# FLUID BALANCE DURING SWIM TRAINING

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A Research Report submitted to the Faculty of Medicine, University of the Witwatersrand, Johannesburg in partial fulfilment for the degree of M.Sc.(Med)

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# DECLARATION

I declare that this research report is my own, unaided work except to the extent indicated in the acknowledgements and in the references. It is being submitted in partial fulfilment for the degree of Master of Science (Medicine) at the University of the Witwatersrand, Johannesburg. It has not been submitted previously as a requirement for any degree or examination in this or any other university.

.........17......... day of ......August.......... 2006

........................

(Mornay Saul Butlion)

I certify that the study contained in this research report has the approval of the Committee for Research on Human Subjects, Clearance certificate number M940221(See Appendix)

.............................. Date: 17 August 2006

(Signature of student)

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(Signature of supervisor)

ABSTRACT

During a typical swimming training session, the volume of fluid lost via sweat is not evident which may contribute to a swimmer not replacing fluid loss effectively. This study investigates fluid balance during a typical swim training session. The physiological responses measured included fluid loss, fluid gain and plasma lactate concentrations

Fifteen male and female swimmers with ages ranging between 16 - 25 years, volunteered to participate in the study. A standardised training procedure was used and measurements were made before and after the swim session. Water intake and urine output were carefully measured and recorded during the training session.

There was no difference between the fluid gain and fluid loss. (p = 0,5562) during the training session. However half of the subjects (n = 7) showed a net body mass loss (-0.66kg) and the other half (n = 8) a net body mass gain (0.41kg).

Therefore the fluid balance demonstrated by the total group of swimmers occurred because one half of the swimmers showed a net fluid gain (410.6ml.h-1) and were counter-balanced by the other half of the swimmers who showed a net fluid loss (-497.2ml.h-1). The former showed a significantly greater water intake (410.6ml.h-1) and the latter a significantly greater sweat loss (425.77ml.h-1). However the plasma volume in both subgroups was increased. The former by 8.64% and the latter by 7.52%.

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$Hb_A$: Haemoglobin concentration after the swim session

$Hb_B$: Haemoglobin concentration before the swim session

$Hct_A$: Haematocrit levels after the swim session

$Hct_B$: Haematocrit levels before the swim session

$\%\Delta PV$: Percentage change in plasma volume

SR: Sweat rate

$W_A$: Body mass after the swim session

$W_B$: Body mass before the swim session

# CHAPTER 1. INTRODUCTION

Few studies have been done on the loss of body fluids in swimmers. The nature of swimming training involves being constantly immersed in water. Hence the swimmer and the coach are not able to visually assess the level of fluid loss through sweating. We tested the hypothesis that swimmers do not rehydrate adequately during a training period.

Henane et al (1977) reported that numerous studies have shown that heat is well dissipated in training subjects (32). Dehydration may occur as a result of sweating if fluid loss is not adequately replaced, a condition that may well impair performance (1). Leiper and Maughan (2004) noted that excess metabolic heat is produced during exercise and must be eliminated from the body in order to maintain body core temperature and normal metabolic function (38). In swimmers heat is mainly dissipated via conduction and convection.

Kirwein et al (1988) measured haemoglobin and haematocrit on successive days during intense training in competitive swimmers and found a relative increase of 11,4 ± 2.7% in estimated plasma volume during training. It is pertinent that Kirwein et al's study (35) dealt with day- to-day or session-to-session changes, not actual changes within the training session. Therefore Kirwein et al showed that in their study, adequate hydration took place during a training period. The studies by Kirwein et al (35) and Henane et al (32) indicate that no supporting evidence exists that this is an invariable response amongst swimmers during a single training session. In a larger study conducted by Cox et al (2002) at the Australian Institute of Sport, data was collected from swimmers over thirteen training sessions, during a three week camp, immediately prior to a major international meet. The total number of fluid balance observations made for male and female swimmers were 155 and 140 respectively from 21 males and 20 females. During this study, it was found to be impractical to measure sweat rate and fluid intake in units of time. Instead, it was measured as millilitres per kilometre. The calculated mean sweat rate during training for males and female swimmers was 138 ml/km and 107ml/km respectively. On average it appeared that swimmers drank at a rate that slightly exceeded their sweat rate(12).

Dehydration seems to be a major medical problem for sportsmen training or competing for lengthy periods. This study will examine the fluid balance of swimmers during a single training session. We hypothesise that swimmers do not rehydrate sufficiently to replace lost body fluids within a training session, and this will influence the effectiveness of the training session (56).

# CHAPTER 2. LITERATURE REVIEW

## 2.1 Dehydration

Dehydration although not a disease, may result from a diseased state or from an imbalance in the body's homeostasis. Dehydration refers to fluid loss, resulting in a depletion of body fluid volume (43).

Most sporting disciplines will result in the athlete losing fluid via sweating. In most activities, sweating is obvious. However, in an aquatic environment, sweating is masked and the prevention of fluid imbalance tends to be ignored by coaches (33).

### 2.1.1 Types of Dehydration

Three main types of dehydration exist.

i) Hypertonic dehydration:

A hypertonic volume depletion occurs when body fluid is lost faster than the body's electrolytes, resulting in the loss of a hypotonic solution (11, 33, 42). Consequently body fluids become hypertonic to their normal state. Hypertonic dehydration usually occurs as a result of extensive sweating, for example exercising in hot humid conditions without appropriate rehydration (42).

Hypertonic dehydration occurs first in extracellular fluid as the result of sweating which is a hypotonic solution. Osmotic forces cause cellular water to enter the extracellular spaces resulting in intracellular fluid loss (5) Leiper and Maughan (2004b) suggested that the intensity of swim training produced sufficient thermal stress to promote significant sweat secretion. The faster rate of water turnover and intake during swimming compared with a sedentary group could be attributed to exercising in water, but unrelated to exercise induced sweating. Human skin has a low permeability to water and only about 4ml of pool water per hour of emersion would be expected to penetrate the wetted skin of swimmers(38). Water immersion causes redistribution of body fluid leading to haemodilution and subsequent diuresis. Greenleaf (1979), suggested the greater water turnover in the swimmer may have been as a result of immersion induced diuresis with urine being voided into the pool(28).

Blood eventually could become viscous enough to result in an increase in vascular resistance (5). Reduced blood flow and perfusion of the kidneys can result in a reduction of renal clearance, causing excessive blood urea and acid-base disturbances (33). In extreme cases breathing disturbances as well as shrinkage of the brain may result. It may be so severe that brain haemorrhage occurs and death may result (5, 33, 42). During a competitive sporting event it is unlikely that hypertonic dehydration will progress to the point of death (42).

ii) Isotonic Dehydration

Isotonic dehydration differs to that of hypertonic dehydration in that there is volume depletion without a significant change in electrolyte concentrations. This form of dehydration is normally as a result of a trauma (21, 22). The body reacts quickly through homeostatic mechanisms. If blood pressure continues to fall death may occur (42).

iii) Hypotonic Dehydration

This form of dehydration is a result of body fluid and excess electrolyte depletion. Hypotonic dehydration is characterised by sodium loss, resulting in muscle weakness, cardiac disturbance and eventual seizure (32). Fluid volume is replaced by drinking water in which essential electrolytes are absent (1).

### 2.1.2 Thirst Sensation and the control of Dehydration

Dehydration is directly linked to thirst and its role in controlling extra cellular fluid osmolality and sodium concentrations. The thirst phenomenon is important in the control of body water loss during competitions (42, 43).

In humans the thirst centre is located in the wall of the third ventricle promoting anti-diuresis, as well as the desire to drink (2, 4). There are other areas which contribute to the onset of drinking, namely the preoptic hypothalamus (2). An increase in osmotic pressure of the third ventricle along with pre optic-hypothalamic stimulation will lead to the onset of drinking (42, 43).

Any factor causing intracellular dehydration will cause a thirst sensation. Drinking offers temporary relief from the sensation of thirst (1). However, studies have shown that partial relief from thirst occurs when water enters the mouth, but is not swallowed (2). If water enters the GIT the relief period is extended. This may explain why swimmers do not supplement regularly enough with fluids whilst training. A swimmer may take pool water into his mouth without swallowing, thereby temporarily relieving the desire to drink or rehydrate sufficiently (1, 2, 6). Eichner 1998 suggests several tips in avoiding dehydration or heat illness. They include not relying entirely on the thirst sensation, but rather to drink on a specific time schedule. A low carbohydrate flavoured replacement drink is best, especially for prolonged exercise activity lasting longer than one hour(18).

### 2.1.3 Exercise induced Dehydration

Exercise induced dehydration will occur in athletes who compete in endurance type events, when fluid intake is deficient.

- Latzka and Montain 1999, in their study, found that hydrating prior to exercise (400 - 600 ml two hours before) and drinking during exercise prevented dehydration from reaching 2% of body weight, which would compromise power and energy output. They recommended the replacement of 150 -300ml every 15 - 20 minutes (36).
- Lack of water causes dehydration and even though swimmers are surrounded by water (8, 49, 50), an exercising muscle can create up to ten times more heat than an inactive muscle.

A swim practice of 2500m to 5000m is able to significantly increase blood muscle temperature (35, 26), body temperature and sweating. Little published information exists regarding sweat loss during swimming. Lemon and co-workers *(1989)* reported average sweat rates of 0.48 litres.hr$^{-1}$ for swimmers undertaking 62 minutes of interval training at moderate water temperatures (26.6°C)(39). Claybaugh et al *(1986)* found that university swimmers lost between 1.18 - 1.62 litres.hr$^{-1}$ during a two hour hard swim session (9). In a more recent study conducted in Australia, a mean sweat loss of 0.42 litres.hr$^{-1}$ for men and 0.31 litres.hr$^{-1}$ for females was indicated (Leiper and Maughan, 2004b)(38)

Pool temperature and air temperature can influence the sweat rate and also increases fluid needs.

- It has been shown that dehydration may occur even in cold water (8).
- Hard physical training requires a normal mileau interieur to maintain the homeostasis associated with heavy exercise (49, 50).

However, it is important to note that rarely do back-of-pack runners present with typical symptoms of dehydration.

- These runners may over hydrate due to excessive fluid intake, during the event (42).
- These individuals present with disorientation not dissimilar to that of dehydration as well as thirst craving (42, 49).

However, this should not be confused with dehydration.

### 2.1.4 Temperature Regulation as an Aspect of Dehydration

Body temperature or more accurately core temperature is in a dynamic equilibrium as a result of a balance between factors which either add or subtract body heat (16). This balance is regulated by the integration of mechanisms altering heat transfer to the periphery or shell of the body. A distinct difference exists between body skin and body core temperature (62).

- Body skin temperature is affected by external factors such as physical activity, environmental determinants and activity type (16, 42).

- Oral temperature is normally lower than core temperature. The range for normal (resting) oral temperature is (36,5°C - 37,5°C) and approximately 0,6°C (on average) lower than core temperature (16).

Swimmers usually show a greater difference between oral and rectal temperature readings due to water entering the mouth during training sessions (16, 42).

A protective insulating layer of skin, subcutaneous tissue and fat exists in all humans. Certain sporting types result in individuals presenting with lower levels of subcutaneous fat (16, 42). As recently as 10 years ago it was believed that swimmers presented with more fat for insulation purposes than other athletes, for example runners. However, Lavoie and Montpetit (1986) showed in experimental data that there was greater leanness particularly in females than was seen 10 year previous. Females presented with an average of between 14 - 19% body fat whereas their male counterparts had also dropped down in body fat to as low as 5 - 10% (37).

### 2.1.5 Control and regulation of temperature

The control centre of thermoregulation is located in the hypothalamus, found in the base of the brain. The hypothalamus helps to protect the body from an excessive build up or loss of heat (49, 50). Heat regulation is set up in two ways.

- Thermal receptors in skin feed back directly to the central control centre in the brain.
- Direct stimulation of the hypothalamus via blood temperature changes (45)

Heat loss is particularly important whilst exercising, especially if done in hot weather. There are various ways of losing heat,

- radiation
- evaporation
- and most importantly for swimming, convection (17, 56).

Convection is the process of thermal loss that is most relevant to swimmers.

- Convection involves the movement of a fluid i.e. water past the body (42), transporting heat away from the body.
- Convection is most effective when the medium round the body is in motion, or if the body is moving rapidly through the medium (42).

- Before loss from the body surface, heat is transferred from the body core. This occurs by convective heat transfer by blood flow and by conductive tissue transfer of heat from the core of the body to the surface, along a temperature gradient (26, 59). This will allow the effective loss of heat via surface convection (2, 45, 49, 50)

### 2.1.6 Physiological Consequence of Possible Dehydration

Strenuous exercise may lead to dehydration due to fluid loss reaching proportions which impede the heat dissipation mechanism, thereby severely compromising cardiovascular function and work capacity (3, 8, 16, 28).

As plasma volume decreases due to the onset of dehydration, the sweat rate will therefore start to decline. It is for this reason that thermoregulation may not be well maintained (6, 15). A pre exercise dehydration of 5% of total body weight will increase body's rectal temperature and heart rate, and will decrease the sweat rate (31, 55). An increased heart rate is due to a decreased central blood volume, causing reduced ventricular filling pressure and a reduced final stroke volume and lowered cardiac output (12, 19, 29).

A fluid loss during exercise equivalent to 1% of body mass is associated with an increased rectal temperature (52, 4). When water loss reaches 4 - 5% of body mass, a definite impairment in work ability occurs (52) and performance becomes severely compromised (63). A large portion of water loss via sweating comes from the blood, therefore the circulatory capacity is adversely affected (55, 56). If fluid is not adequately replenished, one can expect a 48% reduction in an activity such as walking (27, 60). Clearly, dehydration reduces the capacity of the circulatory and temperature regulatory system to meet the metabolic and thermal stress caused by exercise (27)

In a study conducted by Cox et al (2002), dehydration incurred during prolonged high intensity exercise in an aquatic environment was less than what has been reported in typical land based sports(12).

## 2.2 Preventing dehydration

### 2.2.1 Water replacement

The primary aim of fluid replacement during a bout of exercise is to maintain plasma volume, so that circulation and sweating can progress at optimal levels (46). Sweating, although a physiological reaction to heat build-up in the system, would have little cooling benefits in an aqueous environment (51). Nevertheless a rigid water replacement schedule is necessary in the prevention of dehydration and other related complications (6). The most effective defence against fluid imbalance is an adequate water intake (45, 48).

### 2.2.2 Fluid Replacement Considerations

Various theories exist regarding the prevention of dehydration. One of the most popular techniques is that of hyper hydration or fluid loading, which not only delays dehydration, but also slows the rise in rectal temperature. Hyper hydration is best practised amongst athletes exercising or competing in hot humid weather conditions. In this regard it is advised to consume 400 - 600 ml of cold water 15 minutes prior to exercise (43). The amount consumed is variable, depending on the size of the individual participating in the sporting activity (24, 43, 51). Maresh et al (2001) demonstrated that in swimmers competing in time trial events of 200 metres or less, a state of over hydration offers no benefit(41). Previous unpublished studies by Maresh et al involving college swimmers, showed these athletes frequently consumed inadequate fluid, (less than 0.24 litres per day) during training and competitive seasons. As a result many swimmers may be training and competing in a state of dehydration. Studies on runners and cyclists have demonstrated a decrease in maximum power $VO_2$ max and physical work capacity due to hypohydration (41).

Sawka (1983a) suggested that a decrease in plasma volume as a consequence of acute hypohydration causes cardiac output to become compromised(56). Goodman and Rogers (1985) showed that intense swimming is able to yield a large shift of fluid out of the vasculature(25).

The practice of hyper hydration in exercise may well stall the process of dehydration, it does not, however suggest that replacement during exercise can be neglected. In certain sports such as distance running, matching fluid intake with fluid loss may be virtually impossible, as only 800ml of fluid can be emptied from stomach per hour during extremely vigorous exercise (46). This may not be adequate to match total fluid being lost during the exercise bout (34, 42). The onset of dehydration therefore may gradually start to occur. Similarly this may occur in swimmers who either train long distances, or compete in distance events.

In aquatic type sports such as swimming, the environment is able to affect the onset of thirst. Many swimmers tend to rinse their mouths without the fluid ever reaching the GIT. This delays the thirst mechanism and in turn may prompt more rapid dehydration. Conversely, it is difficult to monitor fluid loss in water, both visually and medically and control measures are, usually not adequate (42).

### 2.2.3 Gastric Emptying of fluid during exercise

The gastric emptying process is facilitated by temperature and activity level (22, 54). Mechanical movement such as exercise along with a fluid temperature of approximately 5°C promotes gastric emptying. Gastric fluid volume is also vital to the emptying process. Studies by Coyle (13) have shown that the rate of gastric emptying increased up to 600ml.h$^{-1}$ during exercise. A volume of 250ml ingested every 15 minutes is realistic and prevents the onset of bloating. Coyle (1978) indicated that Gastric emptying rate is influenced by osmolarity and is retarded when the ingested fluid contains simple sugars, whether in the form of glucose, fructose or sucrose (23). A glucose concentration of 10% will retard emptying from the GIT by up to half (22, 23). If higher concentrations are added to the replacement fluid, clearance from the gastrointestinal tract decreases proportionately. In addition to glucose, the addition of sodium and potassium to the replacement fluid will further slow down the gastric emptying rate. Although the osmolality of the ingested fluid has an impact on gastric emptying, the exact relation between fluid movement out of the stomach and its absorption in the intestine is not yet clear (7, 61).

It has been established that a simple chain carbohydrate, 'glucose polymer' in small concentrated amounts of 7 - 8%, if consumed regularly at 15 minute intervals whilst exercising, inhibits gastric emptying less. The benefit of this replacement fluid is that whilst replacing fluid, it also helps in replenishing carbohydrate stores which is of immense benefit to endurance athletes. Polymerisation of glucose maximised carbohydrate content whilst minimising osmolality (21). This suggests that any athletic fluid supplement with sugar concentrations higher than 7 - 8% may pose significant adverse consequences for fluid balance during prolonged exercise sessions (27).

Environmental factors impact seriously on the benefit of fluid replacement (42). A cooler environment results in less fluid loss by sweating. In the latter case, fluids with greater sugar quantities may be more easily tolerated (43). However, due to the slower rate of emptying from the gastric intestinal tract, the increase in sugar content will only benefit endurance athletes, competing in events greater than 25 minutes in duration (23, 43, 45).

In an article by Gisolfi and Duchman (1992) entitled "Guidelines for Optimal Replacement Beverages for different athletic events" it was established that during exercise especially endurance

exercise in the heat, vital body fluids and essential ions are lost in sweat. The body may also deplete in glycogen stores. According to Gisolfi and Duchman events lasting less than one hour 300 - 500 ml of a 6-10% carbohydrate beverage is recommended 0 - 15 minutes pre event, at a 5 - 15°C temperature(30).
Water replaced thereafter should in a volume approximately half of the subjects sweat rate.
Evens lasting 1 - 3 hours, 300 - 500 ml of water is recommended pre event and 800 - 1600 ml $.h^{-1}$ of a 6 - 8% carbohydrate beverage with 20- 30 mEq $Na^+$ during exercise.
During recovery a beverage containing 5 - 19% carbohydrate with 30 - 40 mEq $Na^+$ should be ingested(30).

### 2.2.4 Adequacy of rehydration

Whilst exercising, it has been established that changes in the individual's body mass can be used to gauge water loss. Time frame of the exercise bout, environmental conditions, as well as exercise intensity, needs to be taken into account (42, 43).

Electrolyte intake may be important during exercise, however no conclusive evidence exists to suggest that electrolyte intake will improve performance or reduce physiological strain during exercise or during competition (20). It has been established that sweat is hypotonic to body fluid; therefore, it is more of a concern to replace water instead of ions during exercise. Adding small quantities of salt to food, post exercise, easily rectifies electrolyte loss (8).

Studies in both humans and animals have suggested that the addition of small amounts of sodium in the water will help to blunt the effect of pure water on the process known as sodium dependent stimulation of thirst (13). In the maintenance of plasma, adding small amounts of sodium will sustain the thirst drive, thereby rapidly restoring lost plasma volume (42).
In a more recent study conducted by Coyle (2004) it was found that the amount of water, carbohydrate and salt that an athlete is advised to ingest during exercise is based upon their effectiveness in attenuating both fatigue as well as illness due to hyperthermia, dehydration or hyperhydration (14). When possible, fluid should be ingested at rates that would best match the sweat rate. If not possible athletes may lose as much as 2% body weight, which may impede power output and performance, especially in hot humid weather conditions. Fluid intake should not exceed the sweat rate, during exercise, fatigue can be reduced by adding carbohydrate to fluids, 30 - 60g of simple rapidly absorbed carbohydrate should be used. Salt supplementation is best tailored to suit individual needs but generally only necessary in events lasting longer than 2 hours or in events that are particularly taxing on the body's sodium concentrations(14).

Coyle (2004), showed that fluid supplementation at a rate matching sweat rate is most favourable he also suggests that the inclusion of simple carbohydrate is beneficial in preventing the onset of fatigue. He, however, states that salt supplementation is rarely necessary (14).

## 2.3 Body Fluid

### 2.3.1 Maintenance

The term, body fluid, refers to the body's water and its dissolved substances. Fluid comprises 45 - 75% of the entire body weight of an individual.

The fluid compartments can be divided basically into intracellular fluid (ICF) and extracellular fluid (ECF). Intracellular fluid comprises about two thirds and extracellular fluid about one third of the total body water (51). The ECF compartment can be divided into interstitial fluid (ISF) and intravascular fluid (IVF). Body fluids are separated into distinct compartments via a selectively permeable membrane (by the cell membrane between ICF and ECF and by the capillary membrane between IVF and ISF). In a healthy individual, fluid content within the two compartments do not fluctuate much. Physical stress may, however, influence this equilibrium (49, 50, 51). Fluid movement from one compartment to the next is controlled by osmosis. Solutes found in fluid affect the osmotic movement (42). Senay Jr *(1978)* suggests that fluid status prior to exercise may influence body fluid adjustments during exercise. Dehydration singularly or concurrently with exercise has shown to result in haemoconcentration due to plasma volume reduction. (57).

### 2.3.2 Movement of body fluids

The movement of body fluids takes place mostly at two sites, firstly between the plasma and interstitial compartments and secondly between the interstitial and intracellular compartments (33).

Movement of fluid between plasma and interstitial compartments takes place across the capillary membrane. Fluid shift is dependent on pressure differences consisting of

i) blood hydrostatic pressure

ii) interstitial fluid hydrostatic pressure

iii) blood osmotic pressure and,

iv) interstitial fluid osmotic pressure

The difference between the forces that move fluid out of plasma and the forces moving it into plasma is known as the effective filtration pressure (Peft). The pressure at the arteriole end of a capillary slightly exceeds the pressure at the venous end. Therefore, fluid moves out at arteriole end and fluid moves in at the venous end (43). Not all fluid filtered at one end is reabsorbed at the other; the remaining fluid is transported via the lymphatic system into the cardiovascular system. Normally a near state of equilibrium prevails (43, 52). Lundvall and Bjerkhoel (1994) showed that moderate to intense exercise results in a decrease in blood and plasma volume, as water shifts from plasma compartments into interstitial and intracellular fluid compartments of working muscles (40). Working muscles acquire lactate causing increase in tissue osmolarity encouraging movement of an ultra filtrate of plasma into the myocytes and interstitium. In addition, sweating and insensible fluid loss increases reduction in plasma volume (40). Goodman et al (1998) showed that swimmers presented with a 16% decrease in percentage change in plasma volume immediately post exercise that involved a short maximum effort ie 100 metres. Normal levels of plasma volume returned after 30 minutes of recovery (25).

Kargotich et al (1998) studied swimmers who performed 100 metres at 95% $VO_2$ max. These swimmers presented with a 7.3% decrease in the percentage of plasma volume immediately post exercise. The plasma volume levels only recovered by a maximum of 5.4 % after 30 - 120 minutes of post exercise recovery (58).

Interstitial fluid and intracellular fluid have the same osmotic pressure under normal circumstances (63). The principal cation inside the cell is potassium. The principal cation outside the cell is sodium. When an imbalance occurs it is usually due to an imbalance in sodium and potassium (45). Plasma concentration is controlled by aldosterone and ADH (50). ADH regulates extracellular fluid electrolyte concentrations by altering water reabsorbtion into the blood. Aldosterone regulates extracellular fluid volume by altering sodium reabsorption (45, 49, 51).

Water intake is the primary source of body fluid, amounting to 2300ml daily. Metabolic water is another source of body fluid produced by catabolism amounting to 200ml daily. Total fluid intake consists of about 2500ml/day (7).

Under normal conditions, fluid input is equal to fluid output. Fluid is eliminated via lung, kidney, skin and GIT. Stress such as intense physical exercise, places a demand on the body, which may become such that normal maintenance and fluid rehydration is not well maintained (55). Ingesting a set quota of fluid at given intervals, may help maintain homeostasis (55).

Fluid loss in certain activities is not easily monitored, for example, distance swimmers or swimmers undergoing a rigorous training regime. Sweating occurs in water and is not visible or easily monitored, making rehydration difficult (49). A risk of either, under or over hydration may occur. Exacerbating this situation is the fact that often elite swimmers train in pool water which is kept at a raised temperature as well as being indoors (31). This situation may not be advantageous due to a build up of heat indoors.

Although over hydration is not very common in short duration exercise, it is still possible. Zelingher et al (1996) showed that hypohydration is a possible complication of moderate exercise, and this may well cause neurologic manifestations. The mechanism of hyponatremia is not clear but may be due to heamodynamically inappropriate stimuli from the anti diuretic hormone (65).

Under normal conditions, fluid input and output is controlled. In the case of an imbalance such as dehydration or over hydration, body function may be altered dramatically. In dehydrated states, blood pressure falls and, glomeruler filtration drops. In an over hydrated state, filtration rate increases due to increased blood pressure, resulting in an increased fluid output (32, 33). Overhydration or hyponatremia, may cause dilutional hyponatremia a potential life threatening conditional Excess water intake can cause cells to swell. Generally over hydration will only occur in events longer than five hours in duration (51). If over hydration did start occurring in a normal healthy subject, urine would be excreted in large pale quantities.

The effects of hydration status have not been adequately emphasised or examined in swimmers. Maresh et al (2001) showed that over hydration may reduce the proportionate fluid loss from circulation during exercise. To explore this more accurately, Maresh et al conducted a study on 5 female and 6 male collegiate swimmers. The study involved swimmers doing 2 x 200yd time trials 3 days apart, in alternate randomised states of euhydration and over hydration(41). Although performance time improved for 7 of the 11 swimmers during over hydration, there was not a statistical significance between eu and over hydrated conditions. The data demonstrated that over hydration provided no performance advantage for the group during the 200 yd time trial (41).

# CHAPTER 3. MATERIAL AND METHODS

## 3.1 Subjects Tested

Fifteen healthy non-smoking subjects (9 male and 6 female) volunteered to participate in the study. All fifteen subjects were competitive swimmers from the Gauteng region and all subjects had attained a minimum of provincial status.

## 3.2 Exercise Testing

### 3.2.1 Information Sheet and Subject Consent Form

All subjects were given a detailed information sheet which explained testing that was to be conducted, before, during and after the training sessions. A signed consent form was obtained from each subject. Clearance was obtained from the University Ethics Committee (Clearance certicate number M940221)(Appendix B)

### 3.2.2 Venue

Testing commenced at 08:00 in a 25-meter indoor swimming pool

The pool temperature was constant (24° ± 1°C) temperature was measured immediately before commencing test session as well as immediately after conclusion of the swim session throughout the testing procedure. Testing was concluded prior to twelve noon for all the subjects

### 3.2.3 Program

All fifteen subjects completed a standardised swim training session (Appendix A). Intensity was individualised according to each subject's personal best time for a particular distance. Time spent swimming during the training session was recorded for each subject. Subjects were required to complete the training session in the freestyle discipline.

### 3.2.4 Blood Collection Procedure

Venous blood samples were collected in evacuated EDTA tubes, via an infusion set in the forearm vein, while subjects remained quiet in a supine position on the pool deck. Samples were collected prior to the training session and immediately after conclusion of the session.

### 3.2.5 Analytical Methods

The blood samples collected pre exercise as well as post exercise, was used to measure haematocrit, haemoglobin and plasma lactate concentrations.

(1) Haematocrit readings were measured immediately in duplicate using a microhaematocrit centrifuge, for all fifteen subjects.

(ii) Haemoglobin was measured successfully for all 15 subjects using a Technicon H3 Coulter Counter.

(iii) Plasma used to measure lactate, was stored at -20°C and was analysed 4 - 8 weeks after collection using a enzymatic technique (Boehringer Mannheim Lactate Testing Kit). Lactate results were repeated twice on each subject to ensure reliability of results.

## 3.3 Procedures

### 3.3.1 Body mass

We measured body mass before and after the training session. The subject wearing wet costumes for all measurements before and after training sessions. The scale used (Seca, Hamburg, Germany) was calibrated to an accuracy of 100g using excised approved weights.

The total body mass lost was calculated for seven of the subjects (Group A), who showed a decrease in total body mass after the training session. This loss was then expressed as a percentage of the total body mass. The total body mass gained was calculated for eight of the subjects (Group B), who showed an increase in total body mass after the training session. This gain was then expressed as a percentage of the total body mass.

### 3.3.2 Sweat Rate (SR)

To determine sweat rate subjects were weighed before ($W_B$) and immediately ($W_A$) after the training period.

- The time between the weighing procedures was recorded.(hours)

- Water intake and urine output was measured to the nearest millilitre.
- Each subject was allowed to drink water ad libitum.
- No mass was lost by defecation.
- Weighing procedures were conducted under the same circumstances for all subjects before and after training sessions.

Sweat rate ($ml.h^{-1}$) was effectively calculated for fifteen subjects

$$SR\ (ml.h^{-1}) = [(W_B + \text{fluid intake}) - (W_A + \text{urine output})] / \text{time}$$

3.3.3 Percentage change in plasma volume (%ΔPV)

Percentage change in plasma volume was examined to assess fluid balance. To correct for possible changes in red blood cell volume, haemoglobin and haematocrit levels before ($Hb_B$ and $Hct_B$ respectively) and after ($Hb_A$ and $Hct_A$ respectively) exercise were incorporated into the calculation to determine the percentage change in plasma volume.

$$\%\Delta PV = 100\ [Hb_B\ (100-HCt_A)]/[Hb_A\ (100-HCt_B\ )]\ -\ 100$$

3.3.4 A standardized swimming session for all subjects was conducted in the freestyle discipline. (Appendix A). Time taken to complete each swim was recorded for each individual subject.

## 3.4 Statistics

The statistical comparison of changes before and after the swim session was done using dependent t statistics. Comparisons between Group A and Group B utilised independent t statistics. Correlations between variables were obtained using Pearson's product moment method. Statistical significance was set at $P \leq 0.05$.

# CHAPTER 4. RESULTS

## 4.1 Body Mass Changes during a Swim Training Session.

Table 1 is a representation of the mean, range and standard deviation for body weight pre and post exercise as well as urine output and water intake during exercise. All fifteen subjects were weighed with wet costumes.

Table 4.1 Body mass pre and post exercise, water intake and urine output during a swim training session, (n = 15).

| | Body Mass before (kg) | Body Mass after (kg) | Water intake ($ml.h^{-1}$) | Urine output ($ml.h^{-1}$) |
|---|---|---|---|---|
| Mean | 68.29 | 68.20 | 410.62 | 71.51 |
| Range | 45.5 to 84.1 | 45.9 to 83.9 | 0 to 895.5 | 0 to 499.1 |
| $\pm$ SD | 10.57 | 10.53 | 277.87 | 146.41 |

No significant difference exists between average body mass before and average body mass after training ($p = 0.6013$). The percentage change in body mass was negligible. Water intake will increase body mass while urine output and sweating will reduce body mass.

## 4.2 Fluid Balance

Table 2 is an indication of the subjects sweat rate that was calculated from the net change in body mass, water intake and urine output. It was not possible to reliably estimate respiratory fluid loss but the latter is small and the error relatively minor.

Table 4.2 Urine output, sweat rate and total fluid loss during a swim training session, (n = 15).

| | Urine output ($ml.h^{-1}$) | Sweat rate ($ml.h^{-1}$) | Total fluid loss ($ml.h^{-1}$) |
|---|---|---|---|
| Mean | 71.51 | 425.77 | 497.28 |
| Range | 0 to 499.1 | 4.3 to 1471.6 | 4.3 to 1471.6 |
| ± SD | 146.41 | 451.69 | 490.22 |

Total fluid loss was calculated by finding the sum of the sweat rate and urine output (Table 2). Total fluid loss (497.28 $ml.\ h^{-1}$) was about 86.66 $ml.h^{-1}$ (21%) larger than the water intake (410.62 $ml.h^{-1}$). However these differences were not statistically significant ($p = 0.5562$).

## 4.3 Changes in Plasma Volume

The percentage change in plasma volume was calculated to assess intravascular fluid volume change.

Table 4.3 Haemoglobin concentration, haematocrit and percentage change in plasma volume before and after a swim training session, (n = 15).

| | Haemoglobin (before) ($g.100ml^{-1}$) | Haemoglobin (after) ($g.100ml^{-1}$) | Haematocrit (before) (%) | Haematocrit (after) (%) | % Δ Plasma Vol. |
|---|---|---|---|---|---|
| Mean | 15.33 | 14.69* | 43.48 | 41.55 * | 8.04 * |
| Range | 13.2 - 16.6 | 13.0 - 16.0 | 38.0 - 47.0 | 37.0 - 47.0 | 2.9 - 16.5 |
| ± SD | 1.03 | 0.86 | 2.87 | 2.88 | 3.99 |

* $p < 0.05$ compared to baseline

The percentage change in plasma volume was statistically significant (8% gain in plasma volume), ($p < 0.0001$). There were large individual variations in the maximum percentage change in plasma volume, but such individual variations have frequently been observed following exercise.

### 4.4 Plasma lactate concentration

Plasma lactate levels were measured before and after the swim training session.

### 4.5 Swimmers that Showed a Decrease in Body Mass after a Swim Training Session. (Group A)

#### 4.5.1 Body mass changes during a swim training session

Dehydration is clinically diagnosed or statistically deduced from a net loss of body mass (usually a loss of more than three percent of total body mass).

Fluid loss can therefore be defined in this study in terms of the total body mass lost during the training session expressed as a percentage of the total body mass before the training session.

The body mass after the training session was measured. The total body mass lost was calculated for seven of the subjects (Group A), who showed a decrease in total mass after the training session. This loss can then be expressed as a percentage of the original total body mass.

Table 4.4 Total body mass lost and percentage body mass lost during a swim training session, (n = 7).

| | Body mass after minus Body mass before (kg) | Percentage body mass lost (%) |
|---|---|---|
| Mean | - 0.66 | -0.96 |
| Range | -0.2 to -1.4 | -0.2 to -2.2 |
| ± SD | 0.43 | 0.70 |

The percentage body mass lost during the training session was less than three percent for Group A (Table 4.5). The average body mass after training was significantly less ($p = 0.0069$) than the average body mass before training.

### 4.5.2 Fluid balance

Body mass loss is highly correlated with the total fluid loss of the swimmer (Pearsons moment correlation coefficient (r) = 0.8744, p-value < 0,001). The relationship shows that the greater the body mass loss, the greater the total fluid loss.

Table 4.5 Fluid intake, urine output, sweat rate and total fluid loss for Group A (n = 7).

| | Fluid intake ($ml.h^{-1}$) | Urine output ($ml.h^{-1}$) | Sweat rate ($ml.h^{-1}$) | Total fluid loss ($ml.h^{-1}$) |
|---|---|---|---|---|
| Mean | 224.14 | 112.21 | 769.07 | 881.28 |
| Range | 0 to 485.4 | 0 to 499.1 | 300.9 to 1471.6 | 334.3 to 1471.6 |
| $\pm$ SD | 220.75 | 198.23 | 450.97 | 447.13 |

Fluid intake was significantly less than total fluid loss (urine output plus sweat rate), ($p = 0.0045$).

4.5.3 Changes in plasma volume

The percentage change in plasma volume was calculated to assess intravascular fluid volume change for Group A.

Table 4.6 Haemoglobin concentration, haematocrit and percentage change in plasma volume before and after a swim training session for Group A (n = 7).

| | Haemoglobin (before) ($g.100ml^{-1}$) | Haemoglobin (after) ($g.100ml^{-1}$) | Haematocrit (before) (%) | Haematocrit (after) (%) | % Δ Plasma Vol. |
|---|---|---|---|---|---|
| Mean | 15.67 | 14.96 * | 44.57 | 42.50 * | 8.64 * |
| Range | 13.8 to 16.6 | 13.5 to 16.0 | 41.3 to 47.0 | 39.5 to 47.0 | 4.4 to 13.7 |
| ± SD | 0.91 | 0.77 | 2.30 | 2.90 | 2.89 |

* $p < 0.05$ compared to baseline

Dependent sample t-tests were performed. There are significant differences between the before and after measurements of haemoglobin ($p = 0.0238$). The haematocrit measurements are also significantly different ($p = 0.0052$). The percentage change in plasma volume was statistically significant (8% gain in plasma volume), ($p = 0.0002$).

#### 4.5.4 Plasma lactate concentration

Table 4.7 Plasma lactate concentration measured before and after a swim training session for Group A, (n = 7).

| | Plasma lactate concentration (before) ($mmol.l^{-1}$) | Plasma lactate Concentration (after) ($mmol.l^{-1}$) |
|---|---|---|
| Mean | 1.96 | 5.59 * |
| Range | 1.0 to 4.1 | 1.6 to 12.2 |
| ± SD | 1.15 | 3.93 |

* $p < 0.05$ compared to baseline

Plasma lactate concentrations for Group A increased significantly during the swim training session, ($p = 0.0149$).

### 4.6 Swimmers that Showed an Increase in Body Mass After a Swim Training Session. (Group B)

#### 4.6.1 Body mass changes during a swim training session

The process of rehydration is quantified as the amount of fluid taken in (ml) whilst exercising. Eight subjects (Group B) showed an increase in or maintenance of total body mass after the training session. The total body mass gain was calculated.

This total body mass gain during the training session can then be expressed as a percentage of the total body mass before the training session.

Table 4.8 Total body mass and percentage body mass gained during the training session for Group B, (n = 8).

| | Body mass after minus body mass before (kg) | Percentage body mass gained (%) |
|---|---|---|
| Mean | 0.41 | 0.64 |
| Range | 0.3 to 0.7 | 0.5 to 0.9 |
| ± SD | 0.14 | 0.17 |

The total body mass gain is almost half a kilogram. The percentage body mass gain is statistically different from zero, ($p < 0.0001$). There is also a significant difference ($p = 0.0001$) between the average body mass before and average body mass after the swim training session.

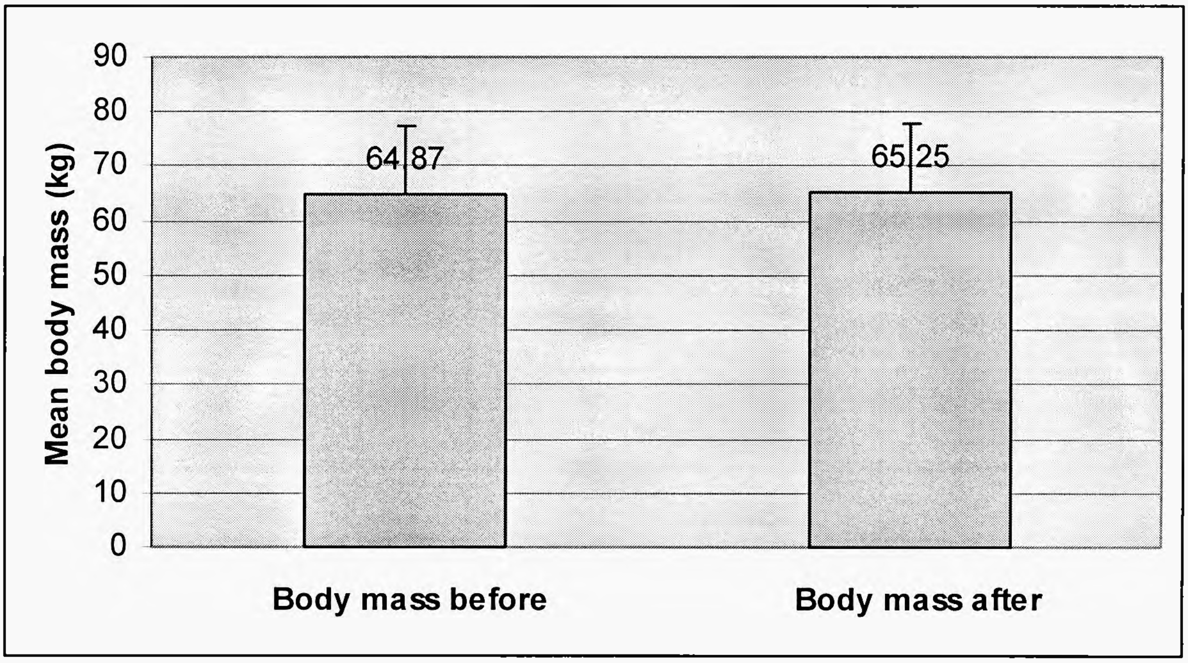


Fig 4.4 Average body mass of Group B (n = 8), before (range 45.5 - 80.8 kg) and after (range 45.9 - 81.3 kg) a swim training session, ($p < 0,05$).

### 4.6.2 Fluid balance

Table 4.9 Fluid intake, urine output, sweat rate and total fluid loss for Group B, (n = 8).

| | Fluid Intake ($ml.h^{-1}$) | Urine Output ($ml.h^{-1}$) | Sweat Rate ($ml.h^{-1}$) | Total Fluid Loss ($ml.h^{-1}$) |
|---|---|---|---|---|
| Mean | 573.78 * | 35.90 * | 125.39 | 161.28 |
| Range | 304.4 to 895.5 | 0 to 220.0 | 4.4 to 332.2 | 4.4 - 552.2 |
| ± SD | 217.84 | 78.01 | 112.96 | 180.70 |

* $p < 0.05$ compared to baseline

There is a significant difference between the total fluid intake (water) and the total fluid loss (sweat rate plus urine output), ($p = 0.0010$).

### 4.6.3 Changes in plasma volume

The percentage change in plasma volume was calculated to assess intravascular fluid volume change for Group B.

Table 4.10 Haemoglobin concentration, haematocrit and percentage change in plasma volume before and after a swim training session for Group B, (n = 8).

| | Haemoglobin (before) ($g.100ml^{-1}$) | Haemoglobin (after) ($g.100ml^{-1}$) | Haematocrit (before) (%) | Haematocrit (after) (%) | % Δ Plasma Vol. |
|---|---|---|---|---|---|
| Mean | 15.05 | 14.45 * | 42.53 | 40.27 * | 7.52 * |
| Range | 13.2 to 16.4 | 13.0 to 15.6 | 38.0 to 46.5 | 37.0 to 46.0 | 2.9 to 16.5 |
| ± SD | 1.20 | 0.92 | 3.11 | 2.76 | 4.9 |

* $p < 0.05$ compared to baseline

There is a significant difference between the before and after haemoglobin concentrations (p = 0,0483). A significant difference was found between the before and after haematocrit measurements (p = 0,0082). There was a significant increase in the percentage change in plasma volume (7% gain in plasma volume), (p = 0.0034).

### 4.6.4 Plasma lactate concentration

Table 4.11 Plasma lactate concentration measured before and after a swim training session for Group B, (n = 8).

| | Plasma lactate concentration (before) ($mmol.l^{-1}$) | Plasma lactate concentration (after) ($mmol.l^{-1}$) |
|---|---|---|
| Mean | 2.03 | 4.90 |
| Range | 1.1 to 4.1 | 1.4 to 15.7 |
| ± SD | 1.18 | 4.66 |

There was no significant increase in lactate during the swim training session for Group B ($p = 0.1241$).

## 4.7 A Comparison of Group A and Group B

### 4.7.1 Fluid balance

Table 4.12 Total fluid loss for Group A and Group B.

| | Total fluid loss Group A (n = 7) ($ml.h^{-1}$) | Total fluid loss Group B (n = 8) ($ml.h^{-1}$) |
|---|---|---|
| Mean | 881.28 * | 161.28 * |
| Range | 334.3 - 1471.6 | 4.4 - 552.2 |
| ± SD | 447.30 | 180.70 |

* $p < 0.05$ compared to baseline

Group A lost more than fivefold the fluid lost by Group B. There is a statistically significant difference between the total fluid loss between Group A and Group B, ($p = 0.0010$).

Table 4.13 Sweat rate for Group A and Group B.

| | Sweat rate Group A (n = 7) ($ml.h^{-1}$) | Sweat rate Group B (n = 8) ($ml.h^{-1}$) |
|---|---|---|
| Mean | 769.07 * | 125.39 * |
| Range | 300.9 - 1471.6 | 4.4 - 332.2 |
| ± SD | 450.97 | 112.96 |

* $p < 0.05$ compared to baseline

Similarly Group A had a sweat rate that was more than sixfold greater than the sweat rate for Group B. The difference in the sweat rates of Group A and Group B is highly significant($p = 0.0018$).

Table 4.14 Water intake for Group A and Group B.

| | Water intake group A (N = 7) ($ml.h^{-1}$) | Water intake Group B (N = 8) ($ml.h^{-1}$) |
|---|---|---|
| Mean | 224.14 * | 573.78 * |
| Range | 0 to 485.4 | 304.35 to 895.5 |
| $\pm$ SD | 220.75 | 217.84 |

On the other hand, the water intake of Group A is almost a third of the water intake for Group B. Difference in water intake between Group A and Group B is statistically significant, ( $p = 0.0087$).

Table 4.15 Urine output for group A and group B.

| | Urine output Group A (n = 7) ($ml.h^{-1}$) | Urine output Group B (n = 8) ($ml.h^{-1}$) |
|---|---|---|
| Mean | 112.21 | 35.9 |
| Range | 0 to 499.1 | 0 to 220 |
| $\pm$ SD | 198.23 | 78.01 |

Although the urine output by Group A was threefold greater than the urine output by Group B, differences were not statistically significant.

### 4.7.2 Changes in plasma volume

Table 4.16 Percentage change in plasma volume for Group A and Group B.

| | % Δ Plasma Vol. Group A (n = 7) | % Δ Plasma Vol. Group B (n = 8) |
|---|---|---|
| Mean | 8.64 | 7.52 |
| Range | 4.4 to 13.7 | 2.9 to 16.5 |
| ± SD | 2.89 | 4.90 |

In spite of the differences in fluid balance between Group A and Group B, the percentage change in plasma volume for group A and group B is not significantly different, (p = 0,6062). Both groups have shown an 8% increase in the plasma volume.

### 4.7.3 Plasma lactate concentration

The difference between the before and after measurements for the Plasma lactate concentration (for both groups) were calculated to derive the change in plasma lactate concentration during a swim training session.

Table 4.17 Plasma lactate concentration for Group A and Group B.

| | Change in Plasma lactate concentration Group A (n = 7) ($mmol.l^{-1}$) | Change in Plasma lactate concentration Group B (n = 8) ($mmol.l^{-1}$) |
|---|---|---|
| Mean | 3.63 | 2.83 |
| Range | 0.2 to 8.1 | 0.2 to 13.9 |
| ± SD | 2.84 | 4.57 |

No significant statistical difference in the change in plasma lactate concentration during a swim training session was found, ($p = 0.6948$).

# CHAPTER 5. DISCUSSION

## 5.1. Fluid balance for the total group

There was no significant fluid imbalance (i.e. fluid loss vs. fluid gain) for the group as a whole ($p = 0.1890$). Minimal weight change occurred amongst the subjects. Water intake replaced approximately 82% of the total fluid lost during the swim training session. According to Miroff and Boss, (1965), this response is normal, usually caused by a thirst mechanism that is not sensitive enough to stimulate adequate water intake(43).

In spite of inadequate fluid replacement the change in plasma volume, in haematocrit and in haemoglobin concentration indicate a haemodilution. The reason for this is not immediately apparent and will be discussed in greater detail later.

Plasma lactate on average increased from ~2 to 5.2 $mmol.l^{-1}$, but the range of the latter extended to 16 $mmol.l^{-1}$. The increase to an average of 5.2 $mmol.l^{-1}$ indicates an intensity of exercise which extended beyond the lactate threshold level.

However it was surprising to note that half of the swimmers showed a net decrease in body weight whilst the other half showed a net increase in body weight after the swim training session. We analysed these two groups in depth.

## 5.2. Fluid balance for Group A

The body mass for Group A decreased significantly during the swim training session. Convertino et al (1996) believe that a 1% loss of body weight can result in mild symptoms of dehydration whereas losses of 3% or more produce more severe symptoms of dehydration. Wyndham et al reported that a loss of more than 3% of body weight can seriously disrupt temperature regulation and physical performance. A loss of about 1% body mass (0.96%) was recorded for group A. This is similar to the 1% loss discussed by Convertino et al, but no obvious symptoms of dehydration were observed(10).

The change in body mass within Group A is due to the total fluid loss (sweat and urine) greatly exceeding water intake. Water intake replaced only 25 - 30% of total fluid loss (water was available ad libitum). Therefore these subjects took in only about a quarter of what was lost.

In spite of the high fluid loss compared to the low water intake, group A showed haemodilution. This will be discussed further later.

## 5.3. Fluid balance for Group B

The gain in body mass shown by Group B is due to fluid intake significantly exceeding fluid output. The gain of 0.64% in total body mass indicates that Group B adequately replaced the fluid lost and there was no deficit between fluid intake and fluid output. It would seem that this group of subjects have a thirst mechanism which allows adequate fluid replacement. Not surprisingly the changes in plasma volume, in haematocrit and in haemoglobin concentration indicated a haemodilution.

## 5.4 Comparison of Group A and Group B

Group B has a total fluid loss that is approximately 20% of the total fluid loss shown by Group A. The reason for this is not immediately apparent. Exercise intensity was similar for the two groups demonstrated by the mean lactate levels which were within 0,8 of a $mmol.l^{-1}$ of each other (Table 4.17). Therefore the difference in sweat rate cannot be ascribed to a difference in work intensity and both groups were exposed to the same environmental conditions.

It was surprising that Group A had a water intake which was about 40% of the water intake by Group B. Group A passed over three times more urine than Group B. We were unable to measure aldosterone and ADH activity so that we are not able to comment on kidney function.

Contrary to expectations both groups showed a similar degree of haemodilution measured as change in plasma volume,in haematocrit and in haemoglobin concentrations. While haemodilution would be expected for Group B, it was not expected for Group A. Kirwein et al (1988) showed in their study dealing with session-to-session changes that there was a relative increase of 11,4 ± 2.7% in the estimated plasma volume.

Rogers et al (1997) reported that water is added to the water pool by exogenous sources (water intake) as well as from endogenous sources (water of metabolism and the release of osmotically held water following glycogen utilization). Translocation of the water from one part of the body to another part of the same body results in an increase in the water pool without a change in body mass. This may have contributed to the haemodilution in Group A. If this is the case one would have expected a larger increase in the plasma volume in Group B. Why this did not occur is not clear. In this study we did not take endogenous sources of fluid and renal function into account.

## 5.5 Conclusion

The swim group maintained fluid balance during a swim training session. However this fluid balance occurred because one half of the swimmers showed a net fluid gain and were counter-balanced by the other half of the swimmers who showed a net fluid loss. The former showed a significantly greater water intake and the latter a significantly greater fluid loss (sweat and urine). However both groups showed the same level of haemodilution. It is possible that some of these responses could be explained in relation to endogenous water sources and possible differences in renal function.

Future investigative studies should include larger population groups tested over more consecutive swim training sessions.

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# APPENDIX A

Standardised swimming program

- 1 x 800m freestyle warm up - 40% of personal best for 400m
- 2 minutes rest
- 4 x 400m freestyle 60 second rest between sets at 80% of personal best time
- 2 min rest
- 5 x 200m freestyle 30 sec rest between sets 85% of personal best time for the distance
- 6 x 100m freestyle 20 sec rest between sets 90% of personal best time for the distance
- Body weight after exercise and duration of exercise plus blood extract
- 1 x 300m cool down.

APPENDIX B

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

COMMITTEE FOR RESEARCH ON HUMAN SUBJECTS (MEDICAL)
Ref: R14/49 (Registry)

CLEARANCE CERTIFICATE PROTOCOL NUMBER M940221

PROJECT Body fluid losses during swim training

INVESTIGATORS Professor G Rogers

DEPARTMENT Physiology

DATE CONSIDERED 940225

DECISION OF THE COMMITTEE

Approved unconditionally

DATE 940302 CHAIRMAN ..............................
(Professor P E Cleaton-Jones)

* Guidelines for written "informed consent" attached where applicable.

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DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and ONE COPY returned to the Secretary at Room 10001, 10th Floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

DATE ....................SIGNATURE ..........................