BODY COMPOSITION, DIETARY INTAKE AND SUPPLEMENT USE BY SWIMMERS AT THE HIGH PERFORMANCE CENTRE, PRETORIA

by

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Script submitted in partial fulfilment of the requirements for the degree

Magister in Dietetics (Sports Nutrition)

In the faculty of Health Sciences,

DEPARTMENT OF HUMAN NUTRITION, at the
UNIVERSITY OF THE FREE STATE

June 2006

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DEDICATION

This dissertation is dedicated to my family and my friends.

ACKNOWLEDGEMENTS

Firstly, I would like to acknowledge the greatness and power of God in supporting me in the completion of this mini-dissertation.

Further, I wish to express my thanks and gratitude to the following persons and institutions for their guidance and assistance, in the completion of this study:

Prof A Danhauser (Study leader)
Ms E Du Toit (Co- study leader)
Ms M Nel (Biostatistician)
Mr B Malga (Director at the HPC in Pretoria)
Mr M Wright (Swimming coach)
Ms P Mennen (Language editor)
Ms H Viviers (Statistics editor)

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LIST OF ABBREVIATIONS

AI - Adequate intakes

BMI - Body mass index

% BF - Percentage body fat

CHO - Carbohydrates

FFM - Fat-free mass

FFQ - Food frequency questionnaire

GI - Glycaemic index

HGI - High-GI

HPC - High Performance Centre

LBM - Lean body mass

LDL - Low-density lipoprotein cholesterol

LGI - Low-GI

MAMA - Mid-arm muscle area

MAFA - Mid-upper arm fat area

MGI - Moderate-GI

MUAC - Mid-upper arm circumference

ND - Not determinable

RDI - Reference dietary intakes

RDA - Recommended dietary allowances

TE - Total energy

TSF - Triceps skin-fold

UL - Tolerable upper intake levels

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

A swimmer's goal is to perform at his optimum level (Burke, 2002b, p. 341). Physiological adaptations need to take place for optimal swimming performance and these adaptations occur when the energy requirement of swimmers is correlated with an effective training programme (McArdle et al., 1999, p. 213; Trappe et al., 1997). Some swimmers see nutrition as a way of compensating for a lack of talent, training and motivation, even though it is clear that nutrition alone is not the road to successful performance in a sport. However, at the elite end of the spectrum, where all the competitors have the genetic potential to succeed and where all have undergone the most rigorous preparation, attention to diet can make the difference between success and failure (Maughan, 2002a).

Optimal nutrition provides the fuel for biological work, provides the chemicals for extracting and using the potential energy contained within this fuel and also provides the essential elements for the synthesis of new tissue and the repair of existing cells (McArdle et al., 1996, p. 3; Coetsee, 1995, p. 59). However, inadequate energy consumption can result in loss of muscle mass, menstrual dysfunction, failure to gain bone density, and increased risk of fatigue, injury, and illness (Manore et al., 2000). Therefore body composition assessment and nutritional interventions are important factors for successful training and competition in swimmers (Tsalis et al., 2004).

Burke (2002b, p. 341) states that sports nutrition is based on the principle of implementing nutritional strategies that can reduce or delay the onset of factors that can cause fatigue or performance impairment. Every competitive swimmer needs adequate fuel, fluids and nutrients to perform at his best and there is no doubt that a swimmer's dietary intake can affect health, body weight, body composition, energy availability during exercise, recovery time after exercise and ultimately exercise performance (Manore et al., 2000).

The following factors can influence a swimmer’s nutritional needs: Training intensity, increased energy requirements of the sport itself, age of the swimmer including hormonal changes and use of nutritional ergogenic aids.

Rigorous training of swimmers normally entails six to twelve sessions per week with distances covered in each session ranging for sprinters in a taper phase from one to two kilometers of quality work and up to ten kilometers for distance swimmers in the basal phase of training (Burke, 1998, p. 167). Up to six hours of training per day is usually split up into two to three sessions and the most intense training can total up to 100 km of swimming each week (Burke, 1998, p. 167; Trappe et al., 1997). Training sessions are usually held in the early morning (e.g. 5 to 7 a.m.) and in the late afternoon (e.g. 4 to 6 p.m.) encompassing school or work commitments. Swimming training varies according to the phase of the season and includes an initial aerobic endurance phase, followed by various anaerobic training sessions where single or multi-effort intervals are swum at different percentages of maximal work outputs. In addition to these sessions, swimmers also do weight training, normally three sessions per week. Some swimmers also do aerobic land training, for example running and cycling (cross training) to help reduce body fat levels. In order to “peak” for a competition, the training load is reduced and tapered. Because this involves a period of relative inactivity and rest before the competition day, swimmers who compete in a numerous competitions over the year may not fully prepare for all of them, and may focus on peaking for only the most important competitions (Burke, 1998, p. 167-8).

It is therefore clear that a swimmer has increased energy requirements. The long duration of training sessions can deplete glycogen stores within exercising muscles, and this may have an effect on a swimmer’s response to a training programme (Burke, 1998, p. 168; Trappe et al., 1997). Swimmers who fail to replenish their glycogen stores on a daily basis may be unable to complete such high-intensity training (Tsalis et al., 2004; Burke, 1998, p. 168; McArdle et al., 1999, p. 213).

Competitive swimming places considerable demands on the respiratory, cardiovascular, and energy producing systems of the body, and therefore these systems can also draw heavily on the body's glycogen stores for energy support (Tsalis et al., 2004). The long hours of training can restrict a swimmer's lifestyle by limiting the social and recreational activities typical of teenagers. This can either reduce opportunities of adequate intake in a busy daily schedule, or conversely, enhance the importance of eating for comfort or entertainment value. Thus, both underweight and overweight problems are fairly common in swimmers, depending on the circumstances of the individual athlete (Burke, 1998, p. 170).

The age of competitive swimmers ranges between 11.6 and 21.6 years. When elite swimmers reach the age of 12 to 13 years, many have already committed themselves to serious training (Burke, 1998, p. 167). The career of elite swimmers usually ends early, at around 20 years for women and 25 years for men. Many top swimmers are therefore in their teens (Tsalis et al., 2004; Burke, 1998, p. 167, 170), and the physical changes experienced with puberty may help to explain an interesting observation that despite equally strenuous training, female swimmers struggle to lose body fat, while male swimmers have difficulty in meeting their daily energy requirements. This is because females undergo hormonal changes which promote an increase in body fat. Not only can these hormonal disturbances become frustrating for female swimmers, but the constant focus on diet and weight loss can also lead to disordered thoughts about food. Adolescence in males is in a period of fast growth and muscular development, requiring high-energy support and the addition of an intense training programme means that total energy needs can reach an almost unbelievable level (Burke, 1998, p. 170-1).

Many swimmers use nutritional ergogenic aids. This is understandable as ergogenic aids are marketed to increase speed, prolong endurance, accelerate recovery, increase muscle mass and strength, reduce body fat and increase resistance to fatigue, illness or infection

(Burke et al., 2002, p. 455; Steen & Coleman, 1999). Swimmers are also bombarded with advertisements and testimonies from other athletes and coaches about their effect on performance (Berning, 2004, p. 635; Burke et al., 2002, p. 455; Steen & Coleman, 1999). Unfortunately, most athletes believe that advertisements and anecdotes are proof of efficacy and safety, and are unaware of both the inherent risks of using untested products, as well as future health problems that may be caused by these products (Schwenk & Costley, 2002; Steen & Coleman, 1999).

1.2 PROBLEM STATEMENT

The development of sports institutions and High Performance Centres have increased worldwide, as is the case in South Africa. A High Performance Centre (HPC) is a type of "athlete village" or hotel where an elite athlete is sent to develop to his full potential. The athlete is placed in a new environment which focuses on a particular sport. He is normally away from home for long periods of the day or may even board at the centre. His new family consists of coaches and fellow athletes. For obvious reasons, his coaches and peers would have considerable influence on his new life style, which would also include his eating pattern. Most factors influencing performance are regulated at the HPC. However, in the end nutrition is the swimmer's own responsibility and it is therefore important for a swimmer to be aware of issues related to sports nutrition (Manore et al., 2000).

Hotels and 'athlete villages' can provide unsuitable food choices and the lack of supervision may further encourage poor eating patterns. A communal dining hall can be problematic for young swimmers, especially when being away from home is a new experience. For many, the change from a family meal to a communal meal provides a huge challenge and bad decisions may be taken regarding food intake. This may result in a swimmer not meeting his nutritional needs and may have both short term and long-term consequences (Burke, 1998, p. 173).

Added to the problem of the responsibility of the swimmer to make the right food choices is the fact that young athletes are particularly vulnerable to nutritional misinformation and unsafe practices that promise enhanced performances. Pressure to achieve optimal performance encourages an athlete to experiment with supplements and ergogenic aids in order to achieve a competitive edge. Inappropriate use of supplements, unsafe weight loss practices and inadequate nutrient intake can adversely affect the adolescent's health and limit growth (Lucas, 2000, p. 267). Some athletes use megadoses of supplements to increase lean body mass (LBM) and such attempts only cause modest increases in muscle tissue, with larger deposits of storage fat. Consequently, this could have the opposite effect and may cause lethargy and tiredness (McArdle et al., 1999, p. 213; Colwin, 1992, pp. 443-4).

One of the facilities at the HPC in Pretoria is called the Rugby House Hotel where all athletes including swimmers are housed. Athletes are provided with the option of a buffet breakfast, lunch and dinner, or dining à la carte, or may choose to enjoy a coffee bar meal at the Time Out Café. The athletes therefore have to make their own food choices. The present study will take a closer look at the group of swimmers practising at the HPC in Pretoria. Body composition, dietary intake, and the use of supplements of this group who made their own food choices have not been studied before.

The findings of this study may identify problems faced by swimmers with regard to their body composition, dietary status or use of supplements and specific nutritional guidelines can be implemented which may contribute to an improved swimming performance.

1.3 PURPOSE AND AIM OF THE STUDY

The purpose of this study is to determine:

a) the body composition (including the body mass index (BMI), percentage body fat, lean body mass (LBM), mid-arm muscle area (MAMA) and mid-upper arm fat area (MAFA) of swimmers,

b) the energy, macronutrient and micronutrient content of the usual diet of swimmers (including the training, pre-competition, competition and recovery diet); and

c) the use of supplements by swimmers.

1.4 STRUCTURE OF SCRIPT

In Chapter 2 existing literature and previous research studies on swimmers are reviewed. Chapter 3 deals with the methods used in this study. In Chapter 4 the results are given. In Chapter 5 the results are discussed and conclusions as well as recommendations are made. The study finishes with summaries in both English and Afrikaans.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

Body composition and nutritional status of swimmers are important factors for successful training and this may lead to optimal performance (Tsalis et al., 2004).

The accurate assessment of body composition serves as an important component in a comprehensive programme of total nutrition and physical fitness. Excess body fat often hinders exercise training and sport competition, particularly activities that demand a high relative physiological capacity, that is, capacity expressed in relation to one’s body mass. The excess body fat may further increase the body drag. Body drag is the amount of resistance that the body encounters while moving through the water, and is influenced by body size, the speed of swimming, and other mechanical factors (Payne et al., 2000, p. 374). Swimmers devote considerable time and energy to alter their body composition, hoping to achieve “ideal” level of muscularity and / or aesthetic look to optimize competitive performance (McArdle et al., 1999, p. 378).

Three distinct aspects of the athlete’s diet must be considered during periodization for swimmer: the diet in training, the diet before and during competition, and the diet in the recovery phase (Maughan, 2002a).

The basic training diet must be consumed on a daily basis for a large part of the year. The traditional concern among athletes has been with dietary preparations for competition, but there is a growing awareness that nutrition can affect the processes by which the body adapts to the training stimulus (Maughan, 2002a). The pre-competition and competition diet include the strategies undertaken in the hours and days prior to competition, to prepare the athletes to perform at their best (Burke, 2002b, p.341).

The recovery diet plays a major role in the active rest phase, one to two days of complete rest, followed by cross training (Burke, 2002a, p. 396-7). Daily and twice daily training sessions call for recovery strategies, especially when two hard sessions are held back to back (Burke, 1998, p.199).

It is important for athletes to appreciate that sport supplements per se do not produce a performance enhancement. Rather, it is the use of a supplement to achieve sports nutrition goals or guidelines that allows the athletes to perform optimally. Nutrition education of athletes is needed to ensure that dietary supplements are used appropriately (Burke et al., 2002, p. 461).

Factors that can influence the performance of swimmers including body composition, dietary intake and supplement use will be discussed using Figure 1 (Hammond, 2004, p. 425; Tsalis et al., 2004; Maughan, 2002a; Burke, 2002a, p. 396-7; Burke, 2002b, p. 341; McArdle et al., 1999, p. 388).

2.2 BODY COMPOSITION

The accurate assessment of body composition serves as an important component in a comprehensive programme of total nutrition and physical fitness (McArdle et al., 1999, p. 378), for the primary reason, to obtain information that may be beneficial to improving athletic performance (Manore et al., 2000; McArdle et al., 1999, p. 378).

There are different methods to evaluate the body composition, and especially body fat level determination are important because increased fat mass can lead to increased body drag that can be detrimental to a swimming performance. Body composition can be interpreted and can be compared to normative data of elite swimmers or monitored over time, especially body fat percentage and the sum of the skin-folds. It is also important to recognize the variability of physique between swimmers (Kerr & Ackland, 2000, p. 77).

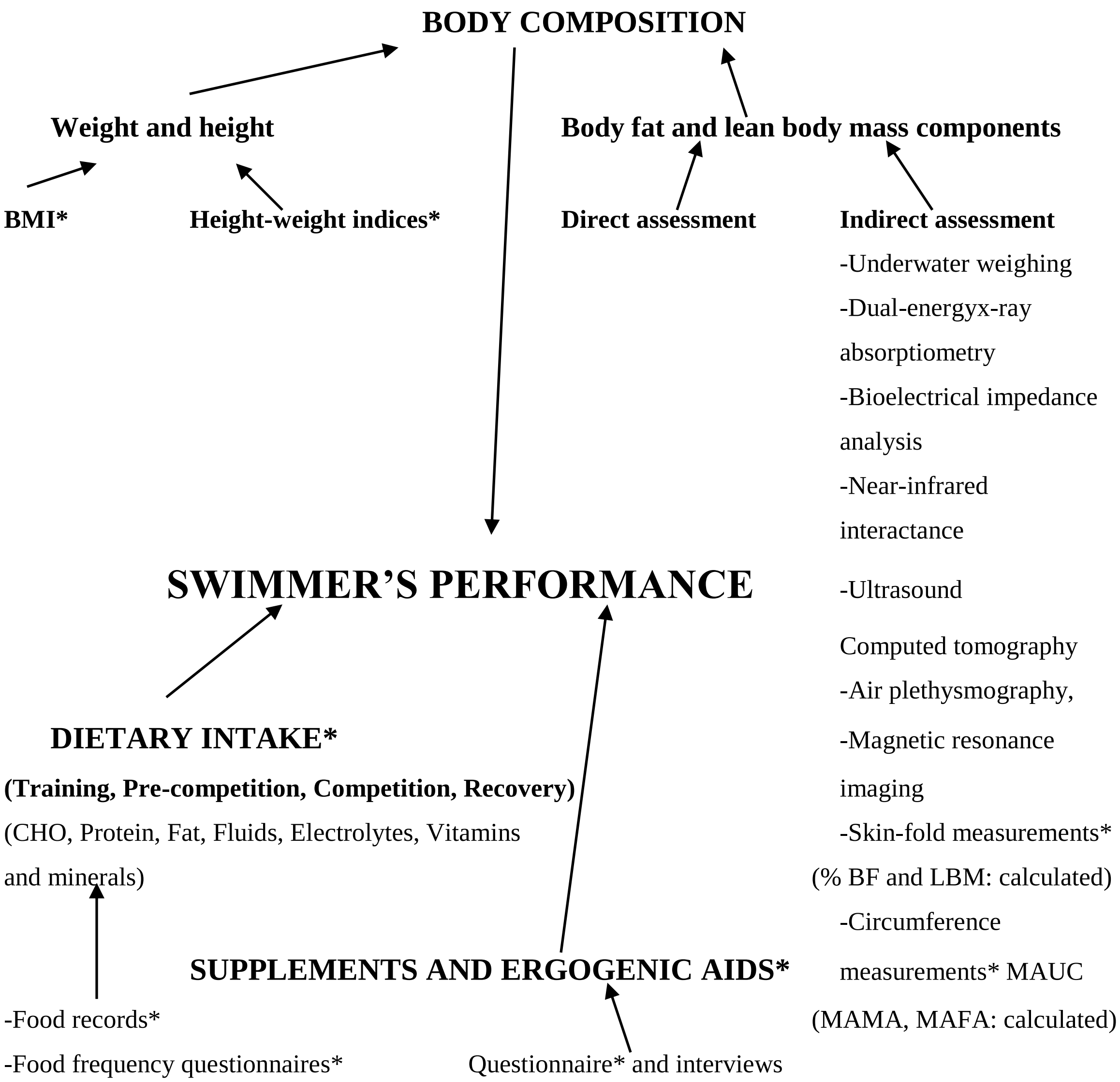

Figure 1: Factors that can have an influence on a swimmer's performance at any stage of periodization

*Variables and methods chosen for this study

2.2.1 Assessment of body composition

Measurement of height, body mass, and sum of skin-folds in highly trained swimmers should be a routine. In younger swimmers, measurements of height and body mass are useful to monitor growth and development. In older swimmers, measurement of body mass and estimation of body fat using the sum of skin-folds technique provide useful feedback on body composition and the cumulative effects of training and diet (Payne et al., 2000, p. 374).

The methods to evaluate body composition will be discussed in terms of body weight and height indices, and body composition. The influence of body composition on body drag will also be discussed.

2.2.1.1 Body weight and height indices

One of the most important measurements in nutritional assessment is body weight and height. Weight is an important variable in equations predicting energy expenditure and in indices of body composition. Approaches to assessing body weight include height-weight tables, relative weight, and height-weight indices (Lee & Nieman, 1996, p. 227, 277).

i) Measurement

Body weight should be obtained using an electronic of balance beam scale with non-detachable weights that is appropriate for the subject. Attention must be given to regular calibration of balance beam scales, especially after they have been moved (Lee & Nieman, 1996, p. 227, 277). Height (stature) can be measured in several ways. The simplest is to fasten a measuring stick or non-stretchable tape measure to a flat, vertical surface and use a right-angle headboard for reading the measurement. Another approach is to use a stadiometer (Lee & Nieman, 1996, p. 225).

ii) Interpretation

After body weight is measured, an ideal body weight needs to be identified for a goal weight for an athlete. The ideal body weight is an acceptable weight and should coincide with optimizing sport specific measures of physiologic functional capacity and exercise performance (McArdle et al., 1999, p. 405). Determining the ideal goal weight is a difficult task especially because inherited genetic factors greatly influence body fat distribution, and certainly impact long-term programming of body size (McArdle et al., 1999, p. 405).

There are three different ways to determine ideal body weight namely through the calculation of BMI, relative weight and height-weight indices, as well as formulas based on desired percentage body fat (Berning, 2004, p. 634; McArdle et al., 1999, p. 405; Colwin, 1992).

a) BMI and height-weight indices

BMI is a mathematical formula that is expressed as weight in kilograms divided by height in meters squared (Lee & Nieman, 1996, p. 669) and is a validated measure of nutritional status that can indicate over nutrition and under nutrition. BMI accounts for differences in body composition according to the relationship of weight to height, thus eliminating dependence of frame size (Hammond, 2004, p. 424).

New standards for BMI published in 1998 classify a BMI less than 18.5 kg/m² as underweight, a BMI between 25 kg/m² and 29 kg/m² as overweight, and a BMI greater than 30 as obese. A healthy BMI for adults is considered between 18.5 kg/m² and 24.9 kg/m² (Hammond, 2004, p. 424). The ideal body weight can be defined in relation to height (e.g. an ideal BMI of 22.5 kg/m² can be used with a height of 1.7 m to calculate an ideal body weight of 65 kg) (Lee & Nieman, 1996, p. 232).

The relationship between weight and height for adolescents can be evaluated by using the Centers of Disease Control (CDC) NCHS BMI tables. Adolescents with BMIs below the 5th percentile should be assessed for organic diseases or eating disorders. Adolescents with BMIs between the 85th and 95th percentiles are at risk for overweight. Adolescents with BMIs at the 95th percentile are overweight (Spear, 2004, 286).

However, BMI and height-weight indices offers limited value when evaluating physique for swimmers because overweight and over fat often relate to different aspects of body composition when describing physically active men and women (McArdle et al., 1999, p. 378; Colwin, 1992). A comparison of height and body mass parameters with 'ideal' or reference standards is therefore inappropriate for many athletes (Deakin, 2002, p. 54), because BMI fails to consider the body's proportional composition, especially on body fat mass and LBM. Specifically factors other than excess body fat (bone and muscle mass, and even the increased quantity of plasma volume induced by exercise training) affect the numerator of the BMI equation. A high BMI could lead to incorrect interpretation of over fatness in lean individuals with excessive muscle mass because of genetic makeup or exercise training (McArdle et al., 1999, p. 382-383). Added to this, refers the term overweight to a body mass for a given stature and athletes often weigh more than the average weight-for-height standards. Being above some "average", "ideal", or "desirable" body mass based on weight-for-height tables should not dictate whether someone should reduce weight (McArdle et al., 1999, p. 378; Colwin, 1992). However, the BMI and height-weight charts are useful for showing very lean athletes that they are not overweight, but provide no true or reliable indication of body composition (Deakin, 2000, p. 54).

Therefore a swimmer's ideal competitive weight should not be determined from an average appearing in standard height and weight charts or BMI, but from assessment of body composition (Berning, 2004, p. 634; McArdle et al., 1999, p. 405; Colwin, 1992).

b) Formula based on desired percentage body fat

The following formula of McArdle et al. (1999, p. 404) recommends that the ideal body weight can be computed using a desired (and prudent) percentage of body fat, therefore using a body composition component to determine the ideal body weight:

$$\boxed{\text{Ideal body weight} = \text{Fat-free body mass} / (1{,}00 - \text{Percent fat desired})}$$

2.2.1.2 Body composition

Two general approaches determine the body fat and LBM components of the human body namely, direct measurement by chemical analysis and indirect estimation by hydrostatic weighing, simple anthropometrical measurements, including skin-fold measurements (Payne et al., 2000, p. 374; McArdle et al., 1999, p. 387; Burke, 1998, p. 65), and girth measurements, including MUAC (Hammond, 2004, p. 425), or other procedures. The indirect procedures that are most commonly used for the assessment of body composition involve skin-fold measurements and circumference (girth) measurements (Hammond, 2004, p. 425; McArdle et al., 1999, p. 388).

i) Skin-fold measurements

Skin-fold measurements are simple anthropometrical procedures that validly predict body fatness and are frequently used to assess body composition (McArdle et al., 1999, p. 394-397; Plowman & Smith, 1997, p. 371). The rationale for using skin-folds to estimate total body fat comes from the relationship among three factors namely fat in the adipose tissue deposits directly beneath the skin (subcutaneous fat), internal fat, and body density (McArdle et al., 1999, p. 392).

a) Measurement techniques

Skin-fold thickness measurements are obtained with calipers at several anatomical locations. Primary sites of measurement are the triceps, abdomen, subscapular area, thigh, and suprailiac area. Secondary sites include the chest, midaxillary, and the medial calf. (Wildman & Miller, 2004, p. 204).

Three general assumptions associated with skin-fold measurements are that a direct relationship exists between the quantity of fat deposited just below the skin and total body fat; the thickness of the skin and subcutaneous adipose tissue has a constant compressibility throughout the body, and the thickness of the skin is negligible and a constant fraction of skin-fold measurements. The use of skin-fold calipers requires training to maximize precision (Wildman & Miller, 2004, p. 204).

b) Interpretation of skin-fold measurements to estimate percentage body fat

There are basically two ways to use skin-folds. The first is the sum of the skin-fold scores and the second is the mathematical equations designed to predict body density or percentage body fat.

1) Sum of skin-fold scores

The first is the sum of the skin-fold scores as an indication of relative fatness among individuals. The sum of the skin-fold measurements is a practical, inexpensive and reliable method to determine body fat or to monitor changes in body composition of athletes over time or ‘before’ and ‘after’ an intervention programme (Deakin, 2002b, p. 54).

Therefore this body profile technique provides a practical method to subdivide anthropometrical dimensions into muscular and non-muscular components and to monitor dimensional changes from training, diet, growth and ageing (McArdle et al., 1999, p. 406). Changes can then be evaluated on either an absolute or percentage value (McArdle et al., 1999, p. 394).

2) Mathematical equations – predict percentage body fat from body density

A second way to use skin-folds incorporates mathematical equations designed to predict body density or percentage body fat (McArdle et al., 1999, p. 394). Body density is calculated by a formula using variables such as skin-fold measurements and age (McArdle et al, 1999, p. 394,7), indicated in Figure 2.

Body density (women):

$1.09700000 - (0.00046971x\ X_1) + (0.00000056\ x\ X_1^2) - 0.00012828\ (X_2)$

Body density (men):

$1,11200000 - (0,00043499\ x\ X_1) + (0,00000055\ x\ X_1^2) - 0,00028826\ (X_2)$

X_1 = sum of triceps, biceps, subscapular, suprailiac, midaxillary and abdominal

X_2 = age

Figure 2: Equation for body density (McArdle et al, 1999, p. 394,7)

Percentage body fat can be predicted through different formulas. The Brozek formula (Figure 3) predicts percentage body fat by using body density.

The Brozek equation to determine percentage body fat:

Percentage body fat = (457 / body density) – 414

Figure 3: The Brozek equation (McArdle et al, 1999, p. 394,7)

Percent body fat can also be calculated using population specific equations. These equations can accurately predict body fatness for subjects that are similar in age, sex, state of training, fatness, and race to the group on which the equations were derived.
For example McArdle et al. (1999, p. 394) developed an equation to predict body fat from triceps and subscapular skin-folds in young women and men (Figure 4).

BF% (women): 0.55 (Triceps) + 0.31 (Subscapular) + 6.13

BF% (men): 0.43 (Triceps) + 0.58 (Subscapular) + 1.47

Figure 4: Equation to predict body fat from triceps and subscapular skin-folds in young women and men (McArdle, 1999, p. 394)

Fat weight is then determined by a calculation of percentage body fat times body weight (McArdle et al, 1999, p. 394,7) to determine LBM. The term LBM or fat-free mass (FFM) refers to specific entities. Lean body mass (a theoretical entity) contains the small percentage of essential fat stores equivalent to approximately 3 % of body mass. In contrast the fat-free mass devoid of all extractable fat. Thus, LBM calculations include the small quantities of essential fat, whereas FFM computations exclude “total” body fat (FFM = Body mass – Fat mass) (McArdle et al., 1999, p. 383-4, 397).

c) Interpretation of the predicted percentage body fat and LBM

The percentage body fat can then be used and compared to previous standards or findings. The recommended percentage body fat for swimmers is 7 % for males, and 16 % for females (McArdle et al., 1999, p. 412). Lee & Nieman (1993, p. 146) recommended that the ideal percentage fat ranges for males are between 5 to 11 % and females are between 14 and 24 %. The estimate minimum level of percent body fat compatible with males is 5 % and females are 12 % (Manore et al., 2000). Storage fat averages 12 % of body mass for men and 15 % body mass for women (McArdle et al., 1999, p. 405).

A difference between distance swimmers and sprint swimmers body fat levels are that distance swimmers generally carry more fat than sprint swimmers (Payne et al., 2000, p. 374). And these higher body fat levels of ultra-endurance long-distance swimmers confer some advantage in buoyancy and thermoregulation (Payne et al., 2000, p. 374; Burke, 1998, p. 169). Therefore distance swimmers should aim for higher percentage body fat levels.

Although there is limited data on the ideal LBM for swimmers, Siders et al. (1993) determined the average for LBM of female sprint swimmers between 40,1 and 55,3 kg, and males between 60.5 and 70.1 kg. The difference of LBM between men and women in the adolescent years is that men gain twice as much lean tissue as women during puberty (Spear, 2004, p. 285).

ii) Circumference measurements

If more complete information on actual body composition is needed, additional anthropometrical data can be obtained. These data include additional circumference measurements. Because of the recognition that fat distribution is an indication of risk, circumferential or girth measurements are used more frequently today (Hammond, 2004, p. 425). Mid upper arm circumference (MUAC), in combination with skin-fold measurements, is needed to calculate body fat and LBM, and will therefore be the only girth measurement to be discussed.

a) Measurement techniques

MUAC is measured halfway between the acromion process of the scapula and the tip of the elbow (Hammond, 2004, p. 426-7).

b) Interpretation of MUAC

The guidelines for interpreting the age-, sex-, and race- specific percentile values for the MUAC are indicated in Table 1.

Table 1: Interpreting the age-, sex-, and race- specific percentile value for MAUC (Lee & Nieman, 1996, p. 306)

PERCENTILE	**CATEGORY**
≤ 5th percentile	Lean
> 5th percentile but ≤ 15th percentile	Below average
> 15th percentile but ≤ 85th percentile	Average
> 85th percentile but ≤ 95th percentile	Above average
> 95th percentile	High muscle

iii) Skin-fold and circumference in calculation of LBM (MAMA) and body fat (MAFA)

Combining mid upper arm circumference (MUAC) with the triceps skin-fold measurements in a calculation allows indirect determination of the mid arm muscle area (MAMA) and mid arm fat are (MAFA) (Hammond, 2004, p. 426-7). An assessment of muscle arm area can confirm a person's muscular composition (Spear, 2004, p. 286).

a) Calculation of MAMA and MAFA

Figure 5 indicates the calculations of MAMA and MAFA using MUAC and the triceps skin-fold measurement (Hammond, 2004, p. 426-7).

$$\text{AA } (\text{mm}^2) = \text{Л}/4 \text{ x } \frac{\text{MUAC}}{\text{Л}}$$

$$\text{MAMA } (\text{mm}^2) = \frac{(\text{MUAC} - \text{Л (triceps)}^2}{4\,\text{Л}}$$

$$\text{MAFA} = \text{AA} - \text{MAMA}$$

$$\text{Bone-free MAMA} = \text{MAMA} - 10 \text{ for males}$$

$$\text{Bone-free MAMA} = \text{MAMA} - 6.5 \text{ for females}$$

Figure 5: Bone-free MAMA equation (Hammond, 2004, p. 427)

b) Interpretation of MAMA and MAFA

The MAMA, or bone-free muscle area, is a good indication of LBM and thus an individual's skeletal protein reserves. The MAMA is important in growing children (Hammond, 2004, p. 427).

Table 2 can be used as a guideline for interpreting the age-, sex-, and race- specific percentile values for lean body mass status (MAMA) and Table 2 can be used as a guideline for interpreting the age-, sex-, and race- specific percentile values for fat mass status (MAFA). These percentile values of Table 3 can also be used to interpret the percentage body fat.

Table 2: Interpreting the age-, sex-, and race- specific percentile value for LBM status (MAMA) (Lee & Nieman, 1996, p. 306)

PERCENTILE	**CATEGORY**
≤ 5th percentile	Lean
> 5th percentile but ≤ 15th percentile	Below average
> 15th percentile but ≤ 85th percentile	Average
> 85th percentile but ≤ 95th percentile	Above average
> 95th percentile	High muscle

Table 3: Interpreting the age-, sex-, and race- specific percentile value for the fat status (MAFA) (Lee & Nieman, 1996, p. 302)

PERCENTILE	**CATEGORY**
≤ 5th percentile	Lean
> 5th percentile but ≤ 15th percentile	Below average
> 15th percentile but ≤ 75th percentile	Average
> 75th percentile but ≤ 85th percentile	Above average
> 85th percentile	Excess fat

Because of marked sex differences in all these parameters, a convenient basis of comparing men and women employs the concept of reference standards (McArdle et al., 1999, p. 383). Percentage body fat can be grouped in broad sport categories, and this method provides a better overview of the distribution of percentage body fat in specific sport groups (McArdle et al., 1999, p. 412).

2.2.1.3 Influence of body composition on body drag

The influence of body composition on body drag is an important factor to consider when body composition of swimmers is evaluated. Body drag is the amount of resistance that the body encounters while moving through the water, and is influenced by body size, the speed of swimming, and other mechanical factors (Payne et al., 2000, p. 374).

Above a certain individual level, an increase in percentage body fat will be detrimental to performance because of increased body drag. Although increased body fat is likely to enhance buoyancy, the increase in body drag will offset any advantage resulting from improved buoyancy (Payne et al., 2000, p. 374). The other key factors that influence this relationship are body maturation, gender and event distance (Payne et al., 2000, p. 374).

2.3 DIETARY INTAKE

Dietary intake will be described using dietary assessment and recommended dietary intake for swimmers.

2.3.1 Dietary assessment

Dietary assessment involves collecting information on dietary intake and to evaluate and interpret these nutrient intakes using the reference guidelines or standards available. The limitations of the methods of dietary evaluation and their reliabilities are not always fully appreciated or described in both clinical practice and in journals. Collection of reliable and accurate dietary intakes of individuals and groups is difficult because of the influence of confounding effects and errors inherent in all dietary survey methods (Deakin, 2002b, p. 31-2).

For research purposes, accurate and reliable measures of food consumption are important for estimating or measuring intakes of nutrients and other food components for individuals or groups of athletes. For the assessment of group intake, qualitative measures of food consumption are used when ranking of food; meals or nutrient intake is the objective. Most of the dietary intakes of elite athletes are data collection methods that derive quantitative estimates of nutrient intake rather than qualitative intakes. The main methods used are food records using household measurements, which are conducted on small numbers of athletes (Deakin, 2002b, p. 33-4).

The techniques for measuring food consumption are categorized into two major types: current dietary intakes (food records) and past dietary intakes (retrospective short and long term recall of foods consumed). Methods for measuring current diet include weighed diet records (sometimes including computerized scales), estimated diet records, and duplicate diets. These methods record food intake at the time of consumption. Retrospective methods include the 24-hour recall, diet history and food frequency questionnaire (FFQ) (Deakin, 2002b, 34).

Although there is no true measure of current dietary intake in free-living people, the diet record is considered the most ‘accurate’ and feasible method for research. The weighed diet record is considered the ‘gold’ standard for measuring dietary intake. In a recent study by Deakin (2002b, p. 37-8), three to four day diet records using household measures were predominantly the method of choice. However, food records are not representative of measuring usual diet unless repeated several times, two to three months apart. The number of days of food records required for 80 % reliable classification of individual intake varies from two to three days for some nutrients like sugar or total carbohydrates (CHO) to two to three weeks for other nutrients, such as dietary cholesterol and fat. The number of days of data collection affects accuracy of responses. Periods longer than three-to four days of food records have shown reduced accuracy and are considered impractical and associated with memory interference, incomplete records and high drop-out rate. A short-term food record, although not considered representative of usual eating habits, does provide a reasonable estimate of the general quality of the diet. Diet records, however, are time consuming for both researcher and respondent, and require a literate and co-operative respondent (Deakin, 2002b, p. 37-8).

FFQs were previously designed as a qualitative method, seeking information on the frequency of consumption of specific food items without specification of the actual serve or portion sizes usually consumed. More recent versions of this approach use portion sizes. Therefore FFQs have been designed and should be validated in research for specific group to assess food and nutrients consumed in the past seven days or even the preceding month. FFQs have shown acceptable validity for assessing group rather than individual intakes of food or nutrients (Deakin, 2002b, p. 39-40).

2.3.2 Recommended dietary intake for swimmers

The training diet, the diet before and during competition, and the recovery diet are three distinct aspects of the athlete’s diet that must be considered during the periodization phases of an athlete (Trappe et al., 1997).

2.3.2.1 Training diet

The basic training diet must be consumed on a daily basis for a large part of the year (Maughan, 2002a). The nutritional needs of the athlete depend on the type of sport, body composition, intensity, duration and frequency of daily physical activity (McArdle et al., 1999, p. 213). The most important aspect of the athlete’s diet is that it allows consistent hard training to be performed, because it is from such training that improvements in performance results (Maughan, 2002a).

Nutritional goals associated with training should include: maintaining energy supply to the working muscles and other tissues, promoting tissue adaptation, growth and repair, promoting immune function and resistance to illness and infection, and rehearsal and refinement of competition strategies (Maughan, 2002b).

The energy, macronutrients (CHO, fats, proteins), micronutrients (vitamins and minerals) and fluid requirements must be taken into consideration for the implementation of strategies to meet the nutritional goals.

i) Energy

Meeting energy needs is the first nutrition priority for athletes (Manore et al., 2000). To stay in energy balance, it is necessary that sufficient amounts of energy in the optimal composition of macronutrients and micronutrients be consumed to balance the energy expenditure. If this is not the case, the athlete may not experience the optimal physiological adaptations to training (Trappe et al., 1997).

Hawley & Burke (1998, p. 256) refer to a study where the female and male daily energy intakes were 10 458 and 14 196 kJ, respectively. The estimated energy requirement for very active adolescents is between 13 700 to16 000 kJ for males, and 11 800 to12 000 kJ for females according to Spear (2004, p. 289). The dietary reference intake (DRIs) for males and females 14 to 18 years are 13 200 kJ for males and 9 945 kJ for females (Spear, 2004, p. 1).

ii) Macronutrients

The macronutrients include CHO, fats and protein.

a) Carbohydrates

CHO are important to maintain blood-glucose levels during exercise and to replace muscle glycogen (Manore et al., 2000). The CHO requirement is determined primarily by training duration and intensity, type of sport performed, gender, body size, fitness, nutritional status and environmental conditions (Maughan, 2002a; Manore et al., 2000; McArdle et al., 1996, p. 12).

The training diet should be high in CHO, with at least 50 to 60 % or more of total energy intake coming from CHO, but ideally 60 to 70 % of the total energy requirements from CHO (Berning, 2004, p. 625; McArdle et al., 1996, p. 62; Costill & Hargreaves, 1992).

A dietary CHO of 400 – 600 g may be necessary to ensure adequate glycogen resynthesis during periods of intensive training, and for some athletes, the amount of CHO that must be consumed on a daily basis is even greater (Maughan, 2002b; McArdle et al., 1999, p.

213; McArdle et al., 1996, p. 62). Burke (1999) suggested an intake of 300 to 700g of CHO per day.

The normal recommendation of CHO is 4.5 g/kg/day (Plowman & Smith, 1997, p. 330). For an individual utilizing high amounts of CHO in training, recommendations ranges from 6 to 10 g/kg body weight per day (Berning, 2004, p. 626; Manore et al., 2000; Plowman & Smith, 1997, p.330). Burke (1999) suggested 6 to 8 g/kg of body weight for active women, and 8 to 10g/kg body weight for active men, and in periods of strength training (Maughan, 2002b; Burke, 1999; Costill & Hargreaves, 1992). Swimmers need to comsume more than 60 % energy as CHO or 8 to 10 g/kg of body weight daily (Wildman & Miller, 2004, p.454).

Figure 6 illustrates that prolonged exercise sessions gradually lead to low glycogen levels when the typical Westernized diet (moderate CHO) is eaten. Switching to a high carbohydrate diet helps to promote daily recovery of muscle glycogen stores (Burke, 1998, p. 119).

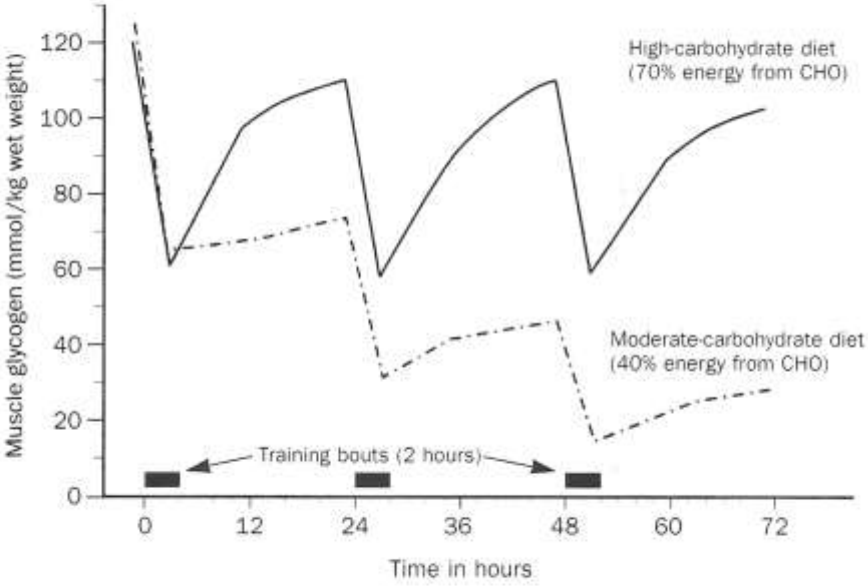

Figure 6: Daily recovery from prolonged exercise (Burke, 1998, p. 119)

Some forms of sugars appear to have different effects on glycogen resynthesis during training. Glucose and sucrose promote muscle glycogen resynthesis, whereas fructose promotes liver glycogen resynthesis. Fructose alone is not recommended, because it must first be broken down to glucose in the liver (Plowman & Smith, 1997, p. 331) and because it may lead to gastro-intestinal distress, but mixtures of glucose and fructose seem to be effective (Table 4) (Manore et al., 2000).

Table 4: Comparison of various beverages used by athletes to replace the fluid loss in exercise (McArdle et al., 1999, p. 223; Plowman & Smith, 1997, p. 330)

BEVERAGES	**CHO SOURCE**	**CHO % CONCENTRATION**	**SODIUM (mg) in 100ml**
Coca-cola	High fructose corn syrup, sucrose	10,7 to 11,3	9,2
Sprite	High fructose corn syrup, sucrose	10,2	28
Cranberry juice cocktail	High fructose corn syrup, sucrose	15	10
Orange juice	Sucrose, glucose, fructose	11,8	2,7
Water	-	-	Low
Powerade	High fructose corn syrup, malto-dextrin	8	73
Energade	Sucrose, dextrose	7	37

The optimal type of CHO for swimmers is still debatable (Wright, 2005; Berning, 2004, p. 626). Earlier research studies took a very simplistic approach to CHO nutrition by dividing foods into simple and complex CHO based on their chemical composition. The ingestion of simple CHO foods was believed to elicit a large, rapid and short-lived rise in blood glucose, while complex CHO foods were thought to give a rise to a flatter and more sustained blood glucose curve. However, this model has recently been challenged with the development of the glycaemic index (GI) (Wright, 2005). Therefore, the question of which type of CHO is better for athletic performance may be better understood if the CHO is classified by its physiologic reaction in the body by its GI rather

than by its structure (Berning, 2004, p. 626). Consequently the GI of CHO foods have been used when selecting foods and CHO-containing fluids to optimize CHO availability during exercise. The GI is also thought to influence the rate of glycogen resynthesis post-exercise, thereby potentially enhancing exercise performance. In general, low-GI (LGI) CHO foods (typically with a GI < 40%) have been recommended before endurance events to promote CHO availability during exercise, CHO with a moderate-GI
(MGI ~63%, 40 – 70%) to high-GI (HGI > 70%) have been recommended during exercise for readily available CHO to maintain blood glucose, and HGI CHO foods have been recommended post-exercise to enhance glycogen storage (Wright, 2005).

b) Fats

Even though maximal performance is impossible without muscle glycogen, fat also provides energy for exercise. Fat is the major, if not most important, fuel for light- to moderate exercise. Although fat is a valuable metabolic fuel for muscle activity during longer aerobic exercise and has many important functions in the body, no attempt should be made to consume more fat than the usual intake unless the athlete is eating less than 15 % of energy from fat. Severe fat restriction (under 15 % of total energy) may limit performance by hindering intramuscular triglycerides storage, which provides a significant proportion of energy at all intensities of exercise (Berning, 2004, p. 630-1).

Therefore the recommendation of between 20 to 30 % fat for sedentary or moderate active individuals remains the best advice, but it may be that a well-trained athletes doing endurance training should not drop below the 30 % fat level in their diets (Berning, 2004, p. 631; Plowman & Smith, 1997; p. 336). The American Dietetic Association recommended a diet containing 20 to 25 % energy from fat (Bean, 2003, p. 107). To promote good health, lipid intake should not exceed 30 % of the energy content of the diet (Brooks et al., 2000, p.690; McArdle et al., 1996, p. 61).

Of this at least 70 % should be in the form of unsaturated fatty acids. The recommendations for the proportions of energy from fatty acids are 7 to 10 % saturated

(SFA), 10 % polyunsaturated (PUFA), and 10 to 18 % monounsaturated (MUFA), regardless of activity level (Krummel, 2004, p. 880; Manore et al., 2000; Plowman & Smith, 1997; p. 336). Bean (2003, p. 107-8) suggested a ratio of not more than 10 % SFA, a maximum intake of 10 % PUFA and up to 12 % MUFA of the total energy intake.

It is, however, unwise to eliminate all lipids from the diet, as it may be detrimental to exercise performance (McArdle et al., 1996, p. 61). Because even though maximal performance is impossible without muscle glycogen, fat also provides energy for exercise. Fat also provides essential fatty acids that are necessary for cell membranes, skin, hormones, and transport of fat-soluble vitamins (Berning, 2004, 630).

c) Proteins

The protein needs for the adult athlete (older than 18 years) are as follows. The consensus of current evidence suggests that strength and speed athletes may need to consume 1.2 to 2 g/kg/day of protein, which should be possible by the recommendation of 12 to 20 % of the total energy intake (Berning, 2004, p. 630; McArdle et al. 1999, p.213). For an endurance athlete, the recommended range is 1.2 to 1.4 g/kg body weight/day. Strength or power athletes have a greater daily requirement for protein than most endurance athletes, between 1.4 to 1.8 g/kg body weight/day (Bean, 2003, p. 39). In the light of the high-energy expenditure associated with swimming, consuming 15 to 20 % of the total energy~~,~~ as protein, should provide enough protein at least to maintain nitrogen balance. A protein intake of 2 g/kg per day should therefore be adequate (Wildman & Miller, 2004, p. 454-5).

Protein needs are enhanced during childhood and adolescents in comparison to adulthood. For instance, the recommended dietary allowances (RDA) for protein is 25 % higher (relative to body weight) for a boy or girl 7 to 18 years old than an adult (Wildman & Miller, 2004, p. 473). In the case of young or small female athletes, protein needs calculated as a percentage of energy intake may be inadequate; a better calculation is based on 1 to 1.5 g/kg of body weight. The liberal allowance for a growing male adolescent is 1.5 g/kg per day or approximately 104g of protein (Berning, 2004, p. 630). Burke (1998) indicated an intake of 2 g/kg of protein for adolescents and growing athletes per day. The use of the United States RDA (Recommended Dietary Allowance) and the Australian RDI (Reference Dietary Intakes) is similar and can be used for most athletes because of the wide safety margins for nutrient recommendations (Deakin, 2000b, p. 52). The DRI (Dietary Reference Intake) is a relatively newly introduced term, which encompasses multiple levels of nutrient intakes including estimated average requirements (EAR), RDA, adequate intakes (AIs) and tolerable upper intake levels (UL) (Dodd & Bayerl, 2004, p. 349-350; Deakin 2000b, p. 52; Earl, 2004, p. 365). RDA serves as a goal for individuals, while adequate intakes (AIs) may also be used for individuals when sufficient scientific evidence is not available to calculate a RDA or an EAR. The RDA has been used extensively for evaluating the micronutrient status of athletes. By convention, nutrient intakes that are below two-thirds of the RDI / RDA are considered inadequate (Stuff et al., 1983 as referred to by Deakin, 2000b, p. 52).

Table 5 indicates the DRIs for protein for adolescents. These recommended protein intakes can generally be met through diet alone, without the use of protein or amino acid supplements, if energy intake is adequate to maintain body weight (Manore et al., 2000).

Table 5: RDI, DRV, RDA and RNI for protein for adolescents in gram (g)

	Age (yrs)	Australia RDI	Age (yrs)	UK DRV	Age (yrs)	US RDA	Age (yrs)	Canada RNI	Age (yrs)	WHO
Males	12-15	42-60	11-14	42.1	11-14	45	13-15	49	12-15	37
	16-18	64-70	15-18	55.2	15-18	59	16-18	58	15-18	38
Females	12-15	44-55	11-14	41.2	11-14	46	13-15	46	12-15	31
	16-18	57	15-18	45.0	15-18	44	16-18	47	15-18	30

RDI = Recommended Dietary Intake

RDA = Recommended Dietary Allowance

DRV = Dietary Reference Value

RNI = Recommended Nutrient Intake

iii) Micronutrients

Micronutrients include vitamins and minerals.

a) Vitamins

Vitamins are organic substances that neither supply energy nor contribute to body mass. Vitamins serve crucial functions in almost all bodily processes. Vitamins regulate metabolism, facilitate energy release, and are important in the process of bone and tissue synthesis (Plowman & Smith, 1997, p. 336; McArdle et al., 1996, p. 43).

A distinct feature of vitamins is that the human body is not able to synthesize most of them. Classifications of vitamins are based on their relative solubility: fat-soluble vitamins (A, D, E and K) are more insoluble solvents in water, and water-soluble vitamins (C and B complex) (Fogelholm, 2002, p. 312).

Athletes who consume an appropriate level of energy for weight maintenance and eat a variety of foods, including whole grains, fruits, vegetables, and animal products, would not have difficulty getting at least the RDA for vitamins. This does not mean that vitamin needs for athletes are the same as those of the general population. It is still unclear whether exercise training increases the requirements for vitamins, but it is likely that the need for certain vitamins involved in energy metabolism is greater for athletes (Wildman & Miller, 2004, p. 253). These increased requirements compensate for losses in sweat, urine and perhaps feces for an increase in free radical formation (Deakin, 2002b, p. 53). Therefore, it is an unresolved issue whether endurance athletes require higher levels of anti-oxidants (Wildman & Miller, 2004, p. 253).

Physical activity increases energy expenditure. High metabolic activity increases the turnover of several vitamins of the B-complex group. Indeed, some old data support the above view. For example, Suaberlich et al. (1979) found that thiamin requirements in male subjects were 30 % higher when daily energy intake was 15 120 kJ, compared to

10 920 kJ. However, an energy-related requirement for thiamin has also been questioned (Fogelholm, 2002, p. 319).

In light of the greater energy consumption of athletes, many sport nutritionists agree that a balanced diet can provide the additional amounts of vitamins that athletes may need, making supplements unnecessary. However, not all athletes consume a balanced diet, and many fall short of meeting the DRI levels (Wildman & Miller, 2004, p. 253). The RDA / AI and UL of these vitamins are summarized in Table 6. Athletes need to understand that more is not always better, and the RDA / AI for vitamins and minerals are sufficient, except when the athlete already has a deficiency (Berning, 2004, p. 632-3).

1) Fat soluble vitamins

i) Vitamin A

Vitamin A is found in fortified dairy products, egg yolks, and fish livers and their oils. Some vitamin A can be formed by the conversion of careteniods from plant foods. Vitamin A interacts with a receptor in the nucleus of cells and influences the differentiation of tissue. Vitamin A is also essential to proper vision. The relationship between exercise and vitamin A is not well researched, and most athletes do not supplement vitamin A in high doses because of toxicity concerns. More research is being conducted on carotenoids because their anti-oxidant properties, but their actual protective potential has not yet been determined (Wildman & Miller, 2004, p. 280).

ii) Vitamin D

The most significant sources of vitamin D are fortified dairy products, margarine, and exposure to sunlight. Vitamin D interacts with a nuclear receptor and increases the production of proteins involved in calcium homeostasis. The relationship between vitamin D and exercise has not yet been investigated thoroughly, but preliminary research suggests that dietary vitamin D intake levels may be below recommendations for some

Table 6: RDA / AI and UL of vitamins for males and females 14 to 18 years and 19 to 20 years of age (Gallagher, 2004, p 114; Folgelholm, 2002, p. 312, 321)

Vitamins	**RDA / AI**	**UL**
Fat- soluble		
Vitamin A (retinal, α-, β-, γ- carotene) (μg)		
14 –18 yrs	700 (f) 900 (m)	2800
19 – 20 yrs	700 (f) 900 (m)	3000
Vitamin E (tocopherol and tocotrienols) (mg)		
14 –18 yrs	15	800
19 – 20 yrs	15	1000
Vitamin D (μg)		
14 –18 yrs	5	50
19 – 20 yrs	5	50
Vitamin K (phylloquinone and menaquinone) (μg)	75	ND
Water- soluble		
Vitamin C (ascorbic acid) (mg)		
14 –18 yrs	65 (f) 75 (m)	1800
19 – 20 yrs	75 (f) 90 (m)	2000
Thiamin (B_1) (thiamin) (mg)		
14 –18 yrs	1 (f) 1.2 (m)	ND
19 – 20 yrs	1 (f) 1.2 (m)	ND
Riboflavin (B_2) (riboflavin) (mg)		
14 –18 yrs	1 (f) 1.3 (m)	ND
19 – 20 yrs	1.1 (f) 1.3 (m)	ND
Niacin (niacin) (mg)		
14 –18 yrs	14 (f) 16 (m)	30
19 – 20 yrs	14 (f) 16 (m)	35
Biotin (μg)		
14 –18 yrs	25	ND
19 – 20 yrs	30	ND
Pantothenic acid (mg)		
14 –18 yrs	5	ND
19 – 20 yrs	5	ND
Vitamin B_6 (pyridoxine) (mg)		
14 –18 yrs	1.2 (f) 1.3 (m)	80
19 – 20 yrs	1.3 (f) 1.3 (m)	100
Folic acid (μg)		
14 –18 yrs	400	800
19 – 20 yrs	400	1000
Vitamin B_{12} (μg)		
14 –18 yrs	2.4	ND
19 – 20 yrs	2.4	ND

ND = Not determinable	RDA = Recommended Dietary Allowance
f = female	AI = Adequate intakes
m = male	UL = Tolerable upper intake level

athletes. This may not be a concern if their training and competition involves sunlight exposure. Because of toxicity issues, the use of vitamin D supplements at several times the RDA is not common among athletes and not recommended by sport nutritionists (Wildman & Miller, 2004, p. 282).

iii) Vitamin E

Vitamin E is a group of related molecules (tocopherols and tocotrienols) with similar properties of anti-oxidation. They are associated with lipid portions of cells (such as membranes) and are transported in the blood aboard lipoproteins (such as low-density lipoprotein cholesterol (LDLs). Vitamin E status and dietary levels are related to decreased free radical activity and the incidence of heart disease and some cancers. Vitamin E does not have an acute ergogenic effect, but athletes with normal to elevated vitamin status may have decreased free radical activity associated with endurance and intermittent exercise (Wildman & Miller, 2004, p. 284).

iv) Vitamin K

Vitamin K is found in a variety of food. Plant-based foods such as spinach, broccoli, Brussels sprouts, cabbage, lettuce, and kale are rich in vitamin K. Cereals, meats, nuts, legumes, diary products, and fruits also provide some vitamin K. Vitamin K is involved in activating clotting factors and in modifying a couple of other proteins after they are made in tissue. Poor vitamin K status is associated with decreased blood-clotting capability. The relationship between vitamin K and exercise is not properly researched, but vitamin K may maintain and increase bone density (Wildman & Miller, 2004, p. 286).

2) Water-soluble vitamins

The water-soluble vitamins are vitamin C and the B-complex vitamins. The B-complex vitamins have two major functions directly related to exercise (Manore et al., 2000). Vitamins of the B-complex group (e.g. thiamin, riboflavin, vitamin B_6, niacin, biotin and pantothenic acid) act as cofactors for enzymes regulating glycolysis, Krebs Cycle, oxidative phosphorylation, B oxidation and amino acid degradation (Folgelholm, 2002, p. 312, Wildman & Miller, 2004, p. 253).

i) Vitamin C

Better food sources of vitamin C include fresh fruits and some vegetables. Vitamin C is required for collagen formation and the production of several molecules, including carnitine and epinephrine (Wildman & Miller, 2004, p. 257). Vitamin C activates enzyme-regulating biosynthesis of carnitine, which is necessary for fatty acid transportation from cell cytosol into mitochondria (Folgelholm, 2002, p. 312).

The effect of vitamin C supplementation on performance has received considerable attention, mainly because athletes consume vitamin C in large quantities, often because of the volume of food they consume. In studies where athletes were deficient in vitamin C, supplementation improved physical performance, but not with normal levels of vitamin C (Berning, 2004, p. 633). However, supplemental vitamin C does not appear to enhance performance in well-nourished athletes, but it might help limit free radical activity associated with sports with high oxygen demands (Wildman & Miller, 2004, p. 257).

ii) Thiamin

Thiamin is found in a variety of foods. The best sources are whole grains and enriched grain products, pork, liver, nuts and green leafy vegetables. Thiamin is involved in several reactions of energy pathways, including the Krebs Cycle, branched-chain amino acid (BCAA) and pyrovate metabolism, and the pentose phosphate pathway. Thiamin supplementation does not appear to positively influence measures of performance and energy metabolism (Wildman & Miller, 2004, p. 259).

iii) Riboflavin

Riboflavin is found in whole grains and animal foods. Milk is a significant source. As a part of flavin adenine dinucleotide (FAD) and flavin mononucleotide (FMN), riboflavin participates in electron transfer in energy metabolism and the production of some amino acids and steroid hormones. Exercise may evoke shifts in riboflavin between tissues, but general riboflavin status is probably not affected and supplementation has not been shown to enhance exercise performance in well-nourished athletes (Wildman & Miller, 2004, p. 262).

iv) Niacin

Niacin is found in foods including meats, whole grains, mushrooms, and potatoes. Niacin is active as nicotinamide adenine dinucleotide (NAD), which is involved in energy metabolism, and nicotinamide adenine dinucleotide phosphate (NADP), which is more involved in synthetic operations. Niacin intake is believed to be adequate for most athletes, and low-dose supplementation probably does not enhance exercise performance (such as endurance) in a well-nourished athlete. Higher doses of niacin may decrease performance by reducing the mobilization of fatty acids (Wildman & Miller, 2004, p. 265).

v) Biotin

Biotin is found in a variety of food (e.g. liver, mushrooms, peanuts, yeast, milk, meat, egg yolk, most vegetables, banana, grapefruit, tomato, watermelon and strawberries) (Gallagher, 2004, p. 115) and is also produced by bacteria in the colon. Biotin is a coenzyme for a few carboxylase enzymes that are involved in glyconeogenesis, fatty acid synthesis, and the metabolism of odd-chain-length fatty acids and certain amino acids for energy (Wildman & Miller, 2004, p. 266).

The relationship between biotin metabolism, and exercise is poorly researched; however, the current consensus is that supplement does not favorably influence performance and energy metabolism in a well-nourished individual (Wildman & Miller, 2004, p. 266).

vi) Pantothenic acid

Pantothenic acid is found in a variety of foods (e.g. all plant and animal foods, eggs, kidney, liver, salmon and yeast) (Gallagher, 2004, p. 115) so the risk of deficiency is low if energy needs are met. Pantothenic acid is a component of coenzyme A (CoA), which activates certain molecules involved in energy operations, and acyl carrier protein (ACP), which is involved in fatty acid synthesis. Intake of pantothenic acid is currently believed to be sufficient in active individuals, but research on how exercise influences its status is incomplete (Wildman & Miller, 2004, p. 268).

vii) Vitamin B_6

Vitamin B_6 is found in the diet mostly in animal foods and is mildly sensitive to prolonged heat in the cooking process. Vitamin B_6 is principally involved in amino acid metabolism (such as transamination) and in glycogen breakdown (Wildman & Miller, 2004, p. 253). Optimal vitamin B_6 is important in support of efficient exercise metabolism by aiding alanine, glutamate, and glutamine formation during glyconeogenesis and amino acid oxidation in muscle fibers. It is unclear what influence vitamin B_6 supplementation may have on glycogen breakdown in prolonged exercise performance, but supplementation at high levels is not common among athletes (Wildman & Miller, 2004, p. 271).

viii) Folic acid and vitamin B_{12}

Folic acid and vitamin B_{12} are needed for haem synthesis (Folgelholm, 2002, p. 312; Wildman & Miller, 2004, p. 253), protein synthesis, and tissue repair and maintenance (Folgelholm, 2002, p. 312).

Folic acid is found in a variety of plant sources and organ meats. Folic acid is involved in the transfer of single-carbon groups, as in the making of nucleic acids. Some research shows that athletes may consume less folic acid than the RDA. However, little is known about the effect of exercise on folic acid metabolism, and researchers have not demonstrated a performance enhancing effect with supplementation, even when folic acid is below normal (Wildman & Miller, 2004, p. 272).

Vitamin B_{12} is found only in animal foods. Because the rate of excretion is normally low; the development of deficiency in a previously well-nourished adult can take years. Vitamin B_{12} is involved in folic acid recycling and has lesser-defined roles in neural tissue. Deficiency results in megoblastic anemia and profound inhabitation of appropriate central nervous system development and function. The relationship between vitamin B_{12} metabolism and exercise is not well researched (Wildman & Miller, 2004, p. 275).

b) Minerals

Approximately 4 % of body mass is composed of minerals. Minerals are part of enzymes, hormones, and vitamins. They are found in muscles, connective tissue, and all body fluids. A primary function of minerals is in the metabolism, in which they serve as important parts of enzymes. Minerals provide structure in the formation of bone and teeth and are also important for the synthesis of glycogen, lipids and protein (Plowman & Smith, 1997, p. 336; McArdle et al., 1996, p. 53).

Based on their daily requirements, minerals can be classified as macro-minerals or micro-minerals. The daily dietary allowance for macro-minerals is more than 100 mg/day, whereas trace elements are needed in much smaller quantities (less than 20 mg/day) (Folgelholm, 2002, p. 312). A balanced diet provides generally adequate mineral intake (McArdle et al., 1996, p. 53). Table 7 and Table 8 indicate the RDA / AI and the UL for the minerals.

Excessive sweating during exercise produces significant losses of body water and the related minerals. Mineral loss should be replaced following exercise through well-balanced meals (McArdle et al., 1999, p. 213). However, the intake of some minerals (calcium, iron and zinc) can be low especially in females. Low intakes of these minerals can usually be attributed to energy restriction or avoidance of animal products (Plowman & Smith, 1997, p. 336).

1) Macro-minerals and electrolytes

Macro-minerals include calcium, magnesium, chloride, phosphorus, potassium, sodium, and sulfur (Plowman & Smith, 1997, p. 336). Electrolytes are mineral salts dissolved in the body's fluid. They include magnesium, chloride, potassium and sodium, and help to regulate the fluid balance between different body compartments and the volume of the fluid in the bloodstream (Bean, 2003, p. 90). Table 7 indicates the RDA / AI and UL for macro-minerals per day.

Magnesium (a macro-mineral) and iron, zinc and copper (micro-minerals), act as enzyme activators in glycolysis, oxidative phosphorylation and in the system responsible for the maintenance of acid-base equilibrium. Iron is also needed for haem synthesis (Folgelholm, 2002, p. 313). Calcium effects muscle contraction. In addition, several minerals, such as copper, iron, selenium, manganese, and zinc, are components of anti-oxidant enzyme systems that help control free radicals produced during exercise (Wildman & Miller, 2004, p. 257).

i) Calcium

Adequate calcium intake and regular exercise provide an effective defense against bone loss at any stage. Paradoxically, women who train intensely and reduce body weight to the point at which menstruation is adversely affected often show advanced bone loss at an early age (McArdle et al., 1996, p. 53; New, 2001).

Table 7: RDA / AI and UL of macro-minerals for males and females 14 to 18 years and 19 to 20 years of age (Anderson, 2004, p. 159, 171; Folgelholm, 2002, p. 315, 321)

Macro-minerals	**RDA / AI**	**UL**
Calcium (mg)		
14 –18 yrs	1300	2500
19 – 20 yrs	1000	2500
Magnesium (mg)		
14 –18 yrs	360 (f) 410 (m)	350
19 – 20 yrs	310 (f) 400 (m)	350
Chloride (chlorine) (mg)	750 mg	ND
Iron (mg)		
14 –18 yrs	15 (f) 11 (m)	45
19 – 20 yrs	18 (f) 8 (m)	45
Phosphorus (mg)		
14 –18 yrs	1250	4000
19 – 20 yrs	700	4000
Potassium (mg)		
14 –18 yrs	< 2000	ND
19 – 20 yrs	< 2000	ND
Sodium (mg)		
14 –18 yrs	< 3000	ND
19 – 20 yrs	< 3000	ND

ND = Not determinable
f = female
m = male

RDA = Recommended Dietary Allowance
AI = Adequate intakes
UL = Tolerable upper intake level

A decreased bone mineral density (BMD) is clinically used to define osteopenia (BMD greater than one standard deviation, but not more than 2.5) and osteoporosis (greater than 2.5 standard deviation) (Plowman & Smith, 1997, p.409).

Moderate exercise will increase bone mineral density in women, but hard training may reduce circulating estrogen levels and accelerate bone loss (Maughan, 2002; McArdle et al., 1996, p. 53). With increased participation in vigorous exercise by women, menstrual disturbances ("athletic amenorrhoea") have become more common.

The mechanism, by which the low estrogen levels presented in amenorrhoea reduce bone mass, is by reducing the rate of bone turnover. The prevalence of stress fractures is also higher among athletes with menstrual disturbances (Kerr et al., 2002, p. 262). Strategies to promote the resumption of menses include estrogen replacement therapy, weight gain, and reduced training. Dietary interventions are to include calcium, vitamin D, and magnesium supplementation (Berning, 2004, p. 632).

In the body, most calcium is found in hard tissue. The calcium in the blood and soft tissues such as muscle and glands is important in functional and homeostatic operations (muscle contraction, blood clotting, and second messenger systems) (Wildman & Miller, 2004, p. 257). Calcium is especially important in the building and repair of bone tissue and the maintenance of bone calcium level (Maughan, 2002; McArdle et al., 1996, p. 53). Optimal calcium status might be crucial for bone remodeling and muscle hypertrophy induced by athletic training (Wildman & Miller, 2004, p. 257).

Calcium is present in dairy products, dark green leafy vegetables, legumes, and often in fortified commercial orange juice (Schwenk & Costley, 2002; Burke, 1999). The best sources for athletes are low-fat and nonfat dietary products, calcium fortified fruit juices, calcium fortified soymilk, and tofu made with calcium sulphate (Berning, 2004, p. 632).
Dietary calcium intake of some athletes is below recommendations, but dietary modifications or numerous types of calcium supplements can correct this (Wildman & Miller, 2004, p. 257).

Calcium supplementation is primarily recommended for athletes who abstain from dairy products, amonorrheic women and young female athletes, at a dose of 1500 mg per day, to increase their BMD (Berning, 2004, p. 632; Schwenk & Costley, 2002). Calcium carbonate / phosphate / lactate can be used as an effective composition of a calcium supplement (Kohler et al., 2004). Calcium must be used in combination with vitamin D (Berning, 2004, p. 632) Excessive amounts of magnesium supplementation can interfere with calcium absorption. Calcium supplementation interferes with iron and zinc absorption, thus must be used with caution (Schwenk & Costley, 2002).

ii) Magnesium

Magnesium is a divalent cation (Mg^{2+}) found in many foods. Whole grains, legumes, and leafy vegetables are good sources (Wildman & Miller, 2004, p. 306). Fifty percent of magnesium is located in the bone, and the remaining 50 % is almost entirely inside body cells, with only 1% located in extracellular fluids (Anderson, 2004, p. 130-1).

The major function of magnesium may be to stabilize the structure of adenosine triphosphate (ATP) in ATP-dependent enzyme reactions (Anderson, 2004, p. 130-1) therefore it can interact with phosphate tails of ATP and improve the efficiency of ATP splitting for energy (Wildman & Miller, 2004, p. 306). Magnesium is a co-factor for many enzymes involved in the metabolism of food (Anderson, 2004, p. 130-1).

The marketing claim of magnesium is to increase physical power through increased muscle mass, and so uninformed athletes consume excessive amounts of magnesium (Schwenk & Costley, 2002).

However, magnesium supplementation for athletes requires further study (Wildman & Miller, 2004, p. 306), and excessive amounts of magnesium supplementation can interfere with calcium absorption (Krause, 2004, Schwenk & Costley, 2002).

iii) Chloride

Chloride is widely distributed throughout the body as the principle anion of extracellular fluids. Together with sodium, it helps to maintain water balance and osmotic pressure (Whitmire, 2004, p. 171). Chloride is a component of hydrochloric acid (HCl) in the stomach acid and is involved in carbonic anhydrase activity to transport carbon dioxide from the tissue to the lungs (Wildman & Miller, 2004, p. 304).

Most dietary sources come from sodium chloride or table salt, which is 60% chloride. The safe range for chloride intake for 10 to 18 years is 750 mg a day (Whitmire, 2004, p.

171). Most athletes get enough chloride through a balanced diet, but imbalances may occur in athletes who sweat excessively or have eating disorders because of vomiting, or the use of laxatives and diuretics (Wildman & Miller, 2004, p. 304).

iv) Potassium

Potassium is a major cation of intracellular fluid, with only small amounts in exstracellular fluid. The functions of potassium are in regulating pH and osmolarity, and in cell membrane transfer (Whitmire, 2004, p. 172). Most athletes get enough potassium through a balanced diet, but imbalances may occur in athletes who have eating disorders because of vomiting, or the use of laxatives and diuretics (Wildman & Miller, 2004, p. 304).

v) Sodium

Sodium, the most abundant cation of the extracellular space, is the major electrolyte lost in plasma. Thirty to forty-five percent of sodium is found in the bone. It regulates body fluid osmolarity, pH, and body fluid volume (Whitmire, 2004, p. 170). When exercise duration is very prolonged and when excessive large volumes of low-sodium drinks are taken during exercise, hyponatremia has been reported (Maughan, 2002c, p. 369).

Electrolytes in sport drinks do not have a direct effect on performance. However, sodium does have one key benefit by causing an increase urge to drink and improves palatability. An increase in sodium concentration and decrease in blood volume that accompany exercise, increases the athlete's natural thirst sensation. If an athlete drinks plain water it effectively dilutes the sodium, thus reducing his urge to drink before he is fully hydrated. Therefore including a small amount of sodium (0,5 to 0.7 g/L) in a sport drink will encourage an athlete to drink more fluid (Bean, 2003, p. 90).

2) Micro-minerals (Trace elements)

Of the 14 essential micro-minerals only five (zinc, chromium, copper, selenium and iron) have been implicated as being affected by or potentially beneficial in enhancing exercise training or performance (Fogelholm, 2002, p. 313). Table 8 summarizes the RDA / AI and UL for micro mineral intake.

Table 8: RDA / AI and UL of micro-minerals for males and females 14 to 18 years and 19 to 20 years of age (Anderson, 2004, p. 159; Fogelholm, 2002, p. 315, 321)

Micro-minerals	**RDA / AI**	**UL**
Zinc (mg)		
14 –18 yrs	9 (f) 11 (m)	34
19 – 20 yrs	8 (f) 11 (m)	40
Chromium (μg)	24 (f) 35 (m)	ND
Copper (μg)		
14 –18 yrs	0.89	8000
19 – 20 yrs	0.9	10000
Selenium (μg)	55	400
Iron (mg)	15 (f) 11 (m)	45

ND = Not determinable
f = female
m = male
RDA = Recommended Dietary Allowance
AI = Adequate intakes
UL = Tolerable upper intake level

i) Zinc

Zinc is found in a variety of food; however, zinc in animal sources like meats seems to be more concentrated and bioavailable (Wildman & Miller, 2004, p. 315). Zinc is involved in the biochemical processes supporting life, such as cellular respiration, DNA reproduction, maintenance of cell membrane integrity and free radical scavenging (Micheletti et al., 2001). Zinc is a component of numerous enzymes including many involved in exercise metabolism and recovery operations (Wildman & Miller, 2004, p. 315).

The nutritional habits of elite athletes during training and competition are quite different from the recommended diet in the majority of the population. Endurance athletes often adapt to an unusual diet, in an attempt to enhance performance: an excessive increase in CHO and low intake of proteins and fat may lead to sub-optimal zinc intake in 90 % of athletes (Micheletti et al., 2001). Zinc is also lost in sweat and urine during exercise (Plowman & Smith, 1997, p. 336).

Zinc deficiency is difficult to detect, but can lead to anorexia, significant loss of body weight, latent fatigue with decrease endurance, risk of osteoporosis (Micheletti et al., 2001) and poor athletic performance stemming from cardiovascular and muscular dysfunctions (Wildman & Miller, 2004, p. 315). However, excess intake of zinc above the RDA can result in impaired immune response and decreased iron and copper absorption. There is not sufficient evidence that zinc can enhance performance (Plowman & Smith, 1997, p. 336), but an excess or deficiency can influence performance, thus the DRI should be consumed every day, and a balanced diet is sufficient for these purposes (Micheletti et al., 2001).

ii) Chromium

Chromium is associated with glucose metabolism. The food sources of chromium are corn oil, clams, whole-grain cereals, brewer’s yeast, meats and drinking water (amount varies) (Anderson, 2004, p. 160).

Chromium supplementation, mainly as chromium picolinate, during training has been proposed to stimulate insulin function and to promote muscle growth. In an earlier controlled trail, chromium (200 μg) or placebo was given to healthy, previously untrained students, during a 12-week weight lifting programme. Supplementation was associated with greater body weight gain in women, but not in men. Strength was not affected. Despite this preliminary fining, more recent studies with athletes have not found any significant effects of chromium on weight, body composition or strength (Fogelholm, 2002, p. 312).

iii) Copper

Copper is found in all body tissues, with the bulk in the liver, brain, heart, and kidney. Copper is a constituent of enzymes and ceruloplasmin and erythrocuprein in the blood. It may be an integral part of DNA or RNA. The food sources of copper are liver, shellfish, whole grains, cherries, legumes, kidney, poultry, oysters, chocolate and nuts (Anderson, 2004, p. 160).

iv) Selenium

Selenium is involved in fat metabolism, cooperates with vitamin E, and acts as an anti-oxidant. The food sources of chromium are grains, onions, meat, milk, and varied amounts of vegetables depending on the selenium content of the soil (Anderson, 2004, p. 160).

v) Iron

Iron plays an important role in exercise, as it is required for the formation of hemoglobin and myoglobin, which bind oxygen in the body, and for enzymes involved in energy production (Manore et al., 2000; Burke, 1999).

Elite and recreational athletes have higher iron requirements and turnover than less physically active people (Deakin, 2002a, p. 273). Females and adolescent athletes are also at greater risk of iron depletion (Deakin, 2002a, p. 273). The high incidence of iron depletion can occur in females with poor energy intake, who avoid meat products, vegetarians, or where increased iron losses are present in sweat, feces, urine or menstrual cycle (Manore et al., 2000; Burke, 1999).

The impact of iron depletion or low serum ferritin is not associated with impaired performance, but if these conditions can lead to iron deficiency anemia, exercise performance can be negatively affected (Maughan, 2002a; Manore et al., 2000).

Strenuous daily training has a negative effect on body iron stores. While swimming does not cause the same physical trauma in iron stores as running, a study by Burke (1998, p. 172) reported that red blood cells in swimmers could be damaged by the continual impact of turbulent water (Burke, 1998, p. 172). Endurance athletes commonly have low circulating hemoglobin levels and serum ferritin, but erythrocyte morphology remains normal. These decreases in hemoglobin and serum ferritin levels are a result of an increase plasma volume, which cause hemodilution, and appear to have no effect on performance (Berning, 2004, p. 632). But, if untreated, iron depletion can ultimately lead to iron deficiency anemia, which severely impairs aerobic performance (Maughan, 2002a; Deakin, 2002a, p. 273; Plowman & Smith, 1997, p. 336; McArdle et al., 1996, p. 53). The incidence of iron deficiency anemia in female athletes is similar to the 9 to 11% found in the general female population (Maughan, 2002a; Manore et al., 2000).

Berning (2004, p. 631) concluded that iron deficiency anemia limits aerobic performance and the capacity of work and partial depletion can have a detrimental effect on exercise performance, even when anemia is not present. Thus low iron stores can have effect on performance.

To treat iron deficiency, a diet rich in iron sources, in combination with high doses of iron supplementation (100 mg per day), is needed to replete exhausted stores. Diet intervention alone is incapable of repleting iron stores. Recovery of iron stores takes around three months (Deakin, 2002a, p. 293). Iron supplementation also minimizes fatigue and increase ability to recover after heavy training, and consistently improves iron status and exercise performance (Burke, 1999).

Although iron is widely distributed in food, its absorption is influenced by the way foods are combined in meals and snacks (Deakin, 2002a, p. 273). The heme form of iron found in red meat, liver products and shellfish is much better absorbed than non-heme iron found in plant foods such as wholegrain cereal foods, legumes and green leafy vegetables. Mixing and matching small amounts of iron rich heme foods into CHO rich meals allows the athlete to achieve several nutritional goals simultaneously (Burke, 1999). The non-heme iron absorption is enhanced by vitamin C (food sources and supplementation), e.g. iron-fortified cereals can be consumed in combination with orange juice (iron supplementation may be prescribe with 500 mg vitamin C) (Kohler et al., 2004). High-CHO diets recommended for athletes may be high in compounds that inhibit iron absorption, e.g. calcium sources (milk products) (Deakin, 2002a, p. 273).

Iron supplementation is not advised except when given to individuals with iron-deficiency anemia (Plowman & Smith, 1997, p. 336). Intolerance, risk of overload and other drug interactions are often associated with high dose iron supplementation. Diarrhea or constipation, abdominal discomfort, nausea, and an increased risk of infection have been reported (Deakin, 2002a, p. 293). Large doses of iron (75 mg/day) can be toxic in persons with the genetic disorder, hemochromatosis (Berning, 2004, p. 632). Intakes as low as 18 mg of elemental iron depressed serum zinc levels in the short term. The reasons for this are unclear. The possibility that iron supplements induce deficiencies of other trace minerals, such as zinc, or induced iron overload is susceptible people with haemochromatosis cannot be ignored (Deakin, 2002a, p. 293).

iv) Fluids

Swimming does not produce as much sweat as land sports due to the cooler water temperature. However the opportunity for dehydration certainly exists and swimmers should employ the same hydrating practices as other athletes (Wildman & Miller, 2004, p. 455). Swimmers can churn up and down the pool for hours, often in the steamy environment of a heated indoor pool, and occasionally outdoors in the late afternoon heat. Hopping out of the pool to get a drink is not always possible. Smart swimming coaches now insist that swimmers bring their own water bottles to the pool deck. Drinking during rest periods or between sets will help a swimmer to train better (Burke, 1998, p. 171).

Athletes need to consume approximately 4 liters of water and other fluids per day (Brooks et al., 2000, p.693; McArdle et al., 1996, p. 56). Hawley & Burke (1998, p. 310) suggest a fluid intake rate of 127 ml per kilometer of training and Wildman & Miller

(2004, p. 455) suggested an intake of at least 1 L of water for each hour in the pool. A dilute aqueous solution containing 4 to 8 % of glucose, may promote rehydation more effectively than water alone by making the thirst mechanism longer (Brooks et al., 2000, p.694). Refer to Table 4.

Because thirst is not always an adequate mechanism to ensure proper rehydration, athletes need to form a habit of weighing themselves daily prior to training. Athletes can easily lose 1 to 2 % of body weight from the previous day's training, which can result in decreased performance and the increased risk of heat injury (Brooks et al., 2000, p.694; Burke, 1999).

2.3.2.2 Pre-competition and competition diet

Diets on pre-competition and competition days refer to the dietary strategies undertaken in the hours and days prior to competition (Berning, 2004, p. 627). Challenges and opportunities for nutritional intervention immediately before and during competition include: enhancing energy supply to delay the onset of fatigue, minimizing the negative effects of dehydration, and minimizing central nervous effects (Maughan, 2002b).

It takes about 25 seconds for an elite swimmer to race over 50 meters and about 15 minutes to complete 1500 m, making swimming a highly anaerobic sport, with aerobic metabolism becoming more important as the race distances increases. Muscle fuel stores may not be depleted even over a 1500 m swim, with the main source of fatigue being a build-up of the accompanying products of anaerobic metabolism, such as hydrogen ions (Burke, 1998, p. 169).

Swimming events are usually held over three to seven days, with swimmers typically competing in heats in the mornings and the final of those events in the evening. In minor galas, swimmers may enter a large number of events and be required to swim two to three times in one day, with twenty minutes to several hours between events. At major competitions, only exceptional swimmers will enter more than three events (Burke, 1998, p. 169).

i) Pre-competition meal

Since events can be held at various times of the day, careful planning of the pre-event meal may be needed (Burke, 1998, p. 173). The ideal meal should be ingested three to four hours before the first event and should consist of 200 to 350 g CHO (4 g/kg of body mass in either solid or liquid form) (Berning, 2004, p. 627). Body size, or more appropriate glycogen storage potential, accounts for the broad range (Wildman & Miller, 2004, p. 102).

The dip in blood glucose that may be experienced after ingesting CHO 30 to 60 minutes prior to exercise seems to reach its low point at approximately 15 minutes after the onset of exercise. For some individuals the transient hypoglycemia can be enough to result in performance reduction. Therefore, each athlete needs to experiment with CHO consumption within an hour of exercise during training periods. The recommendation of CHO ingestion 30 to 60 minutes prior to exercise is 50 to 75 g (Wildman & Miller, 2004, p. 102-4).

Quite often CHO is consumed just prior to exercise (under 5 minutes), such as consuming sport drink just prior to the start of the race. For some athletes the consumption of CHO during a race is problematic due to difficulties with drinking while moving. Therefore ingesting 30 to 50 g of CHO a few minutes prior to the onset of a race would be easier than trying to consume recommended levels during the event. The ergogenic potential of CHO eaten immediately prior to exercise is similar to CHO ingested during exercise (Wildman & Miller, 2004, p. 102-4). Table 9 indicates examples of pre-event meals for swimmers. Foods high in protein and fat content should be eliminated from the diet on the day of competition, because of the slow digestibility of these foods (Manore et al., 2000).

The importance of the pre-exercise meal is largely determined by the degree of recovery from the previous exercise session and the duration of the exercise event. When choosing a pre-exercise meal, gastric emptying, digestion and absorption rate should be considered to limit possible gastrointestinal distress and excessive fullness. Ingesting HGI CHO foods pre-exercise usually results in a drop in blood glucose levels at 15 to 30 minutes of exercise, which stabilizes again at approximately 60 minutes of exercise. However this drop largely does not result in hypoglycaemia (< 3.5 mmol/l) and rarely causes hypoglycaemic symptoms. Furthermore, LGI CHO pre-exercise foods do not increase exercise performance, although these foods cause delayed CHO oxidation and increase FFA oxidation compared with HGI CHO pre-exercise foods. Therefore, HGI CHO foods can be ingested pre-exercise without any detrimental effects if preferred by an athlete, and if the athlete is not sensitive to hypoglycaemia (Wright, 2005).

Fluid intake before an event should include at least 300 to 600 ml fluid with the pre-event meal and then 150 to 300 ml every 15 to 20 minutes up until about 45 minutes to an hour before the event (Burke, 2002b, p. 364; Manore et al., 2000; McArdle et al., 1999, p. 226).

a) CHO loading

Dietary manipulation to increase muscle glycogen content in the few days before exercise has been extensively recommended for endurance athletes following observations that these procedures were effective in increasing endurance capacity in cycle ergometer exercise lasting about 1.5 to 2 hours (Maughan, 2002b; Plowman & Smith, 1997, p. 338).

This was subsequently proposed as an effective means of enhancing muscle glycogen availability and endurance performance (Costill & Hargreaves, 1992). The process by which glycogen concentration is raised to levels two to three times greater than normal is called glycogen supercompensation, also called CHO loading (Plowman & Smith, 1997, p. 338). This results from a program of exercise (submaximal to exhaustion) followed by a high-CHO diet.

Table 9: Examples of pre-event meals for athletes who compete in long duration events (Berning, 2004, p. 627)

TIME	**EXAMPLE OF MEAL**
1 hour or less before competition About 400 kJ	• Fresh fruit such as apples, watermelon, peaches, grapes, oranges, or an energy sport bar • 1 ½ cups (375 ml) of a commercial sport drink
2 to 3 hours before competition About 1300 to 1700 kJ	• Fresh fruit and fruit and vegetable juices • Breads or muffins with limited amounts of margarine or cream cheese, or low- fat yogurt, oatmeal, pancakes with limed amounts of butter and syrup, or a sports bar • 4 cups (1 L) of a commercial sport drink or 1 can of a sport nutritional supplement
3 to 4 hours before competition About 3000 kJ	• Fresh fruit and fruit and vegetable juices • Breads, baked potatoes, cereals with low-fat cream cheese, cereal with low-fat milk, low-fat yogurt, sandwiches with a small amount of peanut- butter or lean meat, or spaghetti with tomato sauce • 7 ½ cups (2 L) of a commercial sport drink or 1 to 2 cans of a sport nutritional supplement

CHO loading can be done in two different ways, namely the classic regime or the modified regime. The classic regime starts three or seven days prior competition, the athlete exercise to near exhaustion (Maughan, 2002b; Brooks et al., 2000, p.686; Plowman & Smith, 1997, p. 338). This process can also include some very hard intervals (sprints) of exercise during and after a brief recovery from prolonged exercise. The purpose of the sprints was to deplete the fast-glycolytic (type Ix) and fast-oxidative-glycolytic (Type II a) fibers of glycogen (Brooks et al., 2000, p.686). Thus depleting muscle glycogen by prolonged exercise about a week before competition and to prevent resynthesis by consuming a low-CHO diet for two to three days. The athlete then rests and tapers off by reducing training volume and eating a high-CHO (60 to 70 %) diet during the remaining days before competition (Brooks et al., 2000, p.686). This procedure can double the muscle glycogen content and is effective in increasing cycling or running performance (Maughan, 2002a; Plowman & Smith, 1997, p. 338).

The modified regime involves three to five days of a CHO intake between 7 to 10 g/kg/day or 70 to 85 % of energy prior competition. Since this may represent an unusual dietary pattern for many athletes, help will be needed to devise suitable food choices and meal plans (Burke & Deakin, 2002, p. 362). Studies have shown that a high-CHO diet during a period of training brings about greater improvements in performance, than a high fat diet, even when a high-CHO diet is fed for only a few days to allow normalization of the muscle glycogen stores before exercise performance is measured. A high-CHO (70 % of energy intake as CHO) enabled runners who were training for two hours per day to maintain glycogen levels, whereas a progressive fall in muscle glycogen content was observed with a 40 % CHO diet (Maughan, 2002a). Wildman & Miller (2004, p. 105) recommended that 70 % CHO of the total energy intake should be consumed during CHO loading.

The decision to CHO load needs to be made based on consideration of physiological requirements of the athlete's event. The athlete needs to have a good comprehension of the rationale for loading; and the requirements, side- effects, and practical difficulties associated with achieving an exercise taper and high-CHO intake. If the event were one of a series of closely held competitions, a complete CHO loading preparation would be deemed impractical and overstated. The full preparation of CHO loading is saved for single events or the most important competition (Burke & Deakin, 2002, p. 343, 359). Factors affecting decisions to CHO load must be taken into consideration, and are described in Table 10.

Table 10: Factors affecting decisions to CHO load (Burke & Deakin, 2002, p. 361)

CHO loading should be considered	**CHO loading is not necessary**
The exercise is moderate intensity, endurance activity where heavy demands are placed on glycogen stores (e.g. marathon)	The exercise is not an endurance activity and normal glycogen stores will be adequate to fuel the event
The activity is likely to involve more than 90 minutes of continues exercise	The event will last less than 60 to 80 minutes
The athletes is currently eating less than 8 to 9g CHO/kg body mass per day, and is motivated to follow a loading regime	The activity is high intensity for a short duration and will be adversely affected by weight gain associated with loading (sprint events)
There are no medical reasons contra-indicating a very high-CHO diet for a three to five day period	The athlete is already eating a very high-CHO diet (for than 8 to 9 g/kg body mass per day or more than 800 g/ CHO/day)
	The athlete has unstable diabetes, or hyperlipidemic, and very high-CHO diet is contra-indicated

ii) Competition diet

CHO consumed during endurance exercise lasting longer than one hour ensures the availability of sufficient amounts of energy during the later stages of exercise and improve performance (Berning, 2004, p. 628). This also applies for swimmers that are between events and between heats and finals that need to replenish their fluid levels and carbohydrate stores (Maughan, 2002c, p. 378).

Ingesting CHO during exercise increases exercise performance (even events ≤ 1 hour in duration), helps to maintain euglycaemia, and decreases the risk of upper respiratory infections. HGI and MGI CHO are generally recommended during exercise because of the rapid digestion of the CHO and maintenance of euglycaemia (Wright, 2005).

If a swimmer has more than three hours between heats and finals a light carbohydrate meal (Table 11) might be eaten in comfort. During swim-down, or when there is only a short interval between races, CHO-containing fluid can be consumed; such as a sport drink, fruit juice, or soft drink (Table 12) (Berning, 2004, p. 628; Maughan, 2002c, p. 378). However, athletes lose more body water than non-athletes due to increased volumes of sweat and breath. Their enhanced energy metabolism also allows for an increased generation of water in cells. However, this cannot compensate for enhanced water loss in athletes. Therefore increased water loss must be compensated for by increased consumption of beverages and to a lesser degree food (Wildman & Miller, 2004, p. 249).

Table 11: Light CHO meal (Maughan, 2002c, p. 378)

DESCRIPTION	**50 g OF CHO**	**COMMENTS**
Banana	2 to 3 medium	Solid foods, especially those containing fiber, may cause GI concerns in some individuals, but may help relieve hunger during long events. Several portions are needed to provide sufficient amounts of CHO. Fluid needs will need separate attention.
Jelly beans	50 g	Compact CHO source. Large amounts (> 50 g) may cause diarrhea. Fluid needs will need separate attention.
Jam sandwich	2 thick slices with 4 teaspoons of jam	Avoid adding fat sources to sandwich. See comments for bananas.
Chocolate bar	1 ½ bars	Portable and well-liked snack. May help relieve hunger. High in fat therefore may be slowly absorbed. Fluid needs will need separate attention.
Muesli bar	2 bars	Solid foods, especially those containing fiber, may cause GI concerns in some individuals, but may help relieve hunger during long events. Fluid needs will need separate attention.
Breakfast bar	1 ½ bars	Lower fat content than muesli bars. See other comments on muesli bars.
Sports bars	1 ½ bars	Compact source of CHO. Varying level of fat. May have herbal additives of unknown function.

a) Solid meals

Solids can be desirable during prolonged competition as they increase flavour options available, provide different textures and help to relieve hunger. Solids and gels also have the advantage of being a compact form of CHO (Maughan, 2002c, p. 388). However foods high in protein and fat content should be eliminated from the diet on the day of competition, because of the slow digestibility of these foods (Manore et al., 2000).

b) Sports drinks

Consumption of sports drinks containing CHO and electrolytes during exercise will provide fuel for the muscles, help maintain blood glucose and thirst mechanism, and decrease the risk of dehydration and hyponatremia (Manore et al., 2000).

1) CHO recommendations

If a sports drink with CHO is consumed during exercise, the rate of CHO ingestion should be about 26 to 30 g every 30 minutes, an amount equivalent to one cup of a 6 to 8 % CHO solution taken every 15 to 20 minutes (Berning, 2004, p. 628). For instance, about 30 to 60 g of CHO an hour is probably sufficient for an endurance athlete of average size (68 kg). This amount can be met by ingesting 4 to 8 % CHO-containing solution (e.g. Energade) (Table 4) at about 625 to 1250 ml/hour (Wildman & Miller, 2004, p. 336). Glucose, sucrose, or maltodextrin are probably the same with regard to enhancing performance; however fructose may be a detriment by causing intestinal discomfort (Wildman & Miller, 2004, p. 108), however mixtures of glucose and fructose seem to be effective (Wright, 2005; Manore et al., 2000).

Sports drinks can be divided into two main categories (Table 12), namely CHO (energy) drinks (5 to 8 % CHO drinks) and fluid replacement drinks (hypotonic or isotonic). CHO (energy) drinks provide more CHO per 100 ml than fluid replacement drinks. The CHO is mainly in the form of glucose polymers. The main aim is to provide larger amounts of

CHO but at an equal or lower osmolality than the same concentration of glucose (Bean, 2003, p. 92).

Table 12: Sports drinks (Maughan, 2002c, p. 378)

DESCRIPTION	**50 g OF CHO**	**COMMENTS**
Water	-	Does not assist with fuel needs, but may be drunk in addition to sports drinks or solid food to make up total fluid needs
Sports drinks (5 to 8% CHO with electrolytes)	600-1000 ml	Best option for meeting fluid and CHO requirements simultaneously. Has a good taste profile to encourage voluntary intake. Provides small amounts of electrolytes
Soft drink (11% CHO)	500 ml	May be more slowly absorbed due to CHO content. Negligible source of electrolytes. Possible risk of gastrointestinal upset if juice is high in fructose
Sports gel (60 to 70% CHO)	1 ½ to 2 gels	Concentrated CHO source. Suitable for large fuel boost. Experiment to avoid GI discomfort. Fluid requirements will need separate attention

2) Fluid recommendations

Fluid replacement drinks are dilute solutions of electrolytes and sugars (CHO). The sugars most commonly added are glucose, sucrose, fructose and glucose polymers. The main aim of these drinks is to replace fluid faster than plain water, although the extra sugars will help to maintain blood glucose levels and spare glycogen (Bean, 2003, p. 92). General recommendations for fluid replacement during exercise are 150 to 350 ml every 15 minutes as tolerated (Wildman & Miller, 2004, p. 336). Swimmers need to drink at least 450 to 675 ml of fluid for every 0.5 g/kg of body weight loss during exercise and competition (Manore et al., 2000). Recommendations can be generated for larger and smaller endurance athletes by dividing their body weight in kilograms by 68 and then multiplying the result by the fluid recommendations for the 68 kg athlete (Wildman & Miller, 2004, p. 336).

The fluid needs are influenced by the amount of sweating. Sweat rates will vary depending on variables such as body size, exercise intensity, ambient temperature, humidity, and acclimation, but can exceed 1.8 kg (1800 ml) water per hour, and substantial amounts of sodium (1 g/L), modest amounts of potassium, and small amounts of minerals such as iron and calcium (Manore et al., 2000).

3) Electrolyte recommendations

Sweat consists of water and electrolytes, including sodium, chloride, potassium, traces of amino acids, bicarbonate, carbon dioxide, copper, glucose, hormones, iron, lactic acid, magnesium, nitrogen, phosphates, urea, vitamins and zinc. Thus these losses must be taken into account during exercise (Plowman & Smith, 1997, p. 342).

Although, the composition of sweat is highly variable, sweat is always hypotonic with regard to body fluids, and the net effect of sweat loss is an increase in plasma osmolality. The plasma concentration of sodium and potassium also generally increase, suggesting that replacement of these electrolytes during exercise may not be necessary (Maughan, 2002c, p. 378).

It has been claimed that electrolytes make sports drinks more palatable and hence encourage drinking. The available evidence indicates that sodium, is the only electrolyte that is physiologically beneficial when consumed during exercise. Since most sports drinks commercially available do contain varying amounts of electrolytes other than sodium, there have been no harmful effects reported (Plowman & Smith, 1997, p. 343). Plowman and Smith (1997, p. 343) also suggested that with large rates of fluid ingestion (even measured just to meet the fluid needs) sodium intake is vital and an increased beverage concentration 1.7 to 2.9 g NaCl /L may be beneficial. However, this can influence the taste negatively.

2.3.2.3 Recovery diet

The recovery diet includes a complex range of nutrition-related issues: restoration of muscle and liver glycogen stores, replacement of fluid and electrolytes lost in sweat and regeneration, repair and adaptation processes following catabolic stress and damage caused by exercise (Maughan, 2002c, p. 396-7). Muscle glycogen stores can be restored within 24 hours with a high carbohydrate diet (Burke, 1998, p. 173).

CHO rich snacks such as yogurt, fruit, sports bars, sandwiches, or rice cakes can be brought to the pool and are suitable for longer gaps between races, or for a recovery snack or commercial liquid meal supplements if your stomach or timetable calls for a "lighter" snack (Burke, 1998, p. 173)

As soon as possible after the end of training or competition at least 50 to 100g of CHO (Table 13), every 2 hours should be consumed or until a high-CHO meal is eaten. Another goal is to consume 500 g CHO in 24 hours after competition (Maughan, 2002a; Plowman & Smith, 1997, p. 330; McArdle et al., 1996, p. 74). CHO with a moderate to high glycemic index (GI) are recommended to be consumed after exercise (Berning, 2004, p. 626), because it is the most rapid method for replenishing CHO after prolonged exercise (McArdle et al, 1999, p. 217).

CHO intake of 1.5 g/kg body weight during the first 30 min, and after every two hours (for four to six hours onwards) will be adequate to replace glycogen stores (Manore et al., 2000; Plowman & Smith, 1997, p. 330). Adding about 5 to 9 g of protein with every 100 g of CHO eaten after exercise increased the rate of glycogen resynthesis (Table 13). It appears that this small amount of protein with the CHO elicits a greater insulin response and therefore activates glycogen synthase, the enzyme responsible for glycogen storage (Wright, 2005; Berning, 2004, p. 628).

HGI and MGI CHO foods appear to be the best choice post-exercise when the recovery period is short (< 8 hours) because of the insulinaemic response of these CHO which stimulates glycogen synthase activity and hence an increase in the rate of glycogen synthesis. LGI CHO food is not recommended during this recovery period, since it has a slower rate of absorption and its indigestible CHO appears to be a poor substrate for glycogen synthesis. However if the recovery period is longer (≥ 22 hours) the total amount of CHO ingested is more important that the GI per se (Wright, 2005).

Table 13: CHO recovery snacks and meals that provide approximately 50 g of CHO (Burke, 2002a, p. 420)

50 g OF CHO SNACKS	**50G CHO SNACKS THAT ALSO CONTAIN AT LEAST 10 g OF PROTEIN**
800 to 1000 ml of sports drink	250 to 350 ml of liquid meal supplement
500 ml of fruit juice	250 to 350 ml of milkshake or fruit smoothie
250 ml of CHO loader drink	2 x 200 g fruit flavored yogurt
60 g packet of jelly beans or sweets	Bowl of breakfast cereal with milk
3 medium pieces of fruit	250 g of baked beans or spaghetti
1 round of jam or honey sandwiches	1 round sandwich including a filling, plus one piece of fruit
3 muesli bars	1.5 cups of fruit salad, with 100 g of yogurt
1 large Mars bar or chocolate bar (70 g)	200 g of yogurt and one muesli bar
2 breakfast bars or cereal bars	2 crumpets with peanut butter
3 rice cakes with jam or honey	1 large potato with a cheese filling
2 crumpets	150 g of crust pizza
1 cup of thick vegetable soup	
1- 2 sports bars or gels	
100 g muffin, fruit bun, or scone	
250 g creamed rice	
250 g (large) baked potato with filling	
100g pancakes (1 to 2 large) with syrup	

2.4 SUPPLEMENTS AND ERGOGENIC AIDS

The sports industry is filled with foods, potions, pills and powders that promise to provide the athlete with a performance edge (Burke et al., 2002, p. 455). Sport supplements include substances purported to enhance performance and/or favorably alter body composition (Wildman & Miller, 2004, p. 351). The term ergogenic means, "work producing" (Schwenk & Costley, 2002) or "capable of enhancing performance (Maughan, 2002a). Ergogenic aids are substances or devices used to improve exercise and athletic performance by improving the production of energy (Bucci, 1993, p. 45-7). The categories for supplements and ergogenic aids are dietary supplements, nutritional ergogenic aids, and banned substances.

The methods to assess the use of supplements and ergogenic aid as well as the types of dietary supplements and ergogenic aids will be discussed.

2.4.1 Methods to assess the use of supplements and ergogenic aids

A questionnaire can be used to gather information on the use of supplements, and people can respond to questions with the assurance that their responses will be anonymous, and so they may be more truthful than they would be in a personal interview, particularly when they are talking about controversial issues. Yet questionnaires have their drawbacks as well, especially with the returning of questionnaire (Leedy & Ormrod, 2001, p. 197).

Interviews can also yield a great deal of useful information on the use of supplements. Face to face interviews have the distinct advantage of enabling the researcher to establish rapport with potential participants and therefore gain their cooperation; thus such interviews yield the highest response rates in survey research. However, such interviews take time, and so may not be practical when very large sample sizes are important (Leedy & Ormrod, 2001, p. 196-7).

The UL is developed for athletes as well as supplement users (Deakin, 2002, p. 53), therefore these values can be used to assess the upper limit adequacy of vitamins and mineral supplementation.

2.4.2 Types of supplements and ergogenic aids

Nutritional supplements increased visibility has occurred primarily because of the passage of the DSHEA in 1994. Under this act, the FDA no longer has regulatory control of supplements, including vitamin, mineral, amino acid, herbal, botanical, and other dietary substances, and any concentrated metabolite, constituent, extract, or combination of such ingredients. This has lead to an increased number of nutritional ergogenic aids on the market (Berning, 2004, p. 635; Steen & Coleman, 1999). Unlike medicines, which are regulated by the Medicines Control Council, there is no governing body to control and regulate the supplement industry in South Africa. Therefore sportspersons should ensure that the decision to use dietary supplements is a safe choice (Kohler et al., 2004).

Many athletes use nutritional ergogenic aids because they are bombarded with advertisements and testimonies from other athletes and coaches about their effect on performance (Berning, 2004, p. 635; Burke et al., 2002, p. 455; Steen & Coleman, 1999). Ergogenic aids are marketed to increase speed, prolong endurance, accelerate recovery, increase muscle mass and strength, reduce body fat, and increase resistance to fatigue, illness or infection (Burke et al., 2002, p. 455; Steen & Coleman, 1999). Unfortunately, most athletes believe that advertisements and anecdotes are proof of efficacy and safety. Most athletes are not aware of the inherent risks in using untested products, nor are they concerned about future health problems that may be caused by these products (Schwenk & Costley, 2002; Steen & Coleman, 1999).

The categories for supplements and ergogenic aids are dietary supplements, nutritional ergogenic aids, and banned substances.

2.4.2.1 Dietary supplements

The proposed definition of a dietary supplement is that it contains nutrients in amounts generally similar to the levels specified in the RDI and is similar to the amount found in foods, provides a convenient or practical means of ingesting these nutrients, particularly in the athletic setting, allows or aids the achievement of known physiological or nutritional requirements of an athlete, contains nutrient(s) in large amounts for use in treating a known nutrient deficiency, has been shown to meet a specific physiological or nutritional need that improves sports performance, is generally acknowledged as a valuable product by sports medicine and science (Burke et al., 2002, p. 461).

But unfortunately, some athletes use megadoses of supplements to increase LBM. Others view dietary supplements as a way of compensating for a lack of talent, training and motivation, even though it is clear that diet alone is not the road to successful performance in sport (Maughan, 2002a). Such attempts only cause modest increases in muscle tissue, with larger deposits of storage fat, and athletes get the opposite effect and this causes slowing down and exercise tiredness (McArdle et al., 1999, p. 213; Colwin, 1992, pp. 443-4). Therefore it is important for the athlete to appreciate that sports supplements per se do not produce a performance enhancement. Rather, it is a supplement to achieve sports nutrition goals or guidelines that allows the athlete to perform optimally (Burke et al., 2002, p. 460).

The swimmers that may require dietary supplements are those who restrict energy intake, use severe weight-loss practices, eliminate one or more food groups from their diet, or consume high-CHO diets with low micronutrient density (Manore et al., 2000). The suggestion is that swimmers should strive to consume diets that provide at least the RDA / AI (Table 6, 7 and 8) for all the micronutrients from food (Plowman & Smith, 1997, p. 338).

The recommendation of vitamins and minerals by Kohler et al. (2004) is one to one and a half times the RDA for vitamins and minerals a day (Wildman & Miller, 2004, p. 253).

An athlete needs to use supplements when his / her diet is inadequate (should be assessed by a dietician or nutritionist through a diet history). Supplementation to normal physiological levels can also improve performance when a deficiency is present (McArdle et al., 1999, p. 213; Plowman & Smith, 1997, p. 336). It is therefore preferable to guide these athletes to improve their eating patterns and a general multivitamin / mineral supplement may be useful for athletes who have low energy intakes or who travel extensively (Burke, 1999; McArdle et al., 1999, p. 213).

Nutrition education of athletes is needed to ensure that dietary supplements are used appropriately. In many cases, this information is specific to the athlete or the sport situation and may require one-to-one counseling. In most situations, the use of the supplement will be part of a larger plan of optimal sports nutrition or the clinical management of a nutritional plan. Effective education will not only ensure that dietary supplements are used for maximum benefit, but will also highlight the general importance of optimal nutrition for the athlete (Burke et al., 2002, p. 461).

Types of dietary supplement that meet the definition are: Sports drinks and high CHO supplements, sports gels, liquid meal supplements (sports shakes), sports bars and vitamin and mineral supplements (Burke et al., 2002, p. 461). These dietary supplements were already referred to in Table 4, 11, 12 and 13).

i) Sports drinks and high carbohydrate supplements

Researchers have demonstrated that CHO-containing sports drinks can enhance performance during endurance and intermittent higher intensity sports. Sports drinks may be broken into two categories: the classic fluid and replacement sports drink in which the CHO content is relatively low, which is more appropriate during exercise, and a higher CHO formulation that is more appropriate for the consumption after training sessions and in preparation for upcoming competition. The second type is sometimes referred to as recovery or loading beverages (Wildman & Miller, 2004, p. 335). Refer to the competition diet in 2.3.2.2.

ii) Sports gels

Sports gels provide a readily available energy source in easy-to-carry packets. A packet of sports gel tends to provide around 420 kJ from CHO. The primary CHO ingredients are often maltodextrin and some fructose. Like many sports foods, sports gels may have other benefits in the products than only providing of energy. For instance some products include BCAAs, anti-oxidant vitamins, potential stimulants, etc. Sports bars usually contain the same ingredients as sports shakes, so that sports bars could be viewed as dry shakes (Wildman & Miller, 2004, p. 337).

iii) Liquid meal supplements (sports shakes)

Sports shakes are a formulation of CHO, protein, fat, vitamins, minerals, and other nutrients and additives. Sports shakes come in powder or ready-to-drink form and are purchased by athletes and active people as well as the general public for use as snacks, meal replacements, and exercise recovery drinks (Wildman & Miller, 2004, p. 334).

iv) Sports bars

Spors bars represent one of the fastest growing areas of the sport food industry. These products provide energy and other nutrients and their composition can vary tremendously based on the intended consumer and purpose of the sports food (Wildman & Miller, 2004, p. 334).

v) Vitamin and mineral supplements

It is well established that performances suffer when an athlete’s diet is deficient in certain vitamins and minerals (Colwin, 1992, pp. 443-4). There is however no evidence that vitamin supplementation, in an adequately nourished individual, improves exercise or athletic performance, speeds up recovery, or decreases injuries (Maughan, 2002a; McArdle et al., 1999, p. 213; Plowman & Smith, 1997, p. 336). Therefore research needs to address the question of whether regular exercise training increases the body's requirements for vitamins and minerals above recommended values (McArdle et al., 1999, p. 213).

A researcher, Colwin (1992, pp. 443-4) suggested that the RDA of the DRI is probably not sufficient to meet the requirements of swimmers in training. But Manore et al. (2000) and Plowman & Smith (1997, p. 334) concluded that swimmers do not need vitamins and mineral supplements if adequate energy to maintain body weight is consumed of a variety of foods (Manore et al., 2000; Plowman & Smith, 1997, p. 334).

The suggestion is that swimmers should strive to consume diets that provide at least the RDA / AI and UL (Table 6, 7 and 8) for all the micronutrients from food (Plowman & Smith, 1997, p. 338). The recommendation of vitamins and minerals by Kohler et al. (2004) is one to one and a half times the RDA for vitamins and minerals a day. However, not all athletes consume a balanced diet, and many fall short of meeting the RDA / AI levels (Wildman & Miller, 2004, p. 253).

However, mega-dosing can be toxic, and can lead to impaired performance, and cause health problems, especially with regular excess intake of fat-soluble and, in some instances water-soluble vitamins (McArdle et al., 1999, p. 213; Plowman & Smith, 1997, p. 336). Supplementation with single micronutrients is also discouraged unless clear medical, nutritional, or public health reasons are present, because of the risk of overdosing (Manore et al., 2000). The UL is developed for athletes and supplement users (Deakin, 2002, p. 53), therefore these values can be used to assess the upper limit adequacy of vitamins and mineral supplementation.

2.4.2.2 Nutritional ergogenic aids

Sports supplements might be termed as nutritional ergogenic aids, and the following characteristics will determine this: contain nutrients or other food components in amounts greater than nutrient RDA levels, or the amounts typically provided by food, propose a direct ergogenic effect on sports performance, often through a pharmacological rather than physiological effect, often rely on theoretical or anecdotal support rather than on documented support from scientific trials, and are generally not supported by sports nutrition experts, except when scientific trials have documented a significant ergogenic effect (Burke et al., 2002, p. 462). But unfortunately, some athletes see ergogenic aids as sports nutrition (Hawley & Burke, 2002, p. 354).

The marketing of ergogenic aids is an international, multimillion-dollar business that preys on the desires of athletes to be the best, and when one item does not work or is discredited by research, another comes along to take its place (Manore et al., 2000). The term ergogenic means, “work producing” (Schwenk & Costley, 2002) or “capable of enhancing performance (Maughan, 2002a). Ergogenic aids are substances or devices used to improve exercise and athletic performance by improving the production of energy (Bucci, 1993, p.45-7).

These nutritional ergogenic aids are divided into three groups: a) nutritional ergogenic aids with clear scientific support, nutritional ergogenic aids with mixed scientific support, and nutritional ergogenic aids lacking substantial scientific support. By contrast the role of most the commonly sold nutritional ergogenic aids remain unsupported (Burke & Deakin, 2002, pp. 462, 505-6)

i) Nutritional ergogenic aids with clear scientific support

There is good evidence that creatine, bicarbonate, caffeine and erythropoeitin (Table 14) offer potential of performance benefits for specific athletes in specific situations (Berning, 2004, p. 653). Well-concluded research is helping to produce better guidelines for the appropriate use of such supplements.

Table 14: Ergogenic aids with clear evidence (Berning, 2004, p. 653; Juhn, 2003; Burke & Deakin, 2002, p. 478; Maughan, 2002; Schwenk & Costley, 2002; Brooks et al., 2000, p. 728; Maughan, 1999; (McArdle et al., 1999, p. 331)

ERGOGENIC AID	**MARKETING CLAIMS**	**COMMENTS**
Creatine	Increases power during anaerobic, short duration, high-intensity activity Enhances energy metabolism Increases muscle isometric strength Increases aerobic exercise performance	Creatine supplementation elevates muscle creatine levels and facilitates the regeneration of phosphocreatine by 12 to 18% which in turn helps regenerate ATP The typical regime involves an oral intake of 20 to 30 g daily (four 5-g doses per day) for 5 to 7 days, followed by a 2 to 5 g/day as a maintenance dose Because of the concerns about muscle cramping, muscle (hamstring) tears, electrolyte dilution, gastrointestinal upset, and dehydration, which may result from this osmotic load, water intake, is usually encouraged to be carefully monitored by trainers
Bicarbonate	Delays fatigue Enhances energy metabolism Improve performance	Increases rate of H^+ efflux from the exercising muscle and reduces the rate of fall of intracellular pH Ingest 0,3 g of sodium bicarbonate/kg body weight, 1 to 2 hours prior to exercise Abdominal cramps and diarrhea may occur about 1 hour after ingestion and vomiting are also frequently reported as a result of ingestion even relatively small doses of bicarbonate
Caffeine	Increases awareness Increases metabolic rate Reduces the perception of fatigue	Caffeine contributes to endurance performance, because of the stimulation of adrenaline secretion resulting in an enhanced mobilization of fatty acids from adipose tissue, increasing fat supply to the muscle, which in turn can increase fat

		oxidation, spare glycogen and thus extent exercise time A reasonable dose would be 5 mg/kg or 300 to 350 mg in a typical male aerobic athlete. This dose would be achieved by two to three cups of coffee, taken 1 to 2 hours before competition The effects of caffeine on the central nervous system are relatively mild and it is only a weak addictive but it can cause withdrawal effects and anxiety Other effects include insomnia, headache, gastrointenstinal irritation and bleeding, stimulation of diuresis, flushing, tachycardia, and trembling
Erythropoeitin	Improve the oxygen carrying capacity of blood Elevate hemoglobin and haematocrit values	A widely abused drug in the sporting world, particularly with the advent of recombinant human EPO, which allowed for convenient subcutaneous blood doping in the older days. Darbepoeitin, a newer product approved for chronic renal failure, is the newest agent The IOC has banned EPO and Darbepoeitin doping Potential adverse effects center on thromboembolic events due to the increased packed red blood cell count and viscosity after administration. The most common adverse effects seen with medical use of EPO are hypertension, seizures and thromboemlolic events.

ii) Nutritional ergogenic aids with mixed scientific support

Further research is needed to clarify the potential for β-hydroxy-β-methylbutyrate, glycerol and L-carnithine (Table 15).

Table 15: Ergogenic aids with mixed scientific evidence (Berning, 2004, p. 636; Juhn, 2003; Burke & Deakin, 2002, p. 485; Schwenk & Costley, 2002; Brooks et al., 2000, p. 726; Maughan, 1999; McArdle et al., 1999, p. 365; Steen & Coleman, 1999)

ERGOGENIC AID	**MARKETING CLAIMS**	**COMMENTS**
β-Hydroxy-β-Methylbutyrate (HBM)	Increase muscle mass Accelerates fat loss Anti-catabolic effect thus not truly anabolic	HBM is found in some foods such as catfish, citrus fruits and breast milk The recommended dose is 2 to 3 g/day and the typical dosage is 3 g/kg/day orally. There are no known contraindications or adverse effects
Glycerol	Promotes hyperhydration	One gram of glycerol per kg of body mass consumed with 1 to 2 liters of water represents the typical recommended pre-exercise glycerol dosage, and lasts up to 6 hours Effective protocols for glycerol hyper hydration are 1 to 1,5 g/kg glycerol with an intake of 25 to 35 ml/kg of fluid Side- effects from the use of glycerol include heartache, nausea, bloating, and head- aches resulting from an increased intra-cranial pressure
L-Carnithine	Improves cardiovascular function and muscle strength Delays fatigue Enhances energy metabolism Decreases muscle pain Decreases body fat	Carnithine is present in the diet in red meat and dairy products, but it can also be synthesized from lysine and methionine in the liver and kidney. Supplementation of the diet with carnithine is unlikely to be beneficial for athletes and certain forms of carnitine can be harmful. D/L-carnithine is toxic and decreases performance It has been shown to cause muscle weakness, muscle cramps and myoglobin in the urine

iii) Nutritional ergogenic aids lacking substantial scientific support

However, the majority of nutritional ergogenic aids sold to athletes seem unlikely to produce benefits, other than placebo effect for the athletes that believe in their promises and claims (Burke et al., 2002, p. 509). Table 16 gives examples of unproven ergogenic aids.

Table 16: Unproven ergogenic aids (Berning, 2004, p. 636, Schwenk & Costley, 2002; McArdle et al., 1999, p.692-6)

HERB	**MARKETING CLAIMS**	**COMMENTS**
Amino acid supplements	Promotes muscle development	E.g. glutamine, arginine, ornithine, glycine
Ginseng and related herbal products	Treat nervous disorders, anemia, wakefulness, dyspneoa, forgetfulness and confusion Prolonged thirst, decreases libido, chronic fatigue, angina and nausea	None of these mechanisms of action have been proven, nor the benefits demonstrated. Even the bioavailability of ginseng is suspect. The overuse of ginseng leads to hypertension, insomnia, diarrhea, and irritability, but all or some of these effects may be due to the coexistent ma haung.
Ginkgo	Improves cognitive function, cardiovascular system, counteracts effects of aging	Those using anticoagulants should not use ginkgo, because it delays blood-clotting time
Guarana	Enhances performance	Do not use if you are pregnant or have anxiety disorders, heart disease, high blood pressure or history of stroke. Keep use to a minimum.
Kelp	Vitamin/ mineral source, especially iodine	Kelp is seaweed Monitor for iodine allergy if kelp is used
Aloe	Supports the immune system, benefits cardiovascular system, increases energy level, promotes recovery and tissue repair	Before using, dab small amount behind ear or on underarm. If stinging or rush result, do not use
Cayenne	Eases stress reactions, supports immune system, assist digestion, improves sleep, promotes recovery and tissue repair	Can be used both internally and topically for pain relief. Do not use for prolonged periods. Keep away from eyes. Used as a pre-training stimulant
Echinacea	Supports immune system, promotes recovery and tissue repair	For internal use, free-dried form or alcohol-free extract is best. Do not use if you are allergic to plants in the sunflower family

Evening primrose	Supports the immune system, benefits cardiovascular system, assists digestion, alleviates pain, helps menstrual pain and cramps	A natural estrogen promoter
Garlic	Eases stress reactions, benefits cardiovascular system	Aged extract is the best form. Odorless supplements are available
Ginger	Benefits the cardiovascular system, relieves nausea	Internal use of large amounts may upset the stomach
St. Johnswort	Eases stress reactions, helps menstrual pains	Internal use in large amounts may heighten sun sensitivity, especially in fair skinned people. Interferes with absorption of iron and other minerals
Panagamic acid (Viatmin B_{15}) Vitamin B	Increases delivery of oxygen Reduces lactic acid build-up	From a nutritional perspective panagamic acid has no vitamin or pro-vitamin properties; it apparently serves no particular purpose in the body, in fact it can be harmful to humans.
Conjugated linoleic acid (CLA)	Anti-oxidant, Addition of LBM, Reduction of body fat Modulates serum glucose	CLA is a structured lipid
Lecithin	Decreases triglycerides and cholesterol levels	Lecithin is a phosphatidylcholine
Boron	Increases testosterone Anabolic agent	Boron is a nonmetallic trace element that influences calcium and magnesium metabolism Boron deprivation significantly affects bone tissue. Studies of postmenopausal women previously deprived of dietary boron showed that supplementing with boron augmented calcium and magnesium metabolism and increased testosterone levels Boron supplementation does not affect testosterone levels in individuals adequately nourished for this mineral. Until more research becomes available, the recommended intake of boron is not more than 10 mg per day An intake of more than 50 mg/day of boron may be toxic
Spirulina	Protein source	Spirulina is microscopic blue- green algae. It is also an excellent source of beta-carotene Probably does not function as a protein source, but supplies beta-carotene, a powerful anti-oxidant for which athletes may have increased needs

Bee pollen	Increases energy Enhances physical fitness	Allergic reactions in bee- sensitive individuals are the most common side-effect It should be avoided by those with gout, because of the content of nucleic acids
Yohimbine/ yohimbe bark	-Function as a alpha-2-adrenoreceptor blocker -Increases blood levels of norepinephrine, and -Stimulant	Yohimbine/ yohimbe can cause anxiety, insomnia, hypertension, dizziness, and head- aches

2.4.2.3 Banned substances

Governing organizations such as the National Collegiate Athletic Association (NCAA) and the International Olympic Committee (IOC) have banned and restricted certain substances. Thus if an athlete takes a banned substance (intentionally or inadvertently) and tests positive for it, the athlete will be disqualified from competition (Steen & Coleman, 1999).

In the case of pharmaceutical products, it is relatively easy and successful to prepare lists of proprietary products categorized into banned and permitted classifications. But laboratories are generally unwilling to test supplements because of the considerable liability involved with providing a false clearance (Burke et al., 2002, pp. 505-6).

There have recently been suggested a more suitable classification system that would include four categories: low risk (e.g. most sport foods, sports drinks, bars, gels, liquid meals, supplements, vitamins and minerals), unknown risk (e.g. supplements obtained via internet, mail-order) restricted (e.g. guarana), and banned (e.g. ephedra, strychnine, dehydroepiandrosterone (DHEA), androstenedione, pro-hormones (Burke et al., 2002, pp. 505-6).

The three most common forms of doping in sports are stimulants, anabolic steroids and narcotic analgesics (Coetsee, 1995, p. 118). Table 17 indicates substances and methods banned by the IOC.

Table 17: List of substances or methods banned by the IOC (Brooks et al., 2000, p. 707, 728; Burke & Deakin, 2002, p. 504)

CATEGORY	EXAMPLES
Stimulants	Pseudo- ephedrine (e.g. Sudafed) Ephedrine Amphetamine
Anabolic agents Anabolic and androgenic steroids Non-steroidal anabolic agents	Nadrolone DHEA Androstenedione Other agents with similar properties (e.g. 19-norandrostenedione and other pro-steroid hormones) Beta-2-antagonsit (excepts for inhalant of salbutamol and terbutaline)
Narcotic analgesics	Morphine
Diuretics	Frusemide (Lasix) Spironolactone (Aldactone)
Peptide and glucoprotein hormones and analogues	Human growth hormone Human chorionic gonatrophin Corticotrophin Erythropoeitin (EPO)
Beta- blockers	Atenolol Alprenolol Propranolol
Restricted β- anatgonists	Salbutamol Salmeterol
Blood doping	Blood doping or induced erthrocythemia, is an increase in blood volume by transfusion for the purpose of increasing oxygen capacity
Pharmacological, chemical and physical manipulations	Catheterization (drawing urine from bladder) Masking agents Swapping urine
Classes of drugs subject to certain restrictions	Alcohol Local anesthetics Corticosteroids Marijuana

2.5 CONCLUSION

Both BMI categories and BMI percentile tables can be used to categories height and weight in ideal ranges. The ideal weight of swimmers should not only be determined from BMI charts, but from the assessment of body composition. The direct measurement of body fat and lean body mass components is by chemical analysis, and the most frequently used indirect methods are skin-fold and girth measurements. Skin-fold measurements can be used to predict percentage body fat. Male and female swimmers have there own ideal percentage body fat. Ideal body weight can then be determined through these sport specific body fat percentages. The sum of the skin-folds scores can be used to monitor changes in body composition over time or “before and after” an intervention programme. Percentage body fat can be used to calculate LBM to give an indication of muscular composition. MUAC is a girth measurement and can be used to calculate MAMA and MAFA, these values also give an indication on lean body mass and fat status, respectively, therefore girth measurements gives a more complete anthropometrical evaluation.

Food records are the main method to assess dietary intake in elite athletes. The energy, macronutrients and micronutrients during training, before and during competition as well as after competition differ because each phase has its specific nutritional needs. Fluid needs should also be taken into consideration during these stages. The training diet should meet the energy demands of an athlete on a daily basis. Interventions immediately before and during competition enhance energy supply to delay the onset of fatigue. Consuming a recovery diet after competition helps to replenish glycogen stores effectively, especially when a swimmer has more than one event on a day or when events are held on consecutive days.

Interviews and questionnaires can be used to assess the use of supplements or ergogenic aids. Although dietary supplements can be used as a means to achieve sport nutrition goals, mega-dosing is contra-indicated, because toxicities can occur. Supplements and ergogenic aids are categorized in three groups: dietary supplements (e.g. sports drinks and high CHO supplements, sports gels, liquid meal supplements, sports bars and vitamin and mineral supplements), nutritional ergogenic aids (with clear, mixed and no scientific evidence), and banned substances (e.g. stimulants, anabolic steroids and narcotic analgesics).

CHAPTER 3

METHODS

3.1 INTRODUCTION AND OUTLINE

The aim of the study was to collect descriptive data of a swimming team practising at the HPC of Pretoria namely data on body composition, dietary intake and the use of supplements.

The methodology of the study will be discussed under the following headings: Study design, ethical considerations, sampling, work definitions, techniques, pilot study, study procedures, statistical analysis and problems encountered in the study.

3.2 STUDY DESIGN

A descriptive study design was used. A descriptive study means to identify the characteristics of an observed phenomenon, and it yields quantitative information that can be summarized through statistical analysis (Leedy & Ormond, 2001, p. 191).

3.3 ETHICAL CONSIDERATIONS

Ethical approval for this research study was gained from the Ethical Committee of the Faculty of Health Sciences of the University of the Free State.

Written consent was obtained from the manager of the HPC (Appendix A) to use their swimmers for the research study. Written informed consent was obtained from each participant (Appendix B) in the language of his / her choice.

3.4 SAMPLING

All the swimmers of the University of Pretoria (TUKS) Club swimming team at the High Performance Centre (HPC) in Pretoria meeting the inclusion criteria were included in the study.

3.4.1 Inclusion and exclusion criteria

Swimmers regardless of gender between the ages of 14 to 20 years that will participate in a competitive swimming event during the time of study.

Swimmers older than 20 years and younger than 14 years were excluded as well as swimmers who did not participate in a competitive swimming event during the time of research.

3.4.2 Sample size

From the 35 swimmers that trained at the HPC in Pretoria in the particular group, 25 of the swimmers met the inclusion criteria and participated in the study. Five of the HPC swimmers that did not meet the inclusion criteria for this study were used for the pilot study. Only 20 participants successfully completed the study.

3.5 WORK DEFINITIONS

Variables defined for the study included body composition, dietary intake and supplement use.

3.5.1 Body composition

Body composition for the purpose of this study refers to the body mass index (BMI), percentage body fat, lean body mass (LBM), mid upper arm circumference (MUAC), mid-arm muscle area (MAMA) and mid-upper arm fat area (MAFA).

3.5.1.1 Body mass index

BMI refers to current weight in kilograms (kg), divided by current height in meters squared (m^2), expressed as kg/m^2. The recommended ranges are > 18.5 to ≤ 24.9 kg/m^2.

For the purpose of the study the BMI percentiles for girls and boys refers to the percentile distribution of the National Centre for Health Statistics (Spear, 2004, p. 1187-8). An adequate BMI is between the 10th and 85th percentile for age.

3.5.1.2 Percentage body fat

Percentage body fat refers to the estimated percentage of body fat using:

(i) sum of six skin-folds (current TSF, biceps, subscapular, suprailiac, midaxillary and abdominal), together with gender and age in a formula to predict percentage body fat

(ii) TSF and subscapular skin-folds in a formula to predict percentage body fat

The average of these two formulas will be used to predict percentage body fat. The adequate percentage body fat for this study will be taken as between 5 to15 % for males and between 12 to 24 % for females (Manore et al., 2000).

3.5.1.3 Lean body mass

The lean body mass refers to the FFM (kg).

FFM is the remaining weight after the fat weight is subtracted from the total body weight. Adequate FFM for this study: female swimmers between 40.1 and 55.3 kg, and male swimmers between 60.5 and 70.1 kg (Siders et al., 1993).

3.5.1.4 Mid upper arm circumference

MUAC refers to the circumference of the upper arm at the triceps skin-fold site, measured half way between the acromion process of the scapula and the tip of the elbow (Hammond, 2004, p. 427; Lee & Nieman, 1996, p. 297). The adequate range of above the 15th or below and equal to the 85th percentile of Spear (2000, p. 1037) will be used for this study.

MAMA refers to the current TSF and MUAC used in a formula to predict MAMA. The adequate range of above the 15th and below or equal to the 85th percentile of Lee and Nieman (1996, p.306) will be used for this study.

MAFA refers to the current TSF and MUAC used in a formula to predict MAFA. The adequate ranges for TSF and MAFA of Lee and Nieman (1996, p. 302) are between the 15th and below or equal to 75th percentile and will be used for this study.

3.5.2 Usual dietary intake

Usual dietary intake refers to the usual energy and macronutrient intake of the training diet, pre-competition, competition, and recovery diets, and the micronutrient intake of only the training diet. Dietary intake will be categorized according to the RDA and / or AI of the DRIs (Spear, 2004, p. 289). Micronutrient intakes on the training diets that are below two-thirds (67 %) of the RDA / AI are considered inadequate.

The sport specific recommendations for the training diet are for energy between 13 700 to 16 000 kJ for males and 11 800 to 12 000 kJ for females per day (Spear, 2004, p. 289), a CHO intake of between 400 to 600 g per day, 60 to 70 % of the total energy per day (Berning, 2004, p. 625) as well as 8 to 10 g/kg per day (Wildman & Miller, 2004, p.454), a protein intake of 2 g/kg for swimmers 14 to 18 years of age (Berning, 2004, p. 630) and 1.2 to 1.4 g/kg for swimmers 19 to 20 years of age (Bean, 2003, p. 39), and a fat intake of between 20 to 30 % of the total energy per day (Berning, 2004, p. 631).

For the purpose of this study the pre-competition diet refers to the dietary intake on the pre-competition day, that is 24 hours before the competition. A CHO intake of 70 % of the total energy will be considered adequate for the pre-competition day.

Wildman and Miller (2004, p. 105) recommend a CHO intake of 70 % of the total energy for the pre-competition day (10 g/kg) as part of a glycogen-loading regime.

For the purpose of this study the competition diet refers to the dietary intake on the competition day. There are no sport specific recommendations to be assessed for adequacy. However, Manore et al. (2000) stated that foods high in protein and fat content should be eliminated from the diet on the day of competition, because of the slow digestibility of these foods. Therefore the protein and fat content of the training and the competition diet will be compared.

For the purpose of this study the recovery diet refers to the dietary intake on the post competition day, that is the period of 24 hours after the competition. A CHO intake of 500g in the 24 hours after the competition will be considered adequate.

3.5.3 Use of supplements

Supplements for the purpose of this study refer to only the use of dietary supplements including vitamins and mineral supplements, high protein replacement meals, high-CHO supplements, herbal supplements, nutritional ergogenic aids including, e.g. creatine, amino acids, glutamine, arginine, β-Hydroxy-β-Methylbutyrate **(**HBM) and other. Supplement use refers to the type, brand, amount, duration and reason for the use of vitamin and mineral supplements, as well as ergogenic aids. For the purpose of this study the nutritional value of the supplements was not included with the usual dietary intake.

3.6 TECHNIQUES

Anthropometrical techniques, food records and questionnaires were used to collect data for the study.

3.6.1 Anthropometrical techniques

Standard anthropometrical measuring techniques were used to determine weight, height, skin-fold thickness, and MUAC (Hammond, 2004, p. 423; (McArdle et al, 1999, p. 394; Lee & Nieman, 1996, p. 228-9, 252-6, 297). All the measurements were done two times by the same researcher and noted in Appendix C and if the two measurements did not correlate a third measurement was taken.

3.6.1.1 Weight and height

Body weight was obtained by the use of a calibrated electronic scale or a balance-beam scale with non-detachable weights. A combination of a stadiometer and an electronic scale were used for these measurements. The scale was placed flat on a flat, hard surface that allowed the scale to sit securely without rocking or tipping. The following procedures were followed to ensure reliability of the methods: The participants stood still in the middle of the scale's platform without touching anything and with the body weight equally distributed on both feet. The weight was read to the nearest 0.1 kg and was recorded. The participants wore minimal clothing, and they were measured with an empty bladder.

Height was measured by a standardized stadiometer. To ensure reliability the participants were measured barefoot and wore minimal clothing to facilitate correct positioning of the body. The participants had to stand with their heels together, arms to the side, legs straight, shoulders relaxed, and head in the Frankfort horizontal plane. Heels and buttocks, scapulae, and back of the head had to be, if possible against the vertical surface of the stadiometer.

As already mentioned should a swimmer's ideal competitive weight not be determined from an average appearing in standard height and weight charts or BMI, because it is not a reliable indication of body composition, therefore were percentage body fat, lean body mass, MAMA and MAFA determined (Berning, 2004, p. 634; McArdle et al., 1999, p. 405; Colwin, 1992). The BMI and height-weight charts are however useful for showing very lean athletes that they are not overweight (Deakin, 2000, p. 54).

3.6.1.2 Skin-fold measurements

A calibrated Harpenden caliper was used to take the following measurements. The following procedures were done to ensure the reliability of the skin-fold measurements: A minimum of two measurements was made at each site on the right side of the body with all the participants in a standing position. The researcher marked the site to be measured once it has been carefully identified.

A flexible, nonstretchable tape measure was used to locate midpoints on the body. Measurements were at least 15 seconds apart to allow the skin-fold site to return to normal.

The measurements were done before the training session, because if measurements are taken immediately after exercise or when a participant is overheated, the shift in body fluid to the skin will inflate normal skin-fold size and this can influence the reliability of the measurements. Readings were recorded to the nearest 0.2 mm. The following skin-folds were measured:

The triceps skin-fold was measured by taking a vertical skin-fold at the posterior midline of the upper arm, halfway between the tip of the shoulder and the tip of the elbow while the elbow remains in an extended, relaxed position.

The biceps skin-fold was measured by taking a vertical fold at the posterior midline of the upper arm.

The subscapular skin-fold was measured by taking an oblique fold just below the bottom of the scapula.

The suprailic skin-fold was measured by taking a slightly oblique fold just above the hipbone (crest of ileum) and the fold followed the natural diagonal line.

The midaxillary skin-fold was measured by taking a slightly oblique fold just above the hipbone (ileum), and the fold followed the natural diagonal line.

The abdominal skin-fold was measured by a horizontal skin-fold 3 cm to the right and 1 cm below the midpoint of the umbilicus.

3.6.1.3 Mid upper arm circumference

MUAC was measured by a flexible, nonstretchable tape at the triceps skin-fold site on the right side of the body. To ensure reliability of the measurements the site was marked and the arm was relaxed to the side with the palm of the hand facing the thigh. The tape was placed in contact with the arm without compressing the soft tissue. The measurement was recorded to the nearest 10 mm.

3.6.1.4 Calculations of percentage body fat, LBM, MAMA and MAFA

The body composition equations that were used for calculating percentage body fat, LBM, MAMA, MAFA are as follows:

Body density was first calculated for men and women by using a formula using skin-fold measurements and age (Figure 7). The Brozek equation was then used to determine percentage body fat. Another equation was used to predict percentage body fat with the TSF and subscapular skin-fold (Figure 8). An average of these two equations was calculated to represent the predicted percentage body fat.

Body density (women):

$1.09700000 - (0.00046971x\ X_1) + (0.00000056 \text{ x } X_1^2) - 0.00012828\ (X_2)$

Body density (men):

$1{,}11200000 - (0{,}00043499 \text{ x } X_1) + (0{,}00000055 \text{ x } X_1^2) - 0{,}00028826\ (X_2)$

X_1 = sum of triceps, biceps, subscapular, suprailiac, midaxillary and abdominal

X_2 = age

The Brozek equation will be used to determine percentage body fat:

Percent body fat = (457 / body density) – 414

Figure 7: Equation for body density and the Brozek equation (McArdle et al, 1999, p. 394,7)

BF% (women): 0.55 (Triceps) + 0.31 (Subscapular) + 6.13

BF% (men): 0.43 (Triceps) + 0.58 (Subscapular) + 1.47

Figure 8: Equation to predict body fat from triceps and subscapular skin-folds in young women and men (McArdle, 1999, p. 394)

LBM was then calculated by the formula of body mass minus fat weight (McArdle et al., 1999, p. 383-4, 397). Fat weight was calculated as percentage body fat times body weight; fat-free weight was determined as body weight minus fat weight (McArdle et al, 1999, p. 397). MUAC was used to calculate MAMA and MAFA in Figure 9.

$$\text{AA (mm}^2\text{) = Л/4 x } \frac{\text{MUAC}}{\text{Л}}$$

$$\text{MAMA (mm}^2\text{) = } \frac{\text{(MAC – Л (triceps)}^{2}}{\text{4 Л}}$$

$$\text{MAFA = AA – AMA}$$

Figure 9: MAMA and MAFA equation (Hammond, 2004, p. 427)

3.6.2 Food records

Food records are considered a valid method to determine usual dietary intake of athletes (Deakin, 2002b, p. 33-4). Food records were developed to assess the dietary intake of the training diet (Appendix D, Section A), and the pre-competition, competition and recovery diet (Appendix D, Section B to D). Examples of standard food records (Hammond, 2004, p. 421; Lee & Nieman, 1996, p. 508) were used to compile the food records. These four days were used to estimate the usual macronutrients intake because food intake differs the most during these days. The micronutrients content of the training diet for all the participants were separately compared to the RDA / AI of the age groups, and the gender was also taken into account.

The training of the participants to complete the food records were done to enhanced reliability of these records. An example of a sport related food item and an estimation the household portion size was added to the food records as well as the FFQ. These examples made the questionnaires more specific for the group and gave a better guidance for the participants to complete these questionnaires because the participants in the pilot study used these specific food items. The researcher also crosschecked the training day food record of each participant with his / her food frequency questionnaire (FFQ) (Appendix D, Section E). The crosscheck was done to see if a participant forgot about food items that were consumed on a daily basis. Food items in the FFQ that were not indicated in the training day food record were analyzed and then added to the energy, macro and micronutrient analysis of the training diet.

3.6.3 Questionnaires

A FFQ, a use of supplements questionnaire and a demographic questionnaire were used for this study.

3.6.3.1 Food frequency questionnaire

A FFQ was used to crosscheck for reliability of the training diet. The FFQ was adapted from Lee and Nieman (1996, p. 542). Sport specific items that were used by this specific group as determined in the pilot study, were included to improve the sport specificity and validity of the questionnaire (Appendix D, Section E).

FFQ measures usual dietary intake and may be more representative of ‘usual’ intake than repeated diet records. The limitations are that it is less accurate than food records. FFQ can overestimate low energy intake and can under-estimate high-energy intakes (Deakin, 2002b, p. 35-6). Burke and Deakin (2002, p. 39-40) suggested by using only the daily interval column with the house hold amount of the FFQ minimized this problem. Therefore in the present study, FFQ were only used to crosscheck the training day food records. Food items in the FFQ that were not indicated in the training day food record were added to the training diet food record and analyzed to calculate the usual macro- and micronutrient intake of the training diet.

3.6.3.2 Use of supplements questionnaire

A questionnaire (Appendix E) was used to gather information on the use of supplements by the participants. The researcher compiled the questionnaire for the use of supplements. An example of a questionnaire on the use of supplements of a previous study done by students of Dietetics of the University of Pretoria (2002) was used as a guideline.

Reliability of the use of supplements questionnaire was enhanced by the training of the participants to complete the questionnaire, as well as by adding examples of nutritional supplements, sport supplements and ergogenic aids that are currently available on the market in South Africa, as well examples used by swimmers in the pilot study. The participants had to complete the questionnaire by themselves and could take the questionnaire to their home. This method was also used suggested by Leedy and Ormrod (2001, p. 197), to ensure reliability so that the participants could respond to questions with the assurance that their responses will be anonymous, and so they may be more truthful than they would be in a personal interview, particularly when they are talking about controversial issues especially if ergogenic aids are being used. The researcher also crosschecked the use of the supplement questionnaire individually.

3.6.3.3 Demographic questionnaire

A demographic questionnaire (Appendix F) was compiled including the age, practicing data and perception of the influence of nutrition on sport performance. The reliability of the practicing data (e.g. hours, distances and days practiced) was enhanced by a cross check with the swimming coach.

3.7 PILOT STUDY

The demographic questionnaire and the use of supplements questionnaire, as well as the training day food record were tested in a pilot study that took place 5 weeks prior to the actual study. Five participants of the TUKS swimming team were used that did not meet the inclusion criteria of the study. They were trained with food models, in order to fill in the food record correctly.

No changes were made in the demographic questionnaire, however the supplements that are currently used by the pilot study participants were included as examples in the use of supplement questionnaire. The researcher included warm-up and practising times in all the food records after the food record were tested. This was done to help the participants to fill in the records correctly especially for the pre-competition, competition and recovery diet evaluation. The need for a FFQ was identified, after the testing of the training diet. This was needed for a crosscheck on the training diet food record for accuracy purposes. To improve the accuracy of the food records further, an example for the completion of the food records and the estimation of household portion sizes was added in all the food records.

It was not easy to get hold of the participants during the pilot study, because all participants were not always present at the practicing sessions. Therefore cell phone numbers were also included as a reference for cross checks if uncertainty arises especially when the food records were analyzed.

3.8 STUDY PROCEDURES

Study procedures are shown in Figure 10 and were planned according to the competition dates. The first competition was held at the end of March 2005 for the younger group, and the 2nd competition was held at the beginning of April 2005 for the older group. The study started in March 2005 and the duration of the study was two months, i.e. from four weeks before competition, to four weeks after competition. The participants were seen for three to five times for data gathering.

3.8.1 Informed consent

The manager of the HPC signed the consent form one week before the start of the research project. Each participant signed an informed consent form before participating in the study, 3 weeks before competition.

3.8.2 First contact session

During the first 3 weeks before competition, the participants were booked for individual sections (4 participants a day). Each participant completed the demographic information section of the questionnaire during this first session, three weeks before competition.

The researcher explained the questionnaire on the use of supplements during the first session and the questionnaire was handed out to the participants. This section was handed in after completion (the duration of one week) to the researcher.

3.8.3 Second contact session

The researcher took the skin-fold measurements during the participant’s second contact session, two weeks before competition. The researcher took the height and weight of all the participants during two separate sessions because not all of the participants were present in the first session. This was also completed in the same week.

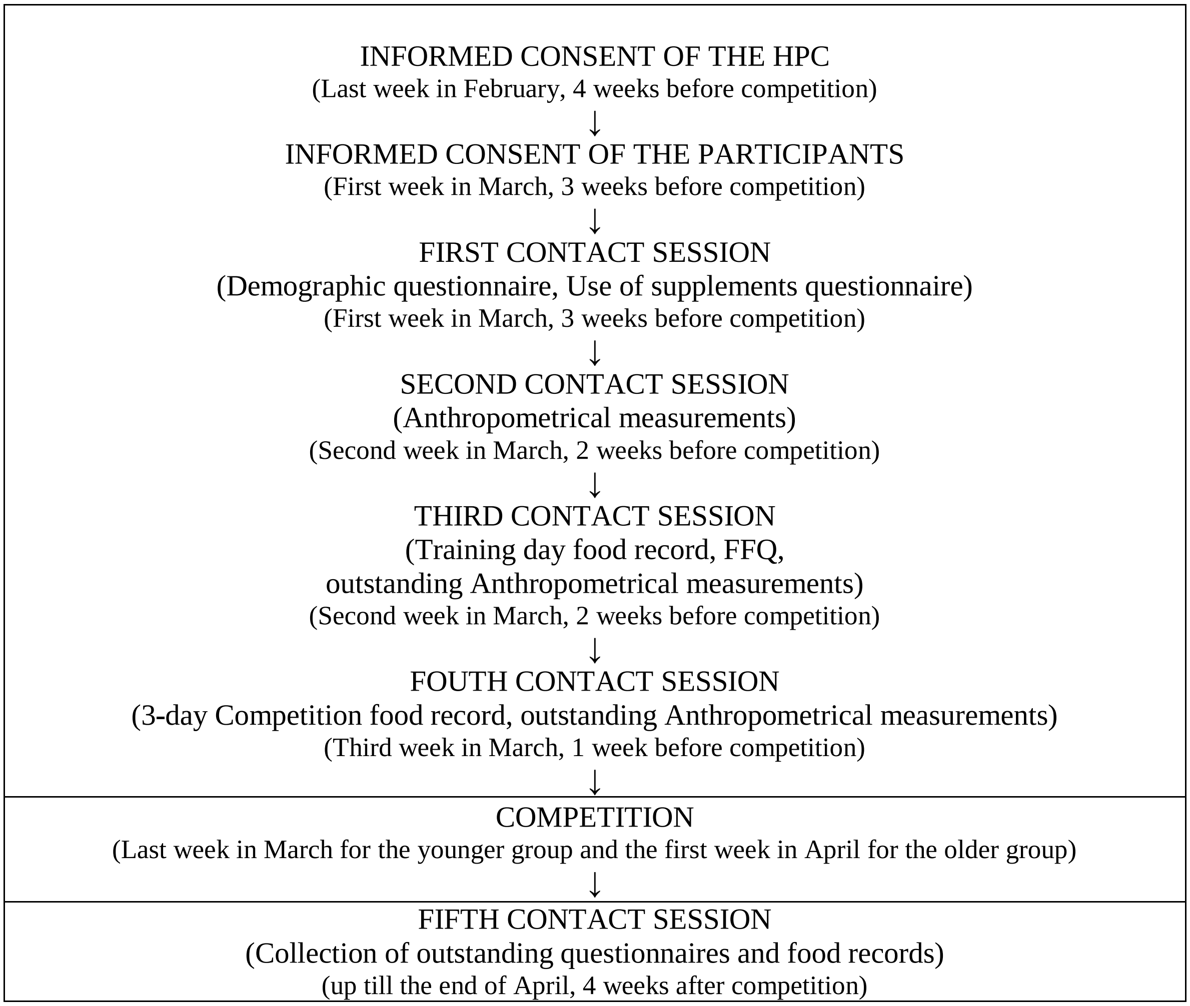

Figure 10: Flow diagram of the procedures of this research study

3.8.4 Third contact session

The researcher handed out the training diet food record together with the FFQ to each participant during the third contact session, also two weeks before competition. The researcher collected the training day food records of the participants individually (1 week before competition), and crosschecked the record to see if there was any problem.

If a participant was not present at the training session the coach collected the outstanding food records. The researcher then phoned these participants if there was any need for clarity of the food record.

3.8.5 Fourth contact session

The three-day competition food record was handed out during the fourth contact session, scheduled during the last week before competition. The researcher trained the coach to explain the importance of accuracy in completing the 3-day competition food record. The competition took place during the last week in March for the younger group, and during the first week of April for the older group.

3.8.6 Fifth contact session

The coach, the personal assistant of the manager of the HPC as well as the researcher herself collected the 3-day competition food records and outstanding training food records. This lasted up to four weeks after the competition (end of April). After the researcher had collected all the records from the above-mentioned persons, she checked the food records and phoned the participants in case of unclear data.

3.9 STATISTICAL ANALYSIS

Descriptive statistics, namely frequencies and percentages for categorical data and medians and percentiles for continuous data was calculated according to the Statistical Analysis System (SAS) by the Department of Biostatistics of the University of the Free State. The researcher used Microsoft Excel to compute dietary intake, use of supplements and demographical and anthropometrical data.

Body composition equations were used to calculate percentage body fat. The average of the Brozek formula, and the TSF and subscapular skin-fold equations were used. LBM was then calculated. MUAC and TSF were used to calculate MAMA and MAFA using the equations indicated by Hammond (2004, p. 427).

Macronutrients and micronutrients were further analyzed using the Food Finder computer programme. Data of male and female participants was analyzed simultaneously taking into account recommendations for age and gender.

3.10 PROBLEMS ENCOUNTERED DURING THE STUDY

3.10.1 Small sample size

The small sample size was the result of the implementation of excluding criteria and fall-out during the course of the study. Initially the sample consisted of 25 participants. Two swimmers then decided not to participate in a competitive swimming event and three more did not complete all the questionnaires that were needed for the study. The sample size finally consisted of 20 participants.

Another factor contributing to the small sample size was the appointment of a new coach and lack of motivation on the participants' side to complete the questionnaires, to train at optimal level and to be present at training sessions.

Although 80 % (20 of 25) of the selected swimmers completed the study successfully, the sample size is still relatively small and therefore the results of the research study cannot be generalized to all swimming populations.

3.10.2 Holidays directly after competition

The competition was held in Durban and some of the participants did not travel back to Pretoria but left to go on holiday directly after the event with the result that some of the food records and questionnaires could only be collected after the holidays.

CHAPTER 4
RESULTS

4.1 INTRODUCTION

The results of the study will be described under following headings: Demographical data, anthropometrical data, usual dietary intake and data on the use of supplements.

4.2 DEMOGRAPHICAL DATA

Demographical data incorporates age and training information (Table 18). The majority of the swimmers were male (60 %) and the median age of the group was 18 years. Training of the participants involved a morning and an afternoon practising session each day**.** The participants trained a median of six days per week with a median distance of 50 kilometers per week. The median training distance was eight kilometers lasting a median of four hours per day.

Table 18: Age and training information of the participants (N = 20)

VARIABLES	**MEAN**	**SD**	**25th PERCENTILE**	**MEDIAN**	**75th PERCENTILE**
Age	17.8	1.9	16	18	19
Practicing hours p/d	3.8	1.1	3	4	5
Practicing distance p/d (km)	7.9	2.8	5.5	8	10
Practicing distance p/week (km)	49	14	36	50	60
Practicing days p/week	5.9	0.4	6	6	6

All the participants indicated that they were aware of the important role that nutrition plays on swimming performance.

4.3 ANTHROPOMETRICAL DATA

Table 19 illustrates the anthropometrical data of the participants. The median weight and height of the group was 69 kg and 1.8 m respectively. The median BMI (22 kg/m^2) of the group was within the recommended range (> 18.5 to ≤ 24.9 kg/m^2), as well as between the recommended percentiles of 10th to 85th (Table 20).

The median of the percentage body fat predicted from the sum of 6 skin-folds equation was 6.2 %, while the predicted percentage body fat calculated from the TSF and subscapular skin-fold equation was 9.7 % (Table 19). The average of the two predicted percentage body fat values was taken as the total percentage body fat of the group and the median was 7.9 % (Table 19). The median LBM, which was calculated from percent body fat, was 62 kg for the group as indicated in Table 19.

Table 20 shows that the median percentage body fat of the group of males (6.1 %) and females (14.3 %) fell between the adequate ranges of between 5 and 15 % for males and 12 and 24 % for females. The median LBM of the group for the males (67.6 kg) and for the females (55.5 kg) was compared to the recommended amount of between 60.5 and 70.1 kg for males, and between 40.1 and 55.3 kg for females (Table 21). The LBM of 58 % of the males (7 of 12), and 50 % of the females (4 of 8) was between the ideal ranges. The LBM of 25 % (3 of 12) of the males and 50 % (4 of 8) of the females was above these ranges and the LBM of 17 % (2 of 12) of the males was under these recommended ranges (Table 21).

The median of MUAC for the group was 30 cm and the median TSF was 0.7 cm. The median MAMA (63.3 cm^2) (Table 19) calculated from MUAC and TSF was within the recommended range (> 15th - ≤ 85th percentile) (Table 20). The median MAFA (9.9 cm^2) also calculated from MUAC and TSF was also within the recommended range (> 15th - ≤ 75th percentile) (Table 20).

Table 19: Mean, SD, 25th, median and the 75th percentile anthropometrical data (N = 20)

VARIABLES	**MEAN**	**SD**	**25th PERCEN-TILE**	**MEDIAN**	**75th PERCEN-TILE**
Weight (kg)	66.7	8.7	66.3	69	74
Height (m)	1.8	0.1	1.7	1.8	1.8
BMI (kg/m^2)	22.2	1.4	21.6	22.2	22.9
MUAC (cm)	29.8	2.6	28.8	30	31
Triceps (mm)	8.9	5.1	5	6.8	12.9
MAFA cm^2	12.3	6.2	7.6	9.9	16.4
MAMA cm^2	58.7	14.4	46.8	63.3	69.0
Biceps (mm)	5	2.6	2.9	3.7	7.1
Subscapular (mm)	8.3	1.8	7.1	8.5	8.9
Supra iliac (mm)	9.8	5.6	6.55	8.2	10.5
Abdomen (mm)	9.3	4	6	9.6	10.5
Midaxillary (mm)	6.7	3.7	5	5.8	7.2
Sum of 6 skin folds (mm)	48.1	19.1	33.7	41.2	52.7
%BF predicted by sum of skin-folds	8.6	5.2	4.5	6.2	12.1
%BF predicted by TSF and subscapular	11.9	4.5	7.9	9.7	15.9
Total %BF	10.1	4.8	6.2	7.9	14.0
LBM (kg)	61.9	9.2	55.8	62.3	67.9

%BF = Percentage body fat

Table 20 illustrates the percentile categories for BMI, MUAC, MAMA, TSF and MAFA. Ninety five percent (n = 19) of the group was within the recommended percentiles of above the 15th to below and equal to the 85th percentile for MUAC. Eighty five percent (n = 17) of the group had above average MAMA percentiles for age. And fifty five percent (n = 11) and 65 % (n = 13) of the group fall between the recommended percentiles of above the 15th to below and equal to the 75th percentile of TSF and MAFA, respectively.

Table 20: Percentage participants in different BMI, MUAC, MAMA, TSF, MAFA percentiles categories

Percentile	n	%	n	%	n	%	n	%	n	%
			< 10		≥ 10 - ≤ 85		> 95			
BMI			-	-	20	100	-	-		
	≤ 5		> 5 - ≤ 15		> 15 - ≤ 85		> 85 - ≤ 95		> 95	
MUAC	-	-	-	-	19	95	1	5	-	-
MAMA	-	-	1	5	2	10	9	45	8	40
Percentile	< 5		5 - < 15		15 - < 75		75 - < 85		85 – 100	
TSF	2	10	7	35	11	55	-	-	-	-
MAFA	1	5	5	25	13	65	1	5	-	-

Table 21: The median percentile of % body fat (%) and LBM (kg) of males (n = 12) and females (n = 8) and comparison with the sport specific recommendations

	N	**%**	**RECOMMENDATIONS**	**MEDIAN**
PERCENTAGE BODY FAT (%)				
MALES	12	100	5 – 15%	6.1
FEMALES	8	100	12 – 24%	14.3
LBM (kg)				
MALES	7	58	60.5 – 70.1%	67.6
	3	25	> 70.1	67.6
	2	17	< 60.5	67.6
FEMALES	4	50	40.1 – 55.3%	55.5
	4	50	> 55 .3%	55.5

4.4 USUAL DIETARY INTAKE

The usual dietary intake of energy, macronutrients and micronutrients will be discussed.

4.4.1 Energy and macronutrients

The energy and macronutrient content of the training-, the pre-competition-, the competition- and the recovery diet was calculated.

4.4.1.1 Training diet

The energy and macronutrient content of the training diet is shown in Table 22. The median energy content of the training diet for the males was 12 832 kJ and for the females was 8 526 kJ. Although not shown in the table, three of 12 males (25 %) and all the female participants (n = 8) had a lower intake than the sport specific recommended energy intake of 13 700 to 16000 kJ for males and 11 800 to 12 000 kJ for females per day.

The median protein intake of the group was 16 % of the total energy per day and this was within the normal recommended ranges of 15 % to 20 % (Table 22). The median protein intake of the group between the ages of 14 and 18 year was 1.5 g/kg/day, which is lower than the recommended 2 g/kg/day (Table 22). The median protein intake of the group between the ages of 19 to 20 years was 1.8 g/kg/day, which is higher than the recommended intake for the age group (1.2 -1.4 g/kg/day) (Table 22).

Eleven out of 12 (92 %) of the swimmers of between 14 and 18 years of age had a lower protein intake than the recommendation of 2 g/kg/day, and one out of eight (13 %) of the swimmers between 19 and 20 years of age had lower protein intake than the recommendation of between 1.2 to 1.4 g/kg/day (not shown in the table).

The median CHO intake of the group was 396 g (59 % of total energy) per day (Table 22). The median CHO intake (g/kg) for the group was 5.8 g/kg, which was much lower than the recommendation of 8 to 10 g/kg CHO per day (Table 22).

Although not shown in the table, 50 % of the participants (10 of 20) had a lower CHO intake than the recommended 400 to 600 g per day. Fifty five percent of the participants (11 of 20) had a lower total CHO % intake than the recommended range of between 60 and 70 % of total energy.

According to Table 22, the median fat intake of the group was 29 % of the total energy per day. Eight of the 20 (40 %) participants had a higher fat intake than the recommended range of between 20 to 30 % of the TE per day (not shown in the table).

Table 22: The 25th, median and 75th percentile of the energy and macronutrient content of the training diet compared to sport specific recommendations

Energy and macronutrients	Sport specific recommendations (R)	25%	Median	75%
ENERGY				
Total energy (kJ)	13700 - 16000 (m)	10891	12832	15997
	11 800 - 12000 (f)	7053	8526	11088
PROTEIN				
Total protein (g)	-	75	103	131
% TE	15 - 20	13	16	18
g/kg	2 (14 – 18 yrs)	1.2	1.5	1.6
	1.2–1.4 (19 - 20 yrs)	1.2	1.8	2.0
CHO				
Total CHO (g)	400-600	310	396	501
CHO (g/kg)	8 – 10	4.4	5.8	7.9
% of TE	60-70	54	59	64
FAT				
Total fat (g)	-	59	82	112
% of TE	20-30	25	29	32

R = Sport specific recommendations f = female

TE = Total energy m = male

4.4.1.2 Pre-competition, competition and recovery diet

The median of the energy and macronutrient content of the pre-competition, competition and recovery diet of the swimmers was determined and compared with available sport specific recommendations (Table 23).

The median CHO for the group was 57 % of TE per day (Table 23). Although not shown in the table, all the participants had a lower CHO intake for the pre-competition diet 24 hours before competition compared to the recommendation of 70 % of TE per day (not shown in the table).

During the day of competition the diet should be low in protein and in fat. The protein and fat content of the training and competition diet was compared to determine if there was a difference in protein consumption and fat consumption. The median total protein intake of the training diet of 103 g (16 % of TE) for the group was more than the protein intake of the competition diet of 72 g (12 % of TE) (Table 23). The median total fat intake of the competition diet of 80 g (32 % of TE) of the group was more than the fat intake of the training diet of 82 g (29 % of TE) (Table 23).

The median CHO intake of the recovery diet (261 g) was compared to the recommendation of 500 g CHO 24 hours after competition (Table 23). Ninety five percent (19 of 20) of the participants did not meet this recommendation of the recovery diet (not shown in the table).

4.4.2 Micronutrients

The vitamin content of the training diet is shown in Table 24, while Table 25 shows the mineral content of the training diet. The mineral and vitamin content of the pre-competition, competition and recovery diet was not calculated. The median of vitamin and mineral intakes was determined for the training diet and the results were compared to the RDA / AI and the UL in percentages.

Table 23: Median macronutrients of the pre-competition and competition day and recovery diet compared to sport specific recommendations

Macronu-trients	**Sport specific recommenda tions(R)**	**Pre-Compe-Tition day**	**Compe-Tition day**	**Sport specific recommen-dations (R)**	**Recovery diet**
ENERGY					
Energy (kJ)	-	8681	8683	-	-
PROTEIN					
Protein (g)	-	87	72	-	-
% TE	-	16	12	-	-
CHO					
CHO (g)	-	276	330	500	261
% TE	70	57	58	-	-
FAT					
Fat (g)	-	71	80	-	-
% TE	-	29	32	-	-

R = Sport specific recommendations

TE = Total energy

The percentage participants below 67 % of the RDA / AI was also illustrated and was seen as an inadequate intake. The different requirements for the age group of 14 to 18 years (n = 12) and the group of 19 to 20 years (n = 8) were taken into consideration.

The following vitamin intakes of the swimmers were below 67 % of the RDA / AI: Vitamin E (n = 14), vitamin D (n = 9), vitamin C (n = 7), vitamin A (n = 5), folic acid (n = 4), biotin (n = 3), panthothenic acid (n = 3), thiamin (n = 3), niacin (n = 2), and riboflavin (n = 1) (Table 24).

Various minerals were taken in amounts below 67 % of the RDA / AI including sodium (n = 7), calcium (n = 5), iron, (n = 3), magnesium (n = 2), manganese (n = 2), phosphorus (n = 1) zinc (n = 1), and copper (n =1) (Table 25).

The median calcium intake (883mg) was lower the RDA / AI for the female swimmers and the median iron intake (15mg) was lower the RDA / AI for the females (19 to 20 years) (not shown in the table).

Table 24: Median vitamin intakes of the training diet compared to the RDA / AI, UL, % of RDA / AI and UL, % <67% RDA / AI (N=20)

VARIABLES	**RDA / AI**	**UL**	**MEDIAN**	**% of RDA/AI**	**% of UL**	**< 67%**	
						n	**%**
Vitamin A (μg)							
14 –18 yrs	700 (f) 900 (m)	2800	1029	119	36	5	25
19 – 20 yrs	700 (f) 900 (m)	3000					
Thiamin (B_1) (mg)							
14 –18 yrs	1 mg (f) 1.2 mg (m)	ND	1.9	165	4	3	15
19 – 20 yrs	1 mg (f) 1.2 mg (m)	ND					
Riboflavin (B_2) (mg)							
14 –18 yrs	1 (f) 1.3 (m)	ND	2.5	224	-	1	5
19 – 20 yrs	1.1 (f) 1.3 (m)	ND					
Niacin (mg)							
14 –18 yrs	14 (f) 16 (m)	30	33	204	106	2	10
19 – 20 yrs	14 (f) 16 (m)	35					
Vitamin B_6 (mg)							
14 –18 yrs	1.2 (f) 1.3 (m)	80	2.9	222	4	0	0
19 – 20 yrs	1.3 (f) 1.3 (m)	100					
Folic acid (μg)							
14 –18 yrs	400	800	326	82	39	4	20
19 – 20 yrs	400	1000					
Vitamin B_{12} (μg)							
14 –18 yrs	2.4	ND	6	250	-	0	0
19 – 20 yrs	2.4	ND					
Vitamin C (mg)							
14 –18 yrs	65 (f) 75 (m)	1800	138	183	7	7	35
19 – 20 yrs	75 (f) 90 (m)	2000					
Pantothenic acid (mg)							
14 –18 yrs	5	ND	6	117	-	3	15
19 – 20 yrs	5	ND					
Biotin (μg)							
14 –18 yrs	25	ND	47	187	-	3	15
19 – 20 yrs	30	ND					
Vitamin D (μg)							
14 –18 yrs	5	50	4	77	8	9	45
19 – 20 yrs	5	50					
Vitamin E (mg)							
14 –18 yrs	15	800	8	56	1	14	70
19 – 20 yrs	15	1000					

ND = Not determinable
f = female
m = male

RDA = Recommended Dietary Allowance
AI = Adequate intakes
UL = Tolerable upper intake level

Table 25: Median mineral intakes of the training diet compared to the RDA / AI, UL, % of RDA / AI and UL, % <67% RDA / AI (N=20)

VARIABLES	**RDA / AI**	**UL**	**MEDIAN**	**% of RDA/AI**	**% of UL**	**< 67%**	
						n	**%**
Calcium (mg)							
14 –18 yrs	1300	2500	1000	85	40	5	25
19 – 20 yrs	1000	2500					
Iron (mg)							
14 –18 yrs	15 (f) 11 (m)	45	23	209	51	3	15
19 – 20 yrs	18 (f) 8 (m)	45					
Magnesium (mg)							
14 –18 yrs	360 (f) 410 (m)	350	438	117	125	2	10
19 – 20 yrs	310 (f) 400 (m)	350					
Phosphorus (mg)							
14 –18 yrs	1250	4000	1653	168	41	1	5
19 – 20 yrs	700	4000					
Potassium (mg)							
14 –18 yrs	< 2000	ND	3021	151	-	0	0
19 – 20 yrs	< 2000	ND					
Sodium (mg)							
14 –18 yrs	< 3000	ND	2477	83	-	7	35
19 – 20 yrs	< 3000	ND					
Zinc (mg)							
14 –18 yrs	9 (f) 11 (m)	34	19	178	55	1	5
19 – 20 yrs	8 (f) 11 (m)	40					
Copper (μg)							
14 –18 yrs	0.89	8000	1.8	204	0.02	1	5
19 – 20 yrs	0.9	10000					
Manganese (mg)							
14 –18 yrs	1.6(f) 2.2 (m)	9	4.6	205	45	2	10
19 – 20 yrs	1.8(f) 2.3 (m)	11					

ND = Not determinable
f = female
m = male

RDA = Recommended Dietary Allowance
AI = Adequate intakes
UL = Tolerable upper intake level

4.5 USE OF SUPPLEMENTS

Thirteen of the twenty participants (65 %) used supplements (Table 26). The participants used these supplements every day (mornings or evenings) and / or before, during and after competition or training.

The participants used the following supplements: Protein supplements (10 of 13), multi-vitamin and mineral (7 of 13), vitamin C (6 of 13), iron (4 of 13), Spirulina (4 of 13), Creatine (3 of 13), calcium (3 of 13), magnesium (3 of 13), B-complex (3 of 13), sport drinks (3 of 13), Oil blends (1 of 13) and Kelp (1 of 13).

Table 26: Types of supplements used (N = 13)

TYPES	**PARTICIPANTS**	
	N = 13	**%**
Protein supplements	10	77
Multi- vitamin and mineral supplements	7	54
Vitamin C supplement	6	46
Iron supplement	4	31
Spirulina	4	31
Creatine	3	23
Calcium supplement	3	23
Magnesium supplement	3	23
B- complex	3	23
Sport drinks	3	23
Oil blends	1	8
Kelp	1	8

The participants used supplements for the following reasons: iron deficiency, to boost the immune function, for better concentration, for energy, to repair and to replenish muscle tissue, to replace losses, to maintain healthy body and mind, to increase muscle strength and endurance, to replace vitamin losses, to replace protein / CHO after training, to help for sprint training, for general health, to provide essential oils and, for a meal replacement.

4.6 SUMMARY

The participants trained mornings and afternoons for four hours in total per day. The training distance completed by the swimmers in one day was eight kilometers and in one week 50 kilometers. The median age of the group was 18 years. All the participants were sure that that nutrition has an influence on swimming performance.

The BMI of all the participants was within the ideal ranges (> 18.5 to ≤ 24.9 kg/m^2), as well as between the 10th and the 85th percentiles for age. The median percentage body fat of the group of males (6.1 %) and females (14.3 %) fell within the adequate ranges of between 5 and 15 % for males and 12 and 24 % for females. The LBM of 58 % of the males (7 of 12), and 50 % of the females (4 of 8) was within the ideal ranges. Twenty five percent (3 of 12) of the males and 50 % (4 of 8) of the females was above these ranges and 17 % (2 of 12) of the males was below these recommended ranges. Ninety five percent (n = 19) of the group was within the recommended percentiles of above the 15th to below and equal to the 85th percentile for MUAC. The MAMA of the group was 85 % (n = 17) above these recommended ranges. And 55 % (n = 11) and 65 % (n = 13) of the group fell between the recommended percentiles of above the 15th to below and equal to the 75th percentile of TSF and MAFA, respectively.

Fifty five percent (11 of 20) of the participants had a lower intake than the sport specific recommended energy intake of 13 700 to 16000 kJ for males and 11 800 to 12 000 kJ for females per day. Twelve of the 20 participants (60 %) had a lower protein intake than the recommended 2 g/kg/day for 14 to 18 years of age and 1.2 to 1.4 g/kg/day for 19 to 20 yrs of age. The mean CHO for the group was 5.8g/kg and were lower than the recommendation of 8 to 10 g/kg CHO per day. Fifty percent (10 of 20) of the participants had a lower CHO intake than the recommended 400 to 600 g per day. Eight of the 20 participants (40 %) had a higher fat intake than the recommended amounts of 20 to 30 % of the TE during training.

Before competition, all the participants had a lower CHO intake than the recommended 70 % of the TE per day. The median total protein intake of the training diet was more than the median protein intake of the competition diet. However the median total fat intake of the competition diet of the group was more than the median fat intake of the training diet. Ninety five percent of the group (19 of 20) had a lower intake of less than 500 g of CHO in the 24 hours of the recovery period after their competitive swimming event.

Three or more of the swimmers had an inadequate intake of the following vitamins and minerals: Vitamin E (n = 14), vitamin D (n = 9), sodium (n = 7), vitamin C (n = 7), vitamin A (n = 5), calcium (n = 5), folic acid (n = 4), biotin (n = 3), panthothenic acid (n = 3), and thiamin (n = 3). The median calcium intake (883mg) was lower the RDA / AI for the female swimmers and the median iron intake (15mg) was lower the RDA / AI for the females (19 to 20 years) (not shown in the table).

Thirteen of the twenty (65 %) participants used supplements. The participants used the following supplements: protein supplements, multi-vitamin and mineral, vitamin C, Iron, Spirulina, Creatine, Calcium, Magnesium, B-complex, CHO supplements, Oil blends and Kelp. The supplements that were mostly used in this group were protein supplements (10 of 13), multi vitamin and mineral supplements (7 of 13) and vitamin C supplements (6 of 13).

CHAPTER 5

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 DISCUSSION

The results of the study regarding body composition, usual dietary intake and the use of supplements will be discussed and compared with other research findings. This chapter will start with the limitations of the study.

5.1.1 LIMITATIONS OF THE STUDY

Due to the small sample size the result of the study cannot be generalized to all swimmers but they can be used to indicate tendencies. The study group is therefore not a representative sample of all swimmers and conclusions are meaningful only for this research population.

For the training diet the average of the three food records were unfortunately not calculated. For a more accurate representative of usual dietary intake an average of the three food records is needed. Also, the pre-competition meal was not separately calculated from the pre-competition day.

The supplements that were used by the participants were not analyzed and therefore could not be added to the usual dietary intake.

5.1.2 BODY COMPOSITION

The primary reason for body composition assessment in swimmers is to obtain information that may be beneficial to improving athletic performance (Manore et al., 2000; McArdle et al., 1999, p. 378).

The median BMI (22 kg/m^2) of the entire group fell within the adequate ranges as well as adequate percentiles range for age. However, the BMI offers limited value when evaluating physique for swimmers because overweight often relates to different aspects of body composition when describing physically active men and women (McArdle et al., 1999, p. 378; Colwin, 1992).

Skin-fold measurements were taken to predict percentage body fat, while MUAC and TSF were taken to calculate MAMA and MAFA. An average of two formulas (Brozek formula and TSF and subscapular skin-fold) were used to predict percentage body fat. The predicted percentage was used to calculate LBM of the swimmers.

The median percentage body fat of the present study group of males (6.1 %) and females (14.3 %) fell within the adequate ranges of between 5 % and 15 % for males and between 12 % and 24 % for females. Avlonitou et al. (1997) found that the percentage body fat of male and female swimmers was 11.8 % and 19.2 % respectively. The present study's results regarding body fat percentages are therefore consistent with Avlonitou's findings. Fifty five percent (11 of 20) and 65 % (13 of 20) of the group fell between the recommended percentile ranges of above the 15th to below and equal to the 75th percentile for TSF and MAFA respectively. Therefore, the risk of too little or too much body fat was probably not a reason for concern in the present study. The body composition of these swimmers was probably not a factor that could adversely affect their performance.

There is a theory that female swimmers have a better hydrodynamic position in the water due to a higher amount of fat tissue in their thighs, which allows them to float more easily, thus enabling better propulsion through water compared to male swimmers (Avlonitou et al., 1997). Avlonitou et al. (1997) found that the fat tissue of females (19.2 %) was higher than that of the male swimmers (11.8 %). This result is consistent with the result of the present study where the mean percentage body fat of the females (14.3 %) was also higher than males (6.1 %). This probably indicates that female swimmers have better hydrodynamic positioning due to higher amounts of fat tissue.

Swimming requires the use of a large portion of the body's musculature. A good portion of the forces needed for the various strokes comes from the large muscles of the upper extremity (Wildman & Miller, 2004, p. 453). The muscles of the legs play a smaller role and function to keep the hips, legs, and lower torso elevated. These large muscle groups need to be strong and high in endurance. Muscles of the abdomen also need to be strong in order to maintain proper body alignment (Wildman & Miller, 2004, p. 453). The LBM of 58 % of the males, and 50 % of the females was within the ideal ranges. The MUAC of 95 % of the group was within the recommended percentiles of above the 15th to below and equal to the 85th percentile. The same tendency was seen with the MAMA, where 85 % of the group had above average MAMA percentiles for their age. Therefore it seems that this group had a greater portion of LBM and this could possibly influence their performance positively.

According to the body composition recommendations of swimmers and the findings of other studies, it appears that the TUKS Club swimming team practicing at the HPC had an adequate BMI and a low percentage body fat level, as well as a greater proportion of LBM for muscular mass, which corresponds with an ideal body composition for swimmers.

5.1.3 USUAL DIETARY INTAKE

Limited research studies investigated the total energy expenditure of swimmers during training with a swimming volume of 16 to 20 km/day and a duration 5 to 6 hours/day (Trappe et al., 1997). Trappe et al. (1997) then determined the total energy requirements of female swimmers during high volume training (17.5 ±1.0 km/d) by the doubly labeled water method. The result for energy requirements was 23 490 ± 2079 kJ for female swimmers per day. Costill et al. (1997) estimate the total energy expenditure of male subject swimming 9.0 km/day as 19 600 kJ/day (Trappe et al., 1997). Hawley and Burke (1998, p. 21) showed that increasing the volume of training two-fold could impair both swim speed and performance over longer distances. These findings have led to the assumption that such a volume overload may not be necessary for optimal swimming performance (Payne et al., 2000). Another investigation by Trappe et al., (1997) examined female swimmers, with training distances (3.3 km/day or less) and found that the total energy expenditure of 11 012 to 12 717 kJ/day was relatively low (Trappe et al. 1997). The finding of Trappe et al. (1997) compares with the present study's median energy intake during the training diet (11 090 kJ) and the median training distances of eight kilometers per day.

In the present study, three of 12 males (25 %) and all the female participants (n = 8) had an inadequate energy intake during training. The estimated energy requirement of Spear (2004, p. 289) for very active adolescents is between 13 700 to16 000 kJ for males, and 11 800 to12 000 kJ for females. These 11 swimmers therefore might be at risk of not meeting energy requirements.

Strenuous daily training calls for a high energy, high-CHO diet (Burke, 1998, p. 170). Fifty percent of the group (10 of 20) had a lower CHO intake than the recommendation of 400 to 600g of CHO per day during training, and the median CHO for the group was 5.8 g/kg and was also lower than the recommendation of 8 to 10 g/kg CHO per day (Wildman & Miller, 2004, p.454). According to Manore et al. (2000), swimmers with inadequate CHO intakes might be at risk of not maintaining blood-glucose levels during exercise and not replenish muscle glycogen stores. In addition, Burke (1998, p. 170) stated that swimmers with inadequate CHO intakes might experience fatigue and muscle soreness. Maughan (2002b) and McArdle et al. (1999, p. 213) furthermore stated that dietary CHO may be necessary to ensure adequate glycogen resynthesis during periods of intensive training and that for some athletes the amount of CHO that must be consumed on a daily basis is even greater than the recommended 60 to 70 % of the TE. Fifty five percent of the present study group (11 of 20) did not meet the recommendations for CHO (60 to 70 % of the TE per day).

Eleven of the 12 swimmers of between 14 and 18 years consumed less protein than the recommended 2 g/kg/day, and only one of the 8 swimmers between 19 and 20 yrs had an inadequate protein intake, of below the recommendation (1.2 to 1.4 g/kg/day). Therefore

12 out of 20 swimmers were probably not meeting their protein needs, and might need to increase their protein intake. The fat intake of 40 % of the group (8 of 20) was higher than the recommended ranges of between 20 to 30 % of the TE per day.

Twenty-four hours before competition all the participants had a lower CHO intake than the recommended 70 % of the TE per day. Therefore the whole group of swimmers might not have the beneficial effect of a high CHO diet before competition. A high CHO diet enhances energy supply to delay the onset of fatigue, minimizes the negative effects of dehydration, and minimizes central nervous effects (Maughan, 2002b).

Manore et al. (2000) stated that foods high in protein and fat content should be eliminated from the diet on the day of competition, because of the slow digestibility of these foods. The median total protein intake of the competition day was 72 g (12 % of TE), and would probably not influence digestibility rate. However the median total fat intake on the competition diet (80 g; 32 % of TE), might lead to a slower digestibility rate.

A recovery diet restores muscle and liver glycogen stores, replaces of fluid and electrolytes lost in sweat and regeneration and repairs processes following catabolic stress and damage caused by exercise (Maughan, 2002c, p. 396-7). Nineteen of the 20 swimmers in the present study had a lower CHO intake after competition compared to the recommended amounts of 500 g in 24 hours. According to these recommendations most of the swimmers were probably at risk of not replenishing their glycogen stores, and this could lead to adverse performance in the next event.

Many researchers have addressed the question of whether regular exercise training increases the body's requirements for vitamins and minerals above recommended values (McArdle et al., 1999, p. 213). A study by Kohler et al. (2004) found that vitamin and mineral needs are increased from one to one and a half times the RDA. The micronutrients of the training diet were compared to the RDA / AI. Less than 67 % of the RDA / AI were seen as an inadequate intake of the specific vitamin or mineral. According to Berning (2004, p. 630) certain nutrients including folic acid, iron, the B-vitamins, calcium and zinc are of concern because of a possible insufficiency. In women athletes' special attention needs to be given to iron and vitamin B_{12}. In the present study there was a possibility of an insufficiency of the following micronutrients: vitamin E, vitamin D, sodium, vitamin C, vitamin A, calcium, folic acid, biotin, panthothenic acid and thiamin.

Research has shown that many athletes consume less folic acid than the RDA (Wildman & Miller, 2004, p. 272). This was confirmed by the present study where 20 % of the participants had an inadequate intake of folic acid. However, there is little known about the effect of exercise on folic acid metabolism, and researchers have not demonstrated a performance enhancing effect with supplementation, even when folic acid is below normal / recommended ranges in the body (Wildman & Miller, 2004, p. 272).

The participants with a low intake of B-vitamins in the present study might be at risk of a deficiency of cofactors for enzymes for the energy metabolism according to Folgelholm (2002, p. 312) and Wildman and Miller (2004, p. 253).

Adequate calcium intake is considered essential for bone remodeling and muscle hypertrophy induced by athletic training (Wildman & Miller, 2004, p. 257) and increased energy expenditure might result in free-radicals production in the body (Folgelholm, 2002, p. 312). As most of the participants in the present study had an inadequate intake of calcium and anti-oxidant nutrients, they might possibly be at risk of deficiencies. Inadequate calcium intake was also confirmed by the median calcium intake (883mg) of the female swimmers that was lower the RDA / AI of 1300mg (14 – 18 years) and 1000mg (19 – 20 years) per day. Therefore these females may be at risk for a decreased bone mineral density (BMD), which can lead to osteopenia and osteoporosis (Plowman & Smith, 1997, p.409).

Iron plays an important role in exercise, as it is required for the formation of hemoglobin and myoglobin, which bind oxygen in the body, and for enzymes involved in energy production (Manore et al., 2000; Burke, 1999). In the present study the participants with a low iron intake (3 of 20) may be at risk for a low iron status and therefore might experience early fatigue during training and competition. If untreated the swimmers might be at risk of developing an iron deficiency anemia (Berning, 2004, p. 631). Females and adolescent athletes are at higher risk of iron depletion and often have difficulty meeting iron requirements (Burke & Deakin, 2002, p. 273). In this present study the female swimmers (19 to 20 years) was at risk of iron depletion because their median iron intake (15mg) was lower the RDA / AI of 18mg per day.

The energy content of the training diet for 45 % (9 of 20) of the group in the present study was within the sport specific recommendations of between 13 700 to16 000 kJ for males, and 11 800 to12 000 kJ for females. However, 12 of the twenty (60 %) swimmers in our study had an inadequate energy intake during training. The mean CHO for the group was 5.8g/kg and were lower than the recommendation of 8 to 10 g/kg CHO per day. Fifty percent (10 of 20) of the participants had a lower CHO intake than the recommended 400 to 600 g per day during training. Twelve out of 20 (60 %) of the swimmers did not meet their protein needs during training and additional protein supplements were necessary. Eight of the 20 (40 %) swimmers had a higher fat intake than the recommended range of between 20 and 30 % of the TE per day. Three or more of the swimmers had an inadequate micronutrient intake and they needed to take a multi-vitamin/mineral supplement to prevent a deficiency. Before competition, all the participants had a lower CHO intake than the recommended 70 % of the TE per day. Ninety five percent (19 of 20) of participants had a lower CHO intake after competition compared to the recommended amounts of 500 g in 24 hours. Therefore, the usual dietary intake of most swimmers in the present study was inadequate. The swimmers who did not meet their energy and macro nutrient requirements needed to be educated.

5.1.4 USE OF SUPPLEMENTS

The need for vitamin and mineral supplementation in exercise has been reviewed by many researchers including, Haymes and Clarkson (1998) with the consensus that unless an individual is deficient in a given nutrient, supplementation with that nutrient does not have a major effect on performance (Berning, 2004, p. 630). There is also no evidence that vitamin supplementation, in an adequately nourished individual, improves exercise or athletic performance, speeds up recovery or decreases injuries (Maughan, 2002a; McArdle et al., 1999, p. 213; Plowman & Smith, 1997, p. 336). Thirteen out of 20 participants (65%) in our study used supplements. The participants used protein supplements, multi-vitamin and mineral, vitamin C, Iron, Spirulina, Creatine, Calcium, Magnesium, B-complex, CHO supplements, Oil blends and Kelp.

The participants with an inadequate intake of vitamin A, thiamin, riboflavin, niacin, folic acid, vitamin C, panthothenic acid, biotin, vitamin D, vitamin E, calcium, iron, magnesium, phosphorus, sodium, zinc, copper and manganese intake could have benefited from using supplements. Multi- vitamin and /or mineral supplements might be the best option, because a general multi –vitamin and/or mineral supplement might be useful for athletes who have low energy intakes (Burke, 1999; McArdle et al., 1999, p. 213) or a low intake of micronutrients. The sport drinks that were used might have increased the intake of CHO during training, pre-competition and after competition. However these supplements were not analyzed and nor were they added to food records. No definite conclusion can thus be made.

Fifty percent of the group (10 of 20) used a protein supplement. Athletes normally consume great amounts of protein or supplements (Lawrence & Kirby, 2002). When athletes have diets that are high in protein, they compromise their CHO status and may therefore affect their ability to train and compete at peak levels (Berning, 2004, p. 630). High protein intakes can also result in diuresis and potential dehydration. Protein foods are often also high in fat and a high protein diet can cause difficulty in maintaining a low-fat diet. In addition, the hyper-calciuric effect of high protein diets is still considered by some to be a significant factor in calcium balance, and until the controversy is settled, a conservative approach is advised (Berning, 2004, p. 630). However in the present study an excessive amount of protein consumption was not present, in fact some swimmers needed extra protein as six of the twenty swimmers had an inadequate protein intake.

Supplements are marketed to increase speed, prolong endurance, accelerate recovery, increase muscle mass and strength, reduce body fat, increase resistance to fatigue, illness or infection (Burke & Deakin, 2002, p. 455; Steen & Coleman, 1999), to prevent over training syndrome, to improve general health (Maughan, 1999; Steen & Coleman, 1999), to improve performance by sparing muscle glycogen (Berning, 2004, p. 636), to improve cardiovascular dynamics (Burke & Deakin, 2002, p. 490; McArdle et al., 1999, p. 355), to enhance energy production through the electron transport chain (Burke & Deakin, 2002, p. 490) and to reduce the oxidative damage in exercise (Burke & Deakin, 2002, p. 490), etc.

These above mentioned marketing claims are consistent with the reports of our study because the participants used supplements for the following reasons: iron deficiency, to boost the immune function, for better concentration, for energy, to repair and to replenish muscle tissue, to replace losses, to maintain healthy body and mind, to increase muscle strength and endurance, to replace vitamin losses, to replace protein / CHO after training, to help for sprint training, for general health, to provide essential oils and, for a meal replacement.

Thirteen of the 20 participants (65 %) in the present study used supplements. The participants used protein supplements, multi-vitamin and mineral, vitamin C, Iron, Spirulina, Creatine, Calcium, Magnesium, B-complex, CHO supplements, Oil blends and Kelp. Fifty percent of the group used a protein supplement. The participants needed these extra protein supplements because 30 % of the participants had a lower intake than recommended. Multi- vitamin and /or mineral supplements might be beneficial to participants with low micronutrient intakes.

5.2 CONCLUSIONS

Due to the small sample size the results cannot be generalized to other groups of swimmers. However the results were compared to other research studies to indicate tendencies.

According to the body composition recommendations of swimmers and the findings of other studies, it seems that an ideal body composition consists of a low body fat level and a high LBM. The median percentage body fat of the present group of male and female swimmers fell between the ideal ranges. The swimmers also had a high-normal LBM. The present study show that swimmers of the TUKS Club swimming team practising at the HPC had an adequate BMI, and a low percentage body fat level and greater proportion of LBM for muscular mass, which correlates with the ideal body composition for swimmers.

The usual dietary intake (training, pre-competition, competition and recovery diet) of the swimmers in the present study was inadequate for most of the swimmers. The energy content of the training diet in the present study was for 45 % of the group within the sport specific recommendations of between 13 700 to16 000 kJ for males, and 11 800 to12 000 kJ for females. However, three of 12 males (25 %) and all the female participants (n = 8) in our study did have an inadequate energy intake during training. The mean CHO for the group was 5.8g/kg and were lower than the recommendation of 8 to 10 g/kg CHO per day. Fifty percent of the participants had a lower CHO intake than the recommended 400 to 600 g per day during training. Twelve out of 20 swimmers were not meeting their protein needs, and additional protein intake is recommended for these swimmers. The fat intake of 40 % of the group was higher than the recommended ranges of between 20 to 30 % of the TE per day during training. Three or more of the swimmers had an inadequate micronutrient intake. Therefore these swimmers need to improve their dietary intake and if needed to add a multi-vitamin/ mineral supplement. Before competition, all the participants had a lower CHO intake than the recommended 70 % of the TE per day. The participants probably need to lower their fat intake of the competition diet. The CHO intake after competition should be increased, because 95 % of the group had a lower CHO than 500 g of CHO in 24 hours after competition. The swimmers that did not meet their energy and macro nutrient requirements during training, pre-competition, competition or recovery, or their micronutrient requirements during training, might not have had the beneficial effect of optimal nutrition during the stages of periodization and this could have made the difference between success and failure.

Thirteen of the 20 participants (65 %) in the present study used supplements. The participants used protein supplements, multi-vitamin and mineral, vitamin C, Iron, Spirulina, Creatine, Calcium, Magnesium, B-complex, CHO supplements, Oil blends and Kelp. An interesting observation was that 50 % the group used a protein supplement. The participants actually needed this extra protein supplement for a higher protein intake, because 30 % of the participants had a lower intake than recommended. The multi-vitamin and / or mineral supplements might also have been beneficial to the participants with low micronutrient intakes. However, with an inadequate dietary intake firstly measures should be taken to improve dietary intake and then if needed supplements can be added.

5.3 RECOMMENDATIONS

Body composition, usual dietary intake and the use of supplements were assessed and evaluated in the present study. Swimmers of the TUKS Club swimming team practising at the HPC had the ideal body composition. However, most of the swimmers had an inadequate dietary intake during training, during pre-competition, during competition and during recovery. Thirteen of the twenty swimmers used supplements and these protein and multi-vitamin mineral supplements might have made a difference in a more adequate protein and micronutrient intake. Nutrition education regarding dietary intake as well as the beneficial effect of supplements, is recommended.

According to the findings of this study nutrition education program that will address the following is recommended:

- Training diet, with special emphasis on the protein CHO and fat intake;
- pre-competition diet, including the pre-competition meal, especially when a swimmer competes in more than one event or an endurance race;
- food and fluid intake during competition; and
- the recovery diet. The recovery diet is especially important when swimmers compete in more than one-day swimming events where recovery is especially important for the next day event. Education on post-exercise nutrition is therefore definitely needed.

A limitation of the study is that the supplements that were used by the participants were not analyzed and therefore could not be added to the usual dietary intake. A new research study, adding these supplements to the usual dietary intake could be done. Another recommendation for a future study can be to take the average of the training, pre-competition, competition and recovery food record for more reliable results on usual dietary intake. A similar study could also be performed to calculate a pre-competition meal separately from a pre-competition day.

The value of this present study lies in identifying problems in the swimming team in body composition, dietary status and the use of supplements. Maughan (2002a) concludes that at the elite end of the spectrum where all athletes have the genetic potential to succeed and where all have undergone the most rigorous preparation, attention to diet can make the difference between success and failure. This present study may therefore contribute to an improved swimming performance because nutrition education programmes could be developed for swimmers according to the problems identified in the study.

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APPENDIX A

INFORMED CONSENT – THE HIGH PERFORMANCE CENTRE

The dietary intake, anthropometrical status and supplement use by swimmers practicing at the High-Performance Centre, Pretoria

The Director
High Performance Centre

The researcher is interested in determining the nutritional status of swimmers in order to use this information for future research, and to determine if there is a need for nutritional intervention.

You are requested to give informed consent that the researcher may use this institution for this research study. The study will investigate the dietary status, anthropometrical profile and the use of supplements by swimmers.

A swimmer's diet needs to contain the essential nutrients in sufficient quantities to support his energy expenditure during training, pre-competition, competition and recovery. The swimmer's performance can be negatively influenced, if he does not have an adequate diet during these periods.

The following information will be obtained from each swimmer:

a) demographic data,
b) information on the use of supplements,
c) anthropometrical measurements and
d) a training food record and 3- day competition food record.

If you have any questions prior to this study or at any time during the study, please do not hesitate to contact the researcher. You will benefit from this study by obtaining information about the swimming team and specifically its diet requirements. These findings will be published in a sports journal.

AUTHORIZATION: I have read the above and understand the nature of this study. I understand and that I may contact the researcher, Liesl Mennen at any time. I agree to give consent that this research study may proceed at the HPC.

Director's name: ________________ Signature: ______________Date:______________

Researcher's name:_______________ Signature: _______________ Date: _____________

APPENDIX B

INFORMED CONSENT OF THE PARTICIPANTS:

The dietary intake, anthropometrical status and supplement use by swimmers practicing at the High Performance Centre, Pretoria

You are being asked to participate in a study investigating the dietary status, anthropometrical profile and the use of supplement of swimmers. These results will be published in as sports journal.

The aim of the study is to determine the nutritional status of swimmers and to use the information to determine the need for nutrition education and further research.

A swimmer's diet needs to contain the essential nutrients in sufficient quantities to support their energy expenditure during training, pre- competition, competition and recovery. The swimmer's performance can be negatively influenced, if he/she does not consume an adequate diet during these periods.

If you agree to participate, the following information will be obtained: a) demographic data b) information on the use of supplements c) anthropometrical measurements and d) a food record of a typical training day and a 3- day food record of typical pre-competition, during competition and post competition days.

Your participation is voluntary. If at any time during this study you wish to withdraw your participation, you are free to do so without any prejudice.

If you have any questions prior to your participation or at any time during the study, please do not hesitate to contact the researcher. You will benefit from this study by obtaining information about your own optimal training diet programme.

AUTHORIZATION: I have read the above and understand the nature of this study. I understand that by agreeing to participate in this study I have not waived any legal or human right and that I may contact the researcher, Liesl Mennen at any time. I agree to participate. I understand that I may refuse to participate or I may withdraw from this study at any time.

Participant's name: ________________Signature: _________Date: _________________
Researcher's name:________________Signature: __________Date: _________________

APPENDIX B

INGELIGTE TOESTEMMING VAN DIE DEELNEMERS

Dieet-inname, antropometriese status en die gebruik van supplemente deur swemmers wat oefen by die High Performance Centre, Pretoria

U word gevra om deel te neem aan ‘n studie om die dieetinname, antropometriese profiel en die gebruik van supplement deur swemmers te bepaal. Die resultate sal gepublisseer word in ‘n erkende sportjoernaal.

Die doel van die studie is om die voedingstatus van swemmers te bepaal om die inligting te gebruik asook om te bepaal of voedingvoorligting en verdure navorsing nodig is.

‘n Swemmer se dieet benodig die noodsaaklike voedingstowwe in toereikende hoeveelhede om die energie-verbruik tydens oefening, voor kompetisie, tydens kompetisie, en tydens herstel te ondersteun. Die swemmer se prestasie kan negatief beïnvloed word, indien die swemmer se dieet nie toereikend is nie gedurende die tydperke.

Indien u sou instem om deelteneem, sal die volgende inligting ingesamel word: a) agtegrondinligting, b) supplementgebruik, c) antropometriese data, en d) ‘n voedselrekord van ‘n tipiese dag in die oefen seisoen,and ‘n 3- dag voedselrekord van ‘n tipiese voor-kompetisie, tydens kompetisie an na kompetiese dag.

U deelname is vrywillig. Indien u gedurende die studie u deelname wil staak, is u vry sonder enige bevooroordeling.

Indien u enige vrae voor of gedurende deelname het, is u welkom om die navorser te kontak. U sal voordeel trek deur deel te neem deur inligting te ontvang van u eie optimale diet- en oefenprogramme.

MAGTIGING: Ek het die bogenoemde gelees, en verstaan die doel van die studie. Ek verstaan deur aan die studie deel te neem al my menseregte steeds geld, en ek enige tyd die navorser, Liesl Mennen, mag kontak. Ek verstaan ook dat indien ek besluit om deelname gedurende die studie te staak, ek dit enige tyd mag doen. Ek verklaar vervolgens dat ek bereid is om aan die studie deel te neem.

Deelnemer naam: ____________Handtekening:___________Datum: ________________
Navorser naam:______________Handtekening:___________Datum: ________________

APPENDIX C

ANTHROPOMETRICAL DATA

For office use

Participant no.:__________________________
Date: _________________________________

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INDICES	**FIRST**	**SECOND**	**THIRD**	**AVERAGE**
Weight (kg)				
Height (m)				
MUAC (mm)				
TSF (mm)				
Subscapular (mm)				
Biceps (mm)				
Subscapular (mm)				
Supra-iliac (mm)				
Abdomen (mm)				
Midaxillary (mm)				
%BF (i)				
%BF (ii)				
Fat weight				
LBM				
Sum of the skinfolds				

Participant no: ____________________
Date: ____________________________

APPENDIX D

FOOD RECORD: Section A: Training diet

Write down everything you eat or drink and the amount in the columns provided for a typical training day. Indicate also the warm-up times and practicing times.

	FOOD OR BEVERAGE	AMOUNT	TIME AND PLACE	DESCRIPTION OR EXTRAS
Example	White bread	2 slices	8.00 (home)	with margarine and cheese
	Tea	1 cup	10.00 (coffee shop) 11.00 (warm-up)	with full cream milk and 2 teaspoons of sugar
Breakfast				
Snack				
Lunch				
Snack				
Dinner				
Snack				

Participant no: ____________________
Date: ____________________________

APPENDIX D

FOOD RECORD: Section B: Pre- competition diet

Write down everything you eat or drink and the amount in the columns provided for a pre-competition day, thus the food and drinks consumed the day before competition. **Indicate also the warm-up times and practicing times.**

	FOOD OR BEVERAGE	AMOUNT	TIME AND PLACE	DESCRIPTION OR EXTRAS
Example	Fruit juice	1 cup	12.00 (home)	Liquifruit
	Energy/ Sports bar	1 small bar	14.00 (pool) (14.30 started practicing)	USN bar
Breakfast				
Snack				
Lunch				
Snack				
Dinner				
Snack				

Participant no: ____________________
Date: ____________________________

APPENDIX D

FOOD RECORD: Section C (a): Competition diet

Write down everything you eat or drink and the amount in the columns provided for a competition day, thus the food and drinks consumed on the day of competition. **Indicate also the warm-up times and competition times.**

	FOOD OR BEVERAGE	AMOUNT	TIME AND PLACE	DESCRIPTION OR EXTRAS
Example	Fruit juice	1 cup	12.00 (home)	Liquifruit
	Energy/ Sports bar	1 small bar	14.00 (pool) (14.30 1st event)	USN bar
Breakfast				
Snack				
Lunch				
Snack				
Dinner				
Snack				

At what time did your last event end? ____________

Participant no: ____________________
Date: ____________________________

APPENDIX D

FOOD RECORD: Section C (b): Competition diet

Write down everything you eat or drink and the amount in the columns provided for a competition day, thus the food and drinks consumed on the last day of competition. **Indicate also the warm-up times and competition times.**

	FOOD OR BEVERAGE	AMOUNT	TIME AND PLACE	DESCRIPTION OR EXTRAS
Example	Fruit juice	1 cup	12.00 (home)	Liquifruit
	Energy/ Sports bar	1 small bar	14.00 (pool) (14.30 1st event)	USN bar
Breakfast				
Snack				
Lunch				
Snack				
Dinner				
Snack				

At what time did your last event end? ____________

Participant no: ____________________
Date: ____________________________

APPENDIX D

FOOD RECORD: Section D: Recovery diet

Write down everything you eat or drink and the amount in the columns provided for a recovery day, thus the food and drinks **consumed for 24 hours after competition (thus day and night)**

	FOOD OR BEVERAGE	**TIME**	**QUANTITY**
Directly after competition			
30 minutes after competition			
1 - 2 hours after competition			
2 - 3 hours after competition			
3 - 4 hours after competition			
4 - 24 hours after competition			

APPENDIX D

FOOD FREQUENCY QUESTIONNAIRE: SECTION E

Mark with an X when applicable.

FOOD GROUP	**FREQUENCY**				
	Every day **Include brand + amount**	**3 to 4 times a week**	**Once to twice a week**	**Every 2- 4 weeks**	**Never**
Example: Soft drink Salad	X (Coke- 370 ml)	X			
Diary					
Milk					
Yogurt					
Cheese					
Protein					
Red meat					
Chicken					
Fish/ seafood					
Egg					
Soy					
Starch					
Cereal					
Porridge					
Bread					
Pasta					
Beans/ lentils					
Starchy vegetables (e.g. potatoes)					
Vegetables					
Fresh/ canned/ frozen/ dried					
Juice					
Fruit					
Fresh/ canned / dried					
Juice					
Fats					
Margarine/ butter					
Oil					
Salad dressing, mayonnaise					
Other					
Alcohol					
Cool drink					
Sweets, cakes					
Chips					
Tea/ coffee					
Sugar					
Sports / Energy bar					

Chocolates					

APPENDIX E

USE OF SUPPLEMENTS QUESTIONNAIRE

For office use

Participant no. ________________________

Date: __________________________________

☐☐ 1-2

Please fill in this table where applicable.

Type	**Type** and **brand name**	**Amount** and **how often?**	**For how long are you using them?**	**When do you use them?**	**Reason for use**
Dietary supplements E.g. Vitamin and mineral supplements, high-protein replacement meals, high carbohydrate supplements, herbal supplements					
Nutritional ergogenic aids E.g. Creatine, amino acids, glutamine, arginine, HBM					
Other					

APPENDIX F

DEMOGRAPHICAL DATA QUESTIONNAIRE

Participant no.:___________________________
Date: ___________________________________

Mark the appropriate block with an X or write your answer on the space provided

1. What is your age?
_____________________________ years

2. What is your gender?

Male (1)	Female (2)

3. How many hours per day do you practise?
___________________ hours

4. Practicing distances per day
___________________________ kilometers

5. Practicing distances per week
__________________________ kilometers

6. How many days do you practise per week?
___________________ days

7. Do you believe nutrition plays a role in your swimming performance?

Yes (1)	No (2)

8. Do you use supplements?

Yes (1)	No (2)

If yes continue with section B, if no do not continue

For office use

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☐☐ 3-4

☐ 5

☐☐ 6-7

☐☐☐☐ 8-11

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☐ 17

☐ 18

☐ 19

SUMMARY

The development of sports institutions and High Performance Centres are on the increase worldwide and also in South Africa. These hotels and ‘athlete villages’ can provide unsuitable food choices and lack of supervision may further encourage poor eating patterns among young swimmers. A swimmer’s diet needs to be adequate in the essential nutrients to support his energy expenditure during training, pre-competition, competition and recovery. The mean ages for elite swimmers fall into the stage of puberty; and this also has an influence on nutrient requirements. The body composition of a swimmer as well as the percentage body fat has a direct relationship with body drag, because body fat increases the resistance of the body in the water. Physiological adaptations of the body take place when an efficient training programme is followed in combination with adequate nutrition.

The purpose of this study was to determine: a) the body composition (including the body mass index (BMI), percentage body fat, lean body mass (LBM), mid-arm muscle area (MAMA) and mid-upper arm fat area (MAFA) of swimmers, b) the energy, macronutrient and micronutrient content of the usual diet of swimmers (including the training, pre-competition, competition and recovery diet) and c) the use of supplements by swimmers.

A descriptive study design was used for data gathering on demographics, anthropometrics, usual dietary intakes as well as information on the use of supplements. The study was done on the University of Pretoria club (TUKS) swimming team practising at the High Performance Centre in Pretoria.

Anthropometrics included skin-fold measurements to predict percentage body fat and to calculate LBM (lean body mass); MUAC (mid upper arm circumference) to determine MAMA (mid arm muscle area) and MAFA (mid arm fat area). Demographical data with information on the use of supplements was obtained by a questionnaire, and the usual dietary intake data was obtained from food records. The data was then compared to the recommended amounts or the RDA (recommended dietary allowances) and AI (adequate intakes).

The swimmers had an adequate BMI, a low percentage body fat level and greater proportion of LBM for muscular mass, which correlates with an ideal body composition profile for swimmers.

The usual dietary intake (training, pre-competition, competition and recovery diet) was inadequate for most of the swimmers. Three of 12 males and all the female swimmers (n = 8) had an inadequate energy intake during training. Fifty percent of the swimmers had a lower CHO intake than recommended. These swimmers might have been at risk of not maintaining blood-glucose levels during training. Twelve out of 20 swimmers were not meeting their protein needs. The fat intake of 40 % of the swimmers was higher than recommended. Before competition all the swimmers had a lower CHO intake than recommended. They might not have had the beneficial effect of a high CHO diet before competition. The group had a high fat intake during competition. Ninety five percent of the swimmers had a lower CHO intake than recommended after competition. Most of the swimmers were at risk of not replenishing glycogen stores. Sixty five percent of the swimmers used supplements.

A need for nutritional intervention was identified, focusing on the nutritional needs of a swimmer during training, pre-competition, competition and recovery.

KEYWORDS: Body composition, body mass index, skin-fold measurements, percentage body fat, lean body mass, mid upper arm circumference, usual dietary intake, supplements

OPSOMMING

Die ontwikkeling van sportinstitusies en hoëprestasiesentrums (‘High Performance Centres’) is wêreldwyd en ook in Suid-Afrika aan die toeneem. Hierdie hotelle en ‘atleetdorpe’ kan ongeskikte voedselkeuses bied en gebrek aan toesig mag by ‘n jong atleet ‘n ongewenste eetpatroon tot gevolg hê. ‘n Swemmer se dieet moet genoegsame essensiële voedingstowwe voorsien om energieverbruik tydens oefening, voor deelname / kompetisies en in die herstelfase te ondersteun. Kompeterende swemmers is meestal in hul puberteitsjare en dit het ook ‘n invloed op voedingsbehoeftes. Die liggaamsamestelling van ‘n swemmer asook vetpersentasie het ‘n direkte invloed op liggaamsweerstand, want ‘n verhoogde persentasie liggaamsvet vermeerder liggaamsweerstand. Fisiologiese veranderinge vind plaas met ‘n effektiewe oefenprogram en optimale voeding.

Die doel van die studie was om die voldende te bepaal: a) die liggaamsamestelling (insluitenede ligaamsmassa-indeks (BMI), persentasie ligaamsvet, maer liggaamsmassa (LBM), middelarm-spierarea (MAMA) en middelarm-vetarea (MAFA) van (swimmers XX) swemmers, b) die energie, makronutriënt- en mikronutriëntinhoud van dieetinname van swemmers (insluitende die oefening-, voor-kompetisie-, kompetisie en na-kompetisiedieet) en c) die gebruik van supplemente by swemmers.

‘n Beskrywende studie-ontwerp is gebruik om data van demografika, antropometrika, dieetinname en inligting oor die gebruik van supplemente in te samel vanaf die Universiteit van Pretoria (TUKS-klub) se swemspan wat oefen by die hoëprestasiesentrum (High Performance Centre) in Pretoria.

Antropometrika het vetvoumetings ingesluit wat persentasie liggaamsvet bepaal en maer liggaamsmassa bereken. Middel-boarmomtrek is gemeet om middel-armspierarea en middel-armvetarea te bereken. Demografiese data en inligting oor die gebruik van supplemente met behulp van vraelyste ingesamel, en die dieetinname is deur voedselrekords ingesamel. Die data is vergelyk met die aanbevole hoeveelhede of die RDA (aanbevole daaglike hoeveelhede) en AI (toereikende inname).

Die swemmers het ‘n geskikte BMI, lae persentasie liggaamsvetvlak en ‘n groot persentasie LBM vir spiermassa gehad, wat gekorreleer het met die ideale liggaamsamestellingsprofiel van swemmers.

Die gewone inname (oefening-, voor-kompetisie-, tydens-kompetisie-, en na-kompetisiedieet) was ontoereikend vir meeste van die swemmers. Drie van die 12 mans en al die vroulike swemmers (n = 8) het ‘n ontoereikende energie-inname tydens oefeninge gehad. Vyftig persent van die swemmers het ‘n laer CHO-inname as die aanbevole hoeveelheid gehad. Hierdie swemmers kon die risiko geloop het van onvoldoende bloedglukosevlakke tydens oefeninge. Twaalf uit die 20 swemmers het ‘n ontoereikende proteïeninname gehad. Die vetinname van 40 % van die swemmers was meer as die aanbevole hoeveelheid. In die voor-kompetisiefase het al die swemmers ‘n laer CHO inggeneem as die aanbevole hoeveelheid, en kon hulle moontlik nie die voordelige effek van ‘n hoë koolhidraatdieet in dié fase benut nie. Die groep het ‘n hoër vet inname tydens deelname gehad. Vyf en negentig persent het nie hulle glikogeenvoorraad voldoende hervul na deelname nie. Vyf en sestig persent van die swemmers het supplemente gebruik.

Daar is ‘n behoefte geïdentifiseer aan voedingsintervensie identifiseer wat fokus op die voedingsbehoeftes van ‘n swemmer tydens oefening, voor deelname, tydens deelname en na deelname.

SLEUTELWOORDE: Liggaamsamestelling, ligaamsmassa-indeks, vetvoumetings, persentasie liggaamsvet, maerliggaamsmassa , middel-boarmomtrek, dieetinname, supplemente.