Energy expenditure, dietary intake and nutritional knowledge of elite, school-aged gymnasts.

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Abstract

Objective. To compare energy balance and nutrient intake of elite and non-elite school-aged gymnasts, as well as to evaluate their nutritional knowledge and eating attitude and its effect on dietary intake and practices.

Methods. Demographic information, anthropometric measurements, menstrual status, sources of nutritional information, nutritional habits as well as supplement use was documented. Eating attitudes were measured by the EAT26 test and nutritional knowledge by a standardised questionnaire. Dietary intake and practices were determined with a 3-day weighed food record, while energy expenditure was measured with an Actical® accellerometer (Mini Mitter Co., Inc. Bend, OR, USA).

Results. The total daily energy intake (non-elite = 6 944.37 ± 1 272.28 kJ vs. elite = 6 543.01 ± 2 570 kJ) in both groups was similar to their daily energy expenditure values (non-elite = 6 393.77 ± 1 244.19 kJ vs. elite = 6 696.09 ± 1 676.58 kJ). Elite gymnasts tended to have higher protein (21.37 vs. 15.4% total energy intake (TE), small effect size, d = 0.1) and lower fat (28.9 vs. 33.6% TE, medium effect size, d = -0.6) intakes. More non-elite gymnasts (n = 7, 88.88%) used micronutrient supplements than elite gymnasts (n = 4, 45.45%, medium effect size, d = 0.45). Most of the gymnasts (55%) ate snacks during the day, which consisted mostly of refined carbohydrates. In the total group of gymnasts the most frequently used source of nutritional information was the coach (60%). There was no difference in nutritional knowledge between the groups (elite = 61.8% vs. non-elite = 62.8% respectively). Lastly, elite gymnasts had a practically significantly higher risk than non-elite gymnasts to follow a diet (large effect size, d = 1.32), while non-elite gymnasts exercised practically significantly more self-control over their food intake compared to elite gymnasts (large effect size, d = - 1.03). **Conclusions**. South African elite gymnasts do not differ from non-elite gymnasts in terms of energy-, carbohydrate-, protein-, or fat intake. There is also no difference in energy expenditure or risk in developing an eating disorder, probably due to less competitiveness compared to other international gymnasts.

Key words: energy balance, dietary intake, nutritional knowledge, eating habits, food choices, diet

Opsomming

Afrikaanse titel: Energieverbruik, voedselinname en voedingskennis van elite, skoolgaande gimnaste.

Doel. Om energiebalans en nutriëntinnames van nie-elite en elite skoolgaande gimnaste met mekaar te vergelyk asook die effek van houding en voedingskennis op voedselinnames en dieetpraktyke te evalueer.

Metodes. Demografiese inligting, antropometrie, menstruele status, dieetgewoontes, inligtingsbronne van voedingskennis, sowel as supplement gebruik is gedokumenteer. Nutriëntinnames, voedselkeuses en eetgewoontes is bepaal met behulp van 'n 3-dae vooraf geweegde voedselrekord, terwyl energieverbruik met 'n Actical® accellerometer (Mini Mitter Co., Inc. Bend, OR, USA) gemeet is. Eethoudings is bepaal met behulp van die EAT26 toets en voedingskennis deur middel van 'n gestandariseerde vraelys.

Resultate. Die totale energie-inname (nie-elite = 6 944.41 ± 1 244.19 kJ vs. elite = 6 543.06 ± 2 569.74 kJ) in beide groepe is soortgelyk aan hul daaglikse energieverbruik (nie-elite = 6 393.77 ± 1244.19 kJ vs. elite = 6 696.09 ± 1676.58 kJ). Elite gimnaste het hoër proteïen- (21.37 vs. 15.4%, klein effek grootte, d = 0.1) en laer vetinnames (28.9 vs. 33.6%, medium effek grootte, d = - 0.6). Meer nie-elite gimnaste (n = 7, 88.88%) as elite-gimnaste gebruik mikro-nutriëntsupplemente (n = 4, 45.45%, medium effek groote, d = 0.45). Meer as die helfte (55%) van alle gimnaste eet tussenvoedings, bestaande uit verfynde koolhidrate, gedurende die dag. Daar was geen verskil in die finale gemiddelde uitslag vir voedingskennis van elite en nie-elite gimnaste (61.8% vs. 62.8% respektiewelik) nie. Addisioneel, het elite gimnaste 'n prakties betekenisvolle verskil en 'n hoër risko as nie-elite gimnaste gehad om 'n dieet te volg (groot effek groote, d = 1.32), terwyl nie-elite gimnaste egter klein, maar prakties betekenisvol meer selfbeheer uitge-oefen het oor voedselinname in vergelyking met elite gimnaste (groot effek groote, d = - 1.03).

Gevolgtrekking. Suid Afrikaanse elite gimnaste verskil nie van nie-elite gimnaste in terme van energie-, koolhidrate, proteïen- of vetinname nie. Daar is ook geen verskil in energieverbruik of 'n risiko vir die ontwikkeling van eetsteurnisse getoon nie, moontlik omdat hulle minder kompeterend is as internasionale gimnaste.

Sleutelwoorde: energiebalans, dieetinname, voedingskennis, eetgewoontes, dieet

List of abbreviations

Abbreviation	Description
ADA	American Dietetic Association
ADT	Aanbevole Daaglikse Toelaag
BD	body density
BM	body mass
BMC	bone mineral content
BMD	bone mineral density
BMI	body mass index
CDC	Centers for Disease Control and Prevention
EAT26	Eating Attitude Test
EER	energy expenditure requirement
EER	Estimated Energy Requirements
FFA	free fatty acids
kg	kilogram
LM	liggaamsmassa
METs	resting metabolism equivalents
RD	registered dietician
RDA	recommended dietary allowance
RER	respiratory exchange ratio
RMR	resting metabolic rate
SD	standard deviation
SKF	skinfold
VO2	peak oxygen consumption

CONTENTS **Page**

CONTENTS (continue) Page

CONTENTS (continue) Page

Addendums

List of Tables **Page**

List of Figures **Page**

Chapter 1: Introduction

1.1 Motivation for the study

Young adolescent elite athletes have increased energy needs because of strenuous exercise and the extra burden of the growth spurt (Papadopoulou *et al.*, 2002). Unfortunately poor nutritional intake is common among female athletes (Papadopoulou *et al.*, 2002, Cupisti *et al.*, 2002), especially those participating in gymnastics, distance running, diving, figure skating and classical ballet due to the prerequisite of a lean body. They are, therefore, at risk for being in a negative energy balance due to low energy diets, which can contribute to delayed growth, menstrual irregularities, nutrient deficiencies, reduced bone mineral density and increased incidence of injury (Thompson, 1998). Furthermore, these athletes are at risk of eating disorders (Yannakoulia *et al.*, 2002) since they often follow erratic eating patterns such as severe food restriction, fasting, binge eating and vomiting as well as use of laxatives and excessive exercise to control body weight (Yannakoulia *et al.*, 2002).

The exercising youngster's energy needs increase, depending on the frequency, intensity and duration of physical training (Jennings & Steen, 1995). Furthermore, they also need more energy and oxygen per unit body weight to perform similar tasks than adults (Bar-Or, 2000; Frost *et al.*, 2001; Thompson, 1998), because they make more use of co-contraction of antagonistic muscles to provide stability in movement (Frost *et al.*, 2001). Optimal carbohydrate intake is important to provide these athletes with energy, otherwise cognitive and emotional functions may be impaired (Benardot *et al.*, 1989; Ziegler *et al.*, 2002) as well as fatigue and poor performance may set in (ADA, 2000; Thompson, 1998; Willenberg & Hemmelgarn, 1991). The adult athlete recommendation for carbohydrates is 55–60% of the total energy or 7–10 g/kg body mass (BM)/day, whereas athletes tend to consume far less (5.1–5.9 g/kg BM/day) (Benardot *et al.*, 1989; Benson *et al.*, 1990; Cupisti *et al.*, 2002; Jonnalagadda *et al.*, 1998 & 2000; Loosli & Benson, 1990; Moffatt, 1984; Papadopoulou *et al.*, 2002; Reggiani *et al.*, 1989). It is also important to meet the increased protein needs of athletes due to intensive training and the growth spurt (Thompson, 1998). Adolescent athletes are recommended to ingest between 25 – 30% of daily energy intake from fat (ADA, 2000; Bar-Or, 2000), while children between the ages of 5 – 14 years could have a fat intake less than 35% of the daily energy intake (National Health & Medical Research Council, 1995). Athletes between the ages of 9 – 13 years usually consume between 18 – 36% of their daily energy intake from fat, while adolescent athletes ingest between 14 – 38.3% (Benardot *et al.*, 1989; Benson *et al.*, 1990; Jonnalagadda *et al.*, 1998 & 2000; Loosli & Benson, 1990; Moffatt, 1984; Papadopoulou *et al.*, 2002; Reggiani *et al.*, 1989). High fat diets in general are not recommended because of possible muscle glycogen depletion (Burke *et al.*, 2004), impaired performance and increased risks for health related disease later in life (Burke *et al.*, 2004; Lambert & Goedecke, 2003). Low fat diets prevent optimal absorption of fat-soluble vitamins and minerals, while cell membrane integrity will be negatively affected (ADA, 2000). A balanced intake in terms of fat intake is, therefore, important.

Young female gymnasts' intake of vitamins C, B6, B12, thiamine, riboflavin and niacin tends to exceed the Dietary Reference Intake (DRI), while they are at risk of having insufficient intakes of vitamin E, folate, iron, magnesium and calcium (Benson *et al.*, 1990; Benardot *et al*, 1989; Cupisti *et al.*, 2002; Jonnalagadda, 1998 & 2000; Loosli & Benson, 1990; Moffatt, 1984; Regigiani *et al.*, 1989). According to the American Dietetic Association (ADA), there is no need for nutritional supplements when a balanced diet is followed (Beshgetoor & Nichols, 2003). Following a balance diet will have a beneficial effect on the immune system, maintain growth of lean tissue mass and eumenorrhea as well as enhance performance (ADA, 2000; Thompson, 1998; Willenberg & Hemmelgarn, 1991). Supplementation is only recommended in exceptional cases and then also with caution (Barr, 1987). However, vitamin and/or mineral supplementation is very common among university athletes (Barr, 1987b). Supplements that are often used include multi-vitamin supplements, vitamin C and iron (Barr, 1987; Jonnalagadda *et al.*, 2001; Sobal & Marquat, 1994). Supplementation in mega doses (e.g. vitamin E) may have deleterious effects on health (Jacobson *et al.*, 2001), while vitamin B1 and B12, folate and niacin supplementation have been shown to have no beneficial effects on performance (Lukaski, 2004).

Coaches are usually the primary nutrition information source of athletes (Galito *et al.*, 2003; Jacobson *et al.*, 2001; Jozwiak & Ancona-Lupez, 2004) and often provide athletes with unreliable or misleading information, which is mainly obtained from non-scientific sources such as magazines (58%), (Jozwiak & Ancona-Lupez, 2004; Rockwell *et al.*, 2001), other coaches (44%) (Jozwiak & Ancona-Lupez, 2004) and the internet or television (Jozwiak & Ancona-Lupez, 2004). Misconceptions might exist about the role of nutrients regarding muscle growth, energy sources, and body composition. There is also a lack of knowledge of the role of nutrition in sport performance (Cupisti *et al.*, 2002; Jacobson *et al.*, 2001; Jonnalagadda *et al.*, 2001 & Rosenbloom *et al.*, 2002). Irregular meal patterns and poor food choices seen amongst athletes could also be due to their lack of nutritional knowledge or unreliable sources of nutrition information (Cupisti *et al.*, 2002; Loosli & Benson, 1990; Van Erp-Baart *et al.*, 1989).

From the literature it is clear that young athletes do not always meet their energy and nutrient needs. Additionally, they often do not have sufficient nutrition and sport nutritional knowledge to help them make sound food and supplement choices and apply healthy eating habits. Regular sport nutrition education sessions by a physician or dietitian specialising in exercise physiology or sport nutrition is, therefore, essential.

1.2 The problem

1.2.1 Energy expenditure and -requirements

Maintaining energy balance is one of the main aims for most athletes, depending on their specific needs. Athletes participating in aesthetic sports usually struggle to maintain their energy balance and are often in a negative energy balance (Deutz *et al.*, 2000). To be able to measure energy balance, energy intake and energy expenditure should be measured. Common methods used to measure energy expenditure include nitrogen balance studies, doubly labelled water techniques, the Actical® accelerometer, keeping exercise logbooks and calculating resting metabolism equivalents (METs) (Puyau *et al.*, 2002). Nitrogen balance studies are time and labour intensive, while the doubly labelled water technique is expensive and requires special equipment (Thompson, 1998). The Actical® accelerometer has the advantages of being non-invasive, small in size, lightweight and waterproof (Puyau *et al.*, 2002). However, the accelerometer has difficulty in detecting upper body movement, load carriage and changes in terrain (Puyau *et al.*, 2002). Calculated energy needs such as the Estimated Energy Requirements (EER) (Jequier *et al.*, 1987) and the Harris Benedict formula (Frakenfield *et al.*, 1998) have been criticized for over-estimation of athlete's energy need (Manore & Thompson, 2000). It is, therefore, better to measure an athlete's actual energy expenditure and thereby also his/her need and compare this value with energy intake to estimate whether an athlete is in energy balance or not. Athletes' energy intakes that are lower than recommendations (i.e. EER) could be due to under-reporting (Jonnalagadda *et al.*, 1998) or restrained eating habits (Beals & Manore, 1998; Deutz *et al.*, 2000). However, it could also be due to overestimation of energy needs by formulas due to athletes being more sedentary during non-exercising periods of the day than expected (Gorsky & Calloway, 1983; Thompson, 1998), or due to increased metabolic sufficiency (Mulligan & Butterfield, 1990), which then contribute to lowered energy requirements (Burke & Deakin, 2000).

1.2.2 Carbohydrates

Carbohydrate is the main source of energy for exercising muscle as well as the central nervous system (Willenberg & Hemmelgarn, 1991). Carbohydrate intake before and during endurance-type physical activity will aid in delaying the onset of fatigue by supplying energy for active muscles and could, therefore, enhance performance (Hargreaves, 1999). To ensure optimal daily muscle glycogen storage, athletes involved in daily training sessions lasting 1 – 3 hours of moderate to high intensity, should consume between 7 – 10 g carbohydrates/kg BM (Burke *et al.*, 2004). A recent review by Burke *et al.* (2004) indicated that female endurance athletes consume approximately 5.5 g carbohydrates/kg BM/day, while non-endurance athletes consume 4.7 g carbohydrates/kg BM/day, which is lower than the recommendation. It is hypothesized that female athletes following energy-restricted diets for a long period of time become metabolically efficient and, therefore, have lowered energy and carbohydrate needs. Some studies, however, failed to prove any metabolic adaptations (Schulz *et al.*, 1992; Wilmore, 1992). It could be that weight conscious female athletes under-report or under-eat when they are involved in studies that document their energy and carbohydrate intakes, but it could also be that their needs differ from that of males. A study by Dolins *et al.* (2003) gave a group of female athletes a low carbohydrate (3 g/kg BM/d), moderate carbohydrate (5 g/kg BM/d), or high carbohydrate (8 g/kg BM/d) diet for six days prior to a cycle test. They found no difference in their performance after a 60-minute cycle test. They drew the conclusion that female athletes might need less carbohydrate than their male counterparts. These results, however, need further investigation. Since most young athletes do not reach their recommended intakes, the importance of adequate carbohydrate intake should be emphasised to those with low intakes (Burke *et al.*, 2004).

1.2.3 Vitamins and minerals

1.2.3.1 Vitamins

Vitamin C supplementation only enhances performance in athletes who are vitamin C deficient (Berning, 2003). Whereas Lukaski (2004) showed in a recent review that vitamin C might indirectly enhance performance by decreasing body temperature in the heat, as well as the development of muscle soreness (Urso & Clarson, 2003). Vitamin C also has physiological functions that help with recovery after strenuous training (Lukaski, 2004). This include protection against free radical damage (Deaton & Marlin, 2003) and reduced levels of thiobarbituric acid reactive substances, which is a marker of lipid peroxidation (Deaton & Marlin, 2003).

Additionally, skeletal muscles seem to be less susceptible to oxidative damage when α-tochopherol (vitamin E) supplementation is used, because it provides protection against run-induced lipid peroxidation in skeletal muscle and blood (Sen, 2001). This is demonstrated by less leakage of muscle enzymes, while the levels of plasma cytokines, namely interleukin (IL)-1β and IL-6 as well as malandialdehydes (MDA), which are markers of lipid peroxidation (Urso & Clarson, 2003), as well as expired pentane are reduced (Thompson & McNaughton, 2001).

Despite these advantages, it is concluded that antioxidant (vitamin C, α-tochopherol and selenium) supplementation does not provide protection against muscle soreness and lipid peroxidation and does not enhance physical performance (Lukaski, 2004; Sen, 2001; Thompson & MacNaughton, 2001). Furthermore, interpretation of studies using large dosages of supplements, which show beneficial effects, should be done with caution since specific oxidative stress markers are not always used (Adams, 2002). Unfortunately, it was indicated that the effect of antioxidant cocktails on exercise performance might be due to different exercise protocols (Sen, 2001). Other possible reasons might be the difficulty to determine any beneficial effects of one nutrient in a cocktail of antioxidants (Thompson & McNaughton, 2001) and one nutrient might also counteract the beneficial effects of another nutrient (Thompson & McNaughton, 2001).

1.2.3.2 Minerals

Young female athletes participating in strenuous physical activities are at risk for iron deficiency with or without anaemia (Constantini *et al.*, 2000). Factors increasing their risk involve: a) increased iron losses, for example during excessive sweating, gastro-intestinal bleeding, breakdown of red blood cells, or menstruation (Burke & Deakin, 2000; Constantini *et al.*, 2000); b) inadequate dietary iron intake and low bio-availability of dietary iron (Beard & Tobin, 2000; Burke & Deakin, 2000; Constantini *et al.*, 2000) and c) increased iron needs during growth (Constantini *et al.*, 2000). Iron deficiency anaemia might result in fatigue, reduced physical work capacity and lower maximal oxygen uptake (Constantini *et al.*, 2000). Iron supplementation for iron deficient athletes with or without anaemia has also been shown to improve performance (Brownlie *et al.*, 2002; Zoller & Vogel, 2004).

Both calcium intake and physical activity influence bone mass (Berning & Steen, 1998). Fehily *et al.* (1992) showed that lifetime exercise, which varied from moderate to strenuous in a group of women for 45 minutes/day, 4 – 7 days/week, increased bone mineral content (BMC) and bone mineral density (BMD) at the distal site. Inadequate dietary calcium intake (<1 300 mg/day, 9 – 18 years) is associated with low BMD and bone mass as well as increased risk for stress fractures (Berning & Steen, 1998). Furthermore, athletes experiencing amenorrhea tend to have lower BMD (Drinkwater *et al.*, 1990). Studies (Jonnalagadda *et al.*, 1998 & 2000; Cupisti *et al.*, 2002; Moffatt, 1984; Papadopoulou *et al.*, 2002) on the dietary intake of jockeys, volleyball players, figure skaters and gymnasts have found calcium intakes to be less than 60% of the DRI. However, not all athletes reported low calcium intakes. Studies by Benardot *et al.* (1989) and Benson *et al.* (1990) amongst gymnasts reported calcium intakes greater than 60% of the DRI. Johnston *et al.* (1992) showed that calcium supplementation is more beneficial before than during puberty in increasing BMC and bone mass. A study by Andon *et al.* (1994) indicated that both 500 and 1 000 mg calcium citrate malate for 6 months increased BMC in female athletes (mean age = 11.4 years). It was also indicated that 1 000 mg calcium citrate malate results in a greater increase in BMC compared to the control group. Whereas Lloyd *et al.* (1993) showed that lumber and total BMD increased significantly in adolescent females (mean age = 12 years), when 500 mg calcium citrate malate was used for 18 months. It is, therefore, recommended to use calcium supplementation during early puberty (10.9 years) rather than during prepubertal (7.7 years) and pubertal (15.2 years) ages (Abrams & Stuff, 1994).

1.2.4 Eating Habits

Breakfast is the most important meal of the day because it helps to restore glycogen stores after an overnight fast (Berning & Steen, 1998). Furthermore, it is recommended that breakfast should supply a quarter to a third of the daily nutrients (Berning & Steen, 1998). However, several adolescent females omit this important meal (Berning & Steen, 1998). Due to young athletes' increased energy and carbohydrate needs, small frequent nutrient-dense meals are recommended (Berning & Steen, 1998; Ziegler *et al.*, 2002). Unfortunately, it is indicated that female figure skaters consumed only 1.36 snacks per day (Ziegler *et al.*, 2002). The types of food chosen as snack differed between low nutrient energy-dense snacks (Loosli & Benson, 1990) and nutrition-dense snacks (Ziegler *et al.*, 2002). Healthier choices might occur due to greater nutritional knowledge (Burke & Deakin, 2000). Another factor determining eating habits and meal patterns is attitude.

1.2.5 Nutritional knowledge

Burke and Deakin, (2000) indicated that 65% of children consider food as important, whereas, 80% consider food as essential for optimal health. Therefore, basic nutrition information should be provided to enable athletes to make correct food choices (Jonnalagadda *et al.*, 2001) to meet their increased energy needs and to ensure optimal carbohydrate intake (Burke *et al.*, 2001), which will enhance performance (Jonnalagadda *et al.*, 2001). Lastly, it is important to establish these healthy eating habits early in life, because it tends to continue in later life (Burke & Deakin, 2000).

Most data on energy balance, nutrient intakes, eating attitudes and nutritional knowledge in young athletes concerns international athletes. This data on young South African athletes is, therefore, lacking.

1.3 Aim, objectives and hypothesis of the study

1.3.1 Aim

The aim of this study is to compare the energy balance and nutrient intake of elite and non-elite school-aged gymnasts, as well as to evaluate their nutritional knowledge and eating attitude and its effect on dietary intake and practices.

1.3.2 Objectives and hypothesis

In order to achieve the above aim the study has the following objectives:

Objective 1

Assess and compare energy expenditure with energy intake between elite and non-elite female gymnasts.

Hypothesis

1. Elite gymnasts will have a higher energy expenditure compared to non-elite gymnasts.
2. Elite gymnasts will have a lower energy intake than non-elite gymnasts.

Objective 2

Assess and compare macro and micronutrient intakes without the use of supplements between elite and non-elite female gymnasts.

Hypothesis

1. Elite gymnasts will have a higher protein intake than non-elite gymnasts.
2. Elite gymnasts will have a lower carbohydrate and fat intake versus non-elite gymnasts.
3. Elite gymnasts will have a lower iron and calcium intake compared to non-elite gymnasts.

Objective 3

Compare the use of supplements between elite and non-elite female gymnasts.

Hypothesis

1. Elite gymnasts will use more performance enhancing supplements than non-elite gymnasts.
2. Elite gymnasts will use more micronutrient supplements than non-elite gymnasts.

Objective 4

Assess and compare nutritional knowledge and source of nutritional knowledge between elite and non-elite female gymnasts.

Hypothesis

1. Both elite and non-elite gymnasts obtain their nutritional knowledge mostly from the coach.
2. Elite gymnasts' basic nutritional knowledge will be greater than non-elite gymnasts.
3. Elite gymnasts will have greater knowledge regarding the role of nutrients in sport performance compared to non-elite gymnasts.

Objective 5

Assess and compare eating attitudes between elite and non-elite female gymnasts.

Hypothesis

1. Elite gymnasts will be more concerned about maintaining a slim physique than non-elite gymnasts.
2. Elite gymnasts will exercise more control over food intake compared to non-elite gymnasts.
3. Elite gymnasts will have a higher risk for eating disorders than non-elite gymnasts.

1.4 Approach to test hypothesis

Because of its scope and multi-disciplinary design, a team of scientists participated in this project. The project was, however, managed and controlled by the author of this dissertation. To test the hypothesis of the project the following team was recruited: sport scientists, 1 MSc student in Dietetics (Mrs. C. Joubert, author of this thesis), sport nutritionist, honours students in sport science, statistician, and staff as well as coaches from two gymnastics clubs in the North-West Province.

1.5 Overall design of the study

This project was a multi-disciplinary study with a comparative design on the basis of availability.

1.6 Structure of thesis

This thesis consists of a combination of chapters, which comply with the requirements of the North-West University (Potchefstroom Campus) and journals to which they will be submitted for publication. Manuscripts meet the requirements of the journals to which they are intended for submission.

Chapter 1 is an introductory chapter and includes the background and motivation of the study, as well as the aim, goals and objectives and overall study design. Chapter 2 is an overview of the current literature, which describes the nutrition needs of the gymnast, as well as their nutritional knowledge and risk for developing eating disorders. In Chapter 3 the nutritional knowledge, food choices, eating habits and eating attitudes of gymnasts in this study as well as the relationships between eating attitudes and nutritional knowledge with food choices and nutrient intakes are documented in article format. Chapter 4 evaluates energy balance and nutrient intakes as well as supplement use of gymnasts also in article format. Chapter 5 integrates the results of Chapters 3 to 4 in a combined discussion and conclusions. Recommendations for further research and practical applications are made.

Chapters 1, 2 and 5 are written according to the format prescribed by the North-West University and have a combined bibliography at the end of the dissertation, while Chapters 3 and 4 are written according to the format prescribed by the journals to which they will be submitted, each with its own bibliography.

Selected questionnaires are attached as addendums.

1.7 Limitations of the study

The following limitations were identified in this study:

- A non-randomised, small sample group was used.
- Lack of detail by gymnasts when completing diet records in terms of commercial and ready-to-eat foods as well as mixed dishes.
- Absence of food models or portion size photo book when dietitian cross-checked diet records received.
- Contributions of breakfast, lunch, dinner and snacks to the daily energy, macro- and micronutrient intakes were not calculated.
- Food finder software package based on the South African food composition tables did not contain all the recorded foods' analysis, thus the dietitian sometimes had to choose similar alternatives.
- Reason for supplement use was not recorded.
- Actical accelerometers might have underestimated energy expenditures.

1.8 Co-authors and co-workers

The principal author of this thesis is Ms. Cornel Joubert. In table 1.1 contributions of the co-authors and co-workers are summarized.

Table 1.1 Co-authors

Chapter	Co-author / Co-worker	Contributions
Chapter 2	Dr. H.H. Wright	Supervisor, assisting in writing article.
Chapter 3	Dr. H.H. Wright	Supervisor, planning of study design, assisting in development of questionnaires, implementation of study, and writing of article.
	Prof. H.S. Kruger	Assistant supervisor, assisting in writing of article.
	Mr. B Coetzee	Taking of anthropometric measurements.
Chapter 4	Dr. H.H. Wright	Supervisor, assisting in development of questionnaires, implementation of study, planning of study design, and writing of article.
	Prof. H.S. Kruger	Assistant supervisor, assisting in writing of article.
	Mr B. Coetzee	Taking of anthropometric measurements.

The following is a statement from the co-authors confirming their individual roles in the study and giving their permission that the manuscripts may form part of this thesis.

I declare that I have approved the above-mentioned manuscripts, that my role in the study, as indicated above, is representative of my actual contribution and that I hereby give my consent that it may be published as part of the MSc thesis of Cornel Joubert.

Prof. H.S. Kruger

Dr. H.H. Wright

A review of the nutritional needs, knowledge and dietary practices of young female gymnasts

Abstract

It is important to maintain a euhydration state, because children do not have an effective regulatory mechanism and are, therefore, at risk for hypo and hyperthermia. Energy requirements of young athletes are higher than their sedentary counterparts due to increased energy expenditure. The recommended intake of young female athletes varies between 246 – 255 kJ/kg body mass/day but most female gymnasts only manage to ingest between 149 – 179 kJ/kg body mass/day. Specific recommendations for young athletes in terms of protein and carbohydrate needs are not yet available, thus adult guidelines are used. Although female gymnasts ingest between 53.86 – 60.14% of their daily energy intake in the form of carbohydrates, they do not reach their goal intake of 7 – 10 g carbohydrate/kg body mass/day since their energy intake is low. On the other hand, their protein intake is sufficient and varies between 1.45 – 1.76 g/kg body mass/day, even when total energy intake is low. Gymnasts on energy-restricted diets are at risk for calcium, magnesium, phosphate, iron and zinc deficiencies. Additionally, many athletes use ergogenic aids as well as vitamin and/or mineral supplements often due to a lack of nutritional knowledge. Furthermore, inadequate knowledge has a negative impact on dietary habits and food choices, which may consequently affect performance. It is, therefore, important to give athletes sound nutrition guidance regarding sport nutrition aspects to aid in achieving or maintaining required body weight and increased exercise performance.

2.1 Introduction

Due to pressure from the coach, parents and/or team mates, young athletes competing in aesthetic sports may have an increased risk of being "trapped" in energy restricted diets (Petrie, 1993). Young athletes have increased energy and nutrient needs due to growth and development, as well as the extra burden of training sessions (Benson *et al.*, 1990). Energy-restricted diets are, therefore, not generally advised for these athletes.

There are no clear benefits in severe energy restriction to maintain a low body weight, due to so many associated health-related disadvantages (Deutz *et al.*, 2000). Inadequate energy intake in young female athletes is associated with lower resting energy expenditure, relatively higher body fat levels, higher injury rates, menstrual abnormalities, lower bone density (Deutz *et al.*, 2000) followed by pre-menopausal osteoporosis (Benardot *et al.*, 1989), delayed growth, anaemia and an increased risk for clinical and subclinical eating disorders (Jonnalagadda *et al.*, 1998; Loosli & Benson, 1990; Ziegler *et al.*, 2001). Consequently this has a negative effect on performance (Brownell *et al*, 1987; Jonnalagadda *et al.*, 1998) and the psychological function of the athlete (Brownell *et al.*, 1987).

This paper will review the general fluid, energy, and nutrition needs of young athletes, specifically that of young female athletes participating in weight-conscious sport e.g. gymnastics. Additionally, normal growth and development will be described in the context of body weight, length and body fat levels to enable sport nutritionists/dieticians to identify those at risk of malnutrition or an eating disorder. Lastly the influence of these athlete's nutrition knowledge and beliefs about their food choices and eating habits will be described.

2.2 General nutrition consideration for young athletes

2.2.1 Thermoregulation

Children do not have a very effective thermoregulatory mechanism compared to adults (Bar-Or, 1998) because they have a greater body surface area and produce more heat during exercise (Meyer & Bar-Or, 1994). They are also at a higher risk for hypo- and hyperthermia due to heat loss or gain from their bodies to the environment (Burke & Deakin, 2000).

Hypohydration occurs when an athlete does not ingest sufficient fluids while training in a hot environment and progresses from an euhydrated to a dehydrated state, mostly due to increased sweat production (Meyer *et al.*, 1994). Hypohydration has a negative effect on cardiovascular function and temperature regulation (Meyer *et al.*, 1994) due to decreased blood flow to the skin (ACSM, 1996) and greater body heat storage (Rivera-Brown *et al.*, 1999). Both water and electrolytes are necessary to maintain euhydration, but children probably need less sodium than adults (Meyer & Bar-Or, 1994) according to the hypothesis that the sodium and chloride concentration of sweat increases with maturation (Meyer *et al.*, 1992; Rivera-Brown *et al.*, 1999). Prepubescent and pubescent children (Meyer *et al.*, 1992) as well as females (Bar-Or, 1998) sweat less than young men (Bar-Or, 1998), because of a possible greater sweating threshold and a minor anaerobic energy turnover in the sweat gland (Bar-Or, 1998). They are, therefore, not as capable as adults to regulate body temperature and have an increased risk of heat stress (Spear, 2004). It has also been shown by Spear (2004) that young athletes often suffer from voluntary dehydration and that core body temperature increases at a higher rate for any given level of dehydration compared to adults. It is, therefore, crucial to avoid dehydration in young athletes.

Children need five to six sessions for acclimatization in a hot environment, whereas adults only need 2 - 3 sessions (Spear, 2004). It is, therefore, recommended that children must exercise at a low intensity in hot weather for the first 4 - 5 days. Thereafter, the intensity can be gradually increased for the following 1.5 weeks. During acclimatization, the following physiological alterations occur: decreased heart rate and body temperature, an increased sweating rate, a lower salt concentration in sweat (Meyer *et al.*, 1992) and great amounts of fluid losses (Rivera-Brown *et al.*, 1999).

2.2.2 Fluid replacement

Thirst is not a good indicator of low hydration status, because dehydration may already occur when thirst is experienced (Burke & Deakin, 2000). Since children and adults do not drink adequate fluids to compensate for sweat losses (Rivera-Brown *et al.*, 1999), it is important to educate them to ensure adequate fluid intake before, during and after exercise (Meyer & Bar-Or, 1994). A general guideline for children younger than 10 years is to drink an additional 100 - 125 ml beyond thirst, and adolescents an additional 200 - 250 ml fluids beyond thirst (Bar-Or, 1995). More practical guidelines are summarized in Table 2.1.

To increase fluid consumption, flavour, composition and temperature of fluids should be considered (Rivera-Brown *et al.*, 1999). Carbohydrate containing drinks with grape and orange flavour seem to be the preferred choice for Caucasian children (Meyer *et al.*, 1994) and have been shown to promote adequate fluid consumption as well as to maintain and even increase body weight post-exercise, compared to carbohydrate containing drinks with apple flavour (Bar-Or & Unnithan, 1994; Meyer *et al.*, 1994b). Flavoured sports drinks containing about 18 – 20 mmol NaCl/L, 2% glucose and 4% sucrose (Bar-Or, 2001) enhance fluid intake in young athletes and are, therefore, the preferred rehydration drink instead of plain or flavoured water (Meyer *et al.*, 1994; Meyer & Bar-Or, 1994; Rivera-Brown *et al.*, 1999) to maintain euhydration (Bar-Or, 2001). If fruit juice is preferred, it should be diluted in a ratio of 1:2 (fruit juice:water) (Berning & Steen, 1998). Undiluted fruit juice, soft drinks and caffeinated beverages are not recommended because of the risk of dehydration and gastro-intestinal upsets (Berning & Steen, 1998). Furthermore, caffeine may impair performance due to the presence of agitation, nausea, muscle tremors, palpitations and headaches (Berning & Steen, 1998) and should, therefore, be avoided. Fluid temperature also determines the degree of rehydration. Although very cold water is considered as the most enjoyable drink, cool water (15 °C) can be consumed in larger quantities, which will help to reach an euhydrated state faster (Hubbard *et al.*, 1990).

Table 2.1 Practical guidelines for fluid replacement in young athletes

1.	Drink at least 8 cups of fluid the day before competition or heavy physical activity (and every day as a general rule).
2.	Drink up to 2 hours before an event.
3.	Drink 1 - 2 cups of water 5 minutes before competition.
4.	When exercising strenuously in hot weather, drink 240 - 300 ml water every 15 - 20 minutes.
5.	Drink before you are thirsty. By the time your brain signals thirst, 1 % of body weight may be lost.
6.	Weigh before and after competition. For each 450 grams of weight loss, drink two cups of fluid. Gradual weight loss during hot weather training may be due to chronic dehydration rather than loss of fat.

Adapted from Willenberg & Hemmelgarn (1991)

2.2.3 Energy expenditure and requirements

Energy balance occurs when energy intake (the sum of energy from food, fluids and supplements) is equal to energy expenditure (the sum of energy expended as basal metabolism, the thermic effect of food and any voluntary physical activity) (ADA, 2000; Thompson, 1998).

Age (Loucks, 2003), sex (ADA, 2000; Deutz *et al.*, 2000), fat free mass, body size, intensity, frequency and duration of an activity all contribute to energy expenditure. Heavier individuals have a greater energy expenditure compared to individuals with a normal weight, because more energy is necessary to move a heavy body (Barr, 1987a; Thompson, 1998). Resting metabolic rate (RMR) can be determined by using the Harris Benedict equation, where variables such as height, weight, age and sex are used (Barr, 1987a). The Recommended Dietary Allowance (RDA) can be used to determine the energy needs of children to maintain normal growth and development (Steen, 1994). However, the exercising school-aged child needs an additional 2 100 - 6 300 kJ more per day, depending on the frequency, intensity and duration of physical training (Jennings & Steen, 1995). The estimated energy requirement (EER) is probably a better option compared to the RDA, since it takes into account the basal metabolic rate, growth, metabolisable energy and physical activity levels of children (World Health Organization, 1989). The reason for the low mechanical economy is that younger children make more use of co-contraction of antagonistic muscles to provide stability in movement than older children (Frost *et al.*, 2001). Co-contraction is considered an inefficient movement and, therefore, a 'waste of energy' (Frost *et al.*, 2001). Stride rate determines both peak oxygen consumption VO_2 peak and efficiency of locomotion, because the former is lower for older children than pre-pubertal girls (Frost *et al.*, 2001).

Adequate energy intake is necessary to enhance the immune system, to maintain growth and lean tissue mass, to improve physical performance, to cope with competition related stress and to maintain normal menstrual status (ADA, 2000; Thompson, 1998; Willenberg & Hemmelgarn, 1991). A chronic negative energy balance may result in a short stature and delayed menses, nutrient deficiencies and dehydration, abnormal menstrual patterns, poor bone health, increased incidence of injury and an enhanced risk for developing eating disorders (Thompson, 1998).

In a group of elite gymnasts it has been shown that those with an inadequate energy intake had lower resting energy expenditures than those who were in energy balance (Deutz *et al.*, 2000). Additionally, due to the greater variations between energy deficiency and energy balance through a 24-hour period, the group with inadequate energy intakes had a greater proportion of body fat followed by lower kilojoule requirements to sustain body weight (Deutz *et al.*, 2000). These results were also found by others (Brownell *et al.*, 1987; Loucks, 2004).

Two studies by Ziegler *et al.* (2001; 1998b) revealed that male and female skaters were lean, had low body fat levels and consumed far less energy than recommended for their age and sex. In the position stand of the American Dietetic Association, the Canadian Dietitians (2000) and the American College of Sports Medicine (2000) it is said that female athletes between the ages of 9 - 13 years with a mean weight of 37.4 kg and an energy intake less than 255 kJ/kg BM/day, as well as female athletes between the age of 14 - 18 years with a mean weight of 53.8 kg and an energy intake below 246 kJ/kg BM/day are likely to encounter weight loss and problems with the reproductive system (ADA, 2000). A study done by Van Erp-Baart *et al.* (1989) on a group of gymnasts between the ages of 13 – 15 years found their daily energy expenditure was higher than their intake (180 kJ/kg BM vs. 158 kJ/kg BM). Insufficient energy intakes (149 - 179 kJ/kg BM/day) amongst female gymnasts between the ages of 9 - 18 years have also been found by others, see Tables 2.2 and 2.3 (Benardot *et al.*, 1989; Benson *et al.*, 1990; Cupisti *et al.*, 2002;

Jonnalagadda *et al.*, 2000 & 1998; Loosli & Benson, 1990; Moffatt, 1984; Regigiani *et al.*, 1989). These reported low intakes might be due to an attempt to maintain a slim physique or to under-reporting (Van Erp-Baart *et al.*, 1989).

2.3 Macronutrient requirements and intakes

An important aspect in assessment of food and nutrient intake is the validity of methods used (Barr, 1987). The instruments through which dietary intake are determined are difficult to validate in light of the fact that it is difficult to ascertain the accurateness of the food intake feedback. The best method to obtain information regarding actual food intake seems to be weighed food records (Barr, 1987a; Van Erp-Baart *et al.*, 1989). Every ingredient during the preparation method, the cooked portion size, leftovers as well as inedible waste must be weighed (Barr, 1987a). Additionally, records should be kept for three week days and 1 weekend day since this is more accurate than a 24-hour recall (Van Erp-Baart *et al.*, 1989).

Self-reported food intake, however, still has limitations such as underreporting, inaccurate record keeping of habitual food patterns, misinterpretation of the recorded data may occur and quantification of the food or liquid portion may be inaccurate (Braakhuis *et al.*, 2003; Cupisti *et al.*, 2002; Jonnalagadda *et al.*, 2000)

Although the assessment of food and nutrient intakes amongst athletes might not be free from error, it is the only available method to obtain an estimation of their intakes. One should, therefore, always interpret dietary data with caution.

2.3.1 Carbohydrates

Carbohydrates are the major source of energy during exercise (Willenberg & Hemmelgarn, 1991) and are stored as glycogen in the liver and skeletal muscles. Muscle glycogen depletion is associated with fatigue and decreased exercise performance (ADA, 2000; Thompson, 1998; Willenberg & Hemmelgarn, 1991). Furthermore, a low carbohydrate diet in gymnasts is discouraged, because it may have a negative impact on behaviour and cognitive function (Ziegler *et al.*, 2002). It is, therefore, important to ingest sufficient amounts of carbohydrate to prevent this (Ziegler *et al.*, 2002).

Limited data is, however, available on the specific carbohydrate needs of young athletes and gymnasts specifically. Therefore, adults' guidelines are mostly prescribed for children as summarized in Table 2.4. Studies by Benardot *et al.*

(1989), Benson *et al.* (1990), Cupisti *et al.* (2002), Jonnalagadda *et al.* (2000 & 1998), Loosli & Benson (1990), Moffatt, (1984) and Regigiani *et al.* (1989) amongst gymnasts revealed that they consumed between 53.86 - 60.14% of the total daily energy intake as carbohydrates and between 5.1 - 5.9 g carbohydrates/kg BM/day (Table 2.2 and 2.3). The latter is insufficient when compared to the recommended daily carbohydrate intake of 7 – 10 g/kg BM to ensure optimal glycogen storage (Burke *et al.*, 2004). Although carbohydrate needs increase during pre-competition preparation and multiday competitive events (Burke *et al.*, 2001), it remains difficult for female non-endurance athletes e.g. gymnasts to meet their carbohydrate needs of 7 – 10 g/kg BM/day, because of weight control issues (Burke *et al.*, 2001). On the other hand, it is important to note that if daily exercise does not challenge glycogen stores, the carbohydrate needs may be less, while during periods of muscle damage the need may be higher (Burke *et al.*, 2004).

Table 2.2 Selected average requirements and macronutrient intakes per day in young athletes aged 9 to 13 years

	Age (y)	Weight (kg)	Protein (% TE)	CHO (% TE)	Fat (% TE)	Energy (kJ/kg)	Energy (kJ/day)	Protein (g/kg)	CHO (g/d) (g/kg)	Fat (g/d) (g/kg)
DRI	**9-13**	**29-45.8**					**9 572**	**34 g/d**	**100 g/d**	
Benson *et al.*, 1990 n=12	12.5	34.7	17.0 ± 3.3	53.1 ± 6.4	30.7 ± 6.4	165 ± 56	6 485 ± 1 672	1.9*	5.9*	1.5*
Bernadot *et al.*, 1989 N=22	11-14	31	15.0 ± 2.2	53± 6	32.5 ± 5.5	230*	7 165 ± 1 768	2.16*	7.3*	2*
Jonnalagadda *et al.*, 1998 N=21	12-15	48.8	17*	66.5*	18	148*	7 220 ± 2 428	1.5*	5.86*	0.71*
Loosli & Benson, 1990 N=97	13.1	42.75	15*	49*	36	181*	7 720	1.66*	5.1*	1.7*
Reggiani *et al.*, 1989 N=26	12.3 ± 1.7	37.9 ± 6.9	15.3 ± 3.1	47.7 ± 6.7	36.0 ± 7.4	171*	6 518 ± 2 138	1.6*	5.1*	1.63*
Mean values	**12.9**	**39.03**	**15.86**	**53.86**	**30.64**	**179**	**7 022**	**1.76**	**5.85**	**1.51**

Table 2.3 Selected average requirements and macronutrient intakes per day in young athletes aged 14 to 18 years

	Age (y)	Weight (kg)	Protein (% TE)	CHO (% TE)	Fat (% TE)	Energy (kJ/kg)	Energy (kJ/day)	Protein (g/kg)	CHO (g/d)	Fat (g/d)
DRI	**14-18**	**49.4-56.2**					**13 238**	**46 g/d**	**100 g/d**	
Cupisti *et al.*, 2002 N=60	16.1 ± 1.5	55.8 ± 9	15.3 ± 2.5	53.6 ± 6.2	30.4 ± 5.5	121 ± 33.6	6 773 ± 1 875	1.09 ± 0.31	4.1 ± 1.1	0.98 ± 0.37
Jonnalagadda *et al.*, 2000										
Low energy reporters	15.1± 1.33	48.7 ± 8.6	18 ± 3	67 ± 3	16 ± 4	113 *	5 485 ± 1 134	1.2*	4.5*	0.5*
Adequate E reporters	15 ± 0.8	42.9 ± 7.2	16 ± 2	64 ± 7	20 ± 7	216*	9 278 ± 1 567	2.05*	8.2*	1.13*
Jonnalagadda *et al.*, 1998 N=8	16-19 ± 1.3	48.8 ± 8.3	17.3 *	70*	14*	135*	6 598 ± 1 911	1.4*	5.65*	0.5*
Moffatt, 1984 N=13	15 ± 4.2	50.4 ± 6.5	15.4 ± 2.1	46.1 ± 4.4	38.3 ± 5.2	159*	8 014 ± 2 830	1.5*	4.4*	1.63*
Mean values	**16.4 ± 1.38**	**49.32 ± 7.92**	**16.4 ± 2.4**	**60.14 ± 2.85**	**23.8 ± 5.42**	**149**	**7 230 ± 1 489**	**1.45**	**5.37**	**0.95**

* value has been calculated according to available data % TE = percentage of total daily energy intake DRI = Dietary Reference Intake

Table 2.4 Guidelines for carbohydrate intake by athletes

Situation	***Recommended carbohydrate intake***
Short term / single event	
Optimal daily muscle glycogen storage (e.g. for post exercise recovery or to fuel up or carbohydrate load prior to an event).	7 - 10 g/kg BM/day
Rapid post-exercise recovery of muscle glycogen, where recovery between sessions is < 8 hours.	1 g/kg BM immediately after exercise, repeated after 2 hours
Pre-event meal to increase carbohydrate availability prior to prolonged exercise session.	1 - 4 g/kg BM eaten 1-4 hours pre-exercise
Carbohydrate intake during moderate-intensity or intermittent exercise of > 1 hour.	0.5 - 1 g/kg BM/h (30-60 g/h)
Long term or routine situation	
Daily recovery/fuel needs for athlete with moderate exercise programme (i.e. < 1 hour or exercise of low intensity).	5 - 7 g/kg BM/day
Daily recovery/fuel needs for endurance athlete (i.e. 1 - 3 hours of moderate to high intensity exercise).	7 – 10 g/kg BM/day
Daily recovery/fuel needs for athlete undertaking extreme exercise programme (i.e. > 4-5 hours of moderate to high intensity exercise such as Tour de France.	10 - 12+ g/kg BM/day

BM = Body mass

Adapted from Burke *et al.* (2001).

2.3.2 Protein

Young athletes have higher protein needs in order to maintain growth as well as the extra burden of physical training (Thompson, 1998). Currently there is no published data on protein requirements for young athletes (Thompson, 1998). Adult recommendations are 12 – 15% protein of daily energy provided that of total energy intake (ADA, 2000 & 1996; Willenberg & Hemmelgarn, 1991). A general estimation of 1.2 - 1.4 g protein/kg BM/day is recommended for adult endurance athletes and 1.6 - 1.7 g protein/kg BM/day is recommended for adult resistance and strength trained athletes (ADA, 2000). Female gymnasts seem to consume between 1.45 - 1.76 g protein/kg BM/day (Table 2.2 and 2.3) (Benardot *et al.*, 1989; Benson *et al.*, 1990; Cupisti *et al.*, 2002; Jonnalagadda *et al.*, 2000 & 1998; Loosli & Benson, 1990; Moffatt, 1984; Regigiani *et al.*, 1989). It is, therefore, not necessary to promote protein intake amongst these athletes since it is already high. To maintain a positive protein balance it is, however, important that gymnasts also ingest food that contains sufficient energy food (ADA, 2000).

Currently, protein and amino acid supplements are not promoted amongst young athletes since there is no evidence to support the claim that they build muscle or enhance performance (Willenberg & Hemmelgarn, 1991). Additionally, their safety and efficacy has not been established in young athletes (ADA, 2000).

2.3.3 Fat

Although adults have greater fat stores than children (Ziegler, 1982), it was noted that children depend more on aerobic metabolism, where fat is the major energy source, than anaerobic metabolism in which muscle glycogen is the primary energy source during exercise. (Bar-Or, 2000). Possible mechanisms for this (Bar-Or & Unnithan, 1994) are that children have lower levels of muscle phosphofructokinase, reduced glycolytic flux, higher citrate-cycle enzyme activity and increased lactate dehydrogenase activity compared to adults. Furthermore, adolescents have a greater fumarase/pyruvate kinase ratio than young adults (Bar-Or & Unnithan, 1994).

One of the first studies to show increased aerobic metabolism during exercise in children was done by Martinez and Haymes (1992). They demonstrated that pre-pubertal girls (9.1 years) who ran for 30 minutes at 70% VO_{2max} on a treadmill had a significantly ($p < 0.05$) lower respiratory exchange ratio (RER) during exercise compared to women (24.4 years). Their blood lactate concentration was decreased, followed by increased post-exercise free fatty acids (FFA) and glycerol levels post-exercise (Bar-Or, 2000; Bar-Or & Unnithan, 1994; Martinez & Haymes, 1992).

Although children use more fat than adults during exercise it does not seem to translate into increased dietary fat requirements (Bar-Or & Unnithan, 1994; Martinez & Haymes, 1992; Thompson, 1998). High fat diets in general are also not recommended due to possible muscle glycogen depletion (Burke *et al.*, 2004), increased body fat percentage and health related diseases (Lambert & Goedecke, 2003; Ziegler *et al.*, 2002).

It is, therefore, recommended that adolescents should not ingest more than 25 – 30% of daily energy intake from fat (ADA, 2000; 1996; Bar-Or, 2000; Willenberg & Hemmelgarn, 1991), while children between the ages of 5 - 14 years should have a fat intake of less than 35% (National Health & Medical Research Council, 1995). From Tables 2.2 and 2.3 it can be seen that athletes between the ages of 9 - 13 years consume between 18 – 36% of their daily energy intake from fat, while adolescent athletes ingest between 14 - 38.3%. This large range of fat consumption emphasizes the need for individual education according to each athlete or team's nutrition needs.

Furthermore, although dietary fat should be reduced, it remains important for general health and development, therefore, lean meats and low fat dairy products should be promoted to reduce dietary fat intake (Willenberg & Hemmelgarn, 1991).

2.4 Micronutrients

2.4.1 Vitamins and minerals

Dietary restriction might cause micronutrient deficiencies in gymnasts (Moffatt, 1984). Vitamins are involved in energy metabolism and consequently the need is enhanced during increased periods of physical activity (Lukaski, 2004). Furthermore, minerals are involved in cellular energy transduction, gas transport, antioxidant defense, membrane receptor functions, second-messenger systems and integration of physiologic systems. Utilization of macronutrients is, therefore, dependent on mineral regulation (Lukaski, 2004).

According to the reviewed literature (see Tables 2.5 and 2.6), the mean intake for vitamin C (689%), vitamin B6 (159%), vitamin B12 (428%), thiamin (296%), riboflavin (198%) and niacin (141%) of children and adolescent female gymnasts are often greater than the RDA, while inadequate amounts of vitamin E (25%) and folate (79%) are generally consumed (Benardot *et al.*, 1989; Benson *et al.*, 1990; Cupisti *et al.*, 2002; Jonnalagadda *et al.*, 2000 & 1998; Loosli & Benson, 1990; Moffatt, 1984; Regigiani *et al.*, 1989).

No side effects have been observed with excess thiamine, riboflavin and vitamin B12 intakes from food or supplements (Alhadeff *et al.*, 1984; Bassler, 1989; Marks, 1989). However, if the intakes of certain vitamins are greater than the RDA, it may have certain side effects. Intakes of 100 mg niacin/day are associated with vasodilatation and flushing (Marks, 1989), while consumption of 2 – 4 g vitamin B6/day may cause neuropathy of the extremities (Bassler, 1989). Furthermore, excessive vitamin C intake may result in osmotic diarrhea and gastro-intestinal disturbances (Alhadeff *et al.*, 1984). Lastly, excessive vitamin A intakes (>10 g retinol daily) may result in joint or bone pain, hair loss, anorexia and liver damage. B-carotene, a water-soluble form of vitamin A, is not toxic and can be used instead of the former (Marks, 1989). In Tables 2.7 and 2.8, studies show that most young athletes don't meet their calcium, phosphate and magnesium needs. Additionally, iron and zinc intakes may be marginal.

Supplementation is very popular amongst university athletes and it is believed that supplements provide more energy (Barr, 1987b), improve performance and build muscles (Rosenbloom *et al.*, 2002). A study conducted by Marques-Vidal (2004) demonstrated that more men consume supplements than women. It was determined by Barr (1987b), Jonnalagadda *et al.* (2001) and Sobal and Marquat (1994) that the most popular supplements taken were general supplements (76%), multivitamin and/or mineral supplements (19 - 73.3%), vitamin C (25 – 36%) and iron supplements (11 – 31%). Other supplements used to a lesser extent included calcium (9%), vitamin A (9%), B vitamins (8%), vitamin E (8%), vitamin D (5%), zinc (3%) and potassium (3%) (Marques-Vidal, 2004). Most of the multi-vitamin supplements contained vitamin C (85%), vitamin B (62%), vitamin E (55%), vitamin A (52%) and vitamin D (48%) (Marques-Vidal, 2004). It has also been found that elite athletes use a great diversity of micronutrient supplements, despite the fact that supplementation is only beneficial if the normal intake of micronutrient food sources are insufficient (Van Erp-Baart *et al.*, 1989).

Vitamin and mineral supplementation is not recommended as a rule since a diet with sufficient energy content and variety will provide adequate amounts (Willenberg & Hemmelgarn, 1991). Promoting a healthy, balanced diet amongst athletes is, therefore, recommended. Vitamin and mineral supplements should only be considered when an athlete is on a severe energy restricted diet or has a specific micronutrient deficiency. The only two minerals that might not be ingested in sufficient amounts by female gymnasts are iron and calcium.

Table 2.5 Average requirements and daily intakes of selected vitamins in young athletes aged 9 to 13 years.

	Age (y)	Vit A (μg RE/d)	Vit C (mg/d)	Vitamin E (mg α-TE/d)	Thiamin (mg/d)	Riboflavin (mg/d)	Niacin (mg/d)	Vitamin B6 (mg/d)	Vitamin B12 (μg/d)	Folate (μg/d)
RDA	**9-13**	**600**	**45**	**11**	**0.9**	**0.9**	**12**	**1.0**	**1.5**	**300**
Benardot *et al.*, 1989	11-14	1 127 ± 750	145 ± 85	-	1.5 ± 0.5	1.8 ± 0.6	18.2 ± 6.5	-	-	-
Benson *et al.*, 1990	12.5 ± 1.1	5 956 ± 4 063	157 ± 103	-	1.48 ± 0.64	-	17.2 ± 9.9	1.47± 1.04	-	-
Jonnalagladda *et al.*, 1998	11-14 ± 1.3	955 ± 1.051	2 019 ± 4 312	1.6 ± 1.8	1.7 ± 1	2.5 ± 1.1	21 ± 10	2 ± 1	11 ± 8	263 ± 166
Reggiani *et al.*, 1989	12.3 ± 1.7	771.3 ± 1 244	56.1 ± 49	2.1 ± 1.1	0.6 ± 0.7	0.7 ± 0.3	8.7 ± 4.8	0.6 ± 0.3	3.0 ± 2.2	
Mean	**12.48**	**2 202 ± 1 514**	**594 ± 1137**	**1.85 ± 1.45**	**1.32 ± 0.71**	**1.67 ± 0.67**	**16.3 ± 7.8**	**1.4 ± 0.78**	**7 ± 5.1**	**263 ± 166**

RDA = Recommended Dietary Allowance

Table 2.6 Average requirements and daily intakes of selected vitamins in young athletes aged 14 to 18 years.

	Age (y)	Vit A (μg RE/d)	Vit C (mg/d)	Vitamin E (mg α-TE/d)	Thiamin (mg/d)	Riboflavin (mg/d)	Niacin (mg/d)	Vitamin B6 (mg/d)	Vitamin B12 (μg/d)	Folate (μg/d)
RDA	**14-18**	**700**	**65**	**15**	**1.0**	**1.0**	**14**	**1.2**	**2.4**	**400**
Cupisti *et al.*, 2002	16.1 ± 1.5	805 ± 500	111 ± 74	-	0.79 ± 0.31	1.25 ± 0.42	13.4 ± 5.4	-	-	-
Jonnalagadda *et al.*, 2000								-	--	-
Low E reporters	15.1 ± 1.33	655 ± 394	127 ± 85	-	1.2 ± 0.41	1.5 ± 0.6	18 ± 6			
Adequate E reporters	15 ± 0.8	1 469 ± 870	100 ± 70		2.0 ± 0.7	3.2 ± 1.6	25 ± 9			
Jonnalagladda *et al.*, 1998	15.1± 1.3	1 079 ± 730	400 ± 362	1.5 ± 1.4	2.4 ± 1.2	3.1 ± 1.9	32 ± 14	2.9± 1.4	17± 12	445 ± 285
Moffat *et al.*, 1984	15 ± 4.2	883.8 ± 527	83.60 ± 27.9	8.1 ± 3.01	1.04 ± 0.40	1.39 ± 0.48	13.36 ± 5.46	1.27 ± 0.44	2.39 ± 0.98	129.2 ± 39.6
Mean	**15.9**	**978.4 ± 604.2**	**164.32 ± 123.78**	**4.8 ± 2.2**	**1.49 ± 0.6**	**2.09 ± 1**	**20.35 ± 7.97**	**2.09 ± 0.92**	**9.7 ± 0.92**	**287 ± 162.3**

RDA = Recommended Dietary Allowance

Table 2.7 Average requirements and daily intakes of selected minerals in young athletes aged 9 to 13 years.

	Age	Calcium (mg)	Iron (mg)	Potassium (mg)	Phosphorus (mg)	Magnesium (mg)	Zinc (mg)	Sodium (mg)	Copper (mg)	Manganese (mg)
RDA/AI	**9-13**	**1300**	**8.0**		**1250**	**240**	**8.0**			
Benardot *et al.*, 1989 N=22	11-14	867 ± 403	11 ± 4	2 391 ± 836	1 116 ± 388	--	-	2 386 ± 810	-	-
Benson *et al.*, 1990 n=12	12.5 ± 1.1	966 ± 339	10.4± 8.8	-	-	-	-	-	-	-
Jonnalagadda *et al.*, 1998 11-14 y 15-18 y	11-14 ± 1.3	1 073 ± 236	18 ± 7	2 448 ± 1 109	1 138 ± 242	233 ± 73	12 ± 7	2 798 ± 995	1.4 ± 1.0	2.6 ± 1.4
Mean	**12.5 ± 1.2**	**969 ± 326**	**13,1 ± 6.6**	**2 420 ± 972.5**	**1 127 ± 315**	**233 ± 73**	**12.7 ± 7**	**2 592 ± 902.5**	**1.4 ± 1.0**	**2.6**

RDA = Recommended Dietary Allowance AI = Adequate Intake

Table 2.8 Average requirements and daily intakes of selected minerals in young athletes aged 14 to 18 years.

	Age	Calcium (mg)	Iron (mg)	Potassium (mg)	Phosphorus (mg)	Magnesium (mg)	Zinc (mg)	Sodium (mg)	Copper (mg)	Manganese (mg)
RDA	**14-18**	**1300**	**15**		**1250**	**360**	**9.0**			
Cupisti *et al.*, 2002	16.1± 1.5	587 ± 187	10.6 ± 5.1	-	888 ± 244	-	5.8 ± 5.1	-	1.25 ± 0.4	-
Jonnalagadda *et al.*, 2000 Low E reporters Adequate E reporters	15.1 ± 1.33 15	707 ± 310 1 123 ± 317	12 ± 4.8 20.6 ± 8.7	-	-	-	-	-	-	–
Moffatt *et al.*, 1984	15.2 ± 4.1	706.7 ± 355.5	11.26 ± 2.94	-	1 196.7 ± 597.5	201.7 ± 68.9	7.43 ± 1.91			
Mean	**15.3 ± 2.31**	**781 ± 292.4**	**13.6 ± 5.4**	**-**	**1 042 ± 421**	**201 ± 68.9**	**6.6 ± 3.5**	**-**	**1.25 ± 0.4**	**-**

RDA = Recommended Dietary Allowance AI = Adequate Intake

2.4.1.1 Calcium

Increased calcium intake results in increased calcium retention (Kirchner *et al.*, 1994), which enhanced bone formation (Ziegler *et al.*, 2002) and BM during puberty (Kirchner *et al.*, 1994). Consequently, this will help to reduce the risk of stress fractures and osteoporosis later in life (Jonalagadda *et al.*, 1998). More than 90% of bone mass is formed during puberty (Rogol *et al.*, 2000). The proximal femur and lumbar vertebrae reach optimal BMD at an age of 18 years. In females the peak trabecular and cortical BMD of the distal forearm is reached at 15 and 16.5 years respectively (Gunnes & Lehmann, 1996). A study by Kirchner *et al.* (1995) showed that gymnasts who had a low calcium intake, had a higher lumbar, proximal femur and whole BMD density than the control group, possibly due to weight bearing and resistance training.

The adequate intake (AI) for female children between the ages of 9 - 18 years is 1 300 mg/day. Elite gymnasts generally consume approximately half the AI for calcium (FNB, 1997). Female athletes following energy restricted diets tend to avoid dairy products due to their high fat content (ADA, 1996) and this may result in decreased bone mass, which increases the risk for stress fractures (ADA, 2000 & 1996; Beals & Manore, 1998; Rogol *et al.*, 2000) and the development of pre-menopausal osteoporosis (ADA, 1996; Jonnalagadda *et al.*, 1998). To reduce the risk of these complications, amenorrheic athletes should consume >1 300 mg calcium/day (Benardot, 1996; Herbold & Frates, 2000). Calcium intake *per se* does not seem to be the only factor influencing bone density (Van Erp-Baart *et al.*, 1989). A study by Vorster *et al.* (2001) did not find higher bone mineral density at the lumbar spine, left hip and forearm in a group of female endurance athletes compared to controls. This was even though they had greater calcium intakes than the control group. Other possible factors associated with a lower bone mineral density in this study were less than 12% body fat, more than 7.5 hours of endurance exercise per week and the presence of amenorrhea.

To increase calcium intake amongst female athletes, intake of low-fat or fat free dairy products should be promoted. Recently it has been concluded that calcium-rich mineral water, functional foods, soy product derived phytoestrogens, fortified foods, and vitamins K and E may also play an important nutritional role in skeletal health (Bacciottini & Brandi, 2004). This is especially interesting to those allergic to cow's milk or with lactose intolerance. Young athletes following vegan diets should increase their calcium intake by consuming calcium rich plant foods e.g. broccoli, tofu made with calcium precipitate, almonds and brazil nuts as well as calcium-enriched products e.g. soy milk, orange juice and cereal (Herbold & Frates, 2000).

If one wants to recommend calcium supplements to young athletes, it seems to be more effective before puberty and during the early stages of puberty, because greater calcium retention takes place, which enhances BMD (Johnston *et al.*, 1992). Calcium citrate malate (≤500 mg/dose) must be consumed between meals to enhance absorption (NIH Consensus Development Panel on Optimal Calcium Intake, 1994), whereas calcium carbonate must be consumed with meals, since gastric acid is necessary to optimize absorption (Monsen & Cook, 1976).

2.4.1.2 Iron

Iron is an important mineral for athletes since it is needed for the formation of haemoglobin and myoglobin, which binds oxygen and transports it to the muscle for energy metabolism. Additionally, enzymes of the energy metabolic way contain iron (ADA, 2000; Lukaski, 2004).

Due to the adoption of vegetarianism (Herbold & Frates, 2000), high physiological needs, low energy intakes, inadequate dietary iron intake and exercise-induced iron loss (Jonnalagadda *et al.*, 1998) as well as losses through menstruation (ADA, 1996), adolescent female gymnasts have an increased risk of iron deficiency anemia (Jonnalagadda *et al.*, 1998). During puberty, the iron requirement increases, because red blood cell mass and blood haemoglobin concentration increase (Fogelholm *et al.*, 1998).

Athletes have an increased iron loss due to haemolysis, reduced iron absorption, deterioration of the red blood cell membrane, gastro-intestinal bleeding and iron excretion in the stool, urine and sweat (Constantini *et al.*, 2000; Nielsen & Nachtigall, 1998). Iron deficiency anemia is characterized by fatigue (Beard & Tobin 2000; Constantini *et al.*, 2000; Lukaski, 2004; Nielsen & Nachtigall, 1998; Thompson, 1998), reduced physical work capacity, increased exercise heart rate and lactate concentration as well as declined maximal oxygen uptake oxidative capacity at cellular level (Beard & Tobin 2000), which may cause impaired training and performance (Constantini *et al.*, 2000). The diagnostic criteria of anemia include reduced mean corpuscular haemoglobin concentration; decreased size and volume of new red blood cells; reduced myoglobin, less iron-sulphur and haeme-containing cytochromes within cells, (Beard & Tobin 2000) as well as low haemoglobin and ferritin concentrations due to depletion of iron stores (Beard & Tobin 2000). Ferritin defends the intracellular iron atoms against possible oxidative damage (Ashenden *et al.*, 1998). A relationship exists between serum ferritin and tissue iron levels. Therefore, serum ferritin levels can indicate the status of total body iron stores (Ashenden *et al.*, 1998). It is also the first indicator affected during iron depletion, followed by low transferrin saturation (<16%), ferritin concentration (<12 μg/L) (Lukaski, 2004) and decreased haemoglobin levels (Constantini *et al.*, 2000). Decreased ferritin, but normal haemoglobin levels do not have a negative effect on performance (Constantini *et al.*, 2000).

The RDA for iron in children and adolescent females ages 11 - 18 years is 15 mg/day (FNB, 2001). A Western diet typically provides 6 mg iron per 4 200 kJ, therefore, one must consume approximately 12 600 kJ/day (Beard & Tobin 2000; Nielsen & Nachtigall, 1998) to meet one's iron needs, which is highly unlikely in female gymnasts with their reduced energy intakes.

To increase iron intake food products high in iron (lean meats, fish, poultry, enriched whole grains, dried fruits e.g. apricots and raisins and dried peas and beans) should be consumed regularly (ADA, 2000; Beard & Tobin, 2000; Lukaski, 2004; Herbold & Frates, 2000; Van Erp-Baart, 1989; Willenberg & Hemmelgarn, 1991). Iron from animal products is more bioavailable than plant products (ADA, 2000; Beard & Tobin, 2000; Lukaski, 2004; Van Erp-Baart, 1989; Willenberg & Hemmelgarn, 1991). Adding vitamin C-rich food to a meal to enhance non-haeme iron (plant products) absorption is promoted (Beard & Tobin 2000; Herbold & Frates, 2000; Willenberg & Hemmelgarn, 1991). One should, however, note that the presence of bran, hemicellulose, cellulose, pectin, phytic acid, phytate and polyphenols in a mixed diet might inhibit non-haeme iron absorption (Beard & Tobin 2000; Nielsen & Nachtigall, 1998). Additionally, calcium has shown to decrease iron absorption. Therefore, athletes taking calcium supplements should take them between meals.

Supplementation is indicated when iron deficiency anemia is present and should be administered under medical supervision (ADA, 2000 & 1996). High doses of supplemental iron are, however, associated with gastro-intestinal distress and constipation (Beard & Tobin, 2000). Additionally, iron supplementation is contra-indicated in subjects with haemochromatosis (Beard & Tobin, 2000; Nielsen & Nachtigall, 1998) and iron toxicity may develop in subjects who consume ≥75 mg supplemental iron who are not predisposed to iron deficiency (Beard & Tobin, 2000).

2.5 Nutritional knowledge

Nutritional knowledge has a great impact on dietary habits and food choices (Cupisti *et al.*, 2002). Inadequate knowledge has been shown to contribute to inadequate food intake and choices in elite athletes (Cupisti *et al.*, 2002).

It is hypothesized that athletes who participate in sport for a longer time period have greater nutritional knowledge and are less eager to consume supplements (Barr, 1987b; Jacobson *et al.*, 2001). Various studies (Barr, 1987b; Jacobson *et al.*, 2001; Rosenbloom & Jonnalagadda, 2002) have, however, revealed that female univarsity athlete' general and sport nutritional knowledge is not superior to non-athletes. In contrast to these findings, Cupisti *et al.* (2002) demonstrated that high school adolescent athletes had greater nutritional knowledge than non-athletes. This lack of nutritional knowledge can be attributed to the sources that athletes use to obtain their information. It seems that athletes mostly obtain their nutritional knowledge from certified athletic trainers (39.8%), strength and conditioning coaches (17.35%), registered dietitians (14.4%), others (9.7%), magazines (13.7%), family members (5.5%), friends (3.9%), team physicians (3%), television (2.3%) and the Internet (1.3%) (Burns *et al.*, 2004; Jacobson *et al.*, 2001). Only 2% of varsity athletes consider the coach as the "most useful" information source, while it was proved that they have inadequate sport nutritional knowledge in two studies (Cupisti *et al.*, 2002; Jacobson *et al.*, 2001). Both Burns *et al.* (2004) and Jacobson *et al.* (2001) indicated that between 10 – 14% of athletes considered the dietician as the primary information source. These small numbers might be due to the fact that more than 27% of the athletes did not know that a dietician is part of the sports team. Athletic trainers should refer athletes to a registered dietician (RD) who can give guidance on several aspects of nutrition and sport performance (Burns *et al.*, 2004). Emphasis must be placed on the consequences of energy restriction on health and performance (Cherundolo & Levine, 1999). Other aspects that should be addressed are food selection and dietary habits (Chen *et al.*, 1989) as well as the role of certain nutrients in sport performance (Froiland *et al.*, 2004). Lastly, accurate information on supplements should also be provided (Froiland, 2004).

Misconceptions that might exist in the diet involve the role of protein, vitamins, minerals and fluids (Cupisti *et al.*, 2002; Jacobson *et al.*, 2001; Jonnalagadda *et al.*, 2001; Rosenbloom *et al.*, 2002). Two thirds of athletes who participated in a study done by Jacobson *et al.* (2001) thought that more than 26% of total daily intake should be from protein, less than 12% from fat and ≤40% from carbohydrates. The recommendations for athletes are 50 – 60% carbohydrates, 12 – 15% protein and 25 – 30% fat (Jacobson *et al.*, 2001). A study by Rosenbloom *et al.* (2002) revealed that most college athletes and gymnasts considered protein as the main source of energy for muscle building and strength and many believe that sugar has a negative effect on performance when consumed before an event, due to the risk of hypoglycemia. These and other athletes consider the use of protein supplements as a necessity and believe that ergogenic aids and supplements improve performance (Cupisti *et al.*, 2002; Jacobson *et al.*, 2001; Rosenbloom *et al.*, 2002). It does, however, seem that athletes realise the importance of fluid replacement before, during and after an exercise session (Jonnalagadda *et al.*, 2001; Rosenbloom *et al.*, 2002). Inadequate knowledge sometimes exists regarding the preferred choice of rehydration fluid since athletes indicated that sports drinks are not more effective than water for rehydration (Jonnalagadda *et al.*, 2001). The importance of carbohydrate-electrolyte beverages should, therefore, be emphasized for replacement of electrolytes and fluid lost through sweating.

Marques-Vidal (2004) revealed that athletes have a lack of knowledge regarding the use of supplementation. It is, therefore, important to educate athletes and coaches on the use of vitamin and/or mineral supplementation since mega doses (e.g. vitamin E) can have deleterious effects (Jacobson *et al.*, 2001) and most vitamins do not have beneficial effects on performance (Lukaski, 2004).

Basic information regarding the role of macro and micronutrients, ergogenic aids and nutrition supplements should be provided to enable athletes to make correct food choices and to enhance performance (Jonnalagadda *et al.*, 2001), as well as to prevent obesity, dyslipidemia, diabetes and cardiovascular complications during later stages of life (Cupisti *et al.*, 2002).

Jacobson *et al.* (2001) compared athletes' knowledge in a follow-up study and concluded that the amount of misinformation was reduced; it seems, therefore, useful to educate athletes on sound nutrition practices and supplementation.

2.6 Growth and maturation

2.6.1 Skeletal growth

The ADA recommends optimal nutrition (ADA, 1996) during puberty, which includes increased protein and energy requirements as well iron, zinc and copper (Fogelholm *et al.*, 1998) to meet the nutrition needs for the growth spurt (ADA, 1996). The sex-specific Centers for Disease Control and Prevention (CDC) growth monitoring charts and the National Health Centre for Health Statistics growth charts can be used to monitor growth on a regular basis (Hamill *et al.*, 1979). The weight-for-height growth chart gives an indication of an athlete's current growth status (Garn & Rohmann, 1966; Himes *et al.*, 1985). The height-for-age assessment chart can be used to determine a subject's previous nutrition and growth status (Steen, 1994). Growth failure is characterized by a low body weight-for-age, which is accompanied by a minimal deficit in weight–for–height, followed by no linear growth (Rogol *et al.*, 2000).

Growth involves alterations in body size and composition (Malina, 1994; Steen, 1994), physique and specific body systems (Malina, 1994). Skeletal growth involves an increase in bone length and bone mass (bone mass accrual) (Preece & Ratcliffe, 1992).

During childhood, growth of the legs is predominant (Lucas, 2004), while growth in the trunk length is predominant during puberty (Karlberg, 1989). At the onset of menarche, approximately 97% of the final stature has been attained (Faulkner *et al.*, 1993). The pubertal growth spurt is characterized by physical and hormonal changes, which is followed by sexual development (Cara, 2003).

A common feature among highly trained gymnasts is short legs, which may occur due to delayed growth rate of leg length (Malina, 1994). Inadequate energy and nutrient intake (Burke & Deakin, 2000), genetic factors as well as intensive exercise before the onset of menarche may contribute to reduced growth of gymnasts (Malina, 1994; Rogol *et al.*, 2000). Familial short stature (e.g. short parents) may also be responsible for reduced stature of some gymnasts (Rogol *et al.*, 2000). Fogelholm *et al.* (1998) as well as Malina and Bielicki (1996) demonstrate that regular training does not have a negative effect on growth, skeletal age as well as sexual and somatic (age at peak height velocity) maturation (Rogol *et al.*, 2000). However, intensive exercise for an extended period of time may contribute to reduced growth (Benardot, 1996; Burke & Deakin, 2000), low body weight and percentage body fat when compared to athletes participating in less strenuous exercise or in exercise where weight is supported (e.g. canoeing and kayaking) (Hergenroeder & Klish, 1990; Robert *et al*, 1982; Rogol *et al.*, 2000). Therefore, athletes should be assessed on a regular basis to identify those at risk for reduced growth and delayed maturation.

Gymnasts (12 - 16 years) who participate internationally usually have a weight and height between the 10th and 50th percentile (Malina, 1994). The growth curve of gymnasts usually remains flattened, which indicates that they remain prepubescent for an extended time period, depending on the duration of training. This could contribute to delayed maturity (Benardot, 1996) followed by attenuated growth (Theintz *et al.*, 1993). When exercise is less strenuous or discontinued (Lindholm, 1994), catch-up growth can occur and is usually similar to the median height-for-age (Baxter-Jones *et al.*, 1995).

Puberty is characterized by an increase of 80 – 85% of peak bone mass. Half of the peak bone mass is attained during the pre-pubertal stage, while the other half is accrued during the two to four years of pubertal growth (Faulkner *et al.*, 1993). In the presence of inadequate energy and intensive exercise, bone resorption will probably take place due to suppression of reproductive hormones (Barr, 1987; Loucks, 2004; Vorster *et al.*, 2001). Promotion of adequate energy intake is, therefore, important to optimize peak bone mass during puberty and decrease the risk for osteoporosis and osteopenia later in life (Loucks, 2004; Snow, 1996). Furthermore, irreversible trabecular bone loss may result when amenorrhea is present for more than three years (Benardot, 1996).

The age of maximal peak BMC velocity for boys is 14.0 ± 1.0 years and 12.5 ± 0.9 years for girls (Whiting *et al.*, 2004). Boys have a greater BMC accrual at an age of 18 years compared to girls. This may be due to biological reasons or because of greater calcium consumption (Whiting *et al.*, 2004). Bone metabolism also increases during weight bearing endurance activities (30 minutes, 3 times per week for 10 months) as well as during highly intensive repetitive box jumping (Eliakim & Beyth 2003). Prepubertal children who participated in weight bearing activities for 8 months had an increase in BMC (Eliakim & Beyth 2003), while college-age gymnasts had a higher lumbar and femoral neck BMD compared to age-match controls (Benardot, 1996; Snow, 1996). It is, therefore, hypothesized that weight-bearing activity amongst pre-pubertal children has a greater effect on BMD compared to the type and intensity of exercise (Eliakim & Beyth 2003).

Menstrual status is another important factor in bone health. No menses characterizes delayed maturation at the age of 14.5 - 16 years among highly trained females. Additionally, their bone age is usually two years younger according to chronological age (Malina, 1994). Possible reasons for delayed menarche or menstrual dysfunction include 1) hormones may play a role in the late onset of menarche when a female athlete participates in intensive training (Robert *et al.*, 1982); 2) the onset of menarche may be familial (Malina, 1994) and 3) a negative energy balance, followed by low circulating levels of gonadotrophic and ovarian hormones may also be responsible for this effect (Robert *et al.*, 1982). Amenorrhea is common among endurance and aesthetic activities e.g. gymnasts, dancers and long distance runners (ADA, 2000; Loucks, 2004; Robert *et al.*, 1982; Rogol *et al.*, 2000). Amenorrheic athletes have lower BMD than eumenorrheic athletes (Thompson, 1998). Gymnasts also have a greater percentage of muscle mass, which could result in an additional risk on bone health, namely a greater torque force on bones causing frequent skeletal injuries (Benardot, 1996).

2.6.2 Body weight and body composition

In gymnastics, extra body weight may be detrimental to performance. If appropriate measures are used to lose weight, performance will be enhanced (Wilmore, 1992). Gymnasts usually use energy restriction methods or increased physical activity (Loucks, 2004) to control body weight, which are not always ideal (ADA, 2000; Rogol *et al.*, 2000) for body fat levels (Deutz *et al.*, 2000). Table 2.9 summarizes safe dietary guidelines for weight management (ADA, 2000).

Table 2.9 Weight management strategies for athletes

Setting and monitoring goals

Set realistic weight and body composition goals. Ask the athlete the following:

- Encourage less focus on the scale and more on healthful habits such as stress management and making good food choices.
- Monitor progress by measuring changes in exercise performance and energy level, the prevention of injuries, normal menstrual function and general overall well being.
- Help athletes to develop lifestyle changes that maintain a healthful weight for themselves – not for their sport, for their coach, for their friends, for their parents or to prove a point.

Suggestions for food intake

- Low-energy diets will not sustain athletic training. Instead, decreases in energy intake of 10% to 20% of normal intake will lead to weight loss without the athlete feeling deprived or overly hungry. Strategies such as substituting lower-fat foods for whole-fat foods, reducing intake of energy-dense snacks and doing activities other than eating when not hungry can be useful.
- If appropriate, athletes can reduce fat intake and increased energy expenditure. Fat intake should not be decreased below 15% of total energy intake, because some fat is essential for good health.
- Emphasize increased intake of whole grains and cereals, beans and legumes.
- Dieting athletes should not skimp on protein and need to maintain adequate calcium intakes. Accordingly, use of low-fat dairy products and lean meats, fish and poultry is suggested.
- A variety of fluids – especially water – should be consumed throughout the day, including before, during and after exercise workouts. Dehydration as a means of reaching a body weight goal is contraindicated.

Other weight management strategies

- Encourage athletes not to skip meals, especially breakfast and not to get too hungry. They should be prepared for times when they might get hungry, including keeping nutritious snacks available for those times.
- Athletes should not deprive themselves of favourite foods or set unrealistic dietary rules or guidelines. Instead, dietary goals should be flexible and achievable. Athletes should remember that all foods could fit into a healthful lifestyle; however, some foods are chosen less frequently. Developing lists of "good" and "bad" food is discouraged.
- Help athletes identify their own dietary weaknesses and plan strategies for dealing with them.
- Remind athletes that they are making lifelong dietary changes to sustain a healthful weight and optimal nutritional status rather than going on a short-term "diet" that they will someday stop.

Adapted from the American Dietetic Association, (2000).

A distinction (Rogol *et al.*, 2000) should be made between inadequate protein intake for a prolonged period of time due to protein energy malnutrition and acutely sub-optimal intake due to illness or intensive exercise, which may suppress growth and limit catch-up growth. Malnutrition secondary to limited food intake or malabsorption can cause osteopenia, anemia, vitamin, mineral, essential fatty acid and amino acid deficiency, as well as delayed menarche (Rogol *et al.*, 2000).

Too much emphasis on the ideal body weight in young athletes should be avoided since it could contribute to eating disorders. Skinfold (SKF) measurements in conjunction with growth charts are the preferred choice to determine a range of weights for a young athlete, which are based on optimal health (Steen, 1994). In Table 2.10, the Siri equation can be used for calculating the percentage body fat in children 8 - 18 years (Slaughter *et al.*, 1988). Another alternative is to monitor the sum of specific skinfolds over time (Berning & Steen, 1998)

Table 2.10 Skinfold equations

Skinfold equations	
For predicting % body fat in children and youth (8 - 18 years)	
***Method 1**	
For sum of triceps and subscapular less than 35 mm use:	
White male:	
Prepubescent	$\%fat = 1.21\,(T + S) - 0.008\,(T + S)^2 - 1.7$
Pubescent	$\%fat = 1.21\,(T + S) - 0.008\,(T + S)^2 - 3.4$
Postpubescent	$\%fat = 1.21\,(T + S) - 0.008\,(T + S)^2 - 5.5$
Black male:	
Prepubescent	$\%fat = 1.21\,(T + S) - 0.008\,(T + S)^2 - 3.2$
Pubescent	$\%fat = 1.21\,(T + S) - 0.008\,(T + S)^2 - 5.2$
Postpubescent	$\%fat = 1.21\,(T + S) - 0.008\,(T + S)^2 - 6.8$
All females	$\%fat = 1.33\,(T + S) - 0.013\,(T + S)^2 - 2.5$
For sum of triceps and subscapular greater than 35 mm use:	
All males	$\%\ fat = 0.783\,(T + S) + 1.6$
All females	$\%\ fat = 0.546\,(T + S) + 9.7$
For triceps and calf:	
Males	$\%\ fat = 0.735\,(T + C) + 1.0$
Females	$\%\ fat = 0.610\,(T + C) + 5.1$
Note: C = calf; S = subscapular; T = triceps	
#Method 2	
BD (Body density)	= 1.07878 – 0.00035(sum of skin folds) + 0.00032(age)
Fat%	= 495/BD – 450

*Slaughter et al. (1988). Skinfold equations for estimation of body fatness in children and youth. *Human Biology*, 60(5):709-723.
#Withers, R.T., Whittingham, N.O., Norton, K.I., La Forgia, J., Ellis, M.W. & Crockett, A. 1987. Relative body fat and anthropometric prediction of body density of female athletes. *European journal of applied physiology*. 56(2):169-180.

Prepubertal boys have a greater percentage of fat free mass than girls and prepubertal females more adipose tissue than males (Hergenroeder & Klish, 1990). Body composition is important for athletes since a greater percentage of subcutaneous fat has been associated with a decline of performance (Claessens *et al.*, 1999). It should, however, be kept in mind that it is difficult to determine the percentage of fat and lean tissue in children (Slaughter *et al.*, 1988), since the constituents of fat free mass alter during puberty; potassium content and bone density increases, while water content decreases (Hergenroeder & Klish, 1990) all of which have an influence on skin fold thickness (Steen, 1994).

2.7 Eating disorders

An eating disorder is not only diagnosed when a certain weight target is met, the presence of a distorted body image and inappropriate compensatory behaviour is adequate enough to diagnose a subclinical eating disorder (Beals & Manore, 2000). *Anorexia nervosa* and *bulimia nervosa* may occur in female athletes who participate in sport, where leanness is a prerequisite as in gymnastics (Beals & Manore, 1998; Petrie, 1993; Ziegler *et al.*, 1998a & 1998b).

The "female athlete triad", namely the presence of menstrual abnormalities (Herbold & Frates, 2000; Ziegler *et al.*, 1998b), an eating disorder and premature osteoporosis (Weimann, 2002) are often found among female athletes participating in aesthetic sports. This may be elicited by extended periods of dieting, weight fluctuations (from 3.6 – 4.5 kg/year), intensive training sessions or a traumatic event (Herbold & Frates, 2000).

Anorexia athletica is a subclinical variant of *anorexia nervosa* (Beals & Manore, 2000). Although an athlete may reach a state of exhaustion, depression and irritability, training continues followed by poor performance (Herbold & Frates, 2000). *Anorexia athletica* is characterized by an intense fear of becoming fat or gaining fat even though underweight combined with a disturbed perception of the way one's body weight or shape is experienced (Beals & Manore, 2000). *Anorexia athletica* is more prevalent amongst female athletes than male athletes and controls (Sudi *et al.*, 2004). These athletes are involved in inappropriate compensatory behaviour to lose body weight e.g. self-induced vomiting and/or the abuse of laxatives and diuretics, excessive exercise and severe energy restricting (consume less than 5 040 kJ/day) (Beals & Manore, 2000; Petrie, 1993).

Oligomenorrhea or amenorrhea may be a result of anorexia athletica due to extensive exercise, which may also result in shorter periods of the luteal phase and anovulatory cycles (Thompson, 1998). Oligomenorrhea (Eliakim & Beyth, 2003) is defined as cycles, which occur at intervals of 39 - 90 days. Amenorrhea is defined as absence of menses or occurs in periods of more than 90 days (Barr, 1987b). Factors contributing to this include low body weight and body fat (Brownell *et al.*, 1987; Ziegler *et al.*, 1998a), late menarche, extensive training prior to menarche, prior menstrual irregularities, high volumes of training, hypothalamic immaturity, nulliparity and psychological stress (Brownell *et al.*, 1987; Eliakim & Beyth, 2003; Thompson, 1998), as well as the adoption of vegetarianism (Barr, 1987b; Thompson, 1998;

Vorster *et al.*, 2001). Other factors that may also contribute to amenorrhea could be the result of decreased levels of estrogen and progesterone, kilojoule restriction and inhibition of the secretion of gonadotropins releasing hormone (Eliakim & Beyth, 2003; Rickenlund *et al.*, 2003; Ziegler *et al.*, 1998b). According to Rickenlund *et al.* (2003), hyperandrogenism may be another cause of menstrual irregularities. Athletic amenorrhea can be defined as amenorrhea that cannot be explained by any etiology other than the exercise training and, therefore, its diagnosis is made by exclusion (Eliakim & Beyth, 2003). Amenorrhea is 4 - 20 times higher among athletes than in the general population (Barr, 1987b; Eliakim & Beyth, 2003).

Nutritionists/Dietitians involved with athletes with eating disorders should highlight having a positive attitude towards body and body shape; help the athlete to re-evaluating societal and dance body standards; help to alter existing views regarding fat and eliminate misconceptions regarding "bad and good" foods (Yannakoulia *et al.*, 2002). Furthermore, during nutritional education sessions no referral should be made to eating disorders and symptoms that may be experienced. Instead, a discussion session should refer to complications of rapid weight loss, weight cycling, fasting or severe food restriction and avoidance of "high-kilojoule or fattening" foods (Yannakoulia *et al.*, 2002).

2.8 Conclusion

Maintaining euhydration in young athletes is an important dietary goal since children have an increased risk of heat stress and voluntary dehydration (Meyer & Bar-Or, 1994a). Education regarding adequate fluid replacement before, during and after exercise is, therefore, essential (Berning & Steen, 1998).

Exercising school-aged children have an increased daily energy need to enhance the immune system, maintain growth and lean tissue mass, improve physical performance, cope with competition related stress and to maintain normal menstrual status in girls (ADA, 2000; Berning & Steen, 1998; Thompson, 1998; Willenberg & Hemmelgarn, 1991). Young female athletes, however, seem to be at risk for energy intakes below their actual needs and should be motivated to increase their intake of energy (total amount of food per day) and carbohydrate. Inadequate carbohydrate intakes amongst young female gymnasts might be due to the large volume and bulk of complex carbohydrate foods. Sport nutritionists/dietitians should, therefore, aid them in choosing some refined, nutrient-dense carbohydrate foods daily to help them reach their goals, especially during pre-competition preparation periods and multiday competitive events for enhanced performance (ADA, 2000; Burke *et al.*, 2001; Hargreaves, 2000; Hawley & Burke, 1997; Willenberg & Hemmelgarn, 1991). Although protein needs of young athletes are higher than their sedentary peers, they seem to reach adequate intakes even when following energy-restricted diets. Currently there are no specific carbohydrate and protein recommendations for young athletes; their needs are, therefore, based on those of adult athletes. This is a limitation and should be addressed in future research projects. Young athletes should still follow prudent guidelines regarding moderate fat intake, even though they depend more on aerobic metabolism during physical activity than adult athletes (Bar-Or, 2000; Bar-Or, & Unnithan, 1994; Martinez & Haymes, 1992; Thompson, 1998).

Most athletes participating in aesthetic sports inflict dietary restrictions and are, therefore, prone to develop micronutrient deficiencies, especially calcium and iron (Constantini *et al.*, 2000; Lukaski, 2004; Moffatt, 1984; Willenberg & Hemmelgarn, 1991). Special attention should be given in young athletes' diets to calcium and iron to maximize the achievement of peak BMC (ADA, 2000) as well as prevent fatigue and impaired exercise performance (Constantini *et al.*, 2000).

Many misconceptions exist amongst young athletes regarding the role of protein, vitamins, minerals and fluids in the diet (Cupisti *et al.*, 2002; Jacobson *et al.*, 2001; Jonnalagadda *et al.*, 2001; Rosenbloom *et al.*, 2002). This could be due to the sources where these athletes obtain their nutritional information. Coaches should be encouraged to involve dieticians/nutritionists or physicians specialised in the area of exercise physiology and nutrition to educate young athletes on sound dietary practices. This can aid them in applying healthy eating habits from a young age and prevent or reduce the risk of chronic diseases of lifestyle later in life.

When working with young, especially female, athletes emphasis should not be placed on an 'ideal body weight' but rather on body composition and growth using the growth charts. This will decrease the risk of athletes following energy-restricted diets and developing eating disorders. Eating disorders are known to occur in female athletes who participate in aesthetical sports (Beals & Manore, 1998; Petrie, 1993; Ziegler *et al.*, 1998a & 1998b). These athletes should be educated about healthy ways of losing body fat or weight if necessary, as well as risks and complications associated with rapid weight loss, weight cycling, fasting or severe food restrictions (Yannakoulia *et al.*, 2002).

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On a separate sheet of paper, the manuscript must have an abstract with a limit of 275 words followed by 3 – 6 key words not used in the title. The abstract should have sentences (no headings) related to the purpose of the study, brief methods, results, conclusions and practical applications. Do not end with statements such as "will be discussed."

4. Text

The text must contain the following sections with titles in ALL CAPS in this exact order:

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This section is a careful development of the hypotheses of the study leading to the purpose of the investigation. Limit information that is "chapter like" in nature as this is not an exhaustive review of the topic. Focus the studies lending support to your hypothesis(es) and giving the proper context to the problem being studied. In most cases use no subheadings in this section and try to limit it to 4 – 6 concisely written paragraphs.

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Journal Article

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Book

LOHMAN, T.G. *Advances in Body Composition Assessment.* Champaign, IL: Human Kinetics, 1992.

Chapter in an edited book

YAHARA, M.L. The shoulder. In: Clinical Orthopedic *Physical Therapy*. J.K. Richardson and Z.A. Iglarsh, eds. Philadelphia: Saunders, 1994. pp. 159 – 199.

Software

HOWARD, A. Moments [software]. University of Queensland, 1992.

Proceedings

VIRU, A., M. VIRU, R. HARRIS, V. OOPIK, A. NURMEKIVI, L. MEDIJAINEN, AND S. TIMPMANN. Performance capacity in middle-distance runners after enrichment of diet by creatine and creatine action on protein synthesis rate. In: Proceedings of the 2nd Maccabiah-Wingate International Congress of Sport and Coaching Sciences. G. Tenenbaum and T. Raz-Liebermann, eds. Netanya, Israel, Wingate Institute, 1993. pp. 22 – 30.

Dissertation/Thesis

BARTHOLMEW, S.A. Plyometric and vertical jump training. Master's thesis, University of North Carolina, Chapel Hill, 1985.

6. Acknowledgements

In this section you can place the information related to Identification of funding sources; Current contact information of corresponding author; and gratitude to other people involved with the conduct of the experiment. In this part of the paper the conflict of interest information must be included. Authors are required to state in the acknowledgments all funding sources, and the names of companies, manufacturers, or outside organizations providing technical or equipment support. In particular, authors should: 1) Disclose professional relationships with companies or manufacturers who will benefit from the results of the present study, and 2) State that the results of the present study do not constitute endorsement of the product by the authors or the NSCA. Failure to disclose such information could result in the rejection of the submitted manuscript.

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The units of measurement shall be Système International d'Unités (SI). Permitted exceptions to SI are heart rate—beats per min; blood pressure—mm Hg; gas pressure—mm Hg. Authors should refer to the *British Medical Journal* (1:1334 – 1336, 1978) and the *Annals of Internal Medicine* (106:114 – 129, 1987) for the proper method to express other units or abbreviations. When expressing units, please locate the multiplication symbol midway between lines to avoid confusion with periods; e.g., mL $\cdot$ min^{-1} $\cdot$ kg^{-1}.

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Selected conversion factors:

1 N = 0.102 kg (force);

1 J = 1 N $\cdot$ m = 0.000239 kcal = 0.102 kg $\cdot$ m;

1 kJ = 1000 N $\cdot$ m = 0.239 kcal = 102 kg $\cdot$ m;

1 W = 1 J $\cdot$ s-1 = 6.118 kg $\cdot$ m $\cdot$ min^{-1}.

When using nomenclature for muscle fiber types please use the following terms. Muscle fiber types can identified using histochemical or gel electrophoresis methods of classification. Histochemical staining of the ATPases is used to separate fibers into type I (slow twitch), type IIa (fast twitch) and type IIb (fast twitch) forms. The work of Smerdu et. al (AJP 267: C1723, 1994) indicates that type IIb fibers contain type IIx myosin heavy chain (gel electrophoresis fiber typing). For the sake of continuity and to decrease confusion on this point it is recommended that authors use IIx to designate IIb fibers in theie manuscripts.

Smerdu, V., Karsch-Mizrachi I., Campione M., Leinwand L., Schiaffino S. Type IIx myosin heavy chain transcripts are expressed in type IIb fibers of human skeletal muscle. Am J. Physiol. 267 (6 Pt 1):C1723-1728, 1994.

Nutritional knowledge, eating habits, attitudes and supplement use of young female gymnasts

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Abstract

This study compared the nutritional knowledge, eating habits, attitudes and supplement use of elite and non-elite female gymnasts. **Method**. Twenty gymnasts (mean age = 13.56 ± 2.16 years) participated on the basis of availability (elite = 11; non-elite = 9). Anthropometric data was obtained, while demographic and nutritional knowledge questionnaires, diet records as well as the Eating Attitude Test (EAT-26) were completed. **Results**. Vitamin and mineral supplement use was practically significantly higher in non-elite gymnasts (88.9%) compared to elite gymnasts (45.45%, medium effect size = 0.45), while only 18.18% (n = 2) of gymnasts used other supplements. In the total group of gymnasts the source of nutritional information was the coach (60%) followed by the dietician and parents (45%), team mates, books and magazines (30%), the physician (15%) and the school (10%). Parents were considered as the most useful source of information (50%), followed by the dietician (30%) and the coach (20%). There were no differences in the overall mean score for the nutritional knowledge questionnaire between elite and non-elite gymnasts (61.8% vs. 62.8% respectively). More than half (55%) of the gymnasts ate a low nutrient, high-energy snack twice daily. Although EAT26 scores were low in both groups, elite gymnasts had a higher risk for dieting than non-elite gymnasts (4.45 ± 3.64 vs. 2.11 ± 1.76, large effect size), while non-elite gymnasts practiced more oral control (5.00 ± 3.35 vs. 1.45 ± 1.50, d = 1.03) over food intake. Additionally, there was a positive correlation between the risk for dieting and nutrition knowledge in non-elite gymnasts.

Conclusion. Young South African female gymnasts have inadequate nutrition knowledge and unsatisfactory eating habits, although they don't seem to be at risk for developing eating disorders.

Key words: elite gymnasts, knowledge, eating habits, nutrient intake, supplements

3.1 Introduction

Aesthetic sport and sport with weight categories e.g. gymnastics, figure skating, ballet and wrestling place much emphasis on a lean physique, thinness and appearance (26). Studies indicate that adolescent female figure skaters and gymnasts make use of different methods to lose weight e.g. excessive exercise (18%), dieting/fasting (18.2%) (26; 40), as well as day-long fasting and fad diets (5) to attain an ideal body weight and image of the relevant sport (18, 34). This can contribute to disordered eating and behavioral patterns in these athletes such as severe food restriction (2, 3, 25, 26), which is associated with low energy intakes (18), self-induced vomiting and/or the misuse of laxatives and diuretics (2; 38). This behaviour may have health related consequences such as immuno-suppression and decreased metabolic rate. Additionally, the need for a decreased energy intake may be aggravated, which can induce growth retardation (19). Some female gymnasts have been shown to suffer from *anorexia athletica* (2; 38). These gymnasts have an increased risk for a negative energy balance due to low intakes of proteins and carbohydrates (2). Additionally they have decreased intakes of iron, vitamin B6, folate and calcium, when compared to the recommendations for highly active women (3).

An athlete's nutritional knowledge usually determines or influences his/her dietary habits (28). It is known that many misconceptions regarding the role of certain nutrients (9) and the utilization of dietary supplements exist (25, 37). Barr (1) showed that university athletes mostly obtain their knowledge from magazines (69%) and books (67%), followed by friends and teammates (54%), the school (53%), advertisements (33%) and lastly the coach (30%). Additionally, it has been shown that female gymnasts' nutritional knowledge (9) as well as their sports nutritional knowledge (1) is superior to non-athletes.

Cupisti *et al.* (9) showed that lunch and dinner contributed 37 – 45% and 32 – 37% respectively to the elite gymnasts energy contribution, while snacks provided between 8 – 16% of the daily energy. Gymnasts also reported a higher cereal, fruit and vegetable intake compared to non-athletes. Additionally they consumed more refined sugars than non-athletes (98 ± 40 vs. 71 ± 27 g/day), while sport bars and beverages were used to a lesser extent.

Ziegler *et al.* (40) found similar results in figure skaters with energy contributions from lunch (27 ± 1.3%) and dinner (31 ± 1.6%) being the greatest, followed by snacks (22 ± 1.6%) and breakfast (20 ± 1.1%). Dinner had the highest protein content. On average, 1.36 ± 0.62 snacks were consumed per day and ranged from dairy products (17.6%) being the most commonly consumed, followed by fruit (9.5%), cereals and snack bars (9.3%), processed products (8.9%), and bread products (8.1%). Instant soups (2%), nutritional supplements e.g. Ensure® (2.5%), confectionary (2.1%) and nuts (1%) were the least frequently consumed. Regular meals and snacks are recommended for athletes to aid them in achieving energy balance and carbohydrate needs (4).

Currently, limited data are available on the eating attitudes, nutritional knowledge and eating habits of South African female gymnasts. The aim of this study was, therefore, to investigate the eating attitudes, nutritional knowledge and eating habits, as well as the association between these variables in young South African female gymnasts.

3.2 Methods

3.2.1 Approach to the problem

The gymnasts completed a demographic questionnaire, which included dietary habits, smoking and alcohol usage, as well as vitamin and/or mineral supplement use. Information on the most frequently used and most valuable source of nutrition information was also collected. The gymnasts completed a 3-day weighed food record (2 training days and 1 non-training day). An Eating Attitude Test (EAT26) was completed to measure eating behaviour and body dissatisfaction. A nutritional knowledge questionnaire (9) was completed to measure their nutritional and sport nutritional knowledge.

3.2.2 Subjects

The study population included 20 white female gymnasts between the ages of 10 -18 years, 9 were non-elite gymnasts (levels 3 - 7) and 11 were elite gymnasts (levels 8 - Senior Olympics) within the same range for age and BMI. Gymnasts were recruited from two gymnastics clubs in the North West Province on the basis of availability. Written informed consent was obtained from both the parents and children and the Ethics Committee of the North West University approved the study, ethic number 03M14.

3.2.3 Questionnaires

Gymnasts were trained by a registered dietician (RD) on the completion of these records. For completion of the 3-day weighed food record, each gymnast was given a food scale to measure the food before it was eaten as well as the leftovers. After completion, the dietician reviewed the records for accuracy and completeness and asked the gymnasts for more information if anything was unclear. Food records were analysed using the Food Finder software package based on the South African food composition tables (23).

The EAT26 questionnaire consists of 26 questions divided into three categories namely Dieting (Factor I), Bulimia and food pre-occupation (Factor II) and Oral control (Factor III) (14). Factor I is related to body image, Factor II to bulimia and a heavier body weight, and Factor III is related to self control about food, while high scores in Factor III are associated with a lower body mass (14). For each question 6 options could be chosen which were scored as follows: never (0), rarely (0), sometimes (0), often (1), very often (2) and always (3) (22). A total score of 20 and more for the total questionnaire is indicative of a possible eating disturbance (24).

Lastly, the nutritional knowledge questionnaire (9), consisting of 20 questions including nutritional aspects regarding fats, proteins, carbohydrates, vitamins, minerals, fibre, rehydration as well as weight loss practices.

3.2.4 Anthropometry

Height and weight were measured using a stadiometer and an electronic scale to the nearest 0.1 cm and 0.1 kg respectively. A caliper (Slimguide, Creative Health Products) was used to measure skinfold thickness to the nearest 1mm. The triceps, subscapular, supraspinal, abdominal, frontal thigh and medial calf skinfolds were measure according to the methods of Norton *et al.* Percentage body fat was calculated using the formula of Withers *et al.* (37):

BD (Body density) = 1.07878 - 0.00035(sum of skin folds) + 0.00032(age)

Fat % = (495/BD) – 450.

3.3 Results

In Table 3.1 the gymnasts' anthropometric characteristics are summarized.

Table 3.1. Anthropometric characteristics of young female gymnasts

	Total group (n=20) Mean ± SD	**Non-elite gymnasts (n=9) Mean ± SD**	**Elite gymnasts (n=11) Mean ± SD**
Age (years)	13.56 ± 2.16	13.18 ± 2.17	13.87 ± 2.21
Height (cm)	152.02 ± 9.16	150.42 ± 7.68	153.33 ± 10.39
Weight (kg)	42.97 ± 10.61	39.89 ± 8.65	45.48 ± 11.77
BMI (kg/m²)	18.33 ± 2.68	17.49 ± 2.52	19.02 ± 2.73
Body fat (%)	15.57 ± 2.22	15.60 ± 2.76	15.54 ± 1.82

Both elite and non-elite gymnasts weight for age was within the normal ranges (25^{th} and 50^{th} percentile) when using the CDC growth monitoring charts. The mean body fat percentage was slightly below recommendations (17 – 25%). Both their BMI (25^{th} and 50^{th} percentile) for age as well as their height for age (10^{th} and 25^{th} percentile) are within the normal ranges.

Demographic data indicated that only 18.18% of elite gymnasts were vegetarians while no non-elite gymnasts were vegetarians. Vitamin and mineral supplement use was higher in non-elite gymnasts (88.9%) compared to elite gymnasts (45.45%, medium effect size, d = 0.45). Only elite gymnasts (18.18%, n = 2) used other supplements, namely glutamine and a whey protein-based muscle enhancer. In the total group of gymnasts the most used source of nutrition information was the coach (60%) followed in order of use by the dietician and parents (45%); teammates, books and magazines (30%); the physician (15%); and the school (10%). Gymnasts could choose more than one source, therefore, amounts will not add up to 100%. When looking at differences between groups, more non-elite gymnasts obtained nutrition information from the physician compared to elite gymnasts (33.33 vs. 0%, medium effect size, d = 0.46). More elite gymnasts gained their nutritional knowledge from their coach compared to non-elite gymnasts (81.82 vs. 33.33%, medium effect size = 0.49). There were no further practically significant differences between the groups in terms of sources of nutritional knowledge. Looking at the most useful source of nutrition information, parents were considered as most useful (50%), followed by the dietitian (30%), and the coach (20%) in the total group of gymnasts. All the other sources were either considered as not useful or were second, third or fourth most useful compared to parents, the dietitian and the coach. There were no practically significant differences between the two groups.

Although there were no difference in the overall mean score for all the nutritional knowledge questions between elite and non-elite gymnasts (61.8% vs. 62.8% respectively), more elite gymnasts knew that carbohydrates are the main energy source for athletes (question 1, see Figure 1), milk has a higher protein content than legumes or vegetables (question 4), mozzarella cheese has a higher energy and fat content than chicken or brinjal (question 6) and meat has a higher iron content than spinach (question 11) compared to non-elite gymnasts. None of the gymnasts knew that it is best to ingest sodium-containing beverages instead of water to maintain euhydration (question 12). More non-elite gymnasts knew that mineral water contains less energy than other drinks (question 14) and only one gymnast knew that a hamburger is a better choice than french fries or ice cream for a light meal (question 16). More elite gymnasts knew that increased meat consumption does not enhance muscle mass (question 17). Both elite and non-elite gymnasts did not know that dietary supplements could be used during fasting and when following an unbalanced diet (question 18). All gymnasts, however, knew that one needs to cut down on sugar and fat to loose body fat and not skip meals (question 20). No correlations were found between gymnasts' nutritional knowledge and micro or macronutrient intakes.

Only 55% of the total group of gymnasts ate snacks during the day. An early morning snack (65%) was most often consumed, followed by a mid-afternoon (55%) and late night snack (45%). The most common snack foods consumed by these athletes were sweets (77%), fruits (54%) and cold drinks (41%). Other foods that were also commonly consumed included potato crisps (27%); dairy products (26%) e.g. yoghurt, milk, cheese and ice cream; fruit juice (16%); cakes and pastries (15%); snack bars (10%); meat (8%); dessert (7%) and lastly, peanuts (5%).

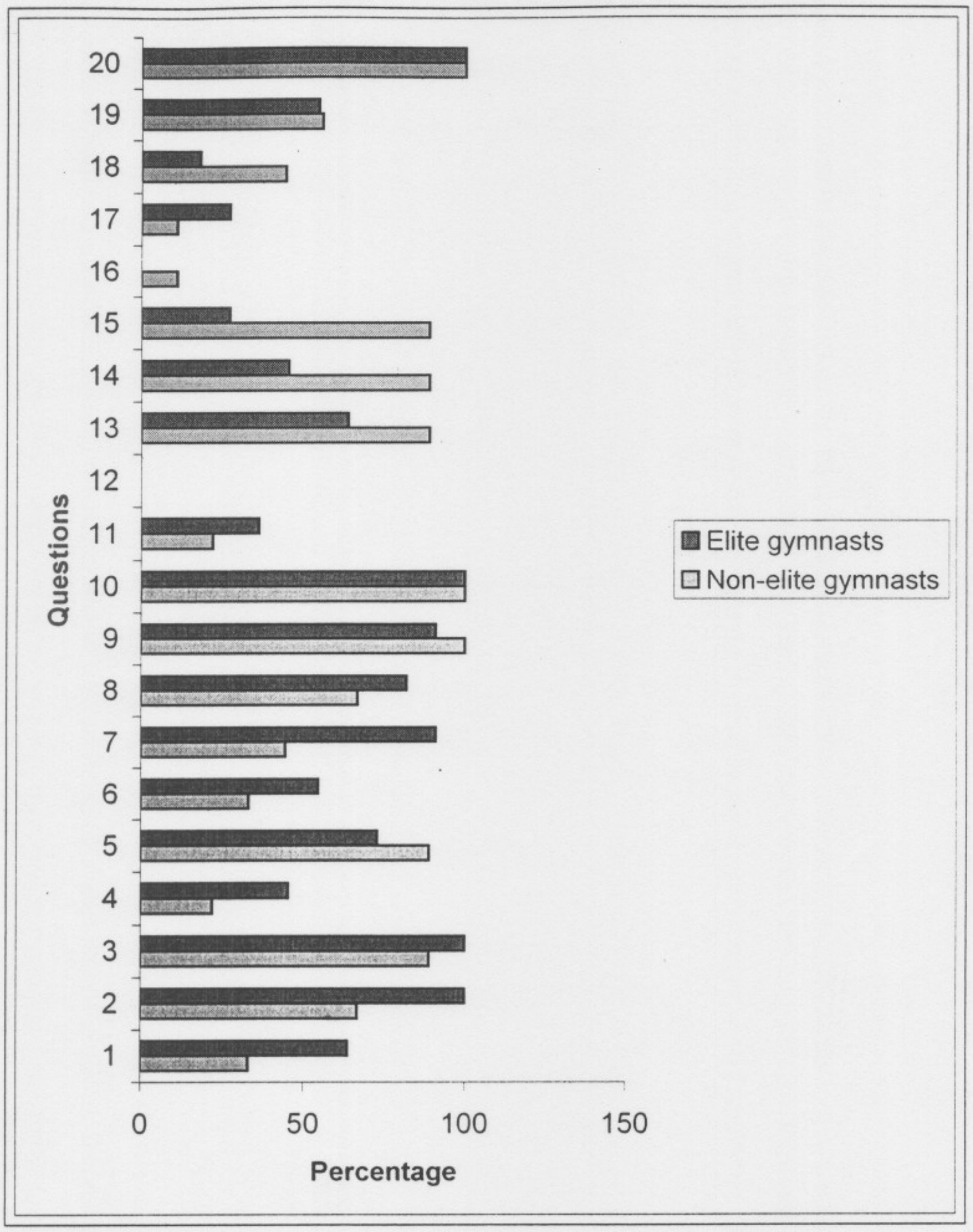

Figure 3.1: Percentage correct answers of elite vs. non-elite gymnasts to the nutrition knowledge questionnaire

Only 22.2% non-elite and 45.4% elite gymnasts reported that they occasionally followed a diet. The EAT26 score for the total group of gymnasts was less than 20 (mean score = 6.95), which indicated that both groups had a low risk of developing an eating disorder (see Table 3.2). Elite gymnasts had a higher risk for dieting than non-elite gymnasts (large effect size, d = 1.32) and non-elite gymnasts had a higher risk of oral control over food intake (large effect size, d = - 1.03) than elite gymnasts (see Table 3.2). Additionally, there was a positive correlation between nutritional knowledge and risk for dieting (r = 0.76) amongst non-elite gymnasts, but no other correlations were found.

Table 3.2 Mean scores of Factors I, II, and III of the EAT26 test in elite and non-elite gymnasts

Factor	Elite gymnasts (n=11)	Non-elite gymnasts (n=9)	Effect size
Factor I: Dieting (SD*)	4.45 (± 3.64)	2.11 (± 1.76)	d = 1.32
Factor II: Bulimia and Food preoccupation (SD)	0.55 (± 1.29)	0.33 (± 1.00)	d = 0.22
Factor III: Oral control (SD)	1.55 (± 1.51)	5.00 (± 3.35)	d = - 1.03

SD = standard deviation

3.4 Statistical Analysis

Descriptive statistics were done by the Statistical Consultation Service of the North-West University using the SAS System for Windows Release 9.1 (2003). Differences between groups were measured using t-tests. The sample was not randomized and large enough to characterize small but clinically important differences between the groups. The tests of statistical significance, have not, therefore, been reported lest readers reach erroneous conclusions about lack of difference between groups. The mean and standard deviation (SD) for the gymnasts' anthropometric and demographic characteristics, supplement use, nutritional knowledge scores, sources of nutrition information, and EAT26 scores were used. The magnitude of the difference between means using effect size (10) was interpreted. The effect size is the difference between means expressed as a proportion of the standard deviation (SD) units (a fraction or multiple of the SD). The scale of effect sizes is as follows: a) small effect: d = 0.2, b) medium effect: d = 0.5, c) large effect: d = 0.8. When the effect size is = 0.8, the data are considered as practically significantly different while effect sizes of 0.5 might indicate a difference that could be important (10). The effect size is calculated by using the standardized difference between the means of the two groups, i.e. the difference between the two means divided by the estimate for standard deviation (10), the formula is:

$$d = \frac{|\bar{x}_E - \bar{x}_K|}{s_K} \quad (10)$$

3.5 Discussion

3.5.1 Supplement use

The use of supplements is popular amongst athletes due to advertising promises of improved strength, speed, recovery and a quick fix when not eating properly (12, 31). Female athletes seem to be more likely to take supplements due to an inadequate diet or "for health reasons", while males take supplements to improve speed and agility, strength and power, or muscle/weight gain (12, 17). An earlier review on vitamin/mineral supplement use among athletes (32) concluded that athletes often use these supplements as ergogenic aids to improve performance and the overall mean prevalence of athlete's supplement use was 46% (data from 51 studies). More recent studies amongst college athletes also indicated high rates of supplement use ranging from 18.9 – 73.3% in both genders (6, 12, 17, 20). Approximately 36% of college athletes (mostly male) used creatine supplements (12, 17, 20). Other popular supplements included energy drinks, caloric-replacements and protein supplements (6, 12, 20). The results in this study were similar (6, 12, 17, 20) in terms of vitamin/mineral supplement use, since 65% of the total group of gymnasts used these supplements. However, more non-elite than elite gymnasts used vitamin/mineral supplements, which is in contrast to some studies (1, 33), but in agreement with others (11, 29). A shortcoming of this study was that reasons for supplement use were not recorded and this combined, with the variation in supplement use among athletes and non-athletes makes it difficult to draw conclusions on supplement use in this group. Sobal and Marquart (33) did, however, find in a group of high school athletes that neither gender nor grade in school had an influence on supplement consumption. Since there were no correlations found between nutritional knowledge and nutrient intakes (with or without vitamin/mineral supplement use), nutritional knowledge does not seem to have influenced either elite or non-elite gymnasts' vitamin/mineral supplement use in this study.

3.5.2 Nutritional knowledge and eating habits

Coaches are usually the primary information source for athletes (13, 17, 21) and the most influential person regarding an athlete's food intake (13). Unfortunately, they often lack nutritional knowledge, since they are not obliged to attend nutrition courses. Their information is mostly obtained from non-scientific magazines (58%), (21, 27), other coaches (44%) (21), the Internet and television (27), which often contains unreliable information. Two studies (21, 27) indicated that trainers and coaches still lack certain nutritional knowledge when they scored between 67 – 70% for a nutritional knowledge questionnaire.

Jacobson *et al.* (17) showed that men mostly received their information from coaches (21.9%) and athletic trainers (19%), while women rather gained sport nutrition knowledge from the university and nutritionists in the form of lectures. While Burns *et* *al.* (6) indicated that both male and female intercollegiate student athletes received most of their information from trainers (39.8%) as well as strength and conditioning coaches (23.7%). In the same study, only 14.4% of athletes received their information from a RD. This small number was probably due to the fact that most athletes did not know there was a dietitian available. In the present study, the main nutrition information sources were the coach, dietitian, and parents. As stated before more of the gymnasts received nutrition information from the coach and dietitians (6; 17). Parents were considered the most useful nutrition source followed by the dietitian and then the coach. Receiving nutrition information from the coach and parents could be the cause of poor nutritional knowledge (mean score = 62.3%). Therefore, the sources they most often use for nutrition information do not seem to be the most useful, and those considered useful are used less often. Possible reasons why the most useful sources are so seldom used could be due to the need for independence (not wanting to ask parents), lack of availability (dietitian), or fear and time constraints (coach). Whatever the reasons, these results highlight the importance for nutrition education by knowledgeable sources to this group of female gymnasts.

Poor nutritional knowledge does not seem to be exclusive to this study group. Other studies (7, 9, 25, 28) also indicate that athletes still have some misconceptions regarding basic nutrition aspects. In these studies it was found that gymnasts did not know the role of most nutrients in sport performance and in most situations, also low nutrient-dense foods are the preferred choice, which may result in fatigue and poor performance (9, 28). Furthermore, they did not have adequate nutritional knowledge to make appropriate food and/or fluid choices during a competition day. The gymnasts also believe that a high protein diet will increase muscle mass and strength. Furthermore, they did not know the indications for nutrition supplements and lastly, they did not know how to maintain a healthy body weight.

Since young athletes have increased energy requirements, small frequent meals are recommended to aid them in achieving their individual energy needs (35). Furthermore, it will also help to prevent gastro-intestinal discomfort, fatigue and overeating (15, 40). Snacks should be nutrient-dense (35; 40) since they contribute a substantial percentage (32 – 37%) to the total daily energy intake (35). In this study, gymnasts consumed mainly large meals instead of small frequent meals. Some gymnasts consumed snacks at 10:00 and 15:00, while a late night snack was seldom utilized. Spacing and periodicity of meals may play an important role in meeting various sport nutrition goals such as high energy needs and sufficient carbohydrate intakes. Various studies have reported 'grazing' food patterns in athletes that have high-energy needs (4). Possible reasons for lack of snacking in the gymnasts in this study could include inadequate nutritional knowledge, possible time constraints, restrained eating habits and under-reporting. More high energy-dense food e.g. sweets, cold drinks and potato crisps were eaten between meals than nutrient-dense snacks, which were eaten to a lesser extent, namely fruits and fruit juices, dairy products and snack bars. Other researchers (9, 25, 35) also found that their athletes selected energy-dense food to enhance energy levels. Ziegler *et al.* (40), however, found in a group of figure skaters that they mostly chose nutrient-dense snacks such as dairy products, fruit, and cereal products, while confectionary and sweets were not frequently selected. This might be due to the fact that they are more health conscious and have some sport nutritional knowledge, unfortunately it was not mentioned whether the gymnasts previously received any dietary education to explain their healthy food choices. Set meal patterns are recommended to aid athletes in making healthy food choices and aid them in optimising micro and macronutrient intake, which could result in increased performance (40).

3.5.3 Eating attitudes

Gymnastics coaches often contribute to the development of eating disorders, because they emphasize the importance of weight management to a greater extent than coaches of other sporting types (16). A recent study (16) indicated that coaches use the following weight control measurements: regular weighing (44%), assessing body fat composition (44%), food restriction (30%) and extra workouts (29%). Whereas, an earlier study by Benson *et al.* (3) showed that swimmers (11%) and gymnasts (1%) are highly preoccupied with weight and may be involved in unhealthy eating behaviour to achieve a desirable body weight. An obsession with weight might give a general feeling of social acceptability, increased self-esteem and a sense of control (30). A study of figure skaters (40) indicated that they are not at risk for disturbed eating behavior and/or disorders as was previously indicated. In contrast with the former, a study conducted by Leydon and Hall (24) showed that 20% of their jockeys were at risk for disordered eating behaviour, because the importance of leanness was frequently emphasized. A study (36) among gymnasts and cross-country runners revealed that the former were more pre-occupied with their body weight. They also have an obsession with leanness, which might be due to a set of aesthetic standards for appearance. The results in this study were in contrast to some (3, 24, 34), but in agreement with others (39), indicating a low risk for disturbed eating behaviour and/or disorders, despite small differences between groups in terms of dieting and control over food intake. It was, however, interesting that it seemed that those non-elite gymnasts with more nutritional knowledge had a higher risk to diet. Since most South African gymnasts are probably not in the same league as other countries' elite gymnasts and, therefore, probably do not experience as much pressure on body weight and eating habits, their risk of developing eating disorders and food preoccupation is probably lower than the studies mentioned above.

3.6 Practical Applications

Vitamin and/or mineral supplements were often used, while meal replacements, energy drinks and protein supplements were used to a lesser extent. Although coaches were the main nutrition information source, parents were considered to be more useful source. Using unreliable sources for nutrition information could have contributed to their poor nutritional knowledge, food choices and dietary habits. From this study and others it is clear that nutrition intervention is important due to many existing misconceptions and malpractices amongst athletes. A physician specialized in exercise physiology or a RD specializing in sport nutrition should provide sport nutrition information to athletes at regular intervals (8). The RD should emphasis the importance of a well balanced diet (7) and the consequences of energy restriction on health and performance (8) in athletes taking part in aesthetic sports. Additionally, education on food selection and eating habits should be addressed. More emphasis should also be placed on the relationship between nutrition and performance (1,9) and the role of certain nutrients in sport performance, followed by accurate information on supplements used (12).

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Nutrient intake, energy balance and supplement use in young female gymnasts

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Abstract

The purpose of this study was to compare the nutrient intakes, supplement use and energy balance of elite and non-elite female gymnasts. **Method**. Twenty gymnasts (mean age = 13.56 ± 2.16 years) participated on the basis of availability (elite = 11; non-elite = 9). Anthropometric measurements were taken, three-day weighed diet records were kept and 24-hour energy expenditure was measured using Actical® accelerometers. **Results**. No practically significant differences were observed between the groups for energy (non-elite = 6 944.37 ± 1 272.3 kJ vs. elite 6 543.06 ± 2 569 kJ), protein (non-elite = 62.81 ± 16.7 g vs. elite = 64.48 ± 24.18 g), carbohydrate (non-elite = 193.44 ± 33.39 g vs. elite = 192.87 ± 86.08 g) and fat (non-elite = 63.5 ± 17.2 g vs. elite = 53.26 ± 27 g) intakes, as well as daily energy expenditure (non-elite = 6 393.77 ± 1 244.19 kJ vs. elite = 6 696.09 ± 1 676.58 kJ). Mean intakes of vitamin E, folate, calcium, magnesium and iron were less than 60% of the RDA when supplementation was not used. **Conclusion**. Despite vitamin and/or mineral supplementation, young South African female gymnasts have inadequate intakes of carbohydrate and certain micronutrients even though they are in energy balance.

Key words: athletes, carbohydrate intake, protein intake, fat intake, energy expenditure.

4.1 Introduction

Leanness is a pre-requisite for aesthetic sports e.g. gymnastics, ballet, figure skating as well as weight category sports such as flat race jockeys and wrestling. Food intake is, therefore, often restricted (22) to achieve or maintain a low body weight (34, 45) and body fat level throughout the season (15). This could contribute to a negative energy balance, which might have the following health risks: a) impaired growth and development, b) immune-suppression, c) decreased bone mineral density (BMD) (24), d) reproductive disorders and e) pre-menopausal osteoporosis (22). Additionally, daily energy imbalances have been associated with higher proportions of body fat (15).

According to the Estimated Energy Requirements (EER), an active female athlete between the ages of 9 - 13 years with a mean weight of 37.4 kg should consume 255 kJ/kg body mass (BM)/day, whereas a female athlete between the ages of 14 - 18 years with a mean weight of 53.8 kg should consume 246 kJ/kg BM/day (2). Various studies (8, 9, 14, 22, 23, 28, 34, 39) showed that the mean energy intake for gymnasts between the ages of 9 – 18 years varies between 7 022 – 7 230 kJ per day (149 - 179 kJ/kg BM/day), which is less than the recommended value of 7 833 – 11 899 (212 – 270 kJ/kg BM/day).

It is well documented that adequate carbohydrate intake is the main energy source during exercise (2) and important for exercise performance. Limited data are, however, available on the carbohydrate needs of young athletes as well as needs according to specific sporting types. Due to this limitation, adult carbohydrate guidelines are mostly prescribed for these athletes, which are 55 – 60% carbohydrates of the total daily energy (1, 2, 8, 46) or 7 - 10 g/kg BM/day for highly active athletes (11). Studies (8, 9, 14, 22, 23, 28, 34, 39) show that gymnasts ingest between 53.86 - 60.14% of the total daily energy intake as carbohydrate or between 5.1 – 5.9 g carbohydrates/kg BM/day. That is difficult for young gymnasts to meet their recommendations, possibly due to body weight issues and the bulk of complex carbohydrate food (10).

Currently there is also no published data on specific protein requirements for young athletes (44). It can be assumed that young athletes' protein needs will be high due to the protein need for growth and participation in exercise. Protein intake amongst gymnasts varies between 15.86 – 16.4% of the total daily energy intake or between 4.1 – 7.3 g/kg BM/day. Gymnasts already ingest more protein than the Recommended Daily Allowance (RDA, 0.8 g/kg BM/day) and it could be assumed that their protein requirements will mostly be met even when on a low energy diet. (1, 2, 8, 46). Fat intake usually varies between 23.7 - 30.64% (8, 9, 14, 23, 24, 29, 35, 40) of the total daily energy intake. Although a low-fat diet is prescribed, care should be taken not to ingest too little fat since it plays an important role in optimal health.

Researchers found, (8, 9, 14, 22, 23, 28, 34, 39) that the mean intake for vitamins C, B6, B12, thiamin, riboflavin, niacin, iron and zinc of children and adolescent female gymnasts is usually greater than the RDA (689%, 159%, 428%, 148%, 198%, 141%, 116% and 114% respectively), while their vitamin E (25% of RDA) and folate (47% of RDA) intakes could be inadequate. Apart from vitamin E and folate, it has been shown (8, 9, 14, 22, 23, 28, 34, 39) that most young athletes do not meet their calcium (875 ± 309 vs. 1 300 mg), phosphate (1 085 ± 368 vs. 1 250 mg) and magnesium (217 ± 70.95 vs. 300 mg) needs when compared with the RDA.

Since female athletes competing in aesthetic sports are such a vulnerable group and limited data is available on South African gymnasts' energy balance, nutrient intakes, and supplement use, the aim of this study was to assess these factors in a group of young, female South African gymnasts. Results will aid dieticians and coaches to identify areas needed for nutrition counselling and thereby improve their performance.

4.2 Methods

4.2.1 Subjects

The study population included 20 white female gymnasts between the ages of 10 and 18 years, 9 were non-elite gymnasts (levels 3 - 7) and 11 were elite gymnasts (levels 8 - Senior Olympics) within the same range for age and body mass index (BMI). Gymnasts were recruited from two gymnastic clubs in the North West Province on the basis of availability. Written informed consent from children and parents was obtained and the Ethics Committee of the North West University approved the study, ethic number 03M14.

4.2.2 Anthropometry

Height and weight was measured using a stadiometer and an electronic scale to the nearest 0.1 cm and 0.1 kg respectively. A caliper (Slimguide, Creative Health Products) was used to measure skinfold thickness to the nearest 1 mm. The triceps, subscapular, supraspinal, abdominal, frontal thigh and medial calf skinfolds were measured. Percentage body fat was calculated using the formula of Withers (48) namely:

Body density (BD) = 1.07878 – 0.00035 (sum of skin folds) + 0.00032 (age)

Body fat percentage = (495/BD) – 450.

4.2.3 Dietary Intake

The gymnasts completed a 3-day weighed food record (2 training days and 1 non-training day). Gymnasts were trained by a RD on the completion of these records. Each gymnast was given a food scale to measure the food before it was eaten as well as the leftovers. After completion, the dietician reviewed the records for accuracy and completeness and asked the gymnasts for more information if anything was unclear. Food records were analysed using the Food Finder software package based on the South African food composition tables (25).

4.2.4 Energy Expenditure

An Actical® accellerometer (Mini Mitter Co., Inc. Bend, OR, USA) was used to determine the level of physical activity and energy expenditure over a period of 24 hours (38). The accellerometer weighed 17.5 g and was worn on the right hip for 24 hours. The Actical® accelerometer has been validated for measurement of physical activity in children by Puyau et al. (38).

4.2.5 Demographics

Menstrual status and supplement use were recorded by means of completion of a demographic questionnaire.

4.3 Statistical analysis

Descriptive statistics were done by the Statistical Consultation Service of the North-West University using the SAS System for Windows Release 6.12 (1996). Differences between groups were measured using t-tests. The sample was not randomized and large enough to characterize small but clinically important differences between the groups. Statistical significance, has not, therefore, been reported lest readers reach erroneous conclusions about lack of difference between groups. The mean and standard deviation (SD) for the gymnasts' nutrient intake, energy balance and supplement were used. The magnitude of the difference between means using effect size was interpreted (44). The effect size is the difference between means expressed in standard deviation (SD) units (a fraction or multiple of the SD). The scale of effect sizes is as follows: a) small effect: d = 0.2, b) medium effect: d = 0.5, c) large effect: d ≥0.8. When the effect size is ≥0.8, the data is considered to be significantly different (16). The effect size is calculated by using the standardized difference between the means of the two groups, i.e. the difference between the two means divided by the estimate for standard deviation (16). The formula is:

$$d = \frac{|\bar{x}_E - \bar{x}_K|}{s_K} \quad (16)$$

4.4 Results

The mean age of the gymnasts was 13.56 ± 2.16 (range 10 - 18 years), height 152.02 ± 9.16 cm, weight 42.97 ± 10.61 kg, percentage body fat 15.57 ± 2.22% and body mass index 18.33 ± 2.68 kg/m².

Only two non-elite gymnasts are experiencing the menstrual cycle and reached menarche at 12 years of age. Five elite gymnasts are also experiencing the menstrual cycle and reached menarche at a mean age of 14.6 ± 1.34 years.

There was no difference in energy and macronutrient intake or energy expenditure between elite and non-elite gymnasts. Elite gymnasts, however, tended to have higher protein (15.4 vs. 21.37%, small effect size, d = 0.1) and lower fat (28.9 vs. 33.6%, medium effect size, d = - 0.6) intakes (see Table 4.1). Although the total daily energy intake (non-elite = 6 944.37 ± 1 272.28 kJ vs. elite = 6 543.06 ± 2 569.74 kJ) in both groups was below the RDA, it was similar to their daily energy expenditure values (non-elite = 6 393.77 ± 1 244.19 kJ vs. elite = 6 696.09 ± 1 676.58 kJ). The carbohydrate intake of both groups was higher than the Dietary Reference Intake (DRI), which indicates a minimum required intake and expressed in g/kg BM/day, they both ingested an average of 4.5 g/kg BM/day. Both elite and non-elite gymnasts between the ages of 14 – 18 years had a low fibre intake (non-elite = 14.06 g/day and elite = 11.53 g/day, respectively). Converting mean protein intake to g/kg BM/day, it was also found to be above the RDA (non-elite = 1.46 g/kg BM/day vs. elite = 1.5 g/kg BM/day).

More non-elite gymnasts (n = 7, 88.88%) used vitamin and/or mineral supplements than elite gymnasts (n = 4, 45.45%, medium effect size, d = 0.45). Only elite-gymnasts (18.18%, n = 2) used other supplements, namely glutamine and a whey protein-based muscle enhancer. No significant differences were, however, found between elite and non-elite gymnasts in terms of micronutrient intake, with or without supplementation (see Table 4.2). Vitamins A, B1, B2, B6, B12 and vitamin C intakes of all gymnasts were adequate. Only the non-elite gymnasts (14 – 18 years of age) vitamin E intake was less than 60% of the RDA. Both non-elite and elite gymnasts (14 – 18 years) had a folate intake less than 60% of the RDA, with and without supplementation.

Mean calcium and magnesium intake in both supplemented and non-supplemented elite and non-elite gymnasts was lower or equal to 60% of the RDA. Both elite and non-elite gymnasts between the ages of 14 – 18 years had an iron intake less than 60% of the RDA, however, the intake increased to more than 60% of the RDA after supplementation was used in both groups.

Supplement intakes of elite gymnasts contribute in the following way to the percentage intakes of the named micronutrients: vitamin A, 37.5%; vitamin B1, 64%; vitamin B2, 55%; vitamin B6, 77.5%; vitamin B12, 194%; vitamin C, 61.5%; vitamin E, 56.5%; niacin, 12.5%; folate, 26%; biotin, 5.5%; calcium, 6.5%; iron, 21.5%; zinc, 26%; magnesium, 9.5% and selenium, 20.5%. Non-elite gymnasts' supplement contribution to intakes was for vitamin A, 34%; vitamin B1 82%; vitamin B2 67%; vitamin B6 66%; vitamin B12 104%; vitamin C 88.5%; vitamin E 35%; niacin 7.5%; folate 34.5%; biotin 52%; calcium 15.5%; iron 26.5%; zinc 22.5%; magnesium 11% and 23.5% selenium.

Table 4.1 Mean daily macronutrient intakes of non-elite and elite gymnasts with and without supplements

	RDA	Non-elite (w/o supplement)	Non-elite (w supplement)	Elite (w/o supplement)	Elite (w supplement)
Kilojoules (kJ/d)	10 – 13 years: 8 698	7 594.47 (± 975.03)	7 594.47 (± 975.03)	6 378.42 (± 2 920.96)	6 378.42 (± 2 920.96)
	14 – 18 years: 9 946	6 131.83 (± 1 209.93)	6 131.83 (± 1 209.93)	6 549.57 (± 2 424.20)	6 637.14 (± 2 590.66)
Protein (g/d)	10 – 13 years: 34	69.47 (± 16.00)	69.47 (± 16.0)	57.99 (± 25.26)	57.99 (± 25.26)
	14 – 18 years: 46	54.50 (± 15.28)	54.50 (± 15.28)	66.04 (± 21.77)	68.18 (± 24.74)
% Protein (g/d)	10 – 13 years:	15.83 (± 3.11)	15.83 (± 3.11)	16.53 (± 2.34)	16.53 (± 2.34)
	14 – 18 years	14.87 (± 3.17)	14.87 (± 3.17)	18.28 (± 4.72)	24.13 (± 14.39)
Carbohydrates (g/d)	10 – 13 years: 100*	209.23 (± 33.20)	209.23 (± 33.20)	184.61 (± 94.27)	184.61 (± 94.27)
	14 – 18 years: 100	173.70 (± 23.85)	173.70 (± 23.85)	194.44 (± 82.63)	197.59 (± 88.52)

RDA = Recommended Dietary Allowance

Table 4.1 Mean daily macronutrient intakes of non-elite and elite gymnasts with and without supplements (continued)

	RDA	Non-elite (w/o supplement)	Non-elite (w supplement)	Elite (w/o supplement)	Elite (w supplement)
% Carbohydrates	10 – 13 years:	50.15	50.15	50.39	50.39
		(± 4.23)	(± 4.28)	(± 4.35)	(± 4.35)
	14 – 18 years	51.96	51.96	55.15	63.73
		(± 6.52)	(± 6.52)	(± 11.14)	(± 26.86)
Fat (g/d)	10 – 13 years:	69.69	69.69	55.45	55.45
		(± 11.26)	(± 11.26)	(± 22.33)	(±22.34)
	14 – 18 years	55.70	55.70	51.95	52.01
		(± 21.59)	(± 21.59)	(± 30.90)	(± 30.98)
% Fat	10 – 13 years:	34.01	34.01	33.06	33.06
		(± 4.81)	(± 4.81)	(± 3.47)	(± 3.47)
	14 – 18 years	33.16	33.16	26.55	26.55
		(±8.90)	(± 8.89)	(± 10.63)	(± 10.63)
Fibre (g/d)	10 – 13 years: 15 – 18 g	16.32	16.32	11.63	11.63
		(± 2.53)	(± 2.53)	(± 6.38)	(± 6.38)
	14 – 18 years: 19 – 23 g	11.24	11.24	11.53	11.53
		(± 3.15)	(± 3.15)	(± 4.16)	(± 4.16)

RDA = Recommended Dietary Allowance

Table 4.2 Mean daily micronutrient intakes of non-elite and elite gymnasts with and without supplements

Nutrient	**RDA/AI (9-13 years)**	**Non-elite (w/o supplement)**	**Non-elite (w supplement)**	**Elite (w/o supplement)**	**Elite (w supplement)**
Vitamin B1 (mg)	10 – 13 years: 0.9	1.25	5.83	1.09	2.24
		(± 0.41)	(± 8.55)	(± 0.59)	(± 2.75)
	14 – 18 years: 1.0	0.95	6.20	1.06	4.63
		(± 0.63)	(± 3.89)	(± 0.38)	(± 9.35)
Vitamin B2 (mg)	10 – 13 years: 0.9	2.05	6.47	1.71	2.71
		(± 0.61)	(± 8.65)	(± 1.07)	(± 2.18)
	14 – 18 years: 1.0	1.91	5.66	1.30	4.87
		(± 1.54)	(± 4.05)	(± 0.44)	(± 9.50)
Niacin (mg)	10 – 13 years: 12	19.73	23.33	16.30	16.30
		(± 7.62)	(± 6.70)	(± 10.36)	(± 10.36)
	14 – 18 years: 15	13.78	13.78	21.96	29.10
		(± 7.01)	(± 7.01)	(± 7.57)	(± 16.74)
Vitamin B6 (mg)	10 – 13 years: 1.0	1.97	4.44	1.31	10.31
		(± 0.93)	(± 4.11)	(± 0.70)	(± 11.10)
	14 – 18 years: 1.2	1.15	4.82	1.65	5.22
		(± 0.87)	(± 4.19)	(± 0.87)	(± 9.23)

Table 4.2 Mean daily micronutrient intakes of non-elite and elite gymnasts with and without supplements (continued)

	RDA/AI	Non-elite (w/o supplement)	Non-elite (w supplement)	Elite (w/o supplement)	Elite (w supplement)
Folate (µg)	10 – 13 years: 300	240.60 (± 77.75)	360.60 (± 192.35)	187.17 (± 158.32)	387.17 (± 537.73)
	14 – 18 years: 400	177.92 (± 103.79)	277.92 (± 46.61)	170.05 (± 55.80)	171.48 (± 55.17)
Vitamin B12 (mg)	10 – 13 years: 1.8	4.79 (± 2.40)	8.99 (± 7.67)	2.77 (± 1.16)	3.77 (± 2.83)
	14 – 18 years: 2.4	3.33 (± 1.74)	7.83 (± 4.64)	3.59 (± 1.63)	10.73 (± 19.54)
Vitamin A (µg)	10 – 13 years: 600	584.67 (± 182.00)	1185.87 (± 899.35)	379.42 (± 151.24)	1530.67 (± 1594.92)
	14 – 18 years: 700	535.75 (± 333.88)	648.25 (± 531.96)	436.24 (± 291.72)	436.24 (± 291.72)
Vitamin C (mg)	10 – 13 years: 45	90.47 (± 54.68)	778.47 (± 996.37)	78.08 (± 89.90)	173.08 (± 169.49)
	14 – 18 years: 65	50.33 (± 36.03)	450.33 (± 512.95)	67.52 (± 28.60)	210.38 (± 380.28)

Table 4.2 Mean daily micronutrient intakes of non-elite and elite gymnasts with and without supplements (continued)

Nutrient	**RDA/AI (9-13 years)**	**Non-elite (w/o supplement)**	**Non-elite (w supplement)**	**Elite (w/o supplement)**	**Elite (w supplement)**
Vitamin E (mg)	10 – 13 years: 11	11.86	24.84	7.12	18.00
		(± 3.30)	(± 18.14)	(± 4.61)	(± 16.42)
	14 – 18 years: 15	6.76	8.26	6.38	13.53
		(± 2.27)	(± 5.15)	(± 2.75)	(± 17.92)
Calcium (mg)	10 – 13 years: 1300	586.13	799.13	523.5	573.5
		(± 98.86)	(± 350.36)	(± 263.58)	(± 290.36)
	14 – 18 years: 1300	419.67	438.42	577.71	602
		(± 166.23)	(± 178.78)	(± 193.17)	(±147.93)
Iron (mg)	10 – 13 years: 8	11.79	17.39	8.13	14.13
		(± 4.03)	(± 9.66)	(± 3.51)	(14.50)
	14 – 18 years: 15	8.58	10.83	9.38	9.52
		(± 4.39)	(± 5.73)	(± 3.32)	(± 3.32)
Phosphorus (mg)	10 – 13 years: 1250	1180.47	1205.47	830.5	838
		(± 269.95)	(± 247.09)	(± 373.70)	(± 385.15)
	14 – 18 years: 1250	757.75	762.00	946.62	946.62
		(± 203.78)	(± 210.10)	(± 261.61)	(± 261.61)

Table 4.2 Mean daily micronutrient intakes of non-elite and elite gymnasts with and without supplements (continued)

Nutrient	RDA/AI (9-13 years)	Non-elite (w/o supplement)	Non-elite (w supplement)	Elite (w/o supplement)	Elite (w supplement)
Zinc (mg)	10 – 13 years: 8	9.54 (± 2.25)	14.54 (± 6.52)	8.47 (± 4.25)	14.97 (± 12.12)
	14 – 18 years: 9	7.34 (± 2.60)	8.28 (± 3.51)	7.05 (± 2.67)	7.77 (± 3.15)
Magnesium (mg)	10 – 13 years: 240	229.13 (± 50.58)	294.13 (± 60.41)	177.33 (± 61.44)	201.58 (± 93.95)
	14 – 18 years: 360	161.58 (± 42.58)	161.58 (± 42.58)	195.29 (± 47.85)	209.71 (± 38.07)
Selenium (ug)	10 – 13 years: 40	51.41 (± 28.99)	76.41 (± 45.74)	38.48 (33.35)	50.98 (± 38.93)
	14 – 18 years: 55	42.05 (± 12.95)	48.80 (± 24.62)	38.29 (± 25.89)	45.43 (± 24.23)

RDA = Recommended Dietary Allowance AI = Adequate Intake

4.5 Discussion

An adequate energy intake is necessary to enhance the immune system, to maintain growth and lean tissue mass, to improve physical performance, to cope with competition related stress and to maintain normal menstrual status (2, 44, 46). A negative energy balance has been shown to reduce the metabolic rate and increase the proportion of body fat in athletes (15). It is recommended that athletes between the ages of 9 – 13 years and 14 – 18 years should consume 233 kJ/kg BM/day and 186.53 kJ/kg BM/day respectively (2). When these guidelines are applied to the gymnasts, they should have an intake of between 10 012 kJ/day and 8 015 kJ/day respectively, which is higher than their reported energy intakes. It could be that the EER overestimates these athletes' needs or that they under-reported their intakes. It could also be that they practice restrained eating habits (6, 15). However, since the athletes' energy expenditure and energy intake were similar it might be that the gymnasts were in energy balance and that the EER recommendations are too high. Some studies (6, 15) showed a negative energy balance amongst elite gymnasts. Other female gymnasts (10 – 18 years) also seem to ingest less energy than the EER with a mean energy intake of 134 - 177 kJ/kg BM/day that is similar to these results of 152.3 – 162.6 kJ/kg BM/day (8, 9, 14, 22, 23, 28, 39).

To reduce fat mass, saturated fat intake must be reduced and fat oxidation should be maximized. The latter could be achieved through exercising for several hours per day (29). During starvation or chronic energy restriction, the metabolic rate decreases, while more fat is stored from the limited food consumed (15). If energy intake exceeds expenditure, energy intake is inversely associated with body fat percentage (15). The recommended percentage body fat for female athletes varies between 17 – 25% (48), while the minimal percentage body fat for females without compromising health is 12% (2). If body fat is less than specified, the risk for eating disorders and menstrual abnormalities increases (2). An earlier study (24) amongst college gymnasts showed that an energy intake of 5 800 kJ/day combined with a mean body fat of 17% resulted in 30% of the gymnasts experienced oligomenorrhea, while 59% reported amenorrhea. Similarly the gymnasts of this study who experienced oligomenorrhea (n = 4) had a mean energy intake of 6 288.17 ± 2 282.56 kJ/day, which is lower than the mean energy intake of all the gymnasts. The last mentioned gymnasts' fat percentage was 16.14 ± 1.06%. Furthermore, oligomenorrhea might occur due to low energy availability and it is also hypothesized that inadequate carbohydrate can be a possible cause of the former (29), as seen in this gymnasts.

Carbohydrates are the major source of energy during exercise (46) and a low intake in gymnasts has been associated with a negative impact on behaviour and cognitive function (49), as well as fatigue and decreased exercise performance (2, 44, 46). Ingesting sufficient amounts of carbohydrates (7 – 10 g/kg/day or 55 – 60% of daily energy intake) is, therefore, important (49), especially during pre-competition preparation and during multi-day competitive events (10) to optimize muscle and liver glycogen stores and improve performance (2, 11, 18, 19, 46). A study by Jonnalagadda *et al.* (23) found that elite female gymnasts consumed 67% of their total daily energy intake from carbohydrates. Although this seems high when converted to gram/kg BM, it was only 4.5 g/kg BM/day, which was similar to the carbohydrate intake in an earlier study with a small sample size (34). Another study by Cupisti *et al.* (14) amongst a group of elite female gymnasts also found a high percentage of their daily energy intake came from carbohydrates (53.6%) but when converted to gram/kg BM, also found it to be lower (4.1 g/kg BM/day) than recommended intakes. These low carbohydrate intakes were probably due to low total daily energy intakes. In this study it was also found that carbohydrate intake seemed to be adequate when looking at percentage from daily energy intake (50.15

– 63.37%), but when calculating the amount of grams/kg BM/day, carbohydrate intakes were low (4.04 – 4.86 g/kg BM/day). This was probably due to a low total daily energy intake. Other studies have, however, shown higher intakes in gymnasts (5.1 – 8.2 g/kg BM/day) (8, 9, 22, 28, 39). Carbohydrates mostly consumed by the gymnasts in this study were energy-dense and not necessarily nutrient-dense e.g. sugars, jam and juice. Additionally, only 12.7 g fibre was ingested per day, which is below the recommended 19 - 23 g/day (31). Although young athletes can ingest 10% of their daily energy intake from refined carbohydrates to aid them in achieving their carbohydrate requirements, too high intakes of refined carbohydrates can cause dental caries or decrease nutrient density of the diet (21).

Adequate protein intake is necessary to maintain growth, increase protein synthesis and maintain nitrogen balance (23). If too little protein is ingested, certain nutrient deficiencies such as vitamin B6 and B12 as well as iron may develop (45), which may impair protein synthesis and red blood cell production (44). On the other hand, ingesting excessive amounts of protein may place an extra burden on the kidneys, followed by increased urinary calcium loss, bone demineralization and dehydration (14, 26). Specific protein requirements for young athletes are lacking. A guideline of 1.2 - 1.4 g protein/kg BM/day is recommended for adult endurance athletes and 1.6 - 1.7 g protein/kg BM/day for adult resistance and strength trained athletes, or 12 - 15% of total daily energy intake (2). These guidelines are also currently applied to young athletes. Various studies have shown mean protein intakes amongst artistic gymnasts to be between 1.1 - 2.16 g/kg BM/day which corresponds to an intake of between 15 – 17% of total daily energy intake (14, 22, 23, 34, 39). Similar results were found in the gymnasts in this study, with a protein intake of between 1.46 – 1.5 g protein/kg BM or 18.7% of the total daily energy intake, which is greater than recommended, even though a relatively low energy intake was documented. There is often a misconception that protein is the main source of energy for physical activity and should be increased for muscle synthesis (14). This could probably be the reason for the intake of protein supplements amongst elite gymnasts in this study. A limitation of this study is that the reasons for supplement use were not recorded, but other studies have shown that the most common reasons for using protein supplements are for energy provision (4), improved performance and increased muscle strength and size (41).

Although children utilize more fat during physical activity due to increased aerobic metabolism compared to adults, it does not seem to translate into increased dietary fat requirements (5, 33, 44). High fat diets, in general, are also not recommended to young athletes due to the possibility of muscle glycogen depletion (11), increased body fat percentage and an increased risk for hypercholesterolemia or cardiovascular disease in later life (12). Current recommendations for fat intake for adolescents are not more than 30% (1, 2) and children (5 - 14 years) less than 35% of their daily energy intake (35), of which not more than 10% must be from saturated fats (35). Elite gymnasts between the ages of 9 – 13 years and 14 – 18 years have been documented to ingest between 30 – 35% of their daily energy intake from fat (Benson *et al.*, 1990; benardot *et al.*, 1989; Cupisti *et al.*, 2002) and in this study, the fat intake ranged between 26.55 – 34.01%, the higher being amongst the 10 – 13 year olds and the lower amongst 14 – 18 year olds. Fat intake, therefore, seems to be within recommendations, but care should be taken by older gymnasts not to ingest too little fat, since fat plays an important part in the absorption of fatsoluble vitamins and minerals as well as the maintenance of cell membrane integrity (2).

A recent review (30) indicated that athletes following a low energy diet and those who consume foods that are not nutrient-dense might be at risk for vitamins A, E, B6, B12, thiamine, riboflavin, niacin and folate deficiencies. Studies (14, 23, 27, 34, 37, 49) amongst jockeys, volleyball players, figure skaters and gymnasts reported an inadequate intake of calcium (45 – 56% of RDA), magnesium (56% of RDA), folate (32.3 – 50% of RDA), zinc (52 – 58% of RDA), selenium (40 - 57% of RDA), vitamin E (10% of RDA) and vitamin B6 (53% of RDA). Similar results were found in this study in terms of inadequate calcium, magnesium, folate and vitamin E intake (less than 60% of the RDA). Not all athletes, however, have low intakes of these nutrients. Some studies found intakes of calcium (66 – 83% of RDA), magnesium (97% of RDA), folate (88 – 111% of RDA), zinc (159% of RDA) and vitamin B6 (147 – 290% of RDA) (8; 9; 23) amongst gymnasts. Calcium is an important mineral for bone health, although hormonal profile as well as training intensity and duration also play important roles in bone health amongst young athletes. Forty five percent of gymnasts of the total group were involved in training for more than 7 years, while 50% exercise more than 4 days per week and most of them (60%) exercise for more than 5 hours per week. Bone health is important for young female athletes since poor bone health could increase the risk for stress fractures (1, 2; 6, 40) and the development of pre-menopausal osteoporosis (1, 22). To reduce the risk of these complications, female athletes with menstrual irregularities should consume >1 300 mg calcium/day (17). Additionally, increasing body fat levels and decreasing training volumes could be beneficial for bone health (46). To increase calcium intake amongst female athletes, the intake of low-fat dairy products, calcium-rich mineral water and soy products and other calcium-fortified foods should be promoted (3, 20).

A dietary iron intake of 8 mg/day for 10 – 13 year olds and 15 mg/day (17, 37) for adolescents is recommended to meet their increased physiological needs and prevent iron deficiency with or without anemia (13, 14). Iron plays an important role in oxygen transportation to muscle cells as well as enzymes involved in the energy systems, therefore, a deficiency will result in poor exercise performance (8; 44). Athletes have an increased iron need due to increased iron losses through sweat during exercise, gastro-intestinal bleeding and through menstrual losses. There is also the extra burden of growth that demands iron (50). Some studies (14, 45) among elite female gymnasts indicated that they had an iron intake between 66 - 70% of RDA, while others (8, 9, 22, 23, 34) reported an intake greater than 70% of RDA. In these study gymnasts between 10 – 13 years of age ingested sufficient amounts of iron, while those between 14 – 18 years not meeting their iron needs, with or without supplementation (although it was greater than 60% of the RDA after supplementation). Sufficient iron intake can be ensured by ingesting adequate amounts of high biological protein (e.g. meat and meat products, as well as milk and milk products). Plant sources of iron are not the best option, since the non-haeme iron form that is contained in these foods is not as well absorbed as the haeme-iron form found in animal foods (2, 7, 30, 45, 47).

Vitamin E intake might be inadequate because of restricted or underreporting of fat intake (34). These are probably not the causes for low vitamin E intake in the gymnasts in this study since fat intake was adequate. What could have played a role is poor food choices since much low nutrient density foods e.g. candy, soda pop, butter, jellies and jam was consumed (34).

Although vitamin and/or mineral supplementation is only effective during an insufficient food intake, it is commonly used (22) due to the belief that it optimizes growth, as well as prevents and treats illness (42), provides energy, builds muscles and improves performance (31, 41). Vitamin C and multivitamin supplements are the most commonly used supplements among endurance, strength, college and team sport athletes (29, 34, 42, 46). In this study, the most popular supplements used were also multi-vitamins (55% of total group) and vitamin C supplements (30% of total group), while utilization of other single micronutrients were in the minority. This was also found in health students and college athletes where iron (11%), calcium (9%), vitamin A (9 %), B vitamins (8%), vitamin E (8%), vitamin D (5%), zinc (3%) and potassium (3%) supplements were used to a minor extent (32; 42). It is, therefore, clear that the type of supplements used by the gymnasts in this study did not contribute significantly to an increased intake of iron or calcium. They, therefore, need to be educated in the importance and usefulness of multi-vitamin and mineral supplement use.

4.6 Limitations

Limitations to this study included a non-randomized, small sample group, reason for supplement use was not recorded, possible underestimation of energy expenditure as well as known limitations associated with dietary records.

4.7 Recommendations

More randomized, controlled studies on larger sample sizes determining energy balance; energy intakes, nutrition knowledge and eating habits are necessary to improve South African athletes' performance.

From this study, it is clear that this group of gymnasts need to be provided with information on healthy eating habits, as well as the consequences of poor dietary habits and food choices on macro and micronutrient status, which ultimately influences their performance and long-term health.

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Chapter 5: Discussion and conclusion

5.1 Introduction

The aim of this study was to compare anthropometry, energy balance and nutrient intake of elite and non-elite school-aged gymnasts, as well as to evaluate their nutritional knowledge and eating attitudes, and its effect on dietary intake and practices. To achieve this, the energy expenditure, energy intake, macro- and micronutrient intakes, as well as supplement use of elite and non-elite gymnasts were evaluated. Additionally, their nutritional knowledge and eating attitudes were measured and the association between these and dietary intakes as well as practices were evaluated.

5.2 Main results

The total daily energy intake (non-elite = 6 944.37 ± 1 272.28 kJ vs. elite = 6 543.06 ± 2 569 kJ) of both groups was similar to their daily energy expenditure values (non-elite = 6 393.77 ± 1 244.19 kJ vs. elite = 6 696.09 ± 1 676.58 kJ). Elite gymnasts, however, tended to have higher protein (15.4 vs. 21.37%, small effect size, d = 0.1) and lower fat (28.9 vs. 33.6%, medium effect size, d = - 0.6) intakes. Converting mean protein intake to g/kg BM/day, it was found to be above the RDA in both groups (elite = 1.5 g/kg BM/day vs. non-elite = 1.46 g/kg BM/day). The elite and non-elite group ingested an average of 4.45 g carbohydrates /kg BM/day, or between 50.15 – 63.37% of the total energy intake.

More non-elite gymnasts (n = 7; 88.88%) used vitamin and/or mineral supplements compared to elite gymnasts (n = 4; 45.45%, medium effect size, d = 0.45). Only the non-elite gymnasts between the ages of 14 – 18 years had a vitamin E intake less than 60% of the RDA. Both groups between the ages 14 – 18 years had a folate, calcium and magnesium intake less than 60% of the RDA, with and without supplementation. Both elite and non-elite gymnasts between the ages of 14 – 18 years had an iron intake less than 60% of the RDA. The intake increased, however, to more than 60% of the RDA after supplementation was used in both groups.

Only 55% of the total group of gymnasts ate snacks during the day. An early morning snack (65%) was most often consumed, followed by a mid-afternoon (55%) and late night snack (45%). The most common snack foods consumed by these athletes were sweets (77%), fruits (54%) and cold drinks (41%). In the total group of gymnasts, the most used sources of nutrition information were the coach (60%), followed by dieticians and parents (45%), teammates, books and magazines (30%), the physician (15%) and the school (10%). Parents were considered as the most useful (50%) nutrition information source, followed by the dietician (30%) and the coach (20%). Gymnasts were allowed to choose more than one option, therefore, the scores do not add up to 100. There were no differences in the overall mean score for the nutritional knowledge questionnaire between elite and non-elite gymnasts (61.8% vs. 62.8% respectively), and there was a positive correlation between nutritional knowledge and risk for dieting ($r = 0.76$) amongst non-elite gymnasts. No other correlations were found.

Elite gymnasts had a practically significantly higher risk than non-elite gymnasts to follow a diet (large effect size, $d = 1.32$). Both non-elite and elite gymnasts, however, reported a low risk for bulimia and food preoccupation. Non-elite gymnasts exercised practically significantly more self-control over their food intake compared to elite gymnasts (large effect size, $d = -1.03$).

5.3 Integrated discussion

5.3.1 Energy balance

Energy balance occurs, when energy intake (the sum of energy from food, fluids and supplements) is equal to energy expenditure (the sum of energy expended as basal metabolism, the thermic effect of food and any voluntary physical activity) (ADA, 2000; Thompson, 1998). Although the dietary intake and energy expenditure was similar in this study, it was less than the recommended intake of 233 kJ/kg BM and 186 kJ/kg BM for athletes between the ages of 9 – 13 years and 14 – 18 years respectively (ADA, 2000). In this study, the mean energy intake of elite and non-elite gymnasts between the ages of 10 – 13 years and 14 – 18 years was 148 – 178 kJ/kg BM/day and 142 – 154 kJ/kg BM/day, respectively. These reported low intakes might be due to an attempt to maintain a slim physique or to under-reporting (Van Erp-Baart *et al.*, 1989). An optimal energy intake is necessary to enhance the immune system, to maintain growth and lean tissue mass; to improve physical performance; to cope with competition related stress and to maintain normal menstrual status (ADA, 2000; Thompson, 1998; Willenberg & Hemmelgarn, 1991). Whereas a chronic negative energy balance may result in a short stature, low body weight and delayed menses, nutrient deficiencies and dehydration, abnormal menstrual patterns, poor bone health, increased percentage body fat, increased incidence of injuries and an enhanced risk for developing eating disorders (Deutz *et al.*, 2000; Thompson, 1998) also occurs. Despite daily energy intakes being lower than the REE, energy expenditure and energy intake were similar in both groups. It, therefore, seems that energy balance was reached within all gymnasts. It is, however, also possible that the Actical® accelerometer did not measure the daily energy expenditure accurately, since only movements of the body as a whole are measured. Therefore, when arm movements or leg movements were carried out without the whole body moving, it is possible that movements were not registered and, therefore, not measured. Since gymnastics involves much arm and leg movement without the body moving, this could have resulted in a slight under-estimation of their daily energy expenditures. Gymnasts were asked to keep an exercise-log, but unfortunately it was not kept in detail and could not be used to calculate METs in order to compare the two method's energy expenditures.

5.3.2 Growth and maturation

The mean weight of the gymnasts was 42.97 ± 10.61 kg, and body mass index (BMI) was 18.33 ± 2.68 kg/m². Their weight for age was within the normal ranges (25th and 50th percentile) for age when using the sex-specific CDC growth monitoring charts and the National Health Centre for Health Statistics growth charts (Hamill *et al.*, 1979). Although their weight was within the normal range of 90 – 100% of the ideal body weight (Hergenroeder & Klish, 1990), the mean body fat percentage was slightly below recommendations (15.57 ± 2.22% vs. 17 – 25%) (ADA, 2000). Their BMI for age was within the normal ranges (25th and 50th percentile) for age as well as their height for age (10th and 25th percentile), although the latter tended to reach levels for increased risk of stunting. Height-for-age indicates a subject's long-term nutrition and growth status (Steen, 1994). Possible reasons for reduced growth include genetic factors, intensive exercise before the onset of menarche (Malina, 1994; Rogol *et al.,* 2000), familial short stature (e.g. short parents) (Rogol *et al.*, 2000) and strenuous exercise for an extended period of time (Benardot, 1996; Burke & Deakin, 2000). The growth curve of gymnasts involved in training for a long period of time may be flattened. This could cause gymnasts to remain prepubescent for a longer time period, followed by delayed maturation (Benardot, 1996) and growth retardation (Theintz *et al.*, 1993). When exercise intensity is, however, decreased or discontinued (Lindholm, 1994), catch-up growth can take place and is usually similar to the median height-for-age (Baxter-Jones *et al.*, 1995).

Puberty is characterized by an increase of 80 – 85% of peak bone mass. Bone mass accrual is established during the pre-pubertal stage, while the other half is accrued during the two to four years of pubertal growth (Faulkner *et al.*, 1993). During an inadequate energy intake and intensive exercise, bone resorption will probably take place due to suppression of reproductive hormones (Barr, 1987; Loucks, 2004; Vorster *et al.*, 2001), thereby increasing the risk for osteoporosis and osteopenia later in life (Loucks, 2004; Snow, 1996). Furthermore, irreversible trabecular bone loss may result when amenorrhea is present for more than three years (Benardot, 1996). Extensive exercise for a prolonged period of time as well as high volumes of training may results in oligomenorrhea and amenorrhea as well as shorter periods of the luteal phase and anovulatory cycles (Eliakim & Beyth, 2003; Thompson, 1998). Other factors contributing to amenorrhea include low body weight and percentage body fat (Brownell *et al.*, 1987; Ziegler *et al.*, 1998a), late menarche, prior menstrual irregularities, hypothalamic immaturity, nulliparity and psychological stress (Brownell *et al.*, 1987; Eliakim & Beyth, 2003; Thompson, 1998), as well as the adoption of vegetarianism and energy restriction (Barr, 1987b; Loucks, 2004; Thompson, 1998; Vorster *et al.*, 2001). These may all contribute to the development of oligomenorrhea. Possible reasons for the presence of oligomenorrhea in the gymnasts in this study include a low daily energy intake (6 288.17 ± 2 282.56 kJ/day), low body fat levels (16.14 ± 1.059%), low carbohydrate intakes (4.5 g/kg BM/day) and high volumes of training (5 hours/day, 4 times/week). Age of menarche in elite gymnasts was also later than in non-elite gymnasts (elite, n = 5 vs. non-elite, n = 2). Since the group was too small, significant differences could not be calculated. The onset of puberty amongst young girls takes place at approximately 10 years of age. While the onset of menarche is usually around 12 years of age (Muskuddem-Petersen & Kruger, 2004; Prader, 1992), it has been shown that female gymnasts participating in sports from an early age (6.2 ± 0.5 years) for extended periods of time (11.1 ± 0.5 years) tend to have delayed menarche (14.7 ± 0.4 years) (Kirchner *et al.*, 1995). This was also showed amongst Polish (n = 9) and Swiss (n = 11) gymnasts with a mean age of menarche at 15.1 ± 0.9 years and 14.5 ± 1.2 years, respectively (Malina, 1994). Therefore, it is indicative that elite female gymnasts might have a pubertal delay of 2.3 years (Weimann 2001; Baxter-Jones *et al.*, 1995).

5.3.3 Macronutrient intake

Carbohydrates are the major source of energy during exercise (Willenberg & Hemmelgarn, 1991). Optimal carbohydrate intake is recommended to prevent glycogen depletion, which could result in early fatigue and decreased exercise performance (ADA, 2000; Thompson, 1998; Willenberg & Hemmelgarn, 1991). Specific recommendations for young athletes in terms of carbohydrate needs are not yet available, therefore adult guidelines are used. The recommended carbohydrate intake varies between 7 – 10 g/kg BM/day and 55 – 60% of the total daily energy intake (Ziegler *et al.*, 2002). In our study, female gymnasts ingest between 50.15 – 63.73% of their daily energy intake in the form of carbohydrates, which seems sufficient, but when it is calculated as g/kg BM/day, both elite and non-elite gymnasts had an average carbohydrate intake of 4.5 g/kg BM/day, which is below recommendations. Most carbohydrates consumed were energy-dense and not nutrient-dense, e.g. sugars, jam, and cold drink, which possibly contributed to their low vitamin and mineral intakes. Ingesting more than 10% of the total daily energy intake as refined carbohydrates also increases the risk of dental caries in young athletes (Herbold & Frates, 2000).

The protein needs of young athletes are increased to sustain growth as well as the extra burden of physical training (Thompson, 1998). Currently, adult athletes' protein recommendations are used due to a lack of available requirements for children. A general estimation of 1.2 - 1.4 g protein/kg BM/day is recommended for adult endurance athletes and 1.6 - 1.7 g protein/kg BM/day is recommended for adult resistance and strength trained athletes (ADA, 2000). Additionally, 12 – 15% protein of daily energy intake can also be used as alternative recommendation (ADA, 1996; 2000; Willenberg & Hemmelgarn, 1991). Various studies (Benardot *et al.*, 1989; Benson *et al.*, 1990; Cupisti *et al.*, 2002; Jonnalagadda *et al.*, 1998; 2000; Moffatt, 1984; Reggiani *et al.*, 1989) reported a mean protein intake of between 1.09 – 2.16 g/kg BM/day or 15 – 17% of the total daily energy intake in gymnasts. The results in this study are similar with a mean protein intake of 1.46 – 1.5 g/kg BM/day, with and without supplementation, which exceeds the RDA of 0.8 g/kg BM/day. Most of the gymnasts consider additional protein intake as a necessity to promote muscle size as seen in the nutritional knowledge questionnaire. This might be why some (n = 2) used protein supplements. Other possible reasons for high protein intakes include energy provision (Barr, 1987b), improved performance and increased strength (Rosenbloom *et al.*, 2002).

Children are mostly dependent on the aerobic metabolic pathway during all types of exercise for energy production. During this pathway, fat is the major source of energy. This differs from adults who are mostly dependent on the anaerobic metabolic pathway during high-intensity activities (Bar-Or, 2000). Although fat is the main energy source amongst children, there is currently no evidence for increased fat intake in order to increase performance (Bar-Or & Unnithan, 1994; Martinez & Haymes, 1992; Thompson, 1998). In fact, a high fat diet can cause muscle glycogen depletion, increase body fat levels and increase the risk for coronary heart disease later in life (Burke *et al.*, 2004; Lambert & Goedecke, 2003; Ziegler *et al.*, 2002). Current recommendations for fat intake for adolescents are not more than 30% (ADA, 1996; 2000; Willenberg & Hemmelgarn, 1991) and for children (5 - 14 years) less than 35% of their daily energy intake (National Health & Medical Research Council, 1995), of which not more than 10% must be from saturated fats (National Health & Medical Research Council, 1995). In this study, elite and non-elite gymnasts between the ages of 14 – 18 years' mean fat intake was between 26.55 – 33.16% of the daily energy intake, with and without supplementation, respectively. Their fat intake, therefore, seems to be within the ranges for their age, but they should probably be educated in the health risks involved when consuming too little fat (ADA, 2000).

5.3.4 Micronutrient intakes

Calcium is used for bone formation and maintenance of blood calcium levels (ADA, 2000; Thompson, 1998). Female athletes following energy restricted diets tend to avoid dairy products due to their high fat content (ADA, 1996; Jonnalagadda *et al.*, 2000). This may result in decreased bone mass, which increases the risk for stress fractures (ADA, 1996; 2000; Beals & Manore, 1998; Rogol *et al.*, 2000) and the development of pre-menopausal osteoporosis (ADA, 1996; Jonnalagadda *et al.*, 1998). Adequate calcium intake *per se* is, however, not the only factor influencing bone health. Vorster *et al.* (2001) showed lower forearm BMD in a group of adult female endurance athletes compared to controls, even though their daily calcium intakes were similar (athletes = 1 035 mg and non-athletes = 879 mg). Possible factors identified that could have contributed to the lower BMD in that study were a body fat percentage of less than 12%, more than 7.5 hours of endurance training/week and the presence of amenorrhea. Almost half (45%) of the gymnasts in this study have been training for more than 7 consecutive years, 50% of them exercised more than 4 days per week, and 60% of them exercised for more than 5 hours per day. Additionally, our gymnasts had a reported low calcium intake with or without supplementation (elite = 638 ± 330 mg and non-elite = 591.64 ± 197 mg respectively). Four gymnasts experienced oligomenorrhea and combining this with their low mean percentage body fat levels (16.14 ± 1.059%) they are at an increased risk for decreased BMD, stress fractures (ADA, 1996; 2000; Beals & Manore, 1998; Rogol *et al.*, 2000), and pre-menopausal osteoporosis (ADA, 1996; Jonnalagadda *et al.,* 1998). It is recommended that amenorrheic athletes consume >1 300 mg calcium/day for improved bone health (Benardot, 1996; Herbold & Frates, 2000).

Iron is an important mineral for athletes, because it is part of the energy metabolic system (ADA, 2000; Lukaski, 2004). Female athletes are at risk for iron deficiency anemia because of their increased physiological needs (Fogelholm *et al.*, 1998), energy restricted diets, inadequate dietary iron intake and exercise-induced iron loss (Jonnalagadda *et al.*, 1998), as well as losses through menstruation (ADA, 1996). The RDA for iron in children and adolescent females between the ages of 9 – 13 years and 14 – 18 years is 13 mg/day and 15 mg/day respectively (FNB, 2001). Some studies showed a reported iron intake greater than 66% of the RDA (Benardot *et al.*, 1989; Benson *et al.*, 1990; Cupisti *et al.*, 2002; Jonnalagadda *et al.*, 1998; 2000; Moffatt, 1984). In this study, gymnasts between the ages of 10 – 13 years ingested sufficient amounts, while both elite and non-elite gymnasts between 14 – 18 years did not meet their needs, with or without supplementation (non-elite, 14 – 18 years = 72%; elite 14 – 18 years = 63%), although it was greater than 60% of the RDA after supplementation). To ensure sufficient iron intake, haeme-iron, present in animal products, must be consumed regularly (ADA, 2000; Beard & Tobin, 2000; Herbold & Frates, 2000; Lukaski, 2004; Van Erp-Baart, 1989; Willenberg & Hemmelgarn, 1991). The absorption of non-haeme iron (plant products) can be enhanced by adding vitamin C rich food to a meal (Beard & Tobin 2000; Herbold & Frates, 2000; Willenberg & Hemmelgarn, 1991). Limited intake of bran, hemicellulose, cellulose, pectin, phytic acid, phytate and polyphenols in a mixed diet is prescribed since it inhibits non-haeme iron absorption (Beard & Tobin 2000; Nielsen & Nachtigall, 1998).

5.3.5 Dietary intakes and practices

Small frequent, nutrient dense-meals (Van Erp-Baart *et al.*, 1989; Ziegler *et al.*, 2002) are recommended to meet athletes' increased energy and carbohydrate needs (Chen *et al.*, 1989). This will help to prevent gastro-intestinal discomfort, fatigue and overeating (Hawley & Burke, 1997; Ziegler *et al.*, 2002). In this study, the total group of gymnasts consumed mainly large meals instead of small frequent meals. More than half (55%), consumed snacks twice during the day, while a late night snack was used to a lesser extent. High-energy foods were preferred for snacks e.g. sweets, cold drinks and potato crisps, while nutrient-dense snacks were eaten to a lesser extent (fruits and fruit juices, dairy products and snack bars). The results were similar to that of other researchers (Loosli & Benson *et al.*, 1990; Rosenbloom *et al.*, 2002), who found that their athletes also preferred energy-dense foods as snacks for increased energy levels. Unfortunately, the gymnasts in this study had inadequate intakes of calcium, iron, folate, zinc and vitamin B6, possibly partly due to low nutrient-dense snacks eaten. Consequently, they are at risk for iron deficiency and bone mineral depletion (Cupisti *et al.*, 2002). Set meal patterns or eating plans are often recommended for athletes to help them in making appropriate food choices, to ensure that nutrient-dense foods are consumed at meals or as snacks, to ensure that healthy snacks are available (especially when travelling), all of which will help to optimize their micro and macronutrient intake and contribute to enhanced performance (Ziegler *et al.*, 2002).

5.3.6 Supplementation

Supplementation is very popular amongst university athletes. Possible reasons for the use of supplements include the belief that supplements provide more energy (Barr, 1987b), improve performance, build muscles (Rosenbloom *et al.*, 2002) and improve health (Froiland *et al.*, 2004) The most popular supplements taken by athletes include general supplements (76%), multivitamin and/or mineral supplements (19 - 73.3%), vitamin C (25 – 36%) and iron supplements (11 – 31%). Other supplements are usually used in the minority (Barr, 1987b; Jonnalagadda *et al.,* 2001; Sobal & Marquat, 1994). In a recent review by Lukaski (2004) who evaluated the vitamin and mineral status on physical performance, it is showed that vitamin B1, B12, A, C and E as well as niacin, folate, magnesium and chromium supplementation has no beneficial effect on performance. Furthermore, Sen (2001) concluded that although antioxidant supplements gave protection against exercise-induced muscle damage, mega-doses of supplements should be avoided, because of side effects that might be experienced, e.g. niacin is associated with vasodilatation and flushing (Marks, 1989), vitamin B6/day may cause neuropathy of the extremities (Bassler, 1989), vitamin C may result in osmotic diarrhea and gastro-intestinal disturbances (Alhadeff *et al.*, 1984) and excessive vitamin A intakes may cause joint or bone pain, hair loss, anorexia and liver damage. Consequently, a prudent diet, containing sufficient amounts of antioxidants should rather be followed (Sen, 2001). Marques-Vidal (2004) showed that more men are prone to consume supplements compared to women. Results of this study indicated that most gymnasts (55%, n = 11) consumed vitamin and/or mineral supplements, while more non-elite (88.88%, n = 7) than elite gymnasts (45.45%, n = 4) used supplements. Similar to others, the most popular supplements used by all gymnasts were multi-vitamins (55%) and vitamin C supplements (30%), while utilization of other single micronutrients was seldom used. Supplement use in young female athletes should only be recommended when energy restricted diets are followed, iron deficiency occurs (Lukaski, 2004), or when dietary calcium intakes are low (Johnston *et al.*, 1992). Supplementation of single micronutrients should also preferably be done with the guidance of a dietitian or a physician to prevent imbalances.

5.3.7 Nutritional knowledge

Coaches are most often the primary nutrition information source of an athlete (Galito *et al.*, 2003; Jacobson *et al.*, 2001; Jozwiak & Acona-Lupez, 2004) and they also have much influence over an athlete's food intake (Galito *et al.*, 2003). However, they might mislead athletes since they obtain their information mostly from non-scientific magazines (58%), (Jozwiak & Ancanona-Lopez, 2004; Rockwell *et al.*, 2001), other coaches (44%), (Jozwiak & Ancanona-Lopez, 2004), the Internet and television (Rockwell *et al.*, 2003), which might contain unreliable or misleading information (Jozwiak & Ancanona-Lopez, 2004). Jacobson *et al.* (2001) indicated that women relied more on universities and nutritionists to provide them with sport nutrition information. Burns *et al.* (2004) indicated that intercollegiate student athletes received information mostly from trainers (39.8%) as well as from strength and conditioning coaches (23.7%). Similar to Burns *et al.* (2004) the gymnasts in this study used the coach as primary information source followed by nutritionists/dietitians. On the other hand, parents were considered the most useful nutrition source, followed by the dietitian and then the coach. Since parents or the coach were often used as nutrition information sources, this might have contributed to the gymnasts' inadequate nutritional knowledge (mean nutrition knowledge score = 61.0 ± 9.94%). Several studies (Cupisti *et al.*, 2002; Loosli & Benson 1990; Rosenbloom *et al.*, 2002) indicated that athletes have inadequate knowledge regarding basic nutrition aspects. The role and function of most nutrients in sport performance is unclear. It was also shown that athletes do not make appropriate food and/or fluid choices during a competition day. Although, both elite and non-elite gymnasts in this study had a similar score for all the nutritional knowledge questions (61.8% vs. 62.8% respectively), they had some misconceptions regarding basic nutrition aspects. Despite the greater nutritional knowledge of elite gymnasts compared to non-elite gymnasts, both groups did not know the role of most nutrients in sport performance and chose foods with low nutrient-density as snacks. Additionally, they could not make appropriate food and/or fluid choices during a competition day and most gymnasts believed that a high protein intake would enhance muscle mass.

5.3.8 Eating attitudes

Athletes participating in sport where leanness is a prerequisite, as in gymnastics, are at risk for eating disorders (e.g. *anorexia nervosa* and *bulimia nervosa*) or food preoccupation (Beals & Manore, 1998; Benson *et al.*, 1990; Leydon & Hall, 2002 Petrie, 1993; Ziegler *et al.*, 1998a, 1998b). Warren *et al.* (1990) indicated that gymnasts were more pre-occupied with their body weight and also have an obsession with leanness compared to swimmers. However, in this study, both elite and non-elite gymnasts had a low risk for dieting, performed little control over food intake and did not seem to have a high risk for eating disorders or food preoccupation.

5.4 Conclusions

Contrary to the hypotheses, both elite and non-elite gymnasts had similar energy intakes and expenditure and seemed to be in energy balance, although energy intake was less than the EER. There were no differences between the groups in terms of carbohydrate, protein and fat intake, with and without supplementation. Both groups' carbohydrate intakes were below recommended intakes which could have been due to inadequate nutritional knowledge as well as poor food choices and eating habits. Diets of both elite and non-elite gymnasts lacked calcium and iron as well as magnesium, folate and vitamin E, despite the use of vitamin and/or mineral supplements. Contrary to the hypothesis that more elite gymnasts will use micronutrient supplements it was found that more non-elite gymnasts used micronutrient supplements, although not significantly more. Elite gymnasts did not use performance-enhancing supplements; only two elite gymnasts used protein supplements compared to no non-elite gymnasts. As hypothesized, both groups mostly obtained their nutritional knowledge from the coach. However, there was no difference between elite and non-elite gymnasts in terms of nutritional knowledge or knowledge on the role of nutrients in sports performance. Despite differences between elite and non-elite gymnasts in terms of risk for dieting and self-control over food intake, all gymnasts had a low risk for developing eating disorders, which is in contrast to the hypothesis. Lastly, the only correlation found between nutritional knowledge and eating behavior was a positive correlation between nutritional knowledge and risk for dieting ($r = 0.76$) amongst non-elite gymnasts.

Limitations to this study included a small, non-randomized sample size, not documenting reasons for supplement use, possible under-estimation of energy expenditure as well as known limitations associated with dietary records. Despite these limitations, results indicate a need for nutrition education amongst young female gymnasts on the basic guidelines in sport nutrition as well as supplement use to enable them to make better food choices and improve their eating habits in order to enhance their exercise performance.

5.5 Recommendations

More randomized, controlled studies on larger sample sizes measuring energy balance, nutrient intakes, nutritional knowledge and eating attitudes are needed on South Africa athletes to enable nutritionists, coaches and physicians to identify areas of improvement to enhance performance.

It is also clear that nutrition intervention is important due to many existing misconceptions and malpractices amongst athletes. To prevent this, athletes should receive sport nutrition information from a registered dietitian (RD) specializing in sport nutrition (Cherundolo & Levine, 1999). Aspects that should be addressed include the importance of a well balanced diet (Chen *et al.*, 1989), consequences of energy restriction on health and performance (Cherundolo & Levine, 1999) as well as food selection and eating habits (Chen *et al.*, 1989) to prevent frequent dieting, food pre-occupation and the development of eating disorders (Leydon & Wall, 2002; Warren *et al.*, 1990). Additionally, the dietitian should also focus on the relationship of nutrition and performance (Barr, 1987b; Cupisti *et al.*, 2002) and the role of certain nutrients in sport performance, which should be followed by accurate information on supplements that are used (Froiland *et al.*, 2004). Lastly, when athletes with eating disorders are consulted, eating disorders and symptoms that may be experienced should not be referred to. Instead, a discussion session should refer to complications of rapid weight loss, weight cycling, fasting or severe food restriction and avoidance of "high-kilojoule or fattening" foods (Yannakoulia *et al.*, 2002).

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Addendum 1

Demographic Information

Date: ________________

Name ____________________ Surname ____

Gender | Male | Female | Age _____ Highest qualification ______________________

Weight ____________ Length ____________ BMI ____________ % body fat ____________

Nutritional habits

Indicate whenever applicable

Eating habits	Yes	No
Omnivorous		
Semi-vegetarian		
Lacto-ovo-vegetarian		
Vegan		

	Yes	No	Amount	Frequency
Do you drink alcohol				

	Yes	No	Amount	Frequency
Do you smoke				

Notes ____

____

____

____

Medical status

Menstrual status:

Have you started to menstruate?

Yes	No

When did you start?

____

____

Do you have a regular cycle?

____

____

Have you ever stopped menstruating for $\geq$ 3 consecutive months?

____

____

What time of the month do you usually have your period?

____

____

Medication used

Do you use oral contraceptives:

Yes	No

Indication ________________ Dose ________________ Frequency ________________
Indication ________________ Dose ________________ Frequency ________________
Indication ________________ Dose ________________ Frequency ________________
Indication ________________ Dose ________________ Frequency ________________

Notes

Supplements

Are vitamin/mineral supplements used?

Yes	No

Are any other supplements used?

Yes	No

If supplements are used, indicate it as follow:

Brand	Amount	Frequency

Notes

Exercise programme

How many exercise sessions do you have per week?

How many hours do you usually sleep?

How active are you apart from training during the day?

Light	Moderate	High	Very high

Training

How many training sessions do you have per week?

Day	Type of exercise	Intensity of session	Duration
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			
Saturday			
Sunday			

Notes

Addendum 2

Food record

- For this day you have to write down everything you eat and/or drink down
- Be specific about the time of the day as well as the type of meal you eat e.g. breakfast or a snack.
- Give details about the dish or food you eat, e.g. a sandwich: brown bread with Rama margarine, tomato, lettuce and regular ham OR stew: chicken thigh with skin, tomato, fish oil, onion and atchar.
- Give details about how the dish is prepared, e.g. fried, cooked, grilled etc.
- Give the amount of each ingredient of a meal or dish, either in grams or in household measurements, e.g. 50 gram, 125ml (1/2 cup), 2 tablespoon, 1 teaspoon, 3 thick slices etc.
- All the food must be weighed before it is eaten **as well as the leftovers**.
- The food record must be completed for two consecutive weekdays and one day over the weekend.

Time	Food item	Amount	Preparation method	Left overs
	Breakfast			
	Snack			
	Lunch			
	Snack			
	Dinner			
	Snack			

Leftovers:
Breakfast

Lunch

Supper

Addendum 3

Please place an (X) in the column which applies best to each of the numbered statements. All of the results will be strictly confidential. Most of the questions relate directly to food or eating, although other types of questions have been included.

The Eating Attitudes Test

Select one of the following as applicable to the relevant questions:

1 = never 2 = rarely 3 = sometimes 4 = often 5 = very often 6 = always

Factor I – Dieting

1. Are you engaged in dieting behaviour?

1	2	3	4	5	6

2. Do you eat "diet" foods?

1	2	3	4	5	6

3. Do you feel uncomfortable after eating sweets?

1	2	3	4	5	6

4. Do you enjoy trying new rich food?

1	2	3	4	5	6

5. Do you avoid foods with sugar in them?

1	2	3	4	5	6

6. Do you particularly avoid foods with high carbohydrate content?

1	2	3	4	5	6

7. Are you preoccupied with a desire to be thinner?

1	2	3	4	5	6

8. Do you like your stomach to be empty?

1	2	3	4	5	6

9. Do you think about burning up calories when you exercise?

1	2	3	4	5	6

10. Do you feel extremely guilty after eating?

1	2	3	4	5	6

11. Are you terrified about being overweight?

1	2	3	4	5	6

12. Are you preoccupied with the thought of having fat on your body?

1	2	3	4	5	6

13. Are you aware of the calorie content of foods that you eat?

1	2	3	4	5	6

Factor II – Bulimia and food preoccupation

14. Do you have the impulse to vomit after meals?

1	2	3	4	5	6

15. Do you vomit after eating?

1	2	3	4	5	6

16. Have you gone on eating binges where you feel that you may not be able to stop?

1	2	3	4	5	6

17. Do you give too much time and thought to food?

1	2	3	4	5	6

18. Do you find yourself preoccupied with food?

1	2	3	4	5	6

19. Do you feel that food controls your life?

1	2	3	4	5	6

Factor III – Oral control

20. Do you cut your food into small pieces?

1	2	3	4	5	6

21. Do you take longer than others to eat meals?

1	2	3	4	5	6

22. Do other people think that you are too thin?

1	2	3	4	5	6

23. Do you feel that others would prefer it if you ate more?

1	2	3	4	5	6

24. Do you feel that others pressure you to eat?

1	2	3	4	5	6

25. Do you avoid eating when you are hungry?

1	2	3	4	5	6

26. Do you display self-control around food?

1	2	3	4	5	6

Garner *et al.* (1982); Garner & Garfinkel (1979).

Addendum 4

Please place (X) against the answer which applies best to each of the numbered statements. All of the results will be strictly confidential. Please answer each question carefully.

Food and Nutrition Questionnaire

1. The main energy sources for the athlete are:
   a) Carbohydrates
   b) Proteins
   c) Fats

2. Bread and pasta are important because they supply:
   a) Vitamins
   b) Proteins
   c) Carbohydrates

3. Meat is important because it supplies:
   a) Vitamins
   b) Proteins
   c) Carbohydrates

4. The protein content is greater in 100 grams of
   a) Legumes
   b) Milk
   c) Vegetables

5. The best "healthy fat" is:
   a) Butter
   b) Margarine
   c) Olive oil

6. The energy and fat content is greater in 100 grams of:
   a) Chicken
   b) Mozarella
   c) Brinjal

7. Do eggs contain cholesterol
   a) Yes, in the yolk
   b) Yes, in the white
   c) No

8. Vegetables, cereals and fruits are important because they supply:
   a) Fats
   b) Fibres
   c) Carbohydrates

9. Fruits are important because they supply:
   a) Fats
   b) Vitamins
   c) Proteins

10. Which is the main source of calcium?
    a) Milk and cheese
    b) Lettuce
    c) Steak

11. Which is the better source of iron?
    a) Meat
    b) Spinach
    c) Bread

12. In the case of abundant sweating, it is better to:
    a) Drink small amounts of fresh water, at regular intervals
    b) Drink great amount of soft saline drinks before the performance.
    c) Drink abundantly only after the end of the physical activity.

13. Do you think sparkling mineral water is fattening?
    a) Yes, it is.
    b) No, it is not.
    c) I don't know.

14. Lower energy intake is supplied by a glass of
    a) Coca Cola
    b) Beer
    c) Sparkling mineral water

15. When do athletes need an extra food ration?
    a) Always
    b) Never
    c) When the performance begins 3 or more hours after the meal

16. Which one of these snacks is the best for the athletes?
    a) Ice cream
    b) "Big Mac"
    c) Chips

17. Does eating a lot of meat increase muscle size?
    a) Yes, it does.
    b) No, it doesn't.
    c) I don't know.

18. Dietary supplements are useful on:
    a) Unbalanced diet
    b) Balanced diet
    c) Fasting (starvation)

19. How do you correct overweight?
    a) Sweating a lot
    b) Fasting all the day
    c) Lowering the energy intake at meals

20. Which is the first procedure to lose weight?
    a) Stop drinking water
    b) Skip meals
    c) Decrease the consumption of pastries, sweetness, oil

Cupisti et al., 2002.

Addendum 5

Please indicate the sources of nutrition information by using the following table. Please answer each question carefully. Thank you.

Sources of nutritional information

Information source	Sources used	"Most useful" sources"
Magazines		
Books		
Friends/team mates		
High school		
Newspaper		
Radio		
Physician		
Fitness class		
Health food store		
Dietician		
Coach		