluid deficit that occurred was partially voluntary as seen in other studies [20].

The average number of drinks taken by all players in all five matches was 4 (mean 4.2), and the average number of drinking opportunities, excluding half time, was 11 (mean 10.8). There may be several reasons for this, drink bottles may not be reaching individuals other than those actively seeking them, players may fear gastric discomfort from drinking and some individuals in the team believed that muscle cramping was caused by drinking water during exercise.

5.3.1 First and second half drinking frequency

The drinking frequency was higher in the first half (mean 2.6) than the second half (mean 1.6). This is an interesting observation and there could be a number of reasons for this preference for drinking in the first half. One of which could be the fluid bolus ingested by the participants during half time. During the half time team talk support staff distribute individual cups of powerade and water to the players with the instruction to drink. During this break for match 6 the mean volume ingested per player was 352 mls. This amount is an estimate as fluid may have been spilled, tipped out, or consumed by some of the reserve players or support staff. There is a risk that a large volume of fluid consumed rapidly could cause gastrointestinal discomfort during exercise, however the volume ingested here is not large enough to exceed gastric emptying or intestinal absorption. More likely a fluid bolus of this size followed by sipping when water is made available would increase gastric emptying [55]. Drinking during half time may have satiated the dipsogenic drive before fluid balance was fully restored as observed in

previous studies [20,50], thus the frequency of fluid ingestion was less in the latter half of the game, even though players were hypohydrated. Another factor contributing to the lower drinking frequency observed during the second half of a match could be a psychological one. A player will know it is past the half way mark of the match and may have the perception that drinking is not as important at this time as water will be readily available immediately at the end of the game. As the urge to drink may not appear until an individual is 2% dehydrated [50], perhaps the only thing making a player ingest fluid during a match is the fact he has been told he should drink to prevent dehydration. As the latter stages of the match are reached a player may have the perception that the fluid ingested earlier will have been enough to stave off or at least reduce the level of dehydration.

5.3.2 Hydration status

Drinking frequencies were not related to hydration status. That is, the players with the greatest level of hypohydration at the end of the game were not the individuals drinking more or less during the game. As sweat rates and therefore fluid loss as a consequence of exercise are highly variable between athletes [28], as is the drinking response, it is not surprising that the mean figures of a group for hydration status and drinking frequency have no correlation. In this study the actual volume of fluid ingested during a rugby match was not measured. It could be assumed that the volume of fluid ingested from a sip is also variable between individuals. A player dehydrated by 3% may have been sipping a greater volume in the latter stages of a match than a player dehydrated by 1%.

5.3.3 Exercise intensity

It could be assumed that as the intensity of exercise increased, drinking frequency would increase. During a rugby match the points differential is an indication of game exercise intensity, and decreases as the teams are evenly matched, often the cause of a more difficult game. In this study the opposite

was observed, as points differential decreased, so did drinking frequency. The reason for this may be due to the lower number of drinking opportunities in a close game involving plenty of forward play. A high points differential occurs because one team has achieved a high score by scoring trys (converted try is 7 points). During each try conversion there is a formal break in play and an opportunity for players to drink. Again actual fluid intake volume would give a better indication of whether fluid ingestion increased as exercise intensity increases and this was not measured in the present study. The reason for the absence of data on the actual volume of fluid ingested is due to the lack of individual drink bottles and is discussed in section 5.6.2.

5.3.4 Environmental conditions

As mentioned previously climatic conditions will influence the rate of heat storage and the extent and rate of hyperthermia and fluid deficit. The drinking response may occur to reduce plasma osmolality and fluid deficit and if the beverage is cool, reduce body heat. There was no clear correlation between frequency of drinking and temperature or humidity, however there was a strong negative correlation ($r = -0.83$) between drinking frequency and wind speed. The lowering of the body periphery temperature due to convection and the resulting lowering in core temperature may reduce the drinking response as the rate of heat storage is reduced.

It was observed by the researcher that during match 6, the hottest and clearest day, reserve players were dampening their boots with water to cool them, and covering their boots in clothing to prevent them from heating up because of the radiative heat of the sun. All rugby boots were supplied by a Super 12 sponsor, and were black, a colour likely to increase radiative heat adsorption by the body. On the days when radiative heat from the sun was high, the boots would heat up to an uncomfortable temperature. Presumably, this radiative heat would heat not just the feet of players but also the entire body. The type of clothing worn may have an impact on body temperature in both

the reserve and starting players [41]. The BD2003 team wore short sleeve bright darkish blue shirts and shorts, blue socks and black boots, and approximately three players on the field (20%) at any time wore black headgear.

5.4 DURATION OF EXERCISE

As expected, players were more dehydrated as the duration of playing time increased. Nonetheless, correlations between play duration and ΔBM were not significant, due to the small number of subjects participating in a range of play durations. Because of resource constraints individuals who did not participate in an entire half were only recorded as being on the field for less than 40 minutes in place of the actual period of time in minutes.

The mean ΔBM for those subjects playing under 60 minutes of rugby (BD < 60) during game 1 was slightly lower at 1.77% than those playing more than 60 minutes overall games (1.87%). Mean pre-match Usg in the BD < 60 group was 1.015 (UV 3.1) which is very similar to the BD > 60 group (Usg 1.015, UV 2.7). Both groups had post-match Usg values of 1.025. While those subjects participating in less than 60 minutes of rugby displayed a lower level of hypohydration, there is still some degree of dehydration occurring.

At regular intervals reserve players will warm-up by shuttle running, ball passing and stretching. Both water and a sports beverage are nearby and players on the bench are able to drink *ab libitum*. The maximum ΔBM recorded for the group BD < 60 was 3.12%, a critical level in regards to performance. This value and the average ΔBM for this group indicates that reserve players and those substituted off before playing 60 minutes are either; not ingesting adequate fluid while on the bench, are not topping up while in play, are not replacing fluid loss after being substituted off, or a combination of the above.

5.5 PRE-MATCH DIETARY ASSESSMENT

It is common practise for an elite rugby team to be accommodated as a group prior to a match. A food requirement plan is sent to the hotel before the team arrives and meals are served buffet style on the premises. Players make a selection in relation to quantities and composition of their meal from the choices placed before them. Exact ingredients are not normally known and weighing of food would be impractical. This puts a limitation on dietary assessment using the method of estimated food records. However the researcher was present at most meals during the 24-hour period and was able to estimate and measure the sizes of bowls, ladles and other food portions. The presence of the researcher was also very useful in regards to determining the composition of a dish. For example a pasta salad was present during a lunchtime meal, and many players simply stated this in their food records. However this salad also contained beef and tomato, and thus these foods were also selected from the New Zealand food and crop database for the lunchtime meal to calculate nutrient content of the 24-hour diet.

This section includes analysis of the macronutrients consumed during the 24-hr period, as well as a brief section on some vitamins, minerals and antioxidants. Recommendations on how the composition of the pre-match meal could be improved conclude the diet analysis section.

5.5.1 Carbohydrate

Population dietary guidelines in westernised countries generally recommend CHO intake to provide 50 – 60% of total energy intake. The average CHO intake calculated from all food records returned was 51%, this barely falls within the minimum recommendation for the general population, and does not reach the recommendations of 65 – 70% for athletes with a heavy training load [201]. Even though players are consuming large quantities of food (mean energy intake of over 19,000 kJ), CHO requirements for athletes are barely being met, (6 – 10g CHO/kg BM per 24 hours [193,194,201]), as the

mean volume consumed is 6.33 g/kg BM per 24 hours (median 6.28, range 4.62 – 8.75). However, as training is unlikely to occur the day before match day, a mean of 588g CHO could be adequate in achieving high muscle glycogen stores, particularly if the athlete has replaced glycogen from prior training days. No clear conclusions can be drawn from this study due to the low sample number (n = 8) and lack of repetition of food intake assessment.

Findings from this study are similar to other studies conducted on football and soccer players. A 1988 study by Burke had 56 Australian rules football players completed food diaries [202]. The mean carbohydrate content was found to be 44% and well under the recommended range. Another study conducted on young male elite soccer players also found carbohydrate intake was below that recommended (range 48% to 56%) [203].

The mean CHO intake observed in this study is the minimum of that recommended for recovery and restoration of glycogen stores, and some players are consuming well under the recommended amounts of CHO in the 24 hours leading up to a match, a time where optimising glycogen stores is the primary goal [136]. Carbohydrate intake in the 24 hours preceding a rugby match should be increased in those participants consuming under 50% of the energy intake and particularly those consuming under 6 g/kg BM. It would seem the players in this study need to be educated on the importance of carbohydrates, and what foods to choose to increase them. Section 5.5.6 outlines recommendations for the pre-match meal based on this study.

5.5.2 Protein

The mean daily protein intake was 2.6 g/kg BM and is higher than the recommended daily intake of protein of 1.4 – 1.7 g/kg BM [195,201]. This high protein intake is similar to that observed in elite Swedish soccer players who were also observed to consume 2 – 3 g/kg BM [204], but considerably higher than that observed in Australian rules football players [202] of 1.5 g/kg BM. Only one player (BD0329) consumed within the amount recommended,

at 1.67 g/kg BM. The highest estimate of protein intake was 3.57 g/kg BM. As with carbohydrate, a high volume of food will influence the volume of protein ingested. The high rate of protein intake makes dietary protein supplementation in the form of powders, drinks or bars unnecessary in this group of athletes.

5.5.3 Fat

Total fat supplied on average 27% of total energy intake and this is within dietary recommendations for the general population of no more than 30%. One participant (BD0329) had a dietary fat percentage of 41%, which is far in excess of what is recommended as a healthy level for the general population, and similar to the mean fat intake observed in Australian rules football players (44%) [202]. A diet consisting of 30% fat may not be unusual for athletes who are not concerned about their weight, as foods rich in fat are energy dense. An individual with a large energy demand due to training and competition would have to eat vast quantities of food if the fat proportion of their diet was low [201].

While the average total fat intake is within the healthy range, saturated fatty acids make up almost half (49%) of the total fat intake. This is in excess of the maximum amount recommended (33% saturated, 33% mono-unsaturated, 33% polyunsaturated of total fat [201]). To obtain a healthy dietary fatty acid profile the amount of monounsaturated fats should be increased. However without other changes this would increase the total fat beyond 30%. Instead monounsaturated fats could be used as replacements to saturated fats.

5.5.4 Other nutrients and non-nutrients

In a well balanced diet most nutrients are supplied in sufficient amounts. As with the macronutrients, vitamin and mineral RDI's for the general populations are easy to attain when the volume of food ingested is high and the composition varied, as is the case with the individuals participating in this

study. However athletes can have different nutritional requirements when compared to sedentary individuals in regards to higher nutrient requirements, and nutrient turnover. There may be increased excretion of vitamins and minerals, a larger vitamin and mineral utilisation due to a high metabolic rate and a greater level of free radical production as a result of exercise. Free radicals are highly reactive and are thought to increase the rate of fatigue and contribute to the muscle damage seen after exercise. Antioxidants such as Vitamins C and E, selenium, β – carotene and others can reduce the cellular damage caused by the metabolic release of free radicals.

In the present study median intakes far exceeded RDI's for all vitamins and minerals assessed, many of which are presented in table 5.3.

The median β – carotene (equivalents) intake of 7958μg (range 1953 – 12119) is of a healthy level, other non-nutrient antioxidants were not assessed. Generally RDI's for the general population are considered to be appropriate for athletes, with a few exceptions [201]. As thiamin, riboflavin, niacin, vitamin B6, biotin and pantothenic acid are involved in energy production during exercise, and folate and vitamin B12 are required for production of red blood cells, protein synthesis, and in the repair and maintenance of tissue, there may be an increased requirement for these in athletes [205]. Requirements may be twice as much as that recommended for the general population [201]. The intakes of selenium, vitamin E (to combat increased free radical production), vitamin B6 and folate while still above the RDI, may not be reaching requirements in these athletes.

The 24 hour intakes of micronutrients in the Blues development players far exceed those found in Australian rules football players [202] (retinol activity, 1439 mg; thiamin, 1.7 mg; riboflavin, 2.8 mg; niacin equivalents, 45.1 mg; vitamin C, 139 mg; iron, 19.6 mg; and calcium, 1016 mg), this indicates there was a large variety of food being consumed by the Blues players, which is also the observation of the researcher.

Table 5-3. Average amount of various nutrients consumed in the 24-hr period preceding match 4, comparing to RDI's for adult males.

Nutrient	BDO3 intake (median)	Range of BD03 intake	RDI [181]	Percentage of max RDI met by intake
Sodium, mg	5835	3695 – 9325	920 – 2300	250%
Potassium, mg	7562	4985 – 9849	1950 – 5460	141%
Magnesium, mg	559	426 – 677	320	178%
Calcium, mg	1507	760 – 2207	800	182%
Phosphorus, mg	3323	2768 – 4525	1000	321%
Iron, mg	48	19 – 108	7	486%
Zinc, mg	28	23 – 34	12	233%
Selenium, μg	178	148 – 64	85	174%
Thiamin, mg	4	3 – 5	1.1	318%
Riboflavin, mg	4	3 – 5	1.7	235%
Niacin, mg	104	75 – 136	19	537%
Vitamin C, mg	341	180 – 741	40	771%
Vitamin E, mg	20	12 – 35	10	185%
Vitamin B6, mg	4	2 – 6	1.3 – 1.9	184%
Vitamin B12, μg	13	9 – 25	2	575%
Folate, μg	617	371 – 843	400	152%
Vitamin A, μg	1967	1134 – 3062	750	261%

To obtain an assessment of nutritional status, food records for at least 4-7 days should be obtained and analysed. Although food records for much longer periods are necessary to get an accurate account of a normal dietary intake [185]. To obtain an assessment of nutritional status it would also be

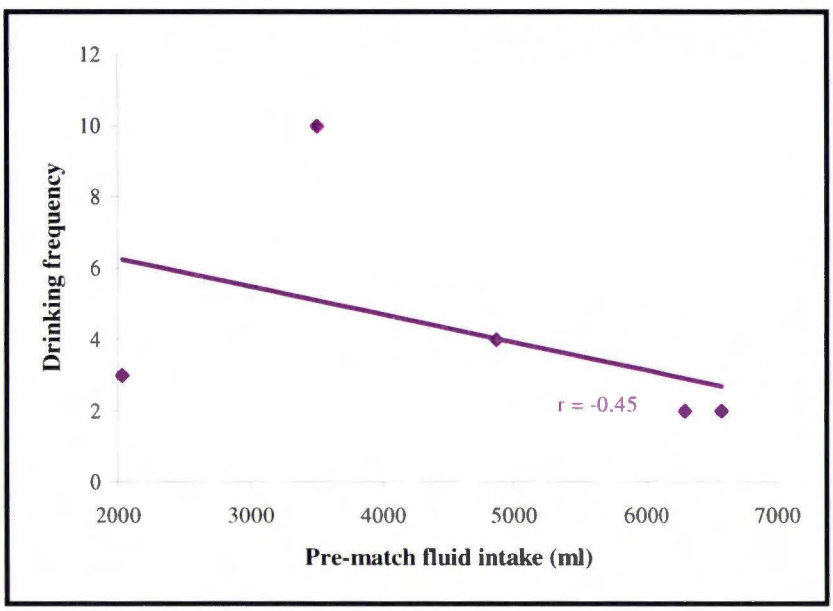
necessary to gather information from a combination of nutritional status markers, by clinical, anthropometric, and biochemical testing. However based on the food records collected from this group, the 24 hour diet preceding a match meets all vitamin and mineral requirements.

5.5.5 Fluid intake

As expected, a high level of fluid intake during the 24 hours preceding a match produced a low Usg reading from the pre-match urine sample as pre-match Usg was strongly and negatively correlated with both relative (ml/kg BM) and absolute (ml) fluid intake, $r = -0.94$ and $r = -0.92$ respectively. This relationship is represented in figure 4.14. The individual (BD0329) with the highest pre-match Usg reading all season of 1.020 (CV = 5), had the lowest estimated fluid intake of 2032 ml.

An observation worth further investigation is the apparent trend for the volume of fluid ingested prior to a match to be negatively correlated to the frequency of drinking during a match (figure 5.1).

Figure 5-1. Relationship between absolute 24-hr pre-match fluid intake and drinking frequency during a match.



It is possible that drinking large volumes of fluid prior to exercise decreases the drive to drink during exercise. However, post-match hydration status does not appear to be worse with higher levels of pre-match fluid ingestion. Therefore if the players with higher pre-match fluid ingestion levels are drinking less frequently during a game, this does not appear to be detrimental to their post-match hydration status. It is likely that ingestion of a large volume of fluid in the days prior to a match results in hyperhydration and increased body water reserves. This has been observed to improve thermoregulation in elite soccer players [135]. However, if hyperhydration limits fluid intake during a match, it could result in players with an end fluid deficit similar to those ingesting usual volumes of fluid pre-match. No assumptions can be made from this data due to the very small sample size (n = 5) and lack of statistical significance in the correlation calculations. Furthermore, and as mentioned in section 5.6.2, drinking frequency as determined in the current study is not an indicator of absolute volume of fluid

ingested during a match. Further research is necessary in relation to the impact of pre-match fluid ingestion on drinking frequency or rates during a match.

Interestingly, carbohydrate ingestion also appears to influence pre-match Usg, as CHO intake is strongly correlated with fluid intake. This correlation may exist because of the high water content of many CHO rich foods, such as fruit, vegetables, pasta, soft drinks, sports beverages and fruit juices. This type of diet (rich in CHO containing foods) potentially has a twofold benefit to exercise performance and fluid balance. A diet rich in carbohydrate will maximise muscle glycogen storage and thus the available energy source. It will also ensure an individual is in a euhydrated state before commencement of exercise.

Post-match Usg was lower when the pre-match Usg was low, indicating hydration status at the beginning of a match influenced hydration status at the end of a match. Presumably as a result of this post-match Usg was seen to decrease as the volume of fluid ingested prior to a game increased. However this result was not statistically significant due to the small sample size ($n = 6$), and does not agree with the lack of correlation between pre-match and post-match UV over all subjects (section 4.2.2).

5.5.6 Pre-match diet recommendations

The guidelines for the pre-competition meal as stated by the American College of Sports Medicine, the American Dietetic Association and the Dietitians of Canada in their joint position stand [201] are listed below.

- Sufficient in fluid to maintain hydration
- Low in fat and fibre to facilitate gastric emptying and reduce gastrointestinal distress

- High in carbohydrate to maintain blood glucose and maximise filling of glycogen stores
- Moderate in protein intake
- Made up of foods familiar to the athlete
- Eaten 3-4 hours before the game or practice.

Based on the results of the present study, it is recommended that the saturated fat content of the pre-match meal be reduced, while still consisting of foods familiar to the players. This may involve a change in portion size rather than actual content of the meal. Carbohydrates should be emphasized while protein portions such as red meat, chicken and fish are reduced. It was common for players to choose a portion of each type of meat present at the buffet table. This resulted in a large area of the dinner plate to be filled with chicken, beef and fish, and will lead to a high proportion of protein and fat in a meal. Players could be educated into selecting only one type of meat from the dishes provided. Replacing butter with polyunsaturated spreads for bread and oils for cooking, and eliminating cheese during this pre-match 24 hour period would reduce dietary saturated fat content. Muffins made with butter were popular at lunch and these could be substituted with a similar baked product such as carrot cake, made instead with oil. To ensure kilojoule requirements are met energy dense foods such as a variety of nuts and bars containing seeds and dry fruit, could be made available during and between meals.

Inclusion of familiar foods pose a challenge due to the different cultural groups making up both development and elite teams in New Zealand and the differences between a western diet and that of the Maori and Pacific Island population. However a buffet style meal means dishes familiar to every cultural group are available for players to choose from.

Another observation made by the researcher was the consistency of the meal content regardless of time of match kickoff. Breakfast was the same, in spite of it being the pre-match meal for match 4 which began at 12:00 noon. Breakfast always consisted of cereals, milk, fruit, toast and various spreads, bacon, eggs and baked beans. Invariably players chose bacon and eggs, which are high in fat and protein. When breakfast is the pre-match meal rugby players should be educated in the importance of adding carbohydrates to this meal. Ingesting cereals and fruit first, or replacing bacon and eggs with other hot alternatives such as baked beans on toast, pancakes and porridge would result in a higher percentage of carbohydrates in this important pre-match meal.

5.6 LIMITATIONS

As this study was observational in nature, there were many limitations when both designing and maintaining protocol in relation to data collection. A schedule of procedures is outlined in Appendix D. Procedures were piloted in the first non-competitive match (game 1), discussed with the team management and then adhered to throughout the Super 12 NZ Development season. The study would not have gone ahead unless the support of the team management was gained. This could only be achieved if it was agreed that the psychological preparations and routines undertaken by each player prior to every match would not be compromised by the presence of the researcher or by the data collection protocol. The build up to a match usually gains momentum when the team arrive at their accommodation the day before a game. Psychological preparation escalates after the pre-match meal. In this study this meal was lunch in four of the matches, and breakfast in the match played at 12:00 noon. Players will eat their meal together and then leave the dining room to prepare for the match in their rooms. The next time they are together as a group is during the team meeting at the hotel 30 minutes prior to departure to the rugby ground. It is at this point where routine and the

maintenance of player focus is important and cannot be compromised. After the team meeting players will board the bus and be transported to the rugby ground. A prolonged warm-up period will take place, and changing into the team match strip will follow this. At half time observations and information relating to the match is passed from the coaches to the players, and between players. Strategies are analysed and a motivational talk takes place. In addition, players are required to ingest fluid and keep muscles warm by moving, this must all be achieved in a very short space of time and again mental focus is important. This focus does not lessen until the after match team talk has been completed.

Time and resource constraints meant the investigation of drinking frequencies and play duration, and analysis of hydration status of all 24 players could lead to observer and measurement error. Thus, during the study and data collection protocol design it was decided that the priority would be to focus on the subjects participating in over 60 minutes of rugby. These subjects were predominantly the run-on 15 players. Reserve players were weighed if they chose to be, and all players were weighed before and after game 1. There was a risk that a usual fluid deficit for the rugby union players in this study may not be attainable due to observer bias, however there was no statistical significance between the changes in body mass of the Blues Development and North Harbour NPC rugby teams. This indicates any influence the presence of the researcher had on the drinking habits of the BD 2003 team was not significant.

Limitations on the accuracy of the data collected existed when weighing the subjects and analysing the urine samples. As mentioned briefly, restrictions on calculating drinking rates were present because of the absence of individual water bottles. The presence of many game variables, including varying climatic conditions, opposition and composition of the team put further challenges on data analysis. While maintaining team focus is vital to

achieving success during a rugby match at this level, the consequence in regards to this study was the presence of many limitations that are outlined in the following sections.

5.6.1 Body mass measurement

Pre-match body mass could only be measured as close to kick-off time as possible. Ideally this would be directly before the team runs on the field to start the game, however in reality the weigh in occurred approximately 90 minutes prior to kick-off, and was a similar period of time to that in research conducted on rugby league players [129]. This delay was due to the mental preparation period that begins when the team sits down for the pre-match motivational team talk. It was assumed that players would maintain fluid intake rates during this time and therefore body weight may not change significantly as fluid is readily available during transportation to the rugby ground and in the changing room. At this point a period of dehydration may occur as a prolonged warm-up period follows. However it is expected to be minimal as fluid is still accessible and players are able to drink *ad libitum*.

Urination by the subjects is likely to occur directly prior to the match commencing, to avoid the need to urinate during the match. Bowel motions also may occur with some individuals prior to a match, and this was not measured due to restrictions placed by team management and resources available. This may mean initial body mass could have been overestimated, but again based on the assumption drinking rates and urination frequency have not altered during the period between weigh in and match kick-off, any overestimation is unlikely to have a large impact on the change in body mass. As this study was investigating hydration status of players at the conclusion of a rugby match, it was relevant to compare post-match BM with a 'normal' initial BM to calculate the change that occurred in this study. If the intention were to calculate fluid loss or sweat rates during a match, there would be a greater importance put on obtaining a pre-match weight directly before the

time of kick-off, collecting the amount of fluid and food ingested, weighing any urine and faeces eliminated and estimating metabolic weight loss due to glycogen utilisation. The level of dehydration in this study is therefore a consequence of both the pre-match warm-up period, when fluid is readily available, and the match itself, where fluid intake is restricted to formal breaks in play.

It was observed after a win, most likely due to the increase in morale, that the post-match weigh-in was completed in a shorter period of time when compared to games where the team was defeated. A shorter period of time required for the weighing session will result in less fluid being consumed between the end of the match and body mass measurement, thus ensuring an accurate calculation for change in body weight. If a large amount of fluid is ingested in this period of time post-match BM will be over-reported, and as a consequence the change in body mass calculated will be lower. Players would arrive at the post-match weighing session in a random order, according to their own routine in relation to the team talk, showering, drinking, changing and eating. This order was different for each match, and may have lead to variability in each individuals change in BM over all five matches studied. One player (BD0307) could not be weighed on the electronic scales at first attempt, as he was shaking from exertion and the scales could not register a weight. Subject BD0307 was usually one of the first players to step on the scales, but his would be one of the last weights to be recorded because of the unsuccessful first attempt and the period of time required for him to get over 'the shakes'. Interestingly BD0307 also recorded the lowest change in body mass (mean of 0.39%) over all subjects in this study. When questioned he thought he hadn't ingested much fluid or food in this period of time, but as this is self-reported it is difficult to determine whether the small change in BM calculated was due to an increased fluid and food consumption when compared with other players, or a lower fluid deficit and therefore lower level of hypohydration. It is unlikely that this subject would consume over 1

kilogram of fluid or food in this short period of time, so it can be assumed that he was less dehydrated than other subjects.

Subjects were consistently weighed barefoot and in the same team uniform prior to a match. However after a match, players would be weighed barefoot and in the team shorts. If the team shirt was on, it was requested that it be removed. This was to avoid the weight of sweat on the shirt being included in the measurement of BM. Ideally shirts would have been removed at the pre-match weigh-in, however the weight of the team shirts when dry was negligible and time constraints and the importance for players to maintain a professional attitude during match preparation did not allow each player to remove his shirt before weighing.

The players who played between 60 and 80 minutes of rugby were likely (in all instances but one) to have been the run-on fifteen players. Those players not finishing an entire game were substituted off in the second half, and would join the reserve bench. It is likely then that hydration status would have improved from the point of substitution to the point where it was analysed upon completion of the match, due to the availability of fluid on the sideline. This may contribute to a certain extent to the lower fluid deficit witnessed in players participating in 60 or 70 minutes of rugby, when compared to those playing 80 minutes. To control for this potential error in the fluid deficit calculation for subjects playing between 60 and 80 minutes participants would have to be weighed as soon as they come off the field. In a match context this is not practical, as players do not leave the field, and any on-field platform devised for the portable scales would differ from that at the beginning of the match, and cause an inaccurate calculation of the difference in pre- and post-match weight.

5.6.2 Fluid intake measurement

Absolute volume of fluid intake for each player could not be measured as it was stipulated from the beginning by the team management that individual

drink bottles would not be used at any stage, as this would interfere with accustomed routines.

It was assumed that players would drink freely during the 90 to 120 minutes prior to a match and that this rate of drinking would not vary greatly from drinking rates earlier in the day. Food records exclude this period, as players were required to focus solely on the game ahead.

Half time drinking could not be observed in games 2 – 7 as the presence of the researcher in game 1 was found to distract the players during the team talk.

Drinking directly upon commencement of a match could not be measured accurately as players would take a cup of water or sports drink, bottles of coke or beer, and drink these during the after match talk. Both the type of drink chosen and the length of time before the weigh in (dependant on the duration of the after match team talk) were related to the performance of the team. Briefly, if the team had done well, the team talk was short and beer was often consumed in celebration, if the team had lost, post-match analysis was longer and the players would not tend to choose alcohol at first. However, players were aware that drinking after a match would affect their post-match weight and they all attempted to be weighed as soon as possible. When questioned about volume of fluid ingested between the final whistle and the weigh in, the most common answer was 'a few mouthfuls'.

5.6.3 Fluid loss and sweat rates

To measure the rates of fluid loss and sweating, the volume of fluid ingested and volume of urine excreted during the period of exercise is required. Actual fluid volumes could not be measured in this study due to the absence of individual drink bottles. If individual water bottles were used during a rugby match, fluid intake is very likely to be overestimated as frequently players were observed to empty water bottles onto their faces and feet, and to rinse their

mouth out by spitting out the water they had sipped. The change in fluid volume calculated from the bottles would include water ingested and spilled. To calculate actual fluid intake accurately subjects would have to be instructed to not spill fluid from the drink bottles. This would not be possible during a game at this level as it would cause a disruption to normal routine and habits, and potentially affect the players focus. This researcher also predicts compliance to the instruction would be minimal, as players are unlikely to remember this instruction during a competitive match.

5.6.4 Urinary analysis

Limitations on the accuracy of urine sample analysis included the assumptions that all players were giving a midstream urine sample. A sample from the beginning of urination may contain more particles than during midstream, and therefore lead to a higher Usg reading. This would in turn overestimate the level of hypohydration for any participant not giving a midstream sample. To combat this, clear instructions were given to each subject individually on how to give a correct sample. During game five one subject who had not been part of the run-on starting 15 in any previous games was heard to question another subject on how to give a urine sample, as he had not been required to do so before. In answer several players told him he must urinate a bit, stop and then fill up the container, this correct explanation indicates the players were giving samples midstream. Another factor that may cause inaccuracy in the analysis of the urine was the potential for players to be adding water to their pre-match sample, thus watering it down to a colour they thought would indicate they had begun the match better hydrated. The occurrence of this was less likely post-match, as players were together after the match with no privacy in which to carry a sample jar over to a water tap. Only one subject (BD0329 in game 7) participating in over 60 minutes of rugby produced a pre-match Usg reading of 1.000. While this reading is the same as for water, this subject had pre-match Usg values in his three previous games of 1.005, 1.010 and 1.020, indicating he had not previously tampered

with his samples. More likely, BD0329 had consumed large quantities of water prior to giving the sample and this was reflected in his urine. The statistical correlation between the change in body mass and the post-match urinary values ($r = 0.92$) further supports the assumption that post-match urine samples were given correctly.

5.6.5 Game variables

There are many external factors influencing the heat production and fluid balance of players during a rugby union match, and as these factors are different for each match, and can be unpredictable, it is impossible to control for them. Game variables can include climatic conditions such as ambient air temperature, relative humidity, radiative heat from the sun, precipitation, wind speed and even wind direction. The opposition, and the combination of players in the team being studied will also influence individual game variation.

5.6.5.1 Climatic conditions

The weather can be very unpredictable, posing a limitation on research into the influence of climate on fluid balance of athletes. The present study observed the change in body mass of rugby players during 5 matches. The climatic conditions measured were ambient air temperature, relative humidity and wind speed, and were seen to vary between matches. While no extremes in air temperature and relative humidity were recorded, there was a wide range in wind speeds (2.5 – 27.5 km/hr). To estimate the effect each one of these variables has during a rugby match, a large pool of data would be required. In the present study, because of the small number of match days, it is impossible to determine whether hydration status on a particular day is influenced primarily by the temperature, humidity or wind speed, and the combination of these variables acting on heat production and storage is probable. Clinical trials controlling for individual climatic variables are only a simulation of the type of exercise undertaken in various types of team sports rather than an actual competitive game, and thus will have limitations also.

5.6.5.2 Variability of competition

Due to the team playing a different opposition every match, the type and intensity of exercise will vary between matches. If the skill level of the two teams is evenly matched the game will theoretically be difficult and consequently the exercise intensity high and less intermittent. As shown previously this has the potential to affect the forward and backs differently. This opposition variability puts a limitation on the current study in regards to determining the impact of various game variables on fluid deficit of the players. The type and intensity of exercise undertaken during a match will have a major impact on metabolic rate, and therefore thermoregulation.

The game point differential is only a vague indication of the type of rugby played, a more accurate estimate of exercise intensity would be to question the players themselves and perhaps instruct them to rate the perceived difficulty of the match in relation to exercise intensity, an example of this type of scale is below in figure 5-2.

Figure 5-2. Example of a likert scale for perceived physical effort.

Easy				Moderate					Extremely Difficult
1	2	3	4	5	6	7	8	9	10

5.6.5.3 Variability of players within a team

While the Blues Development team consisted primarily of young players, it was also utilized as a 'reserve' team for the Blues Super 12 squad. Individuals who were expected to play at some point in the season, due to injury of another player or recovering from an injury themselves, in the Super 12 Competition for the Blues first team were given game time in the development side. The nature of a development side such as this meant the run-on 15 players were constantly changing. A player who may participate for 80 minutes in a match may never play for that side again. This made

obtaining results for a large group of subjects over most of the matches very difficult, and resulted in a small (n = 14) number of subjects in the BD > 60 group. Not one subject played over 60 minutes in all 7 matches, making many statistical correlations non significant, and only one player (BD0330) played over 60 minutes in the five matches used for data analysis. The small sample size, and the small number of matches observed, limits the number of positional groupings that players can be placed into. In previous studies investigating exercise type and intensity four groups were used; props and locks, back row forwards, inside backs and outside backs [126]. These groupings mean players with similar body composition and specific roles during a rugby match are placed together, instead of the wide range of these characteristics present in the groupings (forwards and backs) in the present study.

5.6.6 Dietary analysis

Limitations exist in relation to self-reported 24 hr food records. Under reporting of food and fluid intake may have occurred, as household measures were used. An athlete ingesting a large amount of food may have a different concept compared to the general population of what small, medium and large portions are. To minimize any underreporting of food the researcher was available to answer questions in regard to the food records for most of the meals in the 24-hour period. However as mentioned previously, the presence of the reporter may have caused an observer bias in relation to the food and drink ingested during this pre-match period.

It was the intention to analyse the 24 hour pre-match period for each match, however after the second game when only 1 food record was submitted, a compromise was developed in which players would record their food intake for one game only. While more records were returned, there were only 8 food records from 27 subjects, six of these were from the run-on 15 players for the respective match. This lack of compliance could be due to the

perceived difficulty of filling out a food record, the feeling of intrusion into personal eating habits, or forgetting, as the first meal in the 24-hour period was not with the team. Many players when questioned after the match had 'forgotten to pack' the food records. Some individuals had them back in their rooms and were asked to bring them to the next game, although only one subject did this. At the final game, those that had not returned the food records were given stamped envelopes with the address to return them to written on them, again only one food record was returned in this manner after the championship was over. Greater compliance may have been occurred if participants had been questioned at the first team meal if they had their food records with them. New records could have been provided at this point if required, as interest in returning the food records was reduced once the match and championship were over.

5.7 RECOMMENDATIONS FOR FUTURE STUDIES

There is a gap in research on the dietary habits of high performance rugby union players, including hydration practices and hydration status pre and post match. The studies that have been published are conducted on a small group of players and are not under controlled conditions. Based on both the findings of the current study and the lack of research available, there is a requirement for more nutritional research to be conducted on rugby union players.

5.7.1 Dietary habits of Rugby players

Dietary analysis of the completed and returned food records in the current study indicates the macronutrient profile of these developmental players could be improved upon. Research into the eating habits of developmental and colt rugby union players would be useful and perhaps the effectiveness of an intervention program involving nutritional education in young players could be studied. Nutritional status should be analysed using 3 -7 day food

records, and post-match dietary analysis could also be useful in determining if food and fluid consumption in relation to macronutrient and antioxidant intake is optimising recovery. Further research examining pre-match hydration and post-match hydration status would be useful.

5.7.2 Fluid intake

General guidelines for fluid intake do not take into consideration any individual variance in relation to tolerance of volume, rate of fluid absorption and preference for type of fluid. It is assumed that individual hydration strategies for each player in a team will result in a better hydration status at the end of a match. An intervention study investigating this hypothesis would determine if and to what extent monitoring fluid intake and practicing and instigating hydration strategies during a match will reduce fluid deficit. While previous studies observed greater fluid intake when a beverage is flavoured in comparison to plain water, participants in this study commented on the gluggy feeling left in their mouths after ingestion of a flavoured sports beverage, and their lack of willingness to drink it during a game. There are many types of sports drinks available and perhaps replacing a sports drink[§] (CHO 8%) with a 'sports water'§ (CHO 2.6%) may reduce this anecdotal reporting of uncomfortable aftertaste. Research could be conducted into the variances in flavour, temperature, carbohydrate and electrolyte content of hydration beverages and how this impacts the fluid intake in rugby union players. Many players also felt that drinking even moderate quantities of water during a match caused cramping, and believed consuming a sports drink prior to a game, and then limiting water intake while on the field could overcome this.

The actual drinking rates of players could be calculated using individual drink bottles in a simulated rugby match during training and preseason games. Water bottles could be colour coded for each individual and players would be

§ CHO concentration in Powerade sports drink and sports water currently on the New Zealand market.

instructed to drink only from these bottles. A communal water supply could be used if players wanted to splash water over themselves. This would prevent any overestimation of fluid intake occurring due to spilled water being included as ingested.

A study could be designed to observe the effect pre-match fluid ingestion has on the volume of fluid intake during a match. This would help determine if drinking during a match was reduced when pre-match fluid intake is high.

5.7.3 Factors influencing fluid deficit

Simulated rugby matches during training could be utilised further to determine the influence of climatic conditions on fluid deficit. Players and opposition are likely to be consistent and a greater number of subjects could be studied.

It would be useful to measure body temperature in rugby players and compare this data with hydration status and rates of fluid intake. For practical purposes body temperature would be measured orally or aurally after a match. Perceived effort could also be correlated with hydration status and body temperature, as in the current study very dehydrated subjects talked about feeling exhausted near the end of the game. Climatic conditions could also be measured to calculate the impact the environment has on body temperature.

5.7.4 Dehydration and performance

Lastly, there is no conclusive evidence indicating hypohydration at moderate (2% dehydrated) levels effects rugby performance. To determine whether performance is impaired at the level of hypohydration observed in this study, players could undergo both mental and physical performance tests relevant to rugby under both normal conditions and while hypohydrated as a consequence of exercise.

5.8 CONCLUSION

The main objective of this observational study was to measure the post-match hydration status of rugby union players in a match context. This was determined by measuring the change in body mass from a pre- and post-match weigh-in, and analysing individual post-match urine samples for specific gravity (Usg). All subjects participating in this study showed a loss in body mass after each game. The average change in body mass, or fluid deficit was calculated to be a 1.87% loss from the initial pre-match body mass measurement. This was greater than observed in past studies on rugby players [12,129] where fluid was available. In the final match during this study players were dehydrated to a level (2.23%) similar to that previously observed in rugby players where fluid was withheld (2.52%) [11]. It is probable the physical and mental performance of some of the players was impaired by the level of dehydration incurred as a consequence of playing in a rugby union match. It is possible rugby union players are becoming more dehydrated even under moderate climatic conditions than previously assumed. One participant was observed to be 4.61% dehydrated upon completion of a match, and hypohydration of this degree is very likely to have impaired his performance. The level of fluid deficit varied between players and for players between games. However, It was observed that some players were consistently hypohydrated to a high level upon completion of a match. This indicates individual fluid ingestion strategies are required to meet the needs of all players in a team.

Urine analysis for specific gravity supported the fluid deficit data as the average Usg for players participating in 60 minutes of rugby or more was 1.025, this in consistent with the NATA position statement [200]. Testing for Usg prior to exercise will inform an athlete of his hydration status at a stage where this can be improved upon if necessary. Almost all (98%) of pre-match Usg results showed participants in this study to be euhydrated. This

indicates that an initial Usg test may be useful to develop a pre-match drinking strategy to ensure each player is euhydrated before a game, but further tests may not be required. Post-match Usg analysis can establish if an athlete is hypohydrated, however it cannot determine the extent of this fluid deficit when a subject is at the point where ability to urinate has ceased.

Every rugby union match will involve different intensities, rates of heat storage, heat dissipation and types of exercise. These will be dependent on various factors such as; environmental conditions, opposition, variance of players in a team, and psychological factors, for example the drive to win. Different styles of rugby can influence the intensity of exercise performed by the various positions. This study showed that a small points differential between the two opposing teams can result in the forward pack exhibiting greater degree of dehydration when compared to the backs, and the opposite occurring when the points differential is large. This effect suggests that separate positional groups and perhaps even individual positions will have different hydration requirements dependent on the type of rugby being played.

Participants in the current study did not take the opportunity to drink in all breaks available during play (48% of breaks were utilised). Further education of rugby union players at this level is necessary to increase the proportion of drink breaks being utilised during a rugby match. This is particularly important as the regulations of the game mean there is no way of knowing how many breaks there will be during the match and when the next opportunity to drink will occur.

While there was no significant correlations between hydration status and drinking frequency results and the influence of environmental conditions, it was interesting to see there was a strong negative correlation between wind speed and hydration status. A stronger wind speed can help cool the body thus reducing the need for evaporative cooling via sweating. This in turn will

spare fluid loss as the sweat rate is reduced. Drinking frequency was also reduced as wind speed increased, probably due to the same mechanisms; if fluid is being spared the need for replacement is lessened. Future studies into the role of environmental conditions are required. Research involving a large collection of environmental and player fluid deficit data would be needed to analyse the individual influence of ambient temperature, relative humidity, wind speed and perhaps radiative heat.

The length of time a player is on the field is related to his final hydration status, however even reserve players showed a loss of body mass from the pre-match to the post-match weigh-in. Players on the sideline either waiting to play, or after having played have fluid readily available to them. This suggests that some of these players are not adequately hydrating themselves while on the sideline. Players who are playing under 60 minutes and are still showing a large fluid deficit by the end of a game should be educated in regards to the importance of fluid ingestion while waiting on the sideline.

There were numerous limitations in regards to maintaining accuracy of the data during collection because of the observational nature of the study. The main priority when designing data collection protocol was to ensure player routine, psychological preparation and rugby performance was not interfered with in any way by the study or presence of the researcher. This also meant that data was collected in an environment exactly that of a normal match, therefore it could be assumed that results from the present study reflect end hydration status in rugby union players. Research conducted on simulated rugby union matches calculating actual fluid intake, sweat rates and body temperature, would be useful when determining effectiveness of individual hydration strategies.

Given the limited opportunities to replenish fluid losses during rugby union, there is potential for heat stress and related illnesses to occur. Dehydration may also cause impairment of both physical and mental performance, a

reduced exercise capacity, cardiovascular strain and impairment in temperature regulation. The implication of this in regards to rugby union is that skill levels and therefore performance will diminish as body fluid deficit increases beyond approximately 2% of initial body mass. In the present study many players were dehydrated to a level where their rugby performance may be impaired. It is recommended that players be educated about the importance of hydration. Fluid ingestion strategies, including ingesting a fluid bolus and topping this up by sipping during the breaks in play, should be devised on an individual basis to suit each players limitations and preferences in relation to drinking. Fluid requirement guidelines for Rugby Union players should aim to keep all team members below a deficit of 1% where possible. Bioavailability of fluid should be considered when devising these, especially to optimise gastric emptying and intestinal absorption rates. Players should aim to utilise all of the drinking breaks available during a rugby match, and convey to the referee if a drink break is required as per IRB law 5.7 (g) [124].

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APPENDICES

APPENDIX A

Self-Testing Program for Optimal Hydration

from *Proper Hydration for Distance Running – Identifying Individual Fluid Needs,* by Douglas J. Casa, PhD, ATC, FACSM.

Any time a runner hits the road, track, or trail to perform in a race or training session, the need to properly hydrate becomes an issue. It has long been preached to runners (and all athletes) that you should consume "as much fluid as possible" to ward off the demons of dehydration. More recently, runners and medical staff have been told to limit hydration due to the potential dangers associated with overhydrating that can occur when running for an extended period of time. So what does the runner do to address the issues related to hydration?

In USATF's new hydration guidelines, long-distance runners are instructed to consume 1 liter of fluid for every liter lost during a race. Runners should determine their fluid needs well before any race longer than an hour, by using the following procedure during a 1-hour training run. If possible, do this session in climatic conditions similar to those at the race.

1. Make sure you are properly hydrated BEFORE the workout – your urine should be clear.
2. Do a warm-up run to the point where perspiration is generated, then stop. Urinate if necessary
3. Weigh yourself naked on an accurate scale
4. Run for one hour at an intensity similar to your targeted race.
5. Drink a measured amount of a beverage of your choice during the run if and when you are thirsty. It is important that you keep track of exactly how much fluid you take in during the run.
6. Do not urinate during the run.
7. Weigh yourself naked again on the same scale you used in Step 3.
8. You may now urinate and drink more fluids as needed. Calculate your fluid needs using the following formula:

A. Enter your body weight from Step 3 in Kilograms* *(To convert from pounds to kilograms, divide pounds by 2.2)*		_____
B. Enter your body weight from Step 7 in Kilograms* *(To convert from pounds to kilograms, divide pounds by 2.2)*	–	_____
C. Subtract B from A	=	_____
	x	1000
D. Convert your total in C to grams by multiplying by 1000	=	_____
E. Enter the amount of fluid you consumed during the run in milliliters *(To convert from ounces to milliliters, multiply ounces by 30)*	+	_____
F. Add E to D	=	_____

This final figure is the number of milliliters (ml) that you need to consume per hour to remain well-hydrated. If you want to convert milliliters back to ounces, simply divide by 30.

Now you know how much you need to drink per hour in order to stay properly hydrated during a race or a long hard training run. Keep in mind that as you get in better shape over time, you may need to perform this test again to make sure that your fluid needs have not changed. By the same token, if you reduce or change your training significantly, you may also need to perform the test again.

If the expected climatic conditions for your race or long training runs change, you will also need to perform the test again in as close to the new climatic conditions as possible. Keep in mind that we now know that when conditions get hot, drinking sufficient water will not be enough to prevent heat-related illness. As the temperature rises, you simply have to slow down.

Of additional importance is determining the type of fluids to drink. In many situations, athletes can benefit from including carbohydrates and electrolytes (especially sodium) in their rehydration beverages. However, just as individual differences exist in sweat lost during exercise, individuals also can differ in the types of beverages that are most suitable. Once you have determined how much fluid you need to consume, you should begin incorporating this fluid consumption into your training runs. It is during these practice sessions that you can find out what type(s) of beverage will work best for you.

More information on hydration, including the full paper by Dr. Douglas Casa and other important information on fluid intake from Dr. Lewis Maharam, can be found at www.usatf.org.

APPENDIX B adapted from Rehrer and Burke (1996)[α]

Sweat rate guidelines for running and cycling

Exercise type	Sex	Intensity	Sweat rate (L/hr)	Ambient temperature (°C)	Relative humidity (%)
Running					
10 km	F	12.8 km/hr	1.49	19 – 24	-
	M	14.6 km/hr	1.83	19 – 24	-
80 min	M	79% VO_2max	1.43	20	-
30 km	-	-	1.25	9 – 17	30-90
2 hours	M	63% VO_2max	1.41	22	40-45
42.2 km	M	15.9 km/hr	1.52	20	37
42.2 km	M	8.7 – 16.1 km/hr	0.96	10 – 12	73
42.2 km	F	9 – 12 km/hr	0.54	6 – 24	45 – 85
56 km	M	10.4 – 14.8 km/hr	0.96 – 1.00	11.3 – 25.8	-
Cycling					
17 mins	M	35 – 45 % VO_2max	0.29	30	45
1 hr	M	50% VO_2max	0.39	25	53
80 min	M	70% VO_2max	1.1	20	-
40 km	F	30 km/hr	0.75	19 – 25	-
40 km	M	32 km/hr	1.14	19 – 25	-
2 hours	M	50% VO_2max	1.25	30	-
3 hours	M	60% VO_2max	1.21	31	22
3 hours (intervals)	M	33 – 44% VO_2max	0.62	33 – 44	28

[α] Rehrer, N.J., and Burke, L.M. (1996). Sweat losses during various sports. *Australian Journal of Nutrition and Dietetics*. 53: S13-S16.

Sweat rate guidelines for a variety of team sports

Sport	Sex	Intensity	Sweat rate (L/hr)	Ambient temperature (°C)	Relative humidity (%)
Soccer	F	Competition	0.8	26	78
	M	Competition	1.2	25	41
	M	Competition	1.0	10	56
	F	Training	0.8	30	35
	M	Training	1.0	25	41
	M	Training	0.7	9	61
	M	-	2.1	33	40
Basketball	M	Competition	1.6	23	41
	F	Competition	0.9	26	60
	M	Training	1.4	27	34
	F	Training	0.7	25	43
Cricket	M	-	0.5	23	65
	M	-	1.4	33	22
AFL	M	-	1.4	12 –15	55 – 88
	M	-	1.8	27	53
Rugby Union	M	-	2.2	18 – 20	-
	M	-	1.7	21 – 23	78 – 85
	M	-	2.2	20 – 22	74 – 82
	M	Forwards	2.6	24 – 25	30 – 32
	M	Backs	1.6	24 – 25	30 – 32

APPENDIX C

This project has been reviewed and approved by the Massey University Human Ethics Committee, ALB Protocol MUAHEC 03/002. If you have any concerns about the conduct of this research, please contact Associate Professor Kerry P Chamberlain, Chair, Massey University Campus Human Ethics Committee: Albany,
telephone 09 443 9700 x9078,email K.Chamberlain@massey.ac.nz.

.....If you have any questions?

If you have any questions about the study, either now or in the future, please feel free to call. If you need an interpreter, one can be provided.

Anna Watson
P[redacted]

Or my research supervisor,
Dr Clare Wall
[redacted]

Thankyou for taking the time to read this information sheet.

Massey University
Institute of Food Nutrition and Human Health.
Private Bag 102-904
North Shore Mail Centre

HYDRATION REQUIREMENTS OF HIGH PERFORMANCE RUGBY PLAYERS IN A MATCH CONTEXT

INFORMATION SHEET

WHY AM I DOING THIS STUDY?

In Rugby union, endurance, motor skills and mental function are vital to performance and can be compromised when dehydration occurs. The decline appears to occur progressively throughout all levels of fluid deficiency beginning as low as a loss of 1.8% body mass during competition. Therefore ensuring players are adequately hydrated, during training and matches, is critical.

This study aims to investigate the hydration requirements and voluntary hydration (unforced drinking) rates of high performance Rugby Union players in a match context. Hydration status will be measured in all members of one team in varying climates during approximately six matches. From this information fluid requirements will be calculated and recommendations made.

This study is a Masters Thesis project for Massey University, Albany.

WHO IS IN THIS STUDY?

Participants will be recruited through the Blues Rugby Union Development Squad.

WHAT IS INVOLVED?

Measurements and interviews

- All food and drink consumed 24-hours before the match will be recorded by the player in a diary.
- The following body measurements will be taken by the researcher at the beginning and conclusion of the study

    1. Body Weight
    2. Body Height
    3. Skinfolds at 7 sites
    4. Circumferences at 5 sites
    5. Breadths at knee and elbow

- Before and after each match the following measurements will be taken
    1. Body mass (BM)
    2. Amount of fluid ingested (and during the match)
    3. Urine specific gravity

Time required for each Participant

- It is estimated that participant involvement during the two month study will consist of approximately 5 hours.

DO YOU HAVE TO TAKE PART IN THIS STUDY?

Your participation is entirely voluntary (your choice). If you agree to take part in the study, you are free to withdraw at any time and have the right to refuse to answer any question at any time.

In the unlikely event of a physical injury as a result of your participation in this study, you will be covered by accident compensation legislation with its limitations. If you have any questions about ACC please feel free to ask the researcher for more information before you agree to take part in this trial.

It will not cost you anything to take part in this study.

WHAT WILL HAPPEN TO THE RESULTS?

Data collected from the participants is completely confidential. No material, which could personally identify you, will be used in any reports on this study. The results will be stored by code number in a computer in a locked room throughout the study. Information will be stored for 5 years and then destroyed.

You will receive a copy of your hydration status, fluid intake and body composition data.

Consent form

Massey University
COLLEGE OF SCIENCES
Institute for Food, Nutrition and Human Health
Albany Campus

HYDRATION REQUIREMENTS OF HIGH PERFORMANCE RUGBY PLAYERS IN A MATCH CONTEXT

CONSENT FORM

THIS CONSENT FORM WILL BE HELD FOR A PERIOD OF FIVE (5) YEARS

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: **Date:**

Full Name - printed

I agree to have results obtained from this study released to the Blues Development Squad Management Team.

Signature: **Date:**

Full Name - printed

APPENDIX D

Schedule of events

This schedule was developed during game 1 and then maintained for games 2 through to 7. Hours are rounded to nearest half hour and may have varied slightly between games.

Team Base	
3 – 4 hrs pre-match	▪ Pre-match meal
2.5 hrs pre-match	▪ Fifteen individual pre-match urine collection containers were prepared. ▪ Fifteen individual post-match urine collection containers were prepared ▪ Pre-match urine pots were then distributed to the players
2 hrs pre-match	▪ Urine samples were collected and pre-match body mass recorded ▪ Team meeting
1.5 hrs pre-match	▪ Players on the bus and driven to the stadium
Rugby Ground	
1 hrs pre-match	▪ Warmup and training
0.5 hrs pre-match	▪ Players change into playing strip and finish warming up
Kickoff	▪ Wind speed, humidity and temperature reading taken
First half (40 minutes)	▪ Individual drinking rates recorded for each player
Half time (10 Minutes)	▪ Players in changing room for team talk ▪ Fluid ingested, sports drink and water available. Players reminded to drink. ▪ Carbohydrate gels and sweets available
Second half (40 minutes)	▪ Wind speed, humidity and temperature reading taken ▪ Individual drinking rates recorded for each player
Full time	▪ Players off the field and into changing room ▪ Post-match urine sample pots handed to each player
0-1 hr post-match	▪ Team talk ▪ Post – match body mass measured ▪ Post – match urine samples collected ▪ Players shower and change, and are drinking and eating freely

Combur 10 Test®

(Eng) ***Ten-patch test strip for the semiquantitative determination of specific gravity, pH, leukocytes, nitrite, protein, glucose, ketone bodies, urobilinogen, bilirubin, and blood in urine***

For professional use

FOR IN VITRO DIAGNOSTIC USE

Additionally required materials: A vessel for collection of urine

Instructions for use:

1. Use fresh urine that has not been centrifuged.
   Thoroughly mix the urine sample. The sample should be at room temperature when the test is performed and should not have been standing for more than 2 hours.
2. Take a test strip out of the container. Close the container again with the original desiccant stopper immediately after removal of the strip. This is important as otherwise the test areas may become discolored due to moisture and incorrect results may be obtained.
3. Briefly (about 1 second) dip the test strip into the urine making sure that all test areas are moistened.
4. When withdrawing the test strip, wipe the edge against the rim of the vessel to remove excess urine.
5. After 60 seconds (60–120 seconds for the leukocyte test area), compare the reaction colors of the test areas with the colors on the label.
   Compare the 10th (blood) test area with both color scales as separate color scales are given for erythrocytes and hemoglobin.
   Any color changes appearing only along the edges of the test areas, or developing after more than 2 minutes, do not have any diagnostic significance.

Test principles and notes on individual parameters

Specific gravity: The test detects the ion concentration of the urine. In the presence of cations, protons are released by a complexing agent and produce a color change in the indicator bromthymol blue from blue via blue-green to yellow. If the urine has a pH of 7 or more, 0.005 should be added to the specific gravity obtained.
In the presence of small amounts of protein (100 to 500 mg/dL) or ketoacidosis the specific gravity readings tend to be elevated. An increase in the specific gravity due to glucose concentrations >1000 mg/dL (>56 mmol/L) is not indicated by the test.

pH: The pH values found most frequently in fresh urine from healthy individuals lie between 5 and 6. The test is specific for the detection of hydronium ions, the pH being the negative common logarithm of the hydronium ion concentration. The test pad contains the indicators methyl red, phenolphthalein and bromthymol blue.

Leukocytes: The reaction detects the presence of esterases that occur in granulocytes. These enzymes cleave an indoxyl ester, and the indoxyl so liberated reacts with a diazonium salt to produce a violet dye. Both **intact** and **lysed** leukocytes are detected.
Reaction colors that cannot be unequivocally classed as negative or approx. 10–25 WBCs/µL urine after 60 seconds can generally be more easily assessed after 120 seconds.
The reaction is not affected by bacteria, trichomonads or erythrocytes present in the urine. Formaldehyde (stabilizer) and medication with antibiotics containing imipenem, meropenem or clavulanic acid may cause false-positive reactions. If the urine specimen is strongly colored (for example due to the presence of bilirubin or nitrofurantoin), the reaction color may be masked. Urinary protein excretion in excess of 500 mg/dL and urinary glucose excretion in excess of 2 g/dL may diminish the intensity of the reaction color, as can medication with antibiotics containing cephalexin or gentamicin if administered in high daily doses.

Nitrite: The most common organisms causing urinary tract infections, E.coli and most urinary pathogens, convert dietary nitrate to nitrite, which produces a pink to red coloration of the test area. The reaction thus indirectly detects the presence of nitrite-forming organisms in the urine. Even a slight pink coloration is an indication of significant bacteriuria.
Prolonged urinary retention in the bladder (4–8 hrs; ideally over night) is essential for a valid result. Administration of antibiotics or other chemotherapeutics should be discontinued 3 days before the test. The test is based on the principle of Griess' test and is specific for nitrite.

Protein: The test is based on the principle of the protein error of pH indicators and is particularly sensitive to albumin.
Quinine, quinidine, chloroquine and tolbutamide do not affect the test, nor does a high pH (up to pH 9). False-positive results may be obtained after infusion of polyvinylpyrrolidone (blood substitute), or if the urine specimen collection vessel contains residues of disinfectants based on quaternary ammonium compounds or chlorhexidine.

Glucose: The determination of glucose is based on the specific glucose-oxidase/peroxidase reaction.
This test is independent of the pH and specific gravity of the urine and is not affected by the presence of ketone bodies. The effect of ascorbic acid (vitamin C) has been largely eliminated so that at glucose concentrations of 100 mg/dL (5.5 mmol/L) and above even high ascorbic acid concentrations are not likely to give false-negative results.

Ketone bodies: This test is based on the principle of Legal's test and is more sensitive to acetoacetic acid than to acetone. Phenylketones and phthalein compounds produce red colors on the test area. These are, however, quite different from the violet colors produced by ketone bodies. Captopril, mesna (2-mercaptoethanesulfonic acid sodium salt) and other substances containing sulfhydryl groups may produce false-positive results.

Urobilinogen: A stable diazonium salt reacts almost immediately with urobilinogen to give a red azo dye. No discoloration of the test area or colors lighter than that shown for 1 mg/dL (17 µmol/L) constitute a normal finding.

The test is specific for urobilinogen and is not susceptible to the interfering factors known to affect Ehrlich's test. Larger amounts of bilirubin produce a momentary yellow coloration of the test area which may turn green to blue after about 60 seconds.

Bilirubin: The test for bilirubin is based on the coupling of bilirubin with a diazonium salt to give an azo dye. Even the slightest pink coloration constitutes a positive, i.e. pathologic, result. Other urinary constituents produce a more or less intense yellow discoloration.

Blood: Hemoglobin and myoglobin catalyze the oxidation of the indicator by an organic hydroperoxide contained in the test paper.
Separate color scales for erythrocytes and hemoglobin are given on the label of the test strip container.
Individual to closely packed green dots on the yellow test area are indicative of intact erythrocytes. Hemoglobin, hemolyzed erythrocytes, and myoglobin are indicated by a uniform green coloration of the test area.
Note: In women the test for blood may be falsified from 3 days before to 3 days after a period. It is therefore advisable not to perform the test during this time. After physical activity, e.g. strenuous jogging, raised values for erythrocytes and protein may occur without being signs of disease. Ascorbic acid (vitamin C) has virtually no influence on test results.

Parameter	Visual Reading		
	Range	Practical detection limit	Accuracy
Specific gravity	1.000 – 1.030		≥85% compared with refractometer method
pH	5–9		≥95% compared with pH-meter
Leukocytes	Negative – approx. 500 WBC/µL (3+)	10–25 WBC/µL	≥90% compared with counting chamber
Nitrite	Negative – positive (1+)	0.05 mg/dL (11 µmol/L)	>90% for 10^5 gram-positive organisms compared with Griess' test
Protein	Negative – 500 mg/dL (5 g/L; 4+)	6 mg albumin/dL	90 % compared with radial immunodiffusion
Glucose	Normal – 1000 mg/dL (55 mmol/L; 4+)	40 mg/dL (2.2 mmol/L)	≥90% compared with hexokinase method
Ketone bodies	Negative – 150 mg/dL (15 mmol/L; 3+)	For aceto-acetic acid 5 mg/dL (0.5 mmol/L)	>85% compared with photometric enzymatic determination of acetate
Urobilinogen	Normal – 12 mg/dL (200 µmol/L; 4+)	0.4 mg/dL (7 µmol/L)	≥95% compared with Watson & Henry method
Bilirubin	Negative – 6 mg/dL (100 µmol/L; 3+)	0.5 mg/dL (9 µmol/L)	≥85% compared with total bilirubin determination by Jendrassik's method (direct bilirubin)
Blood and hemoglobin	Negative – approx. 250 RBC/µL (4+)	Intact erythrocytes: 5 RBC/µL Hemoglobin or hemolysed erythrocytes: corresponding to 10 RBC/µL	≥90% compared with counting chamber

Reactive components per cm²: **Specific gravity:** bromthymol blue 36 µg; ethyleneglycoldiaminoethylethertetraacetic acid 182.8 µg; **pH:** bromthymol blue 13.9 µg, methyl red 1.2 µg, phenolphthalein 8.6 µg; **Leukocytes:** indoxyl ester 15.5 µg, methoxy-morpholinobenzene diazonium salt 5.5 µg; **Nitrite:** hydroxytetrahydrobenzoquinoline 33.5 µg, sulfanilamide 29.1 µg; **Protein:** tetrachlorophenoltetrabromosulfophthalein 13.9 µg; **Glucose:** tetramethylbenzidine 103.5 µg, GOD 6 U, POD 35 U; **Ketone bodies:** nitroprusside sodium 157.2 µg, glycine 4.2 mg; **Urobilinogen:** methoxybenzene diazonium salt 67.7 µg; **Bilirubin:** dichlorobenzene diazonium salt 16.7 µg; **Blood:** tetramethylbenzidine 52.8 µg, dimethyldihydroperoxyhexane 297.2 µg.

Please note: Diagnosis or therapy should never be based on one test result alone but should be established in the context of all other medical findings. Not all effects of drugs or their metabolites upon the individual tests are known. In doubtful cases, it is therefore advisable to repeat the test after discontinuation of the medication.
Use only clean, well-rinsed vessels to collect urine. False-positive readings, particularly for glucose, protein and blood, can result from residues of detergent or strongly oxidizing disinfectants in the specimen collection vessel.
Do not add stabilizers to the urine. Do not expose urine specimens to sunlight as this induces oxidation of bilirubin and urobilinogen and hence leads to artificially low results for these two parameters. Drugs that turn red in an acid environment (e.g. phenazopyridine) may produce false-positive readings or reddish discolorations on the test areas for nitrite, protein, urobilinogen, and bilirubin. Large quantities of ascorbic acid (vitamin C) can lead to low or false-negative results for nitrite and bilirubin.

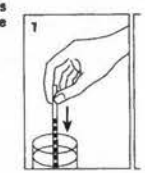
Storage and shelf-life: Do not store the Combur 10 Test® Pack at temperatures below +2°C or above +30°C. In the original container the test strips are stable up to the date printed on the pack, even once the container has been opened.

Disposal: Please dispose of used test strips according to the safety regulations applicable at your facility.

The stopper of the test strip container is filled with a non-toxic silicate-based desiccant. If inadvertently ingested it should be flushed down with plenty of water.

Presentation: Packs of 100 test strips (REF 1203479). Packs of 10 test strips (REF 1203444).

For an explanation of the symbols used and a list of references please refer to the end of this insert.



Last updated: 01/2001

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Roche Diagnostics Ltd
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East Sussex, BN7 1LG
UNITED KINGDOM

APPENDIX F

Data collection sheets

ANTHROPOMETRY DATA COLLECTION

Name of Subject	
Unique Identifier	
Date of Birth	
Date of Interview	
Time of Interview	

MEASUREMENT		RECORDING 1	2	3	MEAN
Mass (kg)					
Height (cm)					
Skinfolds	Tricep				
	Subscapular				
	Bicep				
	Iliac crest				
	Supraspinale				
	Abdominal				
	Front thigh				
	Medial calf				
Girths	Arm (relaxed)				
	Arm (flexed & tensed)				
	Waist (minimum)				
	Gluteal (maximum)				
	Calf (maximum)				
Bone Breadths	Humerus				
	Femur				

PLAYER WEIGHT & URINARY MEASUREMENTS

Date: _____ Game: _____

		PRE-MATCH					POST-MATCH				
Name	Identifier	Weight	Usg	UpH	Uglucose	Uprotein	Weight	Usg	UpH	Uglucose	Uprotein

DRINKING SCORE SHEET

Date: _____ Game: _____

Player	Name	Identifier	Time on	Time off	Time Played	1st Half tally	2nd Half tally	1st Half Total
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

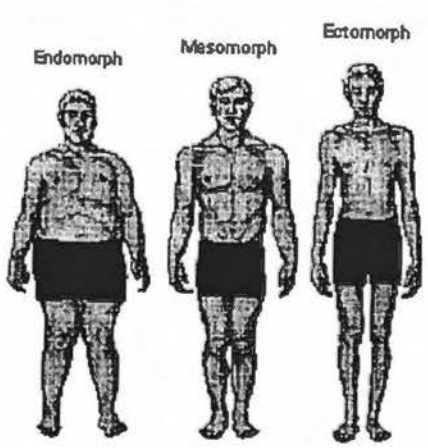
APPENDIX G

Description of Somatotypes

Somatotyping in a way of classifying physical characteristics using both body shape and body composition. A somatotype is a 3-number rating providing a description of physique by stating the levels of three body types. These are endomorphy (adiposity), mesomorphy (muscularity) and ectomorphy (linearity) in that order as illustrated in the figure below. A high score on any body type, means the physique is more like that component. It is possible to score negative levels of any one or more components and there is no upper or lower level. For example a rating of 3 : 12 : 1, would be for a very muscular physique with low body fat, as the mesomorphy score is very high and the other two are low.

The measurements used for calculating somatotype are height, mass, femur girth, humerus girth, calf girth, arm girth flexed and relaxed, calf skinfold, tricep skinfold, supraspinale skinfold and subscapular skinfold. A more in depth description of the methods behind somatotyping can be found in Carter and Honeyman Heath (1990)[144].

Figure A-1. The three body types rated in somatotyping, endomorphy (adiposity), mesomorphy (muscularity) and ectomorphy (linearity).



APPENDIX H

Beaufort wind scale

Beaufort Number	Name	Kilometres per Hour	Effect on Land
0	Calm	Less than 1	Calm; smoke rises vertically
1	Light Air	1-5	Weather vane inactive; smoke drifts with air
2	Light Breeze	6-11	Weather vane active, wind felt on face; leaves rustle
3	Gentle Breeze	12-19	Leaves and small twigs move; light flags extend
4	Moderate Breeze	20-28	Small branches sway; dust and loose paper blow about
5	Fresh Breeze	29-38	Small trees sway; waves break on inland waters
6	Strong Breeze	39-49	Large branches sway; umbrellas difficult to use
7	Moderate Gale	50-61	Whole trees sway; difficult to walk against wind
8	Fresh Gale	62-74	Twigs broken off trees; walking against wind very difficult
9	Strong Gale	75-88	Slight damage to buildings; shingles blown off roof
10	Whole Gale	89-102	Trees uprooted; considerable damage to buildings
11	Storm	103-117	Widespread damage; very rare occurrence
12-17	Hurricane	117 or more	Violent destruction

APPENDIX I

24 - Hour Food Record

All food and drink consumed in the 24 hours before Match 4

DEVELOPMENT 2003

Hydration Study

Players Name:_____

Hydration status of high performance New Zealand rugby union players in a match context

This booklet is to be filled out with all food and drink consumed in the 24 hour period before match 4. Match 4 is in Dunedin and kickoff is at 12:00pm. It is necessary to include all fluid and food consumed from 12:00 pm (lunchtime) Friday the 28th February to the time of the pre-match team meeting on the morning of Saturday the 1st of March.

HOW DO YOU DO THIS?

- Please record all food and drink in the tables in the following pages as it is consumed. Do not do it from memory at the end of the day.
- Please remember to include all DRINKS you have consumed, including tap water, bottled water, milk, tea, coffee, any other hot drinks, soft drinks, fruit juice, sports drinks etc.
- Remember to include all snack foods.
- Record any additions to food such as sauces, dressings, gravy, pickles, sugar, honey, butter.
- Record cooking methods, e.g. boiled, fried, baked etc. and list type and amount of fat or oil used for cooking.
- Record brand names & descriptions e.g. weetbix instead of 'cereal', trim milk instead of 'milk', ginger nut biscuit instead of 'biscuit', Molenberg Swiss bake instead of 'bread'
- Name the types of cheese, fish or meat (e.g. cheddar, cod fillet, topside mince).
- Refer to food quantities in household measures, such as a cup, mug, breakfast bowl, teaspoon etc. Check mls, and grams on packets and containers to get accurate weights.
- Use a new line for each item of food or drink. You can use more than one line for each entry if required.
- Use as many pages of this booklet as you need.
- Check the sample food record to see how this is done.

All information you provide in this diary will be treated with the strictest confidence. Thanks for your time and effort with these food records.

Anna Watson

Eating Time	Name of Food or Drink	Quantity	Brand of food/drink (if any)	Preparation method of food. e.g. boiling, roasting, baking, frying, microwaving

APPENDIX J

Raw Data

ANTHROPOMETRIC DATA

					Skinfolds								Girths					Bone Breadths		INDEXES						Somatotype		
Subject	Age	Position	Mass (kg)	Height (cm)	Triceps	Subscapular	Biceps	Iliac crest	Supraspinale	Abdominal	Front thigh	Medial calf	Arm (relaxed)	Arm (flexed & tensed)	Waist (min)	Gluteal (max)	Calf (max)	Humerus	Femur	WHR	% Body fat	Body fat (kg)	% LBM	LBM (kg)	Sum of Skinfolds	Endomorphic	Mesomorphic	Ectomorphic
BD0301	25.2	Forward	107.7	178.6	11.8	20.8	7.0	34.2	23.2	28.8	17.2	16.0	37.4	40.2	96.5	111.0	42.5	8.0	10.6	0.87	18.73	20.17	81.27	87.53	159.00	5.1	7.4	0.4
BD0306	20.3	Forward	118.6	184.3	12.8	28.4	8.0	32.0	25.1	27.6	12.4	8.7	39.3	41.2	103.5	116.7	43.0	7.9	10.8	0.89	20.15	23.90	79.85	94.70	155.00	5.9	7.9	-0.3
BD0303	25.2	Back	89.1	181.6	8.4	11.8	5.4	22.2	13.4	13.8	11.8	11.8	35.6	39.7	88.0	103.6	40.4	7.2	9.9	0.85	13.04	11.61	86.96	77.49	98.60	3.2	6.5	1.2
BD0304	26.1	Back	98.1	183.5	10.1	18.6	6.4	28.0	15.8	26.4	13.9	8.8	37.7	39.3	94.2	106.6	40.1	7.1	10.1	0.88	16.63	16.31	83.37	81.79	128.00	4.2	6.1	0.8
BD0305	24.3	Forward	103.3	207.4	12.2	11.0	3.8	17.4	11.6	13.2	13.0	10.2	34.6	37.2	86.5	106.0	38.4	7.9	10.4	0.82	13.13	13.56	86.87	89.74	92.40	2.9	3.1	3.8
BD0307	28.8	Back	101	184.4	13.4	18.2	5.6	30.0	23.8	28.4	18.2	13.8	36.8	39.6	92.0	110.4	41.7	7.5	10.5	0.83	18.60	18.79	81.40	82.21	151.40	5.1	6.8	0.7
BD0308	21.6	Forward	110.7	197.7	9.4	15.5	6.2	26.1	13.9	20.4	18.2	12.8	36.6	40.4	93.2	112.9	43.0	7.3	10.1	0.83	14.84	16.43	85.16	94.27	122.50	3.4	5.1	1.6
BD0309	23.6	Back	83.5	180.6	9.2	12.9	5.4	18.4	12.8	18.4	12.6	9.0	35.8	38.6	84.2	102.4	39.4	7.1	9.8	0.82	13.94	11.64	86.06	71.86	98.70	3.1	6.4	1.5
BD0310	24.5	Back	94.5	182.5	9.0	14.5	7.2	19.8	12.8	16.8	16.5	7.4	35.4	37.4	86.2	102.4	41.0	7.2	10.0	0.84	13.91	13.14	86.09	81.36	104.00	3.2	6.2	1.3
BD0311	27.7	Forward	95.8	185.6	12.4	14.8	7.0	29.8	16.4	28.4	18.4	9.2	37.3	39.6	89.0	109.5	40.2	6.6	10.4	0.81	16.80	16.09	83.20	79.71	136.40	4.5	5.6	1.2
BD0312	19.9	Forward	99.9	193	6.8	9.8	4.0	11.6	8.6	10.6	7.2	5.4	37.0	40.5	84.8	103.5	42.4	7.9	10.8	0.82	11.26	11.25	88.74	88.65	64.00	2.2	6.7	1.9
BD0313	19.3	Forward	122	182.8	12.3	19.0	6.1	29.8	23.0	26.4	12.2	7.4	40.3	42.4	105.0	117.0	47.4	8.6	11.4	0.90	18.13	22.12	81.87	99.88	136.20	5.1	10	-0.6
BD0318	20.6	Back	80.4	178.6	8.6	12.4	5.8	20.8	11.0	23.6	18.2	8.6	32.6	36.0	85.8	102.0	36.0	6.9	9.5	0.84	14.29	11.49	85.71	68.91	109.00	3.1	5	1.7
BD0317	21.9	Forward	110	193.6	12.0	17.4	6.8	25.1	16.2	18.0	14.2	15.0	39.2	42.0	91.8	112.3	44.4	7.9	11.4	0.82	15.51	17.07	84.49	92.93	124.70	4.1	7.3	1.1
BD0319	24.0	Forward	104.6	182.3	13.2	22.6	7.2	30.0	19.8	24.4	10.8	10.0	37.0	39.5	94.0	112.3	43.0	7.4	10.3	0.84	18.02	18.85	81.98	85.75	138.00	5.2	7.1	0.3
BD0320	22.5	Back	81.6	182.2	9.0	9.0	5.1	13.1	8.0	12.2	7.4	6.4	35.2	38.2	83.0	102.0	37.0	7.4	10.3	0.81	11.63	9.49	88.37	72.11	70.20	2.4	6	2.2
BD0322	20.4	Back	82.8	179.4	7.1	13.2	3.8	12.0	10.2	13.8	7.4	5.8	35.0	36.5	83.9	96.8	39.0	7.3	9.2	0.87	12.56	10.40	87.44	72.40	73.30	2.9	5.7	1.5
BD0325	22.1	Forward	115.8	177.5	9.6	23.6	7.8	28.0	27.7	29.2	12.2	6.8	42.4	44.0	103.6	116.0	48.0	7.5	10.8	0.89	19.57	22.66	80.43	93.14	144.90	5.7	9.9	0.1
BD0326	21.6	Forward	111	189.3	9.1	14.2	5.2	20.4	13.2	15.8	10.9	9.2	38.4	41.6	93.4	112.0	45.6	8.8	11.4	0.83	13.78	15.30	86.22	95.70	98.00	3.4	8.9	0.6
BD0327	21.1	Forward	143.1	194.2	11.6	25.6	6.0	38.8	25.4	29.0	11.4	8.8	42.4	45.0	108.5	127.6	46.4	8.8	11.3	0.85	19.80	28.33	80.20	114.77	156.60	5.4	9	-0.4
BD0328	24.2	Forward	96.3	197.6	6.2	11.0	3.6	9.6	8.0	11.6	8.4	4.8	34.7	37.5	80.6	105.4	40.5	7.7	10.5	0.76	11.41	10.99	88.59	85.31	63.20	2.1	4.9	3
BD0329	22.0	Back	98.8	189.9	10.4	7.4	5.2	12.8	9.6	14.6	9.0	6.8	36.4	39.3	86.5	104.0	43.7	7.9	10.1	0.83	12.21	12.06	87.79	86.74	75.80	2.5	6.6	1.5
BD0330	19.7	Back	89.6	183.8	9.8	15.1	6.2	8.2	11.2	16.1	14.4	7.8	35.3	38.2	81.8	104.5	41.5	6.8	10.1	0.78	13.77	12.34	86.23	77.26	88.80	3.4	5.9	1.5
BD0331	20.7	Back	90.3	185.5	11.4	15.1	6.2	16.5	10.4	13.6	13.6	10.4	36.7	39.2	85.7	105.5	41.4	7.5	10.5	0.81	15.20	11.92	86.80	78.58	95.00	5.5	6.6	1.3
Averag	Forwa		22.6		10.7	18.0	6.1	25.6	17.9	21.8	12.8	9.6	38.2	40.9	94.6	112.5	43.4	7.9	10.8	0.84	16.24	18.21	83.76	92.47	122.38	4.2	7.1	1.0
	Back		23.1		9.0	182.7	9.7	13.3	5.7	18.3	12.6	18.0	13.0	8.8	35.7	38.4	86.3	103.5	40.1	7.2	10.0	0.83	13.98	12.65	86.02	77.32	99.35	3.3	6.2	1.4
	Total		22.8		101.2	186.4	10.2	15.8	5.9	22.3	15.5	20.0	12.9	9.2	37.0	39.7	90.8	108.4	41.9	7.6	10.4	0.84	15.20	15.66	84.80	85.52	111.82	3.8	6.7	1.2
Range	Forwa		19.3 to 27.7		95.8 to 143.1	177.5 to 207.4															11.26 to 20.15				63.20 to 159.00	2.1 to 5.9	3.1 to 10	-0.6 to 3.8
	Back		19.7 to 28.8		80.4 to 98.8	178.6 to 189.5															11.63 to 18.60				70.20 to 151.40	2.4 to 5.1	5 to 6.8	0.7 to 2.2
	Total		19.3 to 28.8		80.4 to 143.1	177.5 to 207.4															11.26 to 20.15				63.20 to 159.00	2.1 to 5.9	3.1 to 10	-0.6 to 3.8
stdev	Forwa		2.4		12.6	8.7														0.04	3.14	5.11	3.14	8.55	33.1	1.3	2.1	1.3
	Back		2.9		7.4	3.0														0.03	2.02	2.66	2.02	5.49	24.2	0.8	0.5	0.4
	Total		2.6		14.8	7.4														0.03	2.87	4.97	2.87	10.52	31.0	1.2	1.6	1.0
se	Forwa		0.7		3.5	2.4														0.01	0.87	1.42	0.87	2.37	9.17	0.36	0.57	0.37
	Back		0.9		2.2	0.9														0.01	0.61	0.80	0.61	1.66	7.30	0.23	0.15	0.12
	Total		0.5		3.0	1.5														0.01	0.59	1.01	0.59	2.15	6.55	0.24	0.55	0.21

BODY MASS DATA

Game number	2				3				4				6				7				All Games			
Weight	Pre	Post	Change, kg	Change, %	Pre	Post	Change, kg	Change, %	Pre	Post	Change, kg	Change, %	Pre	Post	Change, kg	Change, %	Pre	Post	Change, kg	Change, %	Pre	Post	Change, kg	Change, %
All Subjects																								
BD0305	103.0	101.3	1.7	1.65%	102.7	101.4	1.3	1.27%					105.2	102.3	2.9	2.76%	105.5	102.5	3.0	2.84%	104.1	101.9	2.2	2.14%
BD0307	102.7	102	0.7	0.68%					101.8	101.4	0.4	0.39%	102.6	102.5	0.1	0.10%					102.4	102.0	0.4	0.39%
BD0308	112.9	109.6	3.3	2.92%					111.1	107.1	4.0	3.60%	111.3	109.0	2.3	2.07%	112.9	107.7	5.2	4.61%	112.1	108.4	3.7	3.30%
BD0309									83.0	81.9	1.1	1.33%	85.7	84.3	1.4	1.63%	85.6	84.1	1.5	1.75%	84.8	83.4	1.3	1.57%
BD0310					94.8	92.8	2.0	2.11%	95.0	93.1	1.9	2.00%					97.0	94.9	2.1	2.16%	95.6	93.6	2.0	2.09%
BD0312									99.5	98.3	1.2	1.21%	101.7	100.2	1.5	1.47%	100.1	99.2	0.9	0.90%	100.4	99.2	1.2	1.19%
BD0313	122.7	121.4	1.3	1.06%	122.9	121.2	1.7	1.38%	121.8	121.3	0.5	0.41%					123.6	122.2	1.4	1.13%	122.8	121.5	1.2	1.00%
BD0317	111.1	108.2	2.9	2.61%					110.0	108.1	1.9	1.73%	112.1	109.9	2.2	1.96%					111.1	108.7	2.3	2.10%
BD0318					81.3	80.3	1.0	1.23%	82.2	80.6	1.6	1.95%					83.0	82.7	0.3	0.36%	82.2	81.2	1.0	1.18%
BD0320	83.3	81.7	1.6	1.92%	83.7	81.6	2.1	2.51%	83.5	81.4	2.1	2.51%	82.9	81.0	1.9	2.29%					83.4	81.4	1.9	2.31%
BD0326	111.7	109.3	2.4	2.15%					110.0	107.2	2.8	2.55%	110.7	109.0	1.7	1.54%	111.1	108.2	2.9	2.61%	110.9	108.4	2.5	2.21%
BD0327	142.4	139.5	2.9	2.04%					141.0	137.7	3.3	2.34%	139.8	137.2	2.6	1.86%					141.1	138.1	2.9	2.06%
BD0329	98.2	96.4	1.8	1.83%					97.3	94.8	2.5	2.57%	97.5	96.4	1.1	1.13%	99.1	96.0	3.1	3.13%	98.0	95.9	2.1	2.17%
BD0330	91.1	89.5	1.6	1.76%	90.8	88.3	2.5	2.75%	91.3	89.1	2.2	2.41%	93.3	91.6	1.7	1.82%	92.1	89.5	2.6	2.82%	91.7	89.6	2.1	2.31%
N=	10	10	10		6	6	6		13	13	13		11	11	11		10	10	10		14	14	14	
MEAN	**107.9**	**105.9**	**2.0**	**1.86%**	**96.0**	**94.3**	**1.8**	**1.88%**	**102.1**	**100.2**	**2.0**	**1.92%**	**103.9**	**102.1**	**1.8**	**1.69%**	**101.0**	**98.7**	**2.3**	**2.23%**	**102.9**	**101.0**	**1.9**	**1.87%**
T TEST			0.000				0.000				0.000				0.000				0.000				0.000	
stdev	16.6	16.3	0.8	0.66%	15.3	15.3	0.6	0.67%	16.9	16.6	1.0	0.91%	15.5	15.2	0.8	0.68%	12.6	12.1	1.4	1.25%	16.2	15.9	0.9	0.73%
se	5.3	5.1	0.3	0.21%	6.2	6.2	0.2	0.27%	4.7	4.6	0.3	0.25%	4.7	4.6	0.2	0.21%	4.0	3.8	0.4	0.39%	4.3	4.2	0.2	0.19%
Min	83.3	81.7	0.7	0.68%	81.3	80.3	1.0	1.23%	82.2	80.6	0.4	0.39%	82.9	81.0	0.1	0.10%	83.0	82.7	0.3	0.36%	82.2	81.2	0.4	0.39%
Max	142.4	139.5	3.3	2.92%	122.9	121.2	2.5	2.75%	141.0	137.7	4.0	3.60%	139.8	137.2	2.9	2.76%	123.6	122.2	5.2	4.61%	141.1	138.1	3.7	3.30%
Forwards																								
BD0305	103.0	101.3	1.7	1.65%	102.7	101.4	1.3	1.27%					105.2	102.3	2.9	2.76%	105.5	102.5	3.0	2.84%	104.1	101.9	2.2	2.14%
BD0308	112.9	109.6	3.3	2.92%					111.1	107.1	4.0	3.60%	111.3	109.0	2.3	2.07%	112.9	107.7	5.2	4.61%	112.1	108.4	3.7	3.30%
BD0312									99.5	98.3	1.2	1.21%	101.7	100.2	1.5	1.47%	100.1	99.2	0.9	0.90%	100.4	99.2	1.2	1.19%
BD0313	122.7	121.4	1.3	1.06%	122.9	121.2	1.7	1.38%	121.8	121.3	0.5	0.41%					123.6	122.2	1.4	1.13%	122.8	121.5	1.2	1.00%
BD0317	111.1	108.2	2.9	2.61%					110.0	108.1	1.9	1.73%	112.1	109.9	2.2	1.96%					111.1	108.7	2.3	2.10%
BD0326	111.7	109.3	2.4	2.15%					110.0	107.2	2.8	2.55%	110.7	109.0	1.7	1.54%	111.1	108.2	2.9	2.61%	110.9	108.4	2.5	2.21%
BD0327	142.4	139.5	2.9	2.04%					141.0	137.7	3.3	2.34%	139.8	137.2	2.6	1.86%					141.1	138.1	2.9	2.06%
N=	6	6	6		2	2	2		6	6	6		6	6	6		5	5	5		7	7	7	
MEAN	**117.3**	**114.9**	**2.4**	**2.07%**	**112.8**	**111.3**	**1.5**	**1.32%**	**115.6**	**113.3**	**2.3**	**1.97%**	**113.5**	**111.3**	**2.2**	**1.94%**	**110.6**	**108.0**	**2.7**	**2.42%**	**114.6**	**112.3**	**2.3**	**2.00%**
T TEST			0.000				0.042				0.004				0.000				0.012				0.000	
stdev	13.8	13.7	0.8	0.67%	14.3	14.0	0.3	0.08%	14.3	14.1	1.3	1.11%	13.5	13.3	0.5	0.46%	8.8	8.8	1.7	1.50%	13.6	13.4	0.9	0.76%
se	5.6	5.6	0.3	0.27%	10.1	9.9	0.2	0.06%	5.8	5.7	0.5	0.45%	5.5	5.4	0.2	0.19%	3.9	3.9	0.8	0.67%	5.1	5.1	0.3	0.29%
Min	103.0	101.3	1.3	1.06%	102.7	101.4	1.3	1.27%	99.5	98.3	0.5	0.41%	101.7	100.2	1.5	1.47%	100.1	99.2	0.9	0.90%	100.4	99.2	1.2	1.00%
Max	142.4	139.5	3.3	2.92%	122.9	121.2	1.7	1.38%	141.0	137.7	4.0	3.60%	139.8	137.2	2.9	2.76%	123.6	122.2	5.2	4.61%	141.1	138.1	3.7	3.30%
Backs																								
BD0307	102.7	102	0.7	0.68%					101.8	101.4	0.4	0.39%	102.6	102.5	0.1	0.10%					102.4	102.0	0.4	0.39%
BD0309									83.0	81.9	1.1	1.33%	85.7	84.3	1.4	1.63%	85.6	84.1	1.5	1.75%	84.8	83.4	1.3	1.57%
BDO310					94.8	92.8	2.0	2.11%	95.0	93.1	1.9	2.00%					97.0	94.9	2.1	2.16%	95.6	93.6	2.0	2.09%
BD0318					81.3	80.3	1.0	1.23%	82.2	80.6	1.6	1.95%					83.0	82.7	0.3	0.36%	82.2	81.2	1.0	1.18%
BD0320	83.3	81.7	1.6	1.92%	83.7	81.6	2.1	2.51%	83.5	81.4	2.1	2.51%	82.9	81.0	1.9	2.29%					83.4	81.4	1.9	2.31%
BD0329	98.2	96.4	1.8	1.83%					97.3	94.8	2.5	2.57%	97.5	96.4	1.1	1.13%	99.1	96.0	3.1	3.13%	98.0	95.9	2.1	2.17%
BD0330	91.1	89.5	1.6	1.76%	90.8	88.3	2.5	2.75%	91.3	89.1	2.2	2.41%	93.3	91.6	1.7	1.82%	92.1	89.5	2.6	2.82%	91.7	89.6	2.1	2.31%
N=	3	3	3		4	4	4		6	6	6		4	4	4		5	5	5		6	6	6	
MEAN	**90.9**	**89.2**	**1.7**	**1.84%**	**87.7**	**85.8**	**1.9**	**2.15%**	**88.7**	**86.8**	**1.9**	**2.13%**	**89.9**	**88.3**	**1.5**	**1.72%**	**91.4**	**89.4**	**1.9**	**2.05%**	**89.3**	**87.5**	**1.7**	**1.95%**
T TEST			0.005				0.005				0.000				0.009				0.008				0.000	
stdev	8.5	8.8	0.5	0.58%	6.2	5.9	0.6	0.67%	7.8	8.0	0.7	0.78%	8.2	8.8	0.7	0.84%	7.0	6.1	1.1	1.09%	7.9	8.0	0.7	0.72%
se	4.2	4.4	0.2	0.29%	3.1	2.9	0.3	0.33%	3.0	3.0	0.3	0.30%	3.6	3.9	0.3	0.37%	3.1	2.7	0.5	0.49%	3.0	3.0	0.3	0.27%
Min	83.3	81.7	0.7	0.68%	81.3	80.3	1.0	1.23%	82.2	80.6	0.4	0.39%	82.9	81.0	0.1	0.10%	83.0	82.7	0.3	0.36%	82.2	81.2	0.4	0.39%
Max	102.7	102.0	1.8	1.92%	94.8	92.8	2.5	2.75%	101.8	101.4	2.5	2.57%	102.6	102.5	1.9	2.29%	99.1	96.0	3.1	3.13%	102.4	102.0	2.1	2.31%

URINARY VALUE DATA

Game number	2			3			4			6			7			All Games		
Urinary value	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
All Subjects																		
BD0305	3	6	3	3	7	4				4	8	4	3	8	5	3.3	7.3	4.0
BD0307	3	4	1				3	3	0	2	3	1				2.7	3.3	0.7
BD0308	2	8	6				2	8	6	3	7	4	3	8	5	2.5	7.8	5.3
BD0309							3	5	2	3	6	3	2	6	4	2.7	5.7	3.0
BDO310				2	7	5	2	8	6				3	7	4	2.3	7.3	5.0
BD0312							3	6	3	3	5	2	3	5	2	3.0	5.3	2.3
BD0313	4	7	3	2	5	3	3	4	1				3	6	3	3.0	5.5	2.5
BD0317	3	7	4				2	5	3	3	6	3				2.7	6.0	3.3
BD0318				2	5	3	2	6	4				3	4	1	2.3	5.0	2.7
BD0320	3	8	5	2	8	6	3	8	5							2.7	8.0	5.3
BD0329	2	6	4				5	8	3	3	7	4	1	7	6	2.8	7.0	4.3
BD0330	3	8	5	3	8	5	3	7	4	3	6	3	2	7	5	2.8	7.2	4.4
N=	8	8	8	6	6	6	11	11	11	8	8	8	9	9	9	12	12	12
MEAN	**2.9**	**6.8**	**3.9**	**2.3**	**6.7**	**4.3**	**2.8**	**6.2**	**3.4**	**3.0**	**6.0**	**3.0**	**2.6**	**6.4**	**3.9**	**2.7**	**6.3**	**3.6**
T TEST			0.000			0.000			0.000			0.000			0.000			0.000
stdev	0.6	1.4	1.6	0.5	1.4	1.2	0.9	1.8	1.9	0.5	1.5	1.1	0.7	1.3	1.6	0.3	1.4	1.4
se	0.2	0.5	0.5	0.2	0.6	0.5	0.3	0.5	0.6	0.2	0.5	0.4	0.2	0.4	0.5	0.1	0.4	0.4
Min	2	4	1	2	5	3	2	3	0	2	3	1	1	4	1	2.3	3.3	0.7
Max	4	8	6	3	8	6	5	8	6	4	8	4	3	8	6	3.3	8.0	5.3
Median	3	7	4	2	7	5	3	6	3	3	6	3	3	7	4	2.7	6.5	3.7
Forwards																		
BD0305	3	6	3	3	7	4				4	8	4	3	8	5	3.3	7.3	4.0
BD0308	2	8	6				2	8	6	3	7	4	3	8	5	2.5	7.8	5.3
BD0312							3	6	3	3	5	2	3	5	2	3.0	5.3	2.3
BD0313	4	7	3	2	5	3	3	4	1				3	6	3	3.0	5.5	2.5
BD0317	3	7	4				2	5	3	3	6	3				2.7	6.0	3.3
N=	4	4	4	2	2	2	4	4	4	4	4	4	4	4	4	5.0	5.0	5.0
MEAN	**3.0**	**7.0**	**4.0**	**2.5**	**6.0**	**3.5**	**2.5**	**5.8**	**3.3**	**3.3**	**6.5**	**3.3**	**3.0**	**6.8**	**3.8**	**2.9**	**6.4**	**3.5**
T TEST			0.005			0.045			0.026			0.003			0.008			0.001
stdev	0.8	0.8	1.4	0.7	1.4	0.7	0.6	1.7	2.1	0.5	1.3	1.0	0.0	1.5	1.5	0.3	1.1	1.2
se	0.4	0.4	0.7	0.5	1.0	0.5	0.3	0.9	1.0	0.3	0.6	0.5	0.0	0.8	0.8	0.1	0.5	0.5
Min	2	6	3	2	5	3	2	4	1	3	5	2	3	5	2	2.5	5.3	2.3
Max	4	8	6	3	7	4	3	8	6	4	8	4	3	8	5	3.3	7.8	5.3
Backs																		
BD0307	3	4	1				3	3	0	2	3	1				2.7	3.3	0.7
BD0309							3	5	2	3	6	3	2	6	4	2.7	5.7	3.0
BDO310				2	7	5	2	8	6				3	7	4	2.3	7.3	5.0
BD0318				2	5	3	2	6	4				3	4	1	2.3	5.0	2.7
BD0320	3	8	5	2	8	6	3	8	5							2.7	8.0	5.3
BD0329	2	6	4				5	8	3	3	7	4	1	7	6	2.8	7.0	4.3
BD0330	3	8	5	3	8	5	3	7	4	3	6	3	2	7	5	2.8	7.2	4.4
N=	4	4	4	4	4	4	7	7	7	4	4	4	5	5	5	7	7	7
MEAN	**2.8**	**6.5**	**3.8**	**2.3**	**7.0**	**4.8**	**3.0**	**6.4**	**3.4**	**2.8**	**5.5**	**2.8**	**2.2**	**6.2**	**4.0**	**2.6**	**6.2**	**3.6**
T TEST			0.014			0.002			0.002			0.011			0.004			0.001
stdev	0.5	1.9	1.9	0.5	1.4	1.3	1.0	1.9	2.0	0.5	1.7	1.3	0.8	1.3	1.9	0.2	1.6	1.6
se	0.3	1.0	0.9	0.3	0.7	0.6	0.4	0.7	0.8	0.3	0.9	0.6	0.4	0.6	0.8	0.1	0.6	0.6
Min	2	4	1	2	5	3	2	3	0	2	3	1	1	4	1	2.3	3.3	0.7
Max	3	8	5	3	8	6	5	8	6	3	7	4	3	7	6	2.8	8.0	5.3

DRINKING FREQUENCY DATA

Game number	2						3						4						6						7						All Games					
	Actual drinks taken			Percentage of breaks used			Actual drinks taken			Percentage of breaks used			Actual drinks taken			Percentage of breaks used			Actual drinks taken			Percentage of breaks used			Actual drinks taken			Percentage of breaks used			Actual drinks taken			Percentage of breaks used		
Drinking Frequency	1st half	2nd half	Both halves	1st half	2nd half	Both halves	1st half	2nd half	Both halves	1st half	2nd half	Both halves	1st half	2nd half	Both halves	1st half	2nd half	Both halves	1st half	2nd half	Both halves	1st half	2nd half	Both halves	1st half	2nd half	Both halves	1st half	2nd half	Both halves	1st half	2nd half	Both halves	1st half	2nd half	Both halves
All Subjects																																				
BD0305	4	3	7	80%	50%	64%	8	5	13	89%	83%	87%							3	0	3	43%	0%	27%	3	3	6	60%	60%	60%	4.5	2.8	7.3	68%	48%	59%
BD0307	3	0	3	60%	0%	27%							4	1	5	100%	33%	71%	3	0	3	43%	0%	27%							3.3	0.3	3.7	68%	11%	42%
BD0308	0	0	0	0%	0%	0%							1	1	2	25%	33%	29%	2	1	3	29%	25%	27%	4	3	7	80%	60%	70%	1.8	1.3	3.0	33%	30%	31%
BD0309													2	2	4	50%	67%	57%	2	0	2	29%	0%	18%	2	2	4	40%	40%	40%	2.0	1.3	3.3	40%	36%	38%
BD3010							3	0	3	33%	0%	20%	2	2	4	50%	67%	57%							1	2	3	20%	40%	30%	2.0	1.3	3.3	34%	36%	36%
BD0312													2	0	2	50%	0%	29%	2	2	4	29%	50%	36%	3	3	6	60%	60%	60%	2.3	1.7	4.0	46%	57%	42%
BD0313	3	1	4	60%	17%	36%	8	3	11	89%	50%	73%	3	2	5	75%	67%	71%							2	4	6	40%	80%	60%	4.0	2.5	6.5	66%	53%	60%
BD0317	1	1	2	20%	17%	18%							1	2	3	25%	67%	43%	2	0	2	29%	0%	18%							1.3	1.0	2.3	25%	29%	26%
BD0318							2	0	2	22%	0%	13%	2	0	2	50%	0%	29%							3	2	5	60%	40%	50%	2.3	0.7	3.0	44%	13%	31%
BD0320	2	1	3	40%	17%	27%	3	5	8	33%	83%	53%	7	3	10	175%	100%	143%	4	0	4	57%	0%	36%							4.0	2.3	6.3	76%	50%	65%
BD0326	3	2	5	60%	33%	45%							1	0	1	25%	0%	14%	2	1	3	29%	25%	27%	3	2	5	60%	40%	50%	2.3	1.3	3.5	43%	25%	34%
BD0327	3	1	4	60%	17%	36%							2	7	9	50%	233%	129%	3	1	4	43%	25%	36%							2.7	3.0	5.7	51%	92%	67%
BD0329	1	0	1	20%	0%	9%							1	2	3	25%	67%	43%	3	1	4	43%	25%	36%	2	3	5	40%	60%	50%	1.8	1.5	3.3	32%	38%	35%
BD0330	2	0	2	40%	0%	18%	4	2	6	44%	33%	40%	2	2	4	50%	67%	57%	2	0	2	29%	0%	18%	2	2	4	40%	40%	40%	2.5	1.0	3.5	41%	25%	33%
N=	10	10	10	10	10	10	6	6	6	6	6	6	13	13	13	13	13	13	11	11	11	11	11	11	10	10	10	10	10	10	14	14	14	14	14	14
MEAN	**2.2**	**0.9**	**3.1**	**44%**	**15%**	**28%**	**4.7**	**2.5**	**7.2**	**52%**	**42%**	**48%**	**2.3**	**1.8**	**4.2**	**58%**	**62%**	**59%**	**2.5**	**0.5**	**3.1**	**36%**	**14%**	**28%**	**2.5**	**2.6**	**5.1**	**50%**	**52%**	**51%**	**2.6**	**1.6**	**4.2**	**48%**	**37%**	**43%**
T TEST		0.001			0.000			0.035			0.236			0.234			0.420			0.000			0.003			0.379			0.379			0.000			0.049	
stdev	1.2	1.0	2.0	25%	17%	18%	2.7	2.3	4.4	30%	38%	29%	1.7	1.8	2.7	41%	61%	38%	0.7	0.7	0.8	10%	17%	8%	0.8	0.7	1.2	17%	14%	12%	1.0	0.8	1.5	16%	20%	14%
se	0.4	0.3	0.6	8%	5%	6%	1.1	0.9	1.8	12%	15%	12%	0.5	0.5	0.7	11%	17%	11%	0.2	0.2	0.3	3%	5%	2%	0.3	0.2	0.4	5%	4%	4%	0.3	0.2	0.4	4%	5%	4%
Min	0.0	0.0	0.0	0%	0%	0%	2.0	0.0	2.0	22%	0%	13%	1.0	0.0	1.0	25%	0%	14%	2.0	0.0	2.0	29%	0%	18%	1.0	2.0	3.0	20%	40%	30%	1.3	0.3	2.3	25%	11%	26%
Max	4.0	3.0	7.0	80%	50%	64%	8.0	5.0	13.0	89%	83%	87%	7.0	7.0	10.0	175%	233%	143%	4.0	2.0	4.0	57%	50%	36%	4.0	4.0	7.0	80%	80%	70%	4.5	3.0	7.3	76%	92%	67%
Median	2.5	1.0	3.0	50%	17%	27%	3.5	2.5	7.0	39%	42%	47%	2.0	2.0	4.0	50%	67%	57%	2.0	0.0	3.0	29%	0%	27%	2.5	2.5	5.0	50%	50%	50%	2.3	1.3	3.5	44%	36%	37%
Forwards																																				
BD0305	4	3	7	80%	50%	64%	8	5	13	89%	83%	87%							3	0	3	43%	0%	27%	3	3	6	60%	60%	60%	4.5	2.75	7.25	68%	48%	59%
BD0308	0	0	0	0%	0%	0%							1	1	2	25%	33%	29%	2	1	3	29%	25%	27%	4	3	7	80%	60%	70%	1.8	1.3	3.0	33%	30%	31%
BD0312													2	0	2	50%	0%	29%	2	2	4	29%	50%	36%	3	3	6	60%	60%	60%	2.3	1.7	4.0	46%	57%	42%
BD0313	3	1	4	60%	17%	36%	8	3	11	89%	50%	73%	3	2	5	75%	67%	71%							2	4	6	40%	80%	60%	4.0	2.5	6.5	66%	53%	60%
BD0317	1	1	2	20%	17%	18%							1	2	3	25%	67%	43%	2	0	2	29%	0%	18%							1.3	1.0	2.3	25%	29%	26%
BD0326	3	2	5	60%	33%	45%							1	0	1	25%	0%	14%	2	1	3	29%	25%	27%	3	2	5	60%	40%	50%	2.3	1.3	3.5	43%	25%	34%
BD0327	3	1	4	60%	17%	36%							2	7	9	50%	233%	129%	3	1	4	43%	25%	36%							2.7	3.0	5.7	51%	92%	67%
N=	6	6	6	6	6	6	2	2	2	2	2	2	6	6	6	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	7	7	7	7	7	7
MEAN	**2.3**	**1.3**	**3.7**	**47%**	**22%**	**33%**	**8.0**	**4.0**	**12.0**	**89%**	**67%**	**80%**	**1.7**	**2.0**	**3.7**	**42%**	**67%**	**52%**	**2.3**	**0.8**	**3.2**	**33%**	**21%**	**29%**	**3.0**	**3.0**	**6.0**	**60%**	**60%**	**60%**	**2.7**	**1.9**	**4.6**	**47%**	**45%**	**46%**
T TEST		0.020			0.013			0.078			0.205			0.379			0.248			0.009			0.115			0.500			0.500			0.014			0.362	
stdev	1.5	1.0	2.4	30%	17%	22%	0.0	1.4	1.4	0%	24%	9%	0.8	2.6	2.9	20%	87%	42%	0.5	0.8	0.8	7%	19%	7%	0.7	0.7	0.7	14%	14%	7%	1.2	0.8	1.9	16%	23%	16%
se	0.6	0.4	1.0	12%	7%	9%	0.0	1.0	1.0	0%	17%	7%	0.3	1.1	1.2	8%	35%	17%	0.2	0.3	0.3	3%	8%	3%	0.3	0.3	0.3	6%	6%	3%	0.4	0.3	0.7	6%	9%	6%
Min	0.0	0.0	0.0	0%	0%	0%	8.0	3.0	11.0	89%	50%	73%	1.0	0.0	1.0	25%	0%	14%	2.0	0.0	2.0	29%	0%	18%	2.0	2.0	5.0	40%	40%	50%	1.3	1.0	2.3	25%	25%	26%
Max	4.0	3.0	7.0	80%	50%	64%	8.0	5.0	13.0	89%	83%	87%	3.0	7.0	9.0	75%	233%	129%	3.0	2.0	4.0	43%	50%	36%	4.0	4.0	7.0	80%	80%	70%	4.5	3.0	7.3	76%	92%	67%
Median	3	1	4	60%	17%	36%	8	4	12	89%	67%	80%	1.5	1.5	2.5	38%	50%	36%	2	1	3	29%	25%	27%	3	3	6	60%	60%	60%	2.3	1.7	4	46%	37%	42%
Backs																																				
BD0307	3	0	3	60%	0%	27%							4	1	5	100%	33%	71%	3	0	3	43%	0%	27%							3.3	0.3	3.7	68%	11%	42%
BD0309													2	2	4	50%	67%	57%	2	0	2	29%	0%	18%	2	2	4	40%	40%	40%	2.0	1.3	3.3	40%	36%	38%
BD3010							3	0	3	33%	0%	20%	2	2	4	50%	67%	57%							1	2	3	20%	40%	30%	2.0	1.3	3.3	34%	36%	36%
BD0318							2	0	2	22%	0%	13%	2	0	2	50%	0%	29%							3	2	5	60%	40%	50%	2.3	0.7	3.0	44%	13%	31%
BD0320	2	1	3	40%	17%	27%	3	5	8	33%	83%	53%	7	3	10	175%	100%	143%	4	0	4	57%	0%	36%							4.0	2.3	6.3	76%	50%	65%
BD0329	1	0	1	20%	0%	9%							1	2	3	25%	67%	43%	3	1	4	43%	25%	36%	2	3	5	40%	60%	50%	1.8	1.5	3.3	32%	38%	35%
BD0330	2	0	2	40%	0%	18%	4	2	6	44%	33%	40%	2	2	4	50%	67%	57%	2	0	2	29%	0%	18%	2	2	4	40%	40%	40%	2.5	1.0	3.5	41%	25%	33%
N=	4	4	4	4	4	4	4	4	4	4	4	4	7	7	7	7	7	7	5	5	5	5	5	5	5	5	5	5	5	5	7	7	7	7	7	7
MEAN	**2.0**	**0.3**	**2.3**	**40%**	**4%**	**20%**	**3.0**	**1.8**	**4.8**	**33%**	**29%**	**32%**	**2.9**	**1.7**	**4.6**	**71%**	**57%**	**65%**	**2.8**	**0.2**	**3.0**	**40%**	**5%**	**27%**	**2.0**	**2.2**	**4.2**	**40%**	**44%**	**42%**	**2.6**	**1.2**	**3.8**	**48%**	**30%**	**40%**
T TEST		0.018			0.015			0.171			0.419			0.078			0.230			0.001			0.003			0.311			0.311			0.004			0.036	
SD	0.8	0.5	1.0	16%	8%	9%	0.8	2.4	2.8	9%	39%	18%	2.0	1.0	2.6	51%	32%	37%	0.8	0.4	1.0	12%	11%	9%	0.7	0.4	0.8	14%	9%	8%	0.8	0.6	1.1	17%	14%	12%
SE	0.4	0.3	0.5	8%	4%	4%	0.4	1.2	1.4	5%	20%	9%	0.8	0.4	1.0	19%	12%	14%	0.4	0.2	0.4	5%	5%	4%	0.3	0.2	0.4	6%	4%	4%	0.3	0.2	0.4	6%	5%	4%
Min	1.0	0.0	1.0	20%	0%	9%	2.0	0.0	2.0	22%	0%	13%	1.0	0.0	2.0	25%	0%	29%	2.0	0.0	2.0	29%	0%	18%	1.0	2.0	3.0	20%	40%	30%	1.8	0.3	3.0	32%	11%	31%
Max	3.0	1.0	3.0	60%	17%	27%	4.0	5.0	8.0	44%	83%	53%	7.0	3.0	10.0	175%	100%	143%	4.0	1.0	4.0	57%	25%	36%	3.0	3.0	5.0	60%	60%	50%	4.0	2.3	6.3	76%	50%	65%
Median	2	0	2.5	40%	0%	23%	3	1	4.5	33%	17%	30%	2	2	4	50%	67%	57%	3	0	3	43%	0%	27%	2	2	4	40%	40%	40%	2.3	1.3	3.3	41%	36%	36%

24-HR DIETARY ANALYSIS

Player	BM	Energy		Fluid		CHO		Protein		Fat		Fat		
	kg	kJ	kJ/kg	ml	ml/kg	g	g/kg	g	g/kg	g	g/kg	saturated, g	mono, g	poly, g
BD0308	110.70	21954.57	198.32	6575.56	59.40	725.73	6.56	300.03	2.71	130.52	1.18	46.50	40.80	26.00
BD0319	104.60	17450.03	166.83	5135.68	49.10	482.84	4.62	290.38	2.78	122.76	1.17	51.90	41.50	10.80
BD0329	98.80	18569.23	187.95	2032.02	20.57	485.13	4.91	165.17	1.67	207.36	2.10	98.60	66.50	20.30
BD0320	81.60	16726.19	204.98	3496.62	42.85	489.61	6.00	218.48	2.68	132.26	1.62	62.70	41.30	8.90
BD0311	95.80	19029.83	198.64	4493.07	46.90	570.71	5.96	233.57	2.44	151.79	1.58	60.00	49.30	23.80
BD0303	89.10	20914.48	234.73	5651.65	63.43	646.00	7.25	318.33	3.57	131.07	1.47	55.50	40.00	19.10
BD0330	90.30	18186.53	201.40	4869.61	53.93	596.81	6.61	219.93	2.44	123.72	1.37	57.60	30.50	18.40
BD0318	80.40	19765.63	245.84	6296.62	78.32	703.47	8.75	217.56	2.71	119.39	1.48	45.20	32.50	26.00
Mean	93.91	19074.56	204.84	4818.85	51.81	587.54	6.33	245.43	2.62	139.86	1.50	59.75	42.80	19.16
SD	10.65	1746.72	25.06	1497.01	16.85	98.10	1.31	52.17	0.52	29.01	0.29	16.86	11.19	6.46
Median	93.05	18799.53	200.02	5002.65	51.51	583.76	6.28	226.75	2.69	130.80	1.48	56.55	41.05	19.70
min	80.40	16726.19	166.83	2032.02	20.57	482.84	4.62	165.17	1.67	119.39	1.17	45.20	30.50	8.90
Max	110.70	21954.57	245.84	6575.56	78.32	725.73	8.75	318.33	3.57	207.36	2.10	98.60	66.50	26.00

Percentage of energy

			FAT			
	CHO	Protein	Poly	Mono	Saturat.	Total Fat
BD0308	56%	23%	4.83%	7.56%	8.61%	21%
BD0319	47%	28%	2.50%	10%	12.50%	25%
BD0329	44%	15%	4.51%	14.76%	21.73%	41%
BD0320	49%	22%	2.32%	10.73%	16.24%	29%
BD0311	50%	21%	5.22%	10.73%	13.05%	29%
BD0303	52%	25%	3.91%	8.05%	11.04%	23%
BD0330	55%	20%	4.25%	7.25%	13.50%	25%
BD0318	60%	18%	5.50%	6.82%	9.68%	22%
Mean	51.63%	21.50%	4.13%	9.49%	13.29%	26.88%
Median	51.00%	21.50%	4.38%	9.03%	12.78%	25.00%
SD	5.21%	4.04%	1.18%	2.65%	4.15%	6.42%
min	44.00%	15.00%	2.32%	6.82%	8.61%	21.00%
Max	60.00%	28.00%	5.50%	14.76%	21.73%	41.00%