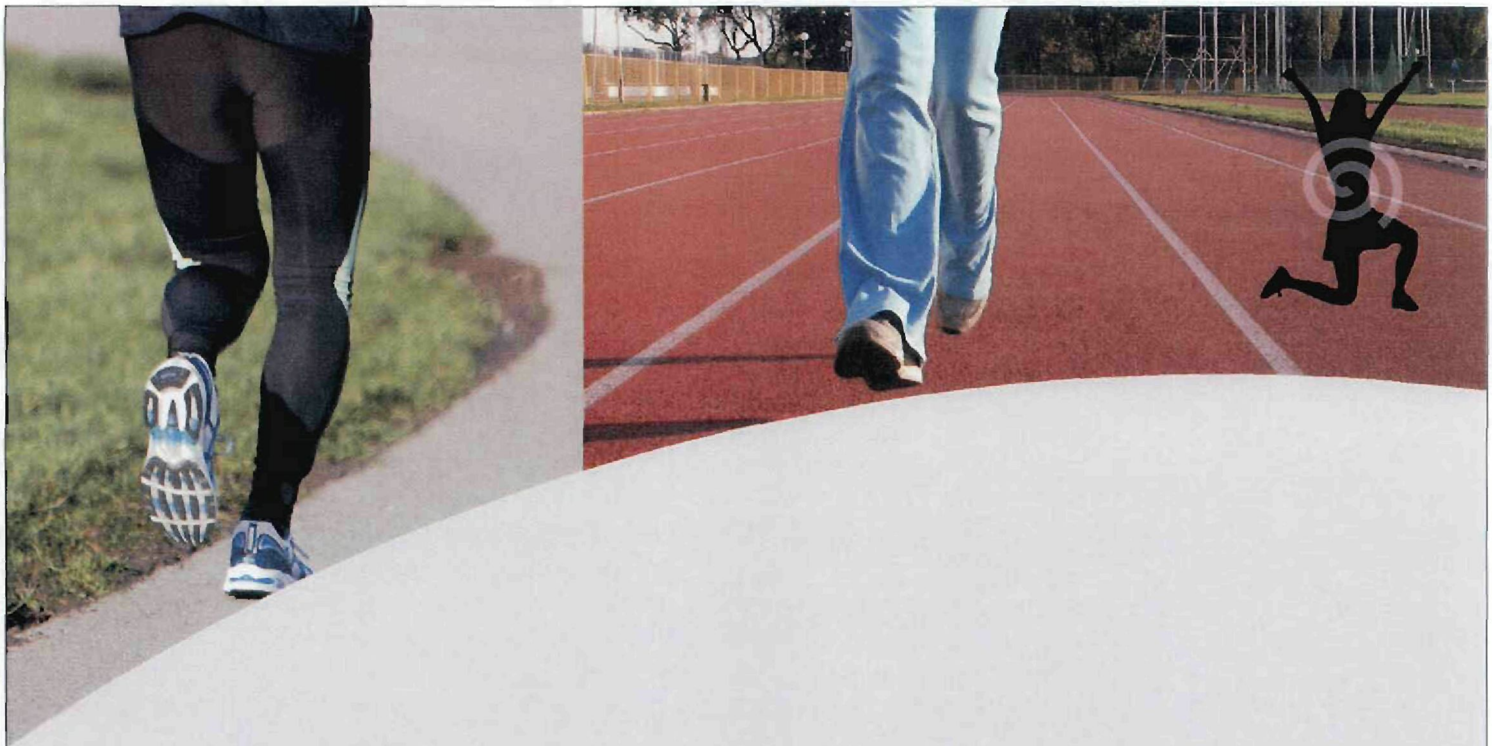

The relationship between body composition components, risk for disordered eating and irregular menstrual patterns among long-distance athletes

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B.A., B.A. Honns

Dissertation submitted in fulfilment of the requirements for the degree Master of Arts at the Potchefstroom campus of the North-West University

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Now faith is being sure we will get what we hope for. It is being sure of what we cannot see.
- Hebrews 11:1 -

Thank you my heavenly Daddy for the amazing opportunity to learn so many new things. You believed in me many so many times when I had given up. Without You I am nothing.

℘

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Declaration

The co-authors of the articles which form part of this dissertation, Prof J. Hans de Ridder (supervisor), Dr H. H. Wright (co-supervisor), Dr S. Péter (assistant supervisor) and Dr S.M. Ellis, hereby give permission to the candidate, Ms Judy Prinsloo, to include the two articles as part of a Masters dissertation. The contribution, both supervisory and supportive, of these co-authors was kept within limits, thereby enabling the candidate to submit this dissertation for examination purposes. This dissertation, therefore, serves as partial fulfilment of the requirements for the M.A. degree within the School of Biokinetics, Recreation and Sport Science in the Faculty of Health Sciences at the North-West University, Potchefstroom Campus.

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Summary

In distance running specifically, a lean body appearance is emphasized as optimum for performance (Greydanus & Patel, 2002). In order to obtain or keep this leaner body, many athletes lower their energy intake and which, in addition to a demanding exercise schedule, consequently creates an energy deficit (Byrne & Mclean, 2001; Warren & Perloth, 2001; Goodman & Warren, 2005; Waldrop, 2005).

Energy deficiency ultimately leads to amenorrhea and lowered bone density (Loucks & Heath, 1994; Van de Loo & Johnson, 1995; Sanborn *et al.*, 2000). Recently, however, the American College of Sports Medicine Position Stand accentuated that low energy availability *with or without* an eating disorder disrupts normal menstrual function (ACSM, 2007:1868). Thus low energy availability may be inadvertent, intentional or psychopathological (ACSM, 2007:1867).

Studies have made contributions to the field of physical science by studying the prevalence of menstrual irregularities and disordered eating amongst athletes, but none have focused on the black South African female athlete, which makes this study unique.

Consequently the first purpose of this study was to determine the prevalence of energy availability, menstrual irregularity and risk for disordered eating in a group of black South African runners. Descriptive measures were calculated. Effect sizes were also determined (Ellis & Steyn, 2003); where practical significance can be understood as a large enough difference to have an effect in practice.

Mean energy availability for the group was 124.16 ± 94.93 kJ/kgLBM/day. Four of the thirty-two athletes (12.5%) reported menstrual irregularities. 40.6% reported risk for disordered eating. It was found that mean energy availability is not low in this group of athletes, but both menstrual irregularity and risk for disordered eating was prevalent.

The second purpose of this study was to assess menstrual status and its association with body composition and energy availability among this group of black South African runners. Subjects were grouped in terms of energy intake, energy output, energy availability, menstrual status and risk for disordered eating, where descriptive measures were calculated. Because this was an availability study, p-values were not applicable and effect sizes were calculated to determine whether any of the differences were practically significant.

Percentage body fat and energy expenditure had a visible effect (both effect sizes = 0.46) on menstrual regularity, but a practically significant relationship emerged between energy intake and energy availability (effect sizes = 0.84 and 1.01 respectively) and menstrual regularity. Energy intake differed significantly between the regular (9793 ± 3504) and irregular groups (6862 ± 1906) with an effect size of 0.84. The energy availability differed significantly between the regular (146 ± 93 kJ/kgLBM/day) and irregular (44 ± 60 kJ/kgLBM/day) groups (effect size = 1.01). It was found that menstrual regularity had a significant relationship with both energy intake and energy availability.

Key words: energy intake, energy expenditure, menstrual regularity, energy availability, black athletes

Opsomming

In langafstandwedlope word 'n lenige liggaam aanvaar as optimaal vir prestasie (Greydanus & Patel, 2002). Menigmaal wend baie atlete hul tot verlaagde energie inname wat, tesame met 'n besige oefenprogram, uiteindelik lei tot 'n energietekort (Byrne & Mclean, 2001; Warren & Perloth, 2001; Goodman & Warren, 2005; Waldrop, 2005).

Energietekort lei uiteindelik tot amenoree en verlaagde beendigtheid (Loucks & Heath, 1994; Van de Loo & Johnson, 1995; Sanborn *et al.*, 2000). Die "American College of Sports Medicine Position Stand" het egter onlangs uitgelig dat lae energiebeskikbaarheid *met of sonder* 'n versteurde eetpatroon normale menstruele funksie ondermyn (ACSM, 2007:1868). Verlaagde energie beskikbaarheid kan dus onopsetlik, opsetlik, of psigopatologies van aard wees (ACSM, 2007:1867).

Studies het al bydraes gelewer tot die terrein van fisieke wetenskap deur die voorkoms van menstruele ongereeldhede en versteurde eetpatrone onder atlete te ondersoek. Geeneen het egter, na ons beste wete, gefokus op die swart Suid-Afrikaanse atleet nie, wat hierdie studie uniek maak.

Gevolglik was die eerste doel van hierdie studie om die voorkoms van energiebeskikbaarheid en menstruele ongereeldheid onder 'n groep swart Suid-Afrikaanse atlete te ondersoek. Beskrywende statistiek is bereken. Effekgroottes is ook bereken (Ellis & Steyn, 2003); waar praktiese betekenisvolheid verstaan kan word as 'n groot genoeg verskil om 'n effek in die praktyk te hê.

Gemiddelde energiebeskikbaarheid vir die groep was 124.16 ± 94.93 kilojoule per kg skraalliggaamsmassa per dag (kJ/kgSLM/dag). Vier van die twee en dertig atlete (12.5%) het menstruele ongereeldhede gerapporteer. 40.6% van die atlete het versteurde eetpatrone gerapporteer. Daar is bevind dat gemiddelde energiebeskikbaarheid in hierdie groep atlete nie laag was nie, maar menstruele ongereeldheid en risiko vir versteurde eetpatrone het wel voorgekom.

Die tweede doel van die studie was om menstruele status en die onderlinge verhoudings met liggaamsamestelling en energiebeskikbaarheid onder hierdie groep atlete te ondersoek. Deelnemers is gegroepeer volgens risiko vir versteurde eetpatrone, energie-inname, energieverbruik en menstruele status, waar beskrywende statistiek bereken is. Aangesien dit 'n beskikbaarheidstudie was hierdie, is p-waardes nie van toepassing nie en is effekgroottes eerder gebruik om te kyk of enige verskille prakties betekenisvol was.

Persentasie liggaamsvet en energieverbruik toon 'n sigbare verband (beide effekgroottes = 0.46) met menstruele gereeldheid, maar 'n prakties betekenisvolle verhouding het te voorskyn gekom tussen beide energie-inname en energiebeskikbaarheid (effekgroottes = 0.84 en 1.01), en menstruele status. Energie-inname het betekenisvol tussen die gereelde groep (9793 ± 3504) en die ongereelde groep (6862 ± 1906) verskil met 'n effekgrootte van 0.84. Die energiebeskikbaarheid het betekenisvol verskil tussen die gereelde (146 ± 93 kJ/kgSLM/dag) en ongereelde (44 ± 60 kJ/kgSLM/dag) groepe. Daar is bevind dat menstruele gereeldheid 'n betekenisvolle verband toon met beide energie-inname en energiebeskikbaarheid.

Sleutelwoorde: energie inname, energieverbruik, menstruele gereeldheid, energie beskikbaarheid, swart atlete

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List of Abbreviations

ACSM___________American College of Sports Medicine

BMD____________Bone Mineral Density

BMI_____________Body Mass Index

E_2______________Oestrogen

EDI_____________Eating disorder inventory

FFM_____________Fat-free body mass

HPO____________Hypothalamic-pituitary-ovarian-uterine

Kcal_____________Kilocalorie

Kcal/kgFFM/day___Kilocalorie per kilogram of fat-free body mass per day

Kcal/kgLBM/day___Kilocalorie per kilogram of lean body mass per day

kJ_______________Kilojoule

LDL_____________Low density lipoprotein

LBM_____________Lean body mass

LPD_____________Luteal phase defect / deficiency

Chapter 1 Problem statement and aims of study

1.1 Problem Statement
1.2 Objectives
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1.1 Problem Statement

In sport, body composition is vital to optimal physical performance (Heyward & Wagner, 2004:159). In distance running specifically, a lean body appearance is emphasized as optimum for performance (Greydanus & Patel, 2002:563). Arrese and Ostariz (2006:75) also found that a lesser skinfold thickness in the lower limb is positively associated with running time over several distances and may be a useful predictor of athletic performance. Because of these performance-related implications, coaches, parents, exercise scientists, sports medicine professionals and athletes themselves have an interest in their body composition (Heyward & Wagner, 2004:159).

Researchers state that many female athletes are at risk of developing the female athlete triad (Triad), because of the belief that a leaner body can enhance athletic performance (Greydanus & Patel, 2002:564; Sherman & Thompson, 2004:198). The American College of Sports Medicine (ACSM) defined the Triad as a syndrome consisting of three components, namely disordered eating, amenorrhea and osteoporosis (ACSM, 1997:i). In order to keep or obtain a leaner body, the athlete resorts to disordered eating (Byrne & Mclean, 2001:146), lowering the energy intake and increasing the energy output; thus creating an energy deficit (Warren & Perloth, 2001:3; Goodman & Warren, 2005:468; Waldrop, 2005:213). Decreased energy availability ultimately leads to amenorrhea (Loucks & Heath, 1994:R822; Van de Loo & Johnson, 1995:694) and lowered bone density (Sanborn *et al.,* 2000:210).

The energy level below which menstrual dysfunction is likely to occur, is approximately 125 kilojoules per kg of fat-free mass per day (kJ/kgFFM per day; equivalent to about 30 kcal/kgFFM per day) or 30 kilocalories per kg lean body mass per day (kcal/kgLBM per day) (Loucks, 2003:147; Ihle & Loucks, 2004:1238)[1]. Additionally, metabolic hormones that promote bone formation are disrupted below this energy availability, and the rate of bone formation is suppressed as well (Loucks & Nattiv, 2005:S50).

Today, the Triad is understood to comprise of interrelated spectrums of energy availability, menstrual function and bone strength, ranging from health to disease (Loucks & Nattiv, 2005:S49). Recently, the ACSM Triad Position Stand highlighted that low energy availability appears to be the factor that impairs reproductive and skeletal health in the Triad, and it may be inadvertent, intentional or psychopathological (ACSM, 2007:1867).

The category of disordered eating is meant to convey a continuum of abnormal eating behaviours, ranging from failure to meet energy demands of exercise (i.e. low energy availability) to the clinical eating disorders, anorexia nervosa, bulimia nervosa and eating disorder not otherwise specified (Beals & Meyer, 2007:72). Athletes with habits of disordered eating attempt to lose weight or body fat by inducing a negative energy balance and/or employing a wide range of disordered

[1] Although the terms lean body mass and fat-free mass are used interchangeably in literature, the term lean body mass will be used in this study.

eating practices including fasting, diet pills, laxatives, diuretics and vomiting (Torstveit & Sundgot-Borgen, 2005:1455).

Primary amenorrhea has recently been redefined by the American Society of Reproductive Medicine (2006:266) as "*an absence of menstrual cycles in a girl who has not menstruated by age 15, although she has experienced other normal developmental changes occurring during puberty*". Secondary amenorrhea, on the other hand, is the absence of at least three consecutive menstrual cycles and is so common among female athletes that it is often viewed as normal by athletes and sport personnel (Sherman & Thompson, 2004:198). Amenorrhea might, however, be due to the athlete not meeting the energy requirements demanded, either as a result of disordered eating or unknowingly due to time constraints, food availability issues or lack of appropriate nutritional knowledge (Beals & Meyer, 2007:73,80) and can hence be the first sign of the Triad (Sherman & Thompson, 2004:198).

In the past, it was postulated that the most deleterious risk of menstrual dysfunction was its impact on bone tissue. This hypothesis proposed that hypoestrogenism can predispose athletes with menstrual dysfunction to osteopenia and osteoporosis and put them at a higher risk for injury, specifically stress fractures (De Souza & Williams, 2005). Recent literature, however, proposes that markers of bone formation and resorption change unfavourably within 5 days in sedentary women who were exposed to low energy availability (Ihle & Loucks, 2004:1239).

The concept of insufficient energy availability is emphasized in the International Olympic Committee Medical Commission's Position Stand (2004:19-21) as the explanation for most cases of exercise-associated amenorrhea. Although low energy availability can, and often does, result from disordered eating, it can also occur in the absence thereof. The profile of the female athlete with menstrual dysfunction may thus be of one who is at increased risk of low bone mass owing to disordered eating patterns and high training loads, rather than to menstrual dysfunction (Micklesfield *et al.*, 2007:682).

Early identification of the Triad or its components, and then referral, of these athletes is vital to their health since it may not only impair athletic performance and increase injury risk but also have other health-related risks (Beals, 2005:74). In this study, we aimed at raising awareness of the prevalence of two of the components of the Triad. This was done by assessment of eating behaviours, determination of energy intake and output, the determination of the prevalence of amenorrhea, and a closer look at body composition in order to improve early identification and referral of at-risk athletes.

During the literature study, it became clear that data regarding the Triad and its components of South African athletes is lacking and no data is available, to our knowledge, regarding black South African athletes. Studies have made contributions to the field of physical science by studying the prevalence of menstrual irregularities and disordered eating among white South African athletes, but none have focused on the black South African female athlete, which makes this study unique.

This study therefore attempted to contribute by informing athletes, the trainer, coach and parent with regard to the Triad and its health-related risks as well as alerting them to the prevalence of two of the components of the Triad (disordered eating and menstrual regularity) among black South African athletes. Knowledge concerning this prevalence could also improve referral of these at-risk athletes, since the benefits of early recognition and referral have been widely documented.

It is within this framework that the proposed research was undertaken. The research questions answered through this investigation are as follows: (1) What is the prevalence of energy availability, menstrual regularity and risk for disordered eating among a group of black South African runners? (2) Is there an association between firstly, menstrual status and body composition and secondly, between menstrual status and energy balance, among these black South African runners?

1.2 Objectives

The specific aims of this study were derived from the above-mentioned research questions and are as follows.

- To study the prevalence of low energy availability, menstrual regularity and risk for disordered eating among a group of black South African runners.
- To investigate menstrual regularity and its association with body composition and energy availability among this group of black South African runners.

1.3. Hypotheses

The following hypotheses were formulated for this investigation:

- Low energy availability, menstrual irregularity and risk for disordered eating are prevalent in this group of black South African runners.
- Menstrual regularity has an association with both body composition and energy availability among this group of black South African runners.

1.4 Structure of the dissertation

This dissertation is presented in four main parts, namely an introduction (Chapter 1), a literature review (Chapter 2), and two research articles (Chapters 3 and 4). Thereafter a summary with conclusions and recommendations follow (Chapter 5).

Chapter 1 introduces the problem, and states the aim and hypotheses of this study. The literature review in Chapter 2 focuses on the relationship between body composition components, amenorrhea and disordered eating. Chapter 3 will take the form of an article: The prevalence of energy availability, menstrual regularity and risk for disordered eating among a group of black South African runners. The second article, Chapter 4, consists of the second research article titled "Menstrual regularity and its relationship with body composition and energy availability among a group of black South African runners." Both articles will be prepared for submission to peer-reviewed journals, the Medicine & Science in Sports & Exercise, as well as the International Journal for Sport Nutrition and Exercise Metabolism. The final chapter will wrap up with the summary, conclusion and recommendations of both research articles. Chapter 5 is followed by a list of appendices.

The structure of the dissertation is displayed in Figure 1.

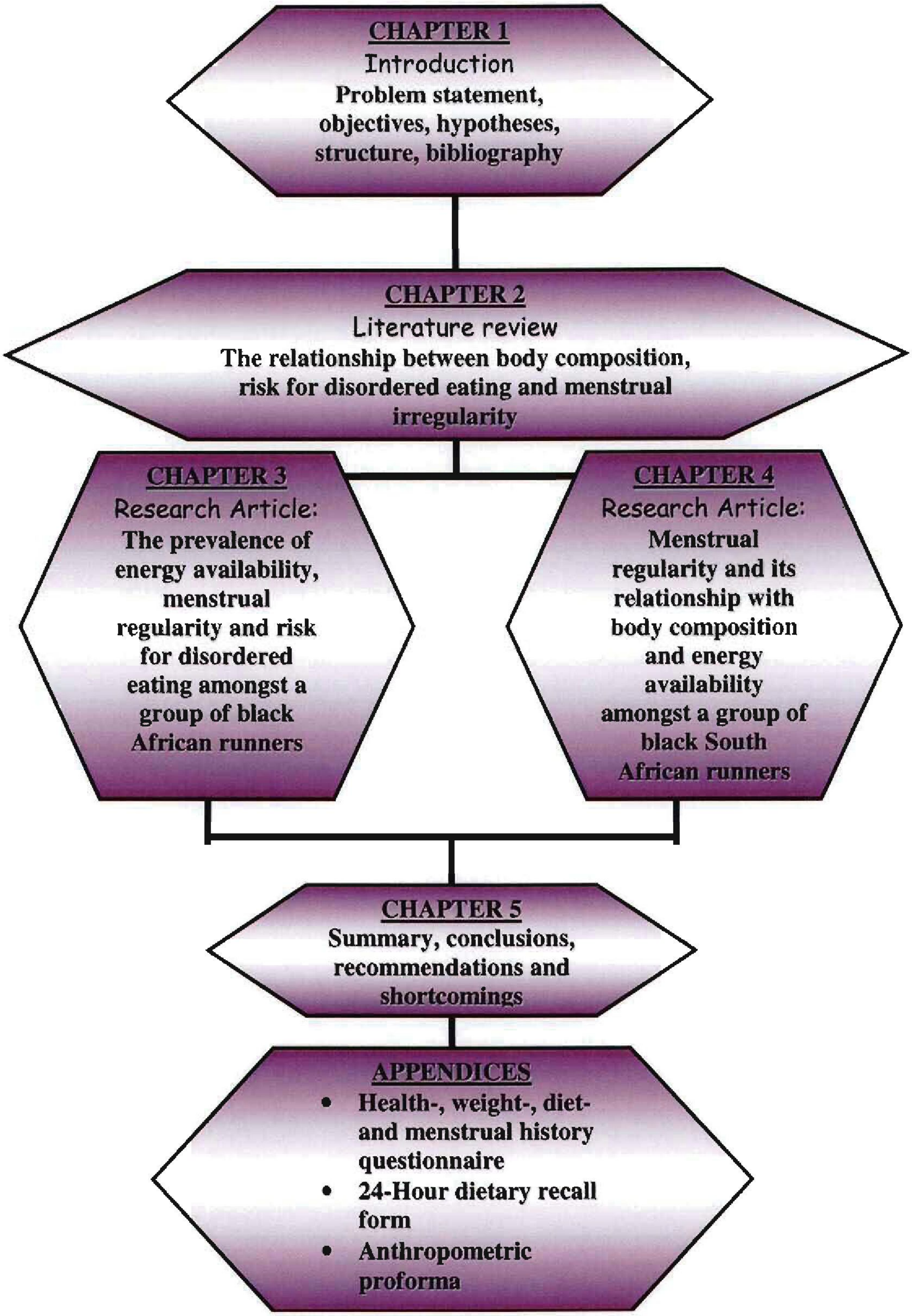

Figure 1: Structure of Dissertation

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Chapter 2 The relationship between body composition, risk for disordered eating, and menstrual irregularity

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2.1 Introduction

Athletic performance is maximized, in part, by a sport-specific optimum body size, body composition and a mix of stored metabolic fuels (Loucks, 2004:7). Increased fat-free body mass is likely to be undesirable for the endurance athlete who must move his or her total body mass horizontally for extended periods of time (Willmore & Costill, 2004:456). Distance runners also typically carry low body fat levels – an advantage when one has to carry one's body weight over many kilometres (Burke, 1998:98). To keep body fat levels low, runners restrict energy intake (Burke, 1998:200) and often the situation becomes progressively worse, because the less they eat, the less they need to eat. Papanek (2003:602) states that decreased energy intake, in combination with elevated energy expenditure from physical training and competition disrupts energy balance.

The energy cost of exercise does impact on energy availability – defined as dietary energy intake minus exercise energy expenditure – and energy balance (Loucks, 2003a:145). Energy balance, defined as dietary energy intake minus total energy expenditure, is the amount of dietary energy added to or lost from the body's energy stores after all the physiological systems have done their full work for the entire day (Loucks, 2007:349). In young adults, energy balance occurs at an energy availability of about 190 kJ per kg fat-free mass per day (kJ/kgFFM/day)[2] (Loucks & Nattiv, 2005:S49).

During severely low energy availability, hormones suppress metabolic processes, and energy balance increases (Loucks, 2007:349). In exercising women, luteinizing hormone (LH) pulsatility is disrupted below a threshold of about 125 kJ/kgLBM/day (Ihle & Loucks, 2004:1238; Loucks & Nattiv, 2005:S49). Thus athletes in endurance sports who do not modify their diet to compensate for the increase in energy expenditure are at a raised risk of disrupted menstrual cycles (Loucks & Nattiv, 2005:S49).

This energy imbalance hypothesis provides an explanation as to why some athletes develop athletic amenorrhea when others do not and also provides the link between disordered eating and amenorrhea (Papanek, 2003:603).

[2] Although the terms lean body mass and fat-free mass are used interchangeably in literature, the term lean body mass will be used in this study.

Studies show that amenorrheic athletes have significantly lower bone density – and bone strength – and this may increase the risk of stress fractures (Cumming, 1996:2193-2195; Burke, 1998:201). Formerly it was believed that reductions in bone mass resulted primarily from hypoestrogenism, which results in a lower peak BMD and a decreased inability to sustain BMD (Burke, 1998:57-58; Miller, 2003:145; Papanek, 2003:600; Rome, 2003:361). Recent studies have, however, also linked bone loss to a nutritional deficiency (Ihle & Loucks, 2004:1235; Micklesfield *et al.,* 2007:682; Barrack *et al.*, 2008). Micklesfield *et al.* (2007:682) examined the relationships between the occurrences of bone stress injuries and disordered eating patterns, as well as high training load, and found that the mechanism may be more related to energy balance than to hypoestrogenism.

The presence of a lowered bone density completes the components of the female athlete triad (Triad), as defined by the ACSM (ACSM, 2007:1868). Today, the Triad is understood to comprise of interrelated spectrums of energy availability, menstrual function and bone strength, ranging from health to disease (Loucks & Nattiv, 2005:S49; ACSM, 2007:1868). Sherman and Thompson (2004:198) state that many athletes are at risk of the Triad because of a belief that a leaner body can enhance athletic performance.

2.2 THE BODY COMPOSITION OF THE LONG-DISTANCE ATHLETE

Body composition refers to the body's chemical composition, which comprises of both fat mass and fat-free mass (Willmore & Costill, 2004:449). The absolute amount of body fat, termed fat mass, includes all extractable lipids from adipose and other tissues (Heyward & Wagner, 2004:5). Fat-free body mass (FFM) is composed of all residual chemicals and tissues including water, muscle, bone, connective tissues and internal organs (Heyward & Wagner, 2004:5; Willmore & Costill, 2004:450).

Willmore and Costill (2004:456-457) state that, for the endurance athlete carrying his/her body for extended periods, a higher fat-free mass is an additional load that might impair the athlete's performance. Also, it is a common experience that light objects can be moved faster than heavy objects. That is because the velocity at which a muscle fibre shortens decreases with increasing loads (Vander *et al.,* 1998:305). This is another reason why most elite distance runners have low total body weights and are small in stature and slightly muscled, particularly in the upper body (Burke, 1998:198).

2.2.1 Skeletal Muscle

Endurance training involves the enhancement of the muscle's energy supply rather than its size (Whiting & Zernicke, 1998:110). Glycogen, which is stored in muscle fibres and the liver, is used extensively in exercise of moderate to high intensity (Whiting & Zernicke, 1998:110, Wilmore & Costill, 2004:191). Muscle glycogen is also used extensively during each training bout, so the mechanisms responsible for its resynthesis are stimulated after each session, allowing the depleted oxygen stores to be replenished. With adequate rest and sufficient dietary carbohydrate intake, trained muscle stores considerably more glycogen than untrained muscle does and can provide maximum energy availability for muscle contractions (Whiting & Zernicke, 1998:110; Wilmore & Costill, 2004:191).

In addition to their greater glycogen content, endurance-trained muscle fibres contain substantially more fat (lipids) stored as triglyceride than untrained fibres do (Wilmore & Costill, 2004:192). The metabolic pathway of the endurance athlete adapts to a more effective use of fatty acids for fuel instead of glycogen (Whiting & Zernicke, 1998:110).

Another important element in endurance training is the changes it produces in muscle fibre type, cappilary supply, myoglobin content, mitochondrial function and oxidative enzymes (Wilmore & Costill, 2004:188).

Every muscle of the body is composed of a mixture of so-called "fast" and "slow" twitch muscle fibres, with still other fibres gradated between these two extremes (Guyton & Hall, 2000:75). The muscles that react rapidly are composed mainly of "fast" fibres with only small numbers of the slow variety. Conversely, the muscles that respond slowly but with prolonged contraction are composed mainly of "slow" fibres (Guyton & Hall, 2000:973).

Slow-twitch fibres are mainly organized for endurance, especially for generation of aerobic energy. Inherently, they have far more mitochondria than fast-twitch fibres, and contain considerably more myoglobin, a haemoglobin-like protein that binds with oxygen (Guyton & Hall, 2000:973; Powers & Howley, 2004:148-149). This extra myoglobin increases the rate of diffusion of oxygen throughout the fibre by shuttling oxygen from one molecule of myoglobin to the next. In addition, the enzymes of the aerobic metabolic system are considerably more active in fast-twitch fibres (Vander *et al.*, 1998:314-315; Guyton & Hall, 2000:973). The number of capillaries is also larger than in the vicinity of fast-twitch fibres (Guyton & Hall, 2000:973).

Aerobic training increases both the number of capillaries per muscle fibre and the number of capillaries for a given cross-sectional area of muscle. Both these changes improve blood perfusion through the muscles, thereby enhancing the exchange of gases, wastes and nutrients between the blood and muscle fibres (Wilmore & Costill, 2004:189). Additionally, with endurance training, the mitochondria size, number and density in skeletal muscle has been shown to increase and this provides the muscle with much more efficient oxidative metabolism associated with improved lipolysis (Whiting & Zernicke, 1998:110, Wilmore & Costill, 2004:189).

All these changes that occur in the muscles, combined with adaptations in the oxygen transport system, enhance functioning of the oxidative system, improve performance and lead to an increase in the capacity for endurance activity with a minimum of fatigue (Vander *et al.*, 1998:314, Wilmore & Costill, 2004:191).

2.2.2 Body Fat

Generally, relatively low body fat is desirable to optimize physical performance in sports requiring jumping and running, especially marathon runners, as they must carry their own body-weight over long distances (Burke, 1998:64; Heyward & Wagner, 2004:159).

According to Heyward and Wagner (2004:171), the average body fat of female long distance runners should be between 10% and 19%. However, they emphasize that these values should only be used as guidelines and that optimal body weight and body composition to maximize performance vary among individuals. Willmore and Costill (2004:459) suggests that any female distance runner should have between 6% and 12% relative body fat if she harbours world-class expectations.

In runners, an excess of adipose tissue usually requires a greater muscular effort to accelerate the legs and, in theory, the energetic expenditure at the same velocity would be higher (Arrese & Ostariz, 2006:69). Very low body fat, on the other hand, can result in serious health complications, e.g. early fatigue, an increased risk of infection and intolerance to cold, and for some females the loss of regular menstrual cycles (Burke, 1998:65). Additionally, a low percentage body fat or weight loss has, in the past, been associated with the loss of regular menstrual cycles, or amenorrhea (Warren & Shanta, 2000:37-53; Burke, 1998:65). Many athletes also turn to unhealthy behaviours (e.g. fasting, purgative behaviour and disordered eating patterns) in an effort to achieve a more desirable body composition (Heyward & Wagner, 2004:169; Beals, 2005).

2.2.3 Skeletal Mass

The skeleton has many functions, including supporting the weight of the body (Martini & Bartholomew, 2000:122). Bones provide points of attachment for the muscles, protect delicate tissues, act as reservoirs for calcium and phosphorus, and some are involved in blood cell formation (Willmore & Costill, 2004:515).

Exercise is essential for proper bone growth. Most of the body's larger bones depend on the daily loading of gravitational forces (Willmore & Costill, 2004:362). Although exercise has little or no influence on bone lengthening, it does increase bone width and bone density by depositing more mineral in the bone matrix, which increases the bone strength (Willmore & Costill, 2004:516). The finding of large increases in bone formation markers in trained subjects strongly supports the hypothesis that relatively brief endurance type training in adolescent males and females specifically stimulates new bone formation independent of the ongoing puberty-associated increases in these markers (Eliakim & Beyth, 2003:202).

Since the early 1980s, many studies have confirmed the problem of low bone mineral density (BMD) in highly trained female athletes, particularly endurance runners, and this evidence continues to accumulate (Vorster *et al.,* 2001; Hind *et al.,* 2006:880). Gibson *et al.* (2000:596) found that the duration of amenorrhea may be an important risk factor in the development of osteoporosis in female athletes younger than 40 years. It was also found that lumbar spine density is positively influenced by weight and menstrual status, while body weight is an important determinant of femoral bone density. The diet, calcium, VO_2 max, miles run per week and percentage body fat had, however, no significant effect on femoral bone density (Gibson *et al.,* 2000:595).

Regarding lumbar spine bone density, a study by Hind *et al.* (2006:880) found that running distance, coupled with BMI, together best predict lumbar spine density scores in females. Having a history of at least one stress fracture was also associated with lower spine and hip density scores. Suggested risk factors for low BMD in female athletes include exercise-induced amenorrhea, disordered eating and low body weight (Hind *et al.,* 2006:880). High running distances will result in large energy expenditures, and one possible explanation for its effect on bone is via decreased bone resorption and suppressed bone formation if energy intake is insufficient (Hind *et al.,* 2006:883; Ihle & Loucks, 2007:1239).

2.3 DISORDERED EATING

The female athlete may attempt to lose body weight or body fat by developing patterns of disordered eating (Rome, 2003:356). Disordered eating may also be a result of attitude and behaviour of coaches, believing that a low percentage body fat results in better performance (Heffner *et al.,* 2003:209-220; Rome, 2003:357; Willmore & Costill, 2004:459).

Disordered eating behaviour ranges from mild to severe and the term *disordered eating* is often used instead of eating disorder since many female athletes have disordered eating behaviour but do not meet the criteria for eating disorders such as anorexia nervosa and bulimia nervosa (Warren & Shanta, 2000:37-53). Disordered eating is portrayed as a spectrum of abnormal patterns of eating, including bingeing, purging, prolonged fasting, use of diet pills, diuretics and laxatives as well as other abnormal eating behaviours (Willmore & Costill, 2004:461; Walsh *et al.*, 2000:577-590).

Another common behaviour is restricting certain foods, particularly those high in fat and/or protein (Waldrop, 2005:213-220). Burke (1998:76) defines a low-energy consumer as any female athlete who chronically consumes less than

6,400 kJ or 1,500 kcal per day. Rome (2003:356) states that an initial drive by the athlete to lose weight to improve performance is eventually replaced by a drive to lose weight as a goal in and of itself, regardless of the negative impact on athletic performance.

2.3.1 Food Restriction vs. Nutrition

As restriction of certain foods and food groups inadvertently leads to diminished performance (Wilmore & Costill, 2004:459), the athlete needs to take a closer look at the recommended dietary requirements in order to optimize performance.

The availability of carbohydrate (CHO) as a substrate for muscle and the central nervous system is a critical factor in the performance of prolonged sessions (>90 minutes) of submaximal or intermittent, high-intensity exercise (Burke *et al,* 2001:268). Optimal CHO requirements are estimated on the basis of muscle glycogen needs to replace the fuel that one burns up in daily exercise (Burke, 1998:44-45). CHO intake ranges of 7 to 10 gram per kg per day (g/kg/day) for the increased needs of endurance athletes are suggested to enhance CHO availability and exercise capacity, as well as performance during a single exercise session (Burke *et al.,* 2001:267, 295).

However, female athletes, especially endurance athletes, have difficulty achieving these ranges due to the long-term or periodic restriction of total energy intake in order to achieve or maintain low levels of body fat (Burke *et al.,* 2001:295). This might be problematic as skeletal muscle has access to liver glycogen stores, and skeletal muscle then directly competes with the brain for all available carbohydrate as energy (Loucks, 2004:9).

Normally, about 5% of energy can come from protein during endurance exercise, particularly if muscle glycogen stores are depleted and blood glucose levels are low (Clark, 2003:162). Daily protein requirements for endurance training athletes should be in the range of 0.8 to 1,6 g of protein for every kg body weight, depending on how professional the athlete is (Burke & Deakin, 2006:95).

Insufficient energy intake increases protein requirement, because more protein is required to maintain nitrogen balance when energy intake is low (Loosli & Ruud, 1998:45). In addition, females who avoid meat may also limit their intake of chicken, fish and eggs – important dietary sources of high-quality protein. A meatless diet in a female athlete should be a warning sign for physicians, trainers and healthcare professionals, because it may indicate potential problems such as inadequate intake of protein, iron, zinc, as well as amenorrhea and possible eating disorders (Rome, 200:353; Loosli & Ruud, 1998:45).

Given the different restrictive dietary practices of athletes, many also have insufficient fat intakes (Horvath *et al.*, 2000:43; Venkatraman *et al.*, 2000:S389). Athletes eating high-carbohydrate, low-fat diets do not consume as much energy as they expend, and reducing fat intake to < 20% of total daily energy intake compromises fat stores and therefore endurance performance (Pendergast *et al.,* 2000:348).

Individuals who consume a low-fat diet are also at risk of not consuming adequate amounts of essential fatty acids (Horvath *et al.,* 2000:49). Essential fatty acids (linoleic acid and linolenic acid) must be supplied by the diet because it cannot be made by the human body in sufficient amounts to meet physiological needs (Whitney & Rolfes, 2002:145). Linoleic acid is the 18-carbon omega-6 fatty acid and linolenic acid is the 18-carbon omega-3 fatty acid (Whitney & Rolfes, 2002:144-145), both of which are essential for making eicosanoids. Eicosanoids help to regulate blood pressure, blood clot formation, blood vessel contractions, nerve impulse transmissions, and – very important for the athlete – immune response (Whitney & Rolfes, 2002:606).

Venkatraman *et al.* (2000:S389) reports that low fat diets (<20% of daily energy intake) increase inflammatory and decrease anti-inflammatory immune factors, depressed antioxidants and negatively affected blood lipoprotein ratios in endurance athletes, whereas increasing the dietary fat intake to 42% of total daily energy intake improves endurance exercise performance.

2.3.2 Health and performance consequences of disordered eating

Energy deficiency is a tool used to slim down, though not many athletes consider the effect it has on performance. Some will improve performance with slightly lower body weight values, while others will not be able to get down to such low relative values or they will find that their performance starts declining before they reach the suggested values (Willmore & Costill, 2004:464). Table 1 shows potential health and performance consequences of disordered eating, depending on the method used.

Table 1: Potential health and performance consequences of disordered eating

Fasting or starvation	Loss of lean body mass Decreased metabolic rate Reduction in bone mineral density Risk of nutrient deficiencies Glycogen depletion resulting in poor performance
Diet pills	Suppression of appetite and possible increase in metabolic rate (if pills contain ephedrine or caffeine) Rapid heart rate Anxiety Inability to concentrate Nervousness, inability to sleep Dehydration Weight loss is quickly regained once use is discontinued

Diuretics	Weight loss from water Weight loss is quickly regained once use is discontinued Possible heart arrhythmia due to electrolyte imbalances
Laxatives or enemas	Weight loss from water Weight loss is quickly regained once use is discontinued Dehydration and electrolyte imbalances Constipation, colon dysfunction Steatorrhea (excessive fat in faeces) Addiction potential Resistance potential requiring larger and larger doses
Self-induced vomiting	Largely ineffective for weight / fat loss Dehydration and electrolyte imbalances Gastrointestinal problems Caries and erosion of tooth enamel Finger calluses or abrasions
Fat-free diets	Lack essential nutrients, e.g., fat-soluble vitamins and fatty acids Total energy intake must still be reduced to produce weight loss Many fat-free foods are highly processed, with high sugar content and few micronutrients Can promote binge eating
Saunas	Water loss Weight loss is quickly regained once fluids are replaced Dehydration and electrolyte imbalances Heart arrhythmia
Excessive exercise	Increased risk of staleness Chronic fatigue Illness Overuse injuries Menstrual dysfunction (women)

Beals & Meyer, 2007:76

Energy deficiency is also linked to athletic amenorrhea (Rome, 2003:361-362). Most likely, exercise-induced menstrual dysfunction is the body's natural adaptation to a prolonged energy deficit, where energy intake remains below energy expenditure over long periods of time (Willmore & Costill, 2004:461).

2.4 THE CHALLENGE OF THE BLACK SOUTH AFRICAN ATHLETE

The traditional ideal body image among Africans has always been inclined towards a larger, fuller body shape. Additionally, in African religious and cultural symbolism, fatness in the female is closely linked to fertility (Gordon 2001:9-10). Ethnicity could consequently be seen as a protective factor against underweight and disordered eating/eating disorders. However, in view of massive socio-economic changes currently taking place in the country, and increased social integration following the abolishment of previous Apartheid legislation, black young South Africans may rapidly become exposed to different belief systems and thereby alter their value systems regarding body size (Caradas *et al.,* 2001:112).

At a superficial level the emergence of eating disorders in black South African women have been viewed as a by-product of 'Westernization'. However, the balance of evidence suggests that the situation is more complex. Urbanization, as opposed to mere proximity to white communities or to Western culture, is a critical factor (Szabo & Le Grange, 2001:31).

Caradas *et al.* (2001:117) found that young women who are similarly accultured, but from different ethnic backgrounds, display a similar prevalence of abnormal eating attitudes or could be considered to be at equal risk of developing an eating disorder. They also found that, although body image problems were less severe in black girls, they were by no means uncommon. Societal pressures of this nature probably develop within the context of an evolving multi-ethnic school environment, where competitiveness and peer influences begin to break down the protective barrier of traditional aesthetic values (Caradas *et al.,* 2001:118). The notion of ethnicity as a protective factor has thus been dispelled.

Also, Le Grange *et al.* (2004:452) studied high school students and found that socio-economic status also plays a significant role, as many of the black students participating in their study were living under conditions of significant poverty and findings need to take this into account.

In addition, Le Grange *et al.* (2004:439) highlighted the need to revisit the methods typically employed in cross-cultural research in eating disorders, as insufficient attention has been paid to the validity or meaning of these questionnaire items for non-Caucasian, particularly black African, respondents. The author used a questionnaire survey, including the EAT-26-, the EDE-, and the EDE-Q questionnaires.

Results for the EAT-26 in one high school indicated that 59 participants (38.3% of the total sample) scored above the cut-off point (i.e. a score of 20 or more). Upon interviewing them, it was found that the EAT, which does not allow for explanations of the reasons for behaviours, yielded important and unexpected findings. For example, when respondents were asked whether they found themselves preoccupied with food, some of the interviewees indicated on the EAT-26 that this was always the case - indicative of someone exhibiting disordered eating symptoms. Instead, the reason given in two cases, as recorded by the interviewer, was that their "family is poor, there is not always food in the house; thus they are always hungry and thinking about food" (Le Grange *et al.,* 2004:449).

When responding to the EAT-26 question whether they vomited after they had eaten, most of the interviewees indicated that they occasionally did. In an interview, two reasons were presented to explain the purging behaviour. Firstly, a participant indicated that she would occasionally vomit after eating pork. When she was hungry and that was the only food available, she would have to eat it. However, it was not allowed to digest in her stomach due to her cultural beliefs, and she would therefore have to vomit it up after she had eaten it. Secondly, she also induced vomiting as part of an internal cleansing ritual to protect the body from sickness. Thus the reasons for endorsing preoccupation with food or vomiting were not due to concerns with shape and weight, but rather due to cultural practices and economic circumstances (Le Grange *et al.,* 2004:449-450).

During the interview it was discovered that many of the participants had originally struggled to understand the questionnaire - a finding that surfaced during the administration of the eating disorder examination (EDE) as well. Here, respondents struggled to answer the questions and had significant difficulty referencing all responses to the "last 28 days" (each EDE question is in reference to the past 4 weeks or 28 days). The author concluded that the interviewees might have been guessing during the EDE because they gave different answers to the same questions when asked at different times, or when the same question was worded slightly differently. The EDE was rejected in favour of the simpler, shorter questionnaire format (EDE-Q).

Just as interviews to validate the questionnaire responses on the EAT-26 revealed many misunderstandings, the answers of participants on the EDE-Q questions revealed a cultural disconnect on this measure as well. Unlike the EAT-26, the EDE-Q specifies that the behaviour must occur for reasons pertaining to weight and shape. This added descriptor proved quite pertinent. For example, it was discovered that laxative use was quite common among the interviewees to prevent constipation given the high carbohydrate content of everyday foods such as pap (maize meal porridge). Had the EDE-Q not specifically requested that the reasons for laxative use be explained, the purging behaviour could have falsely been attributed to eating disorder pathology (Le Grange *et al.,* 2004:450-451).

This study highlighted a few shortcomings of current measurements of eating disorder pathology and suggests follow-up interviews to identify disordered eating among young black South Africans. Le Grange *et al's* study (2004) was done on black high school students, and these students may differ from athletes, who have to contend with both cultural and economic problems, as well as the challenges of the athletic milieu.

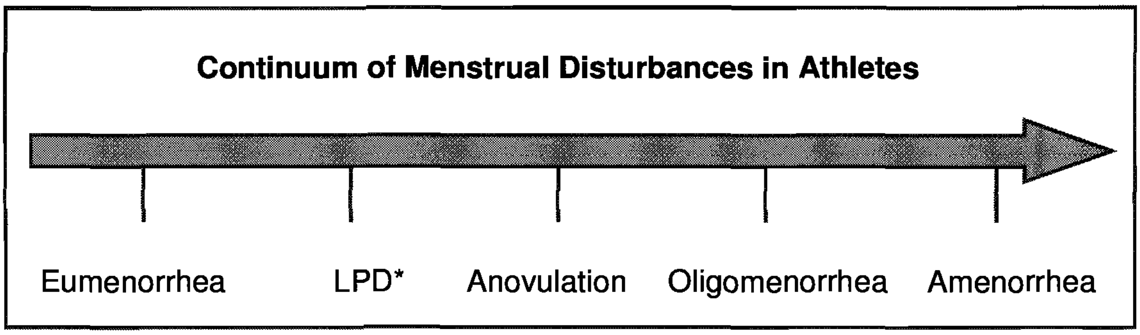
In the sport environment, over-concern with body size is a strong mediator of other risk factors regarding the development of eating disorder symptoms. These other risk factors include socio-cultural pressure for thinness, athletic performance anxiety and negative self-appraisal of sports performance (Hulley *et al.,* 2007:522). The black South African athlete might consequently be at risk of developing disordered eating, with its subsequent consequences.

Recently the American College of Sports Medicine Position Stand accentuated that low energy availability *with or without* an eating disorder disrupts normal menstrual function (ACSM, 2007:1868). Hence athletes who inadvertently increase exercise energy expenditure without increasing energy intake are also at risk. The prevalence of household food poverty in South Africa might lend weight to the fact that the South African athlete is also at risk of the latter proposed by the ACSM.

2.5 AMENORRHEA AND ENERGY AVAILABILITY

2.5.1 The continuum of menstrual disturbances

Menstrual cycle disturbances in athletes and active women have previously been described as existing along a continuum of reproductive disturbances, ranging from subtle presentations of luteal phase defects and anovulatory cycles to the most severe presentation, namely amenorrhea (see Figure 2, De Souza, 2003:1556).



*LPD = Luteal Phase Deficiency

Adapted from De Souza (2003:1556).

Figure 1: Continuum of reproductive disturbances

Eumenorrheic, or regular cycles, are defined as regular flow occurring every 21 to 45 days, with 10 to 13 cycles per year (Rome, 2003:359). The normal menstrual cycle may be divided into two phases, approximately equal in length and separated by ovulation: (1) the follicular phase, during which a single mature follicle and secondary oocyte develop; and (2) the luteal phase, beginning after ovulation and lasting until the demise of the corpus luteum (see Figure 3, Vander *et al.,* 1998:654). During the luteal phase, which starts at about day 14 of the menstrual cycle, the corpus luteum functions and from approximately day 25 to 28, the corpus luteum starts to degenerate, leading to the start of a new cycle (Martini & Bartholomew, 2000:563-565; Vander *et al.,* 1998:654-659).

The most important feature of the luteal phase of a menstrual cycle is the formation of a corpus luteum that develops from the cellular wall of a postovulatory follicle in response to a surge of luteinizing hormone (LH) (De Souza, 2003:1553). LPD is defined as a luteal phase with decreased levels of progesterone (Team Physician Consensus Statement, 2003:1789). In women with a LPD, the ovarian system functions at a level good enough to ovulate, but that level is far from being adequate to support implantation (McNeely & Soules, 1988:2).

De Souza (2003:337) found that exercising women with LPD menstrual cycles exhibit hormonal alterations consistent with a hypometabolic state that is similar to that observed in amenorrheic athletes and other energy-deprived conditions, although not as comprehensive.

Next on the continuum of menstrual disturbances is anovulation: the failure to ovulate. It is associated with appropriate oestrogen but inappropriate progesterone production (Papanek, 2003:599). Cycle length can vary in anovulatory cycles; therefore anovulation can be associated with oligomenorrhea (De Souza & Williams, 2004:436). Oligomenorrhea is a menstrual presentation that is difficult to study due to its inconsistent characteristics (De Souza & Williams, 2004:436). The presence of oligomenorrhea has frequently been grouped together with amenorrhea in a number of studies (Gremion *et al.*, 2001:16; Cobb *et al.*, 2003:712). Cobb *et al.* (2003:712) thus defined menstrual irregularity as 0 to 9 menses per year.

Amenorrhea can be defined as primary or secondary. Primary amenorrhea has recently been redefined by the American Society of Reproductive Medicine (2006:266) as an absence of menstrual cycles in a girl who has not menstruated by age 15, although she has experienced other normal developmental changes occurring during puberty. Secondary amenorrhea is defined as absence of menses after menarche for a total of three cycle intervals (Kleposki, 2002:27; Waldrop, 2005:214). In the first two years after menarche, it is normal to have amenorrhea for 3 to 6 months (Greydanus & Patel, 2002:563; Eliakim & Beyth, 2003:204). Regardless of the reason, or the form of amenorrhea, a disrupted menstrual cycle is never normal. Furthermore, despite popular lore among athletes, coaches and even some clinicians, amenorrhea is not a normal response to physical training (Papanek, 2003:599). Amenorrhea is associated with the most extreme deficiency in oestrogen (E_2), while less severe menstrual perturbations have less severe deficits in E_2 (De Souza & Williams, 2004:436).

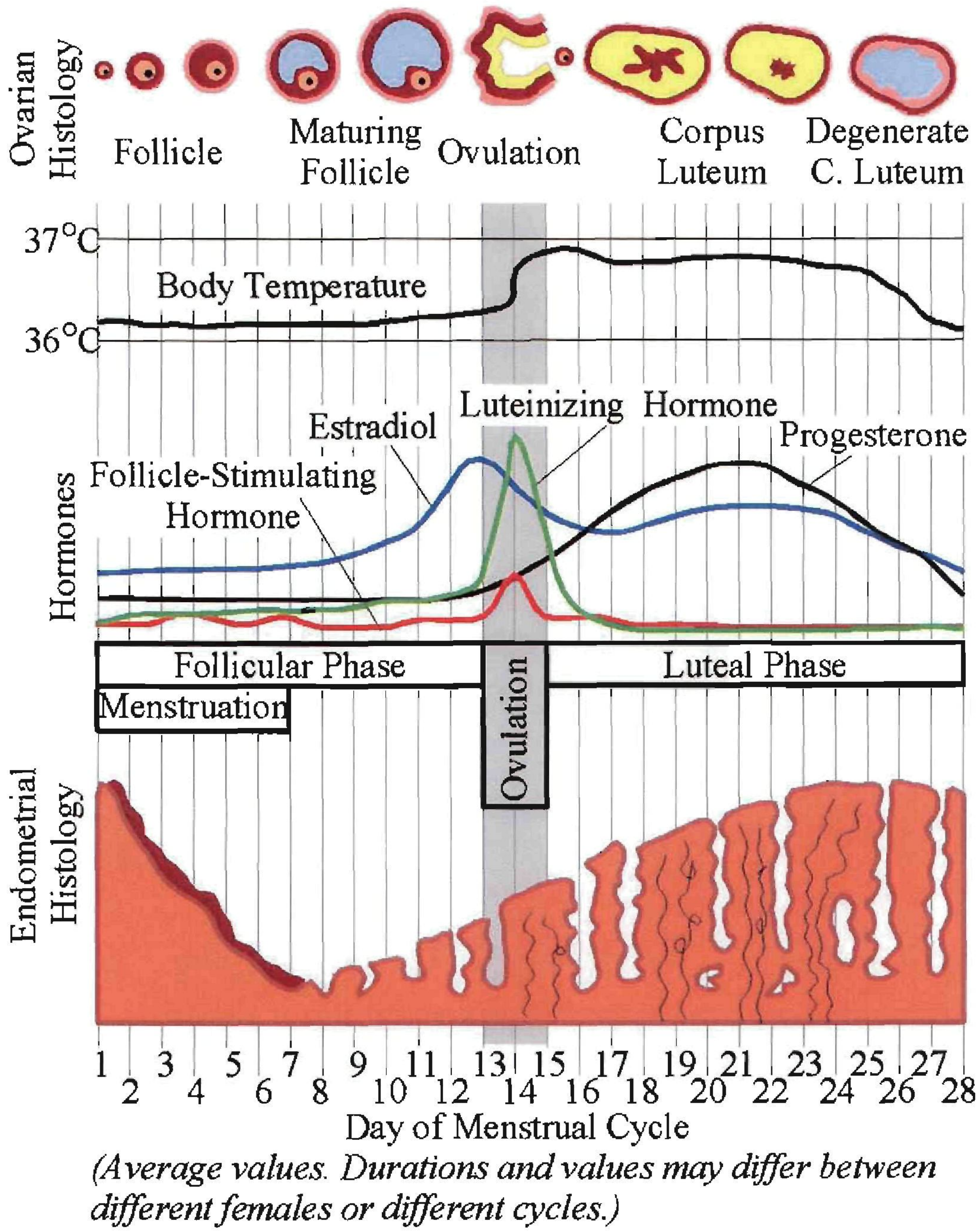


Figure 2: The menstrual cycle

(http://www.thebestlinks.com/Image__3A__MenstrualCycle.png.html)

In the female triad, amenorrhea is associated with exercise and defined as athletic amenorrhea, a diagnosis made by exclusion (Papanek, 2003:599).

2.5.2 Causes of menstrual abnormalities

Normal menstrual cycles imply a responsive hypothalamic-pituitary-ovarian-uterine (HPO) axis which controls the menstrual cycle phases (Greydanus & Patel, 2002:562). Secondary amenorrhea implies that at least one menstrual period has occurred, meaning that all parts of the reproductive axis (hypothalamus, pituitary, ovaries, and uterus) worked together once, but for some reason this integrative function is disrupted (Papanek, 2003:599). Defects that disrupt the HPO axis are outlined in Figure 4.

Thus, when an athlete has amenorrhea, it is important that the diagnosis of the athletic triad be made only after a careful evaluation to rule out multiple other problems (Gidwani & Rome, 1997:605). Eliakim and Beyth (2003:204) add that the term *athletic amenorrhea* refers to amenorrhea that cannot be explained by any known aetiology other than the exercise training. Thus, athletic amenorrhea falls under the broad classification of secondary amenorrhea and under the more specific heading of hypothalamic amenorrhea (Fagan, 1998:328).

In adult athletes with functional hypothalamic amenorrhea, estradiol and progesterone are severely suppressed and average energy availabilities ranging from 76 to 122 kJ/kgFFM/day (18 to 29 kcal/kgFFM/day) have been reported (Loucks, 2007:349). Energy availabilities below 125 kJ/kgFFM/day (30kcal/kgFFM/day) have also been reported in some eumenorrheic athletes, 80% of whom display sub-clinical ovarian disorders in which progesterone suppression may also impair fertility (Loucks, 2007:349). Loucks (2007:349) also reports that menstrual cycles have been restored by increasing energy availability above 125 kJ/kgFFM/day (30kcal/kgFFM/day).

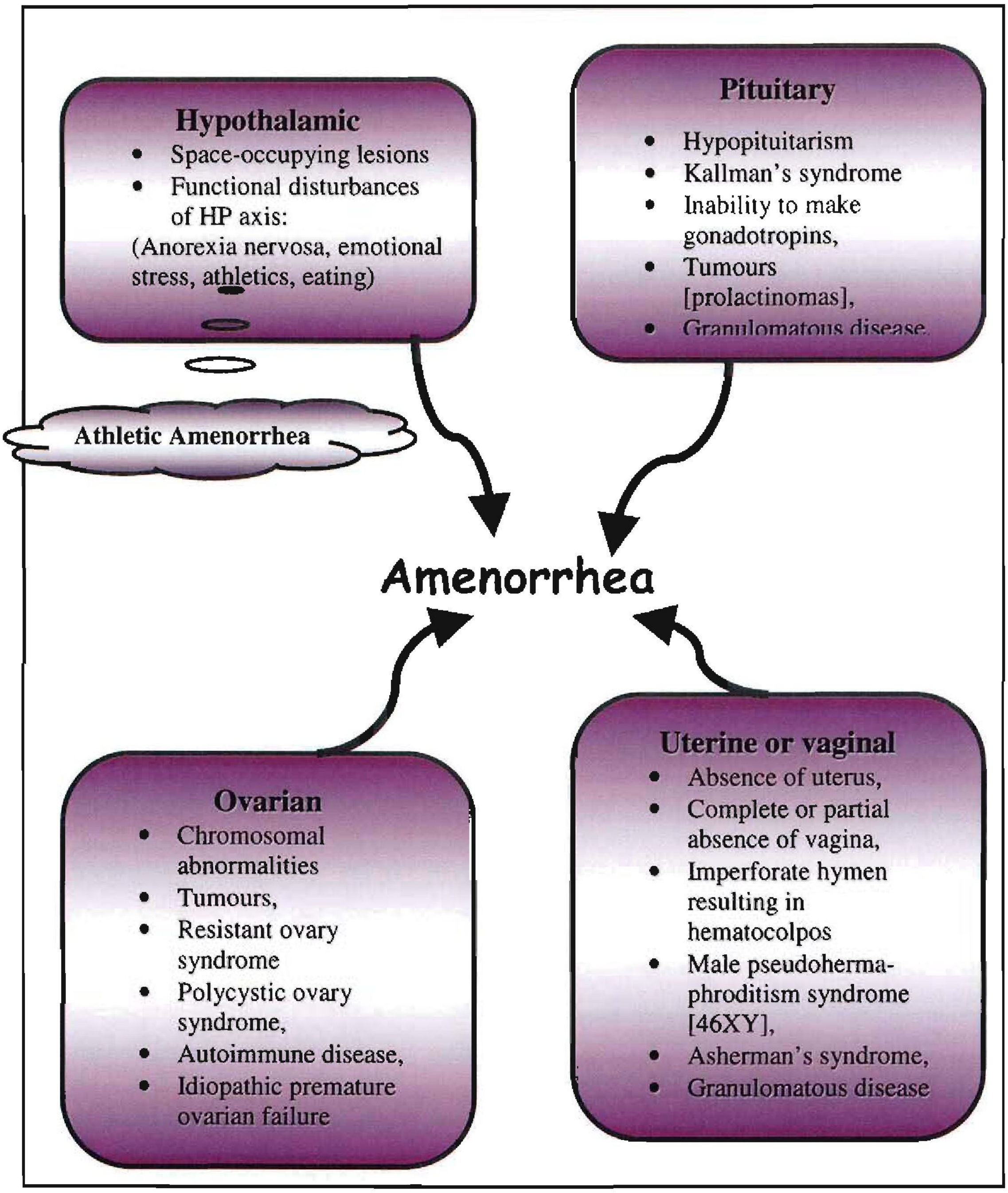


Figure 3: Causes of amenorrhea

Adapted from Gidwani & Rome (1997:606); Fagan (1998:328) and Greydanus & Patel (2002:562)

2.5.3 Body composition opposed to energy availability

Early data obtained by Frisch and McArthur (1974:949) suggested a "critical weight" or percentage body fat necessary for menarche. This theory postulated that 19% of body fat was necessary to initiate menarche, with regular cycles maintained only when percentage body fat remained above 22%. In another study, Swenne (2004:1449) found that the weight level required for return of menstruation is highly individual but can be predicted by the weight at which menstruation ceases.

These studies led to the assumption that a low percentage body fat (body composition) has a direct link with the occurrence of amenorrhea. Current publishings differ by stating that it is rather energy deficiency that directly influences amenorrhea. Di Carlo *et al.* (1999) found that 8 severely obese women who underwent biliopancreatic diversion and eight healthy women of normal weight, lost weight after surgery and became amenorrheic after 3 months. Amenorrhea occurred while they had lost 25% of their initial weight, but were still obese. The hormonal picture at that time was one of hypothalamic amenorrhea with significantly reduced LH pulsatility frequency and amplitude – further adding weight to the argument of low energy availability, and not percentage body fat, playing a causal role.

In another study by Kopp-Woodroffe *et al.* (1999:70-88), 4 amenorrheic athletes were submitted to a diet and exercise training intervention program where their energy intakes and -balances were improved. Three of the participants resumed menstrual function when energy intake was increased above 127 kJ/kgFFM per day (approximately 30 kcal/kgFFM/day), despite the fact that their total minutes of exercise were not reduced. These results suggest that, as energy and nutrient balance improve, the body can support menstrual function.

In contrast, a study by Bullen *et al.* (1985:1340-1353) came to the conclusion that vigorous exercise, particularly if compounded by weight loss, could reversibly disturb reproductive function in women. This study, however, did not consider the fact that "energy drain" might have been a factor resulting in amenorrhea.

The question arises as to whether a negative energy balance might account for athletic amenorrhea. The energy drain hypothesis elucidates that the athlete is expending more kilojoules than she is consuming, resulting in too few kilojoules or too little energy to maintain the endocrine reproductive system (Papanek, 2003:602).

Wade and Schneider (1992) concluded that, during periods of low energy availability, there is a shift of metabolic fuels away from the costly function of reproduction and towards life-sustaining metabolic processes as this possibly is a metabolic effort to conserve energy. This disruption can be prevented by dietary supplementation in compensation for exercise energy expenditure without any moderation of the exercise regimen (Loucks, 2004:6). Williams *et al.* (2001a:2381-2389) demonstrated that both the induction and reversal of amenorrhea was intimately related to energy availability in an exercise training a nonhuman primate model, and that this is not necessarily associated with weight loss.

The causal role of low energy availability was again highlighted by Williams *et al.* (2001b:5184-5193) in a study focusing on first, the induction and then, reversal of amenorrhea using a monkey model (*Macaca fascicularis*). This was done by gradually increasing their daily exercise, while their food intake was kept constant. To test whether amenorrhea is caused by low energy availability, 4 of the 8 amenorrheic monkeys were provided with supplemental kilojoules, while they maintained their daily training. All 4 monkeys re-established ovulatory cycles, with rapidity of recovery related to the amount of energy that was consumed during the period of supplemental feeding. These data provide strong evidence that low energy availability plays a causal role in the development of exercise-induced amenorrhea.

Ovarian function critically depends on luteinizing hormone (LH) pulsatility (Loucks, 2003b:1551). Loucks *et al.* (1998:37) tested the hypothesis that LH pulsatility is disrupted by the stress of exercise and found that it is not affected by the stress of exercise, but that LH pulsatility in women depends on energy availability. Loucks (2007:349) corroborates this theory by adding that LH pulsatility is disrupted when energy availability is reduced below 125 kJ/kgFFM/day (~30 kcal/kgFFM/day) from energy balance at 190 kJ/kgFFM/day (~45 kcal/kgFFM/day).

The female athlete sees amenorrhea as a convenience during training and welcomes it, seeing that many consider their training as adequate when they stop menstruating (Papanek, 2003:599). There are, however, certain health risks and medical concerns associated with amenorrhea, including a decreased bone mineral density and osteoporosis, increased fracture rates and hypoestrogenism (Papanek, 2003:599).

2.6 RISKS ASSOCIATED WITH AMENORRHEA

Amenorrhea associated with reduced energy intake and strenuous exercise leads to hypoestrogenism and is associated with clinical manifestations that include disordered eating, as well as a potential increase in the risk of premature cardiovascular disease (De Souza & Williams, 2004:433; Thrash & Anderson, 2000:168).

Several risks concerning premature cardiovascular disease have been found in premenopausal amenorrheic athletes. Athletic amenorrhea is known to have a hormonal profile similar to menopause, characterized by low oestrogen levels, which is etiologic in the development of osteoporosis in postmenopausal women (Hoch *et al.,* 2003:377).

In a study done by Stacey *et al.* (1998:3056) it was found that amenorrheic athletes have reduced nitric oxide metabolites, a very important vasodilator released by endothelial cells, contributing to arteriolar vasodilatation in the basal state (Vander *et al.,* 1998:414). Stacey *et al.* (1998:3056) also found that both the amenorrheic athletes and the postmenopausal women displayed reduced bone density. However, unlike the postmenopausal women, the athletes did not have a raised bone turnover. Their results did, however, show that reduced nitric oxide production is a common denominator in both conditions. Corresponding results by Hoch *et al.* (2003:382) found that young women with athletic amenorrhea have decreased endothelium-dependant vasodilatation (a precursor of early cardiovascular disease) compared with oligomenorrheic and eumenorrheic runners.

Friday *et al.* (1993:1605) found that exercise-induced amenorrhea may also adversely affect cardiovascular risk by increasing plasma low density lipoprotein (LDL) and total cholesterol. However, cardioprotective elevations in high density lipoproteins in this group may neutralize the risk of cardiovascular disease.

Although exercise is widely believed to be cardioprotective, excessive exercise to the point of amenorrhea may obviate these benefits and actually accelerate cardiovascular morbidity in young women (Hoch *et al.,* 2003:382).

2.7 Energy availability and bone health

Today it is recognised that bone strength, as a Triad component, also occurs along a spectrum that spans from low bone mass and stress fractures to osteoporosis, which is considered to be the most severe condition (Beals & Meyer, 2007:81). Bone density is determined by the sum of 2 opposing processes, namely osteoblastic (bone formation) and osteoclastic (bone resorption) activities.

For many years, the low BMD observed in anorexia nervosa patients and amenorrheic athletes had been attributed to their chronic hypoestrogenism, because the principal role of oestrogen in bone turnover is to suppress osteoclast activity (Ihle & Loucks, 2004:1232). However, a study by Warren *et al.* (2003:398) found no difference in BMD between groups receiving hormone replacement therapy or placebo groups, indicating that mechanisms other than hypoestrogenism may be involved with the osteopenia associated with exercise-induced amenorrhea.

The most convincing evidence that low energy availability may have a direct effect on bone mass was published by Ihle and Loucks (2004:1235-1236) who showed that markers of bone formation and resorption change unfavourably within 5 days in sedentary women who were exposed to low energy availability through dietary restriction or increased exercise energy expenditure. Barrack *et al.* (2008) also found that, in adolescent runners, dietary restraint may be the disordered eating behaviour most associated with negative bone health effects. Micklesfield *et al.* (2007:682) examined the relationships between the occurrences of bone stress injuries and disordered eating patterns, as well as high training load, and also found that the mechanism may be more related to energy balance than to hypoestrogenism.

Stress fractures are a major concern for athletes, not only because of the physical consequences but also because of the temporary (or permanent) cessation of training (Thrash & Anderson, 2000:171). It usually results when there is a temporary disturbance in the equilibrium between bone resorption (osteoclastic activities) and bone formation (osteoblastic activities) (Arendt, 2000:131). Nattiv (2000:269) adds that stress injury to bone occurs on a continuum (ranging from the normal dynamic processes of bone modelling and remodelling occurring on one end of the continuum), progressing to a bone fatigue and, with further stress, to a frank cortical stress fracture.

2.8 FOCUS ON TOTAL BODY COMPOSITION – NOT ONLY PERCENTAGE BODY FAT

There are considerable professional demands and pressures within women's sports for athletes to minimize body fat, and in many instances, to aspire to an unrealistically slender form for performance advantages. The athletes and trainers alike do not realize that a too low fat percentage has an unfavourable effect on performance (Davis, 1992:179-192). Because of the problems stemming from monitoring body composition, Papanek (2003:610) argues that body fat determinations must be eliminated from coaching.

Body composition assessment can, however, be a beneficial tool to screen athletes at risk of disorders associated with low body fat, to safely and effectively monitor athletes as they progress through diet and training programs, and to help athletes set and reach realistic body weight and body composition goals (Heyward & Wagner, 2004:170). Also, monitoring body composition is a necessary and valuable tool for the athlete, as it is indispensable in order to write individualised dietary programmes, currently using body composition as a guideline (Burke *et al.,* 2001:267,295). Also, it is necessary in order to obtain information regarding the energy needs, because energy balance has been documented to occur at an energy availability of about 190 kj per kg fat-free mass per day (Loucks & Nattiv, 2005:S49).

The problem then does not lie with the determination of body fat, but rather the complete focus on body fat as a determinant of optimal body composition, and not focusing on total body composition. Optimal performance does not rely solely on the percentage body fat of an athlete, since lean body mass may be increasing as fat mass is declining, and this may not necessarily involve a reduction in energy intake, energy balance or body weight (Loucks, 2004:9).

2.9 CONCLUSION

Because of the close relationship between body composition and performance in any given sport, many athletes strive to obtain the ideal body for their sport. For many athletes, this entails a reduction in energy intake and a rise in energy expenditure in order to accomplish said body composition goals.

As is evident from the preceding discussion, diet clearly plays a significant role in the prevalence of exercise-associated amenorrhea, as positive associations have been observed between amenorrhea and energy deficiency. Exercise-associated amenorrhea has also been positively associated with increased risk of premature cardiovascular disease.

Hence it is evident that the focus on low percentage body fat, mediated by low energy diets and high energy expenditure, has several health and performance-related implications. Quite a few athletes do not understand that in order to perform optimally on the sports field, the correct fuel is imperative. An athlete can be appropriately proportioned for the given sport, but without sufficient energy intake, it would be impossible for her to perform optimally.

As such, the notion that the monitoring of body composition as a whole should be eliminated might not be the best route to take, since several benefits have been noted.

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Chapter 3 The prevalence of energy availability, menstrual regularity and risk for disordered eating amongst a group of black South African runners

J. Prinsloo, J.H. de Ridder, H.H. Wright, S. Péter and S.M. Ellis

Abstract:

Endurance female athletes are at risk of having low energy availability which can have detrimental effects on their health and performance. It is also linked to exercise-induced menstrual dysfunction and disordered eating, collectively referred to as the female athlete Triad. Research regarding the prevalence of these components among black South African female athletes is limited. **Method:** Thirty two (n=32) recreational competitive black South African female distance runners, between ages 15 and 40 years (mean age: 21.44 ± 6.69), were selected on the basis of availability. Two 24-hour dietary recalls were completed for each athlete to assess mean daily energy intake, Actical® physical activity monitors measured daily and exercise energy expenditure, the Bod Pod® measured body composition, and menstrual irregularity was assessed with a questionnaire compiled from reviewed literature. Risk for disordered eating was assessed via the EAT-26 questionnaire. **Results:** Mean energy availability for the group was 124.16 ± 94.93 kJ/kg LBM/day, even though 11 of the athletes were below the recommended daily energy availability to ensure menstrual health. Four of the thirty two athletes (12.5%) reported menstrual irregularities. 40.6% reported risk for disordered eating via the EAT-26 questionnaire. In the total group two athletes presented with low energy availability and irregular menstrual function, while five presented with low energy availability and a high risk for disordered eating. **Conclusion:** This group of black female athletes is at risk to develop the Triad since some already present with early stages of one or more components.

Key words: [energy intake, energy expenditure, menstrual regularity, energy availability, black athletes]

Introduction

The traditional ideal body image among African females has always tended towards a large, full form (Gordon 2001:9-10). Ethnicity could consequently be seen as a protective factor against disordered eating/eating disorders. Caradas *et al.* (2001:118), however, found that competitiveness and peer influences in an evolving multi-ethnic school environment might begin to break down the protective barrier of traditional aesthetic values. The author also noticed that, although body image problems were less severe among black girls, it was by no means uncommon (Caradas *et al.,* 2001:117). The black South African athlete might thus be at risk of developing disordered eating with its subsequent consequences, including low energy availability.

Energy deficiency, where energy intake remains below energy expenditure over long periods of time, is linked to exercise-induced menstrual dysfunction as the body's natural adaptation to a prolonged energy deficit (Cobb *et al.,* 2003:715; Rome, 2003:361-362; Willmore & Costill, 2004:46). Energy availability, defined as the difference between dietary energy and exercise energy expenditure, below 125 kilojoules per kg lean body mass per day (kJ/kgLBM/day) (30 kcal/kgFFM/day) is detrimental to menstrual health[3] (Ihle & Loucks, 2004:1231; Loucks, 2007:349).

Recently the American College of Sports Medicine Position Stand accentuated that low energy availability *with or without* an eating disorder disrupts normal menstrual function (ACSM, 2007:1868). Hence athletes who inadvertently increase exercise energy expenditure without increasing energy intake are also at risk.

[3] Although the terms lean body mass and fat-free mass are used interchangeably in literature, the term lean body mass will be used in this study.

Several studies have reported on the prevalence of disordered eating in black South Africans but none have, to our knowledge, focused on the prevalence of disordered eating, energy availability, and menstrual regularity among black South African athletes (Szabo & Hollands, 1997:524; Le Grange *et al.,* 1998:250; Wassenaar *et al.,* 2000:225; Senekal *et al.,* 2001:45; Marais *et al.,* 2003:44; Szabo & Allwood, 2004:43).

Many studies (Kopp-Woodroffe *et al.,* 1999:70-88; Cobb *et al.,* 2003:711-719; Torstveit & Sundgot-Borgen, 2005:1449-1459; Beals & Hill, 2006:1-23; Nichols *et al.,* 2006:137-142; Hoch *et al.,* 2007:681-682; Loucks, 2007:348-352; Nichols *et al.,* 2007:364-377; Thompson, 2007:126-136) have made a contribution to the field of physical science by studying the prevalence of energy availability and menstrual irregularity among athletes, but more information amongst South African athletes is needed.

Our objective was therefore to study the prevalence of energy availability, menstrual regularity and risk for disordered eating among a group of black South African runners.

Methodology

Subjects: Thirty two (n=32) black South African female distance runners, between the ages of 15 and 40 years (mean: 21.44 ± 6.69), were selected on the basis of availability. The recreational competitive athletes were recruited from local running clubs in Potchefstroom and surrounding areas, including Klerksdorp and Randfontein. Details of the study, as well as testing procedures, were explained to each subject, where after written informed consent was obtained. Approval for this study was granted by the Ethics Committee at the North-West University (project nr 06M05).

24-Hour recall: 24-hour dietary recalls were used for assessment of energy intake (Waldrop, 2005:215). The recalls were completed by trained final-year dietetic students in accordance with the multiple pass method (Conway *et al.,* 2004). Each athlete completed two 24-hour recalls on two non-consecutive days, and 24-hour recalls of all subjects were taken on different days of the week to enable the researchers to obtain a representative sample of their dietary intake.

Measurement of energy expenditure with Actical® Physical Activity Monitors: A sub-sample of nineteen athletes each wore an Actical® monitor for a period of 3 consecutive training days during all waking hours, except while bathing. The monitors were initialized with the resulting data exportable as text files (Heil, 2006:66-67).

Body composition and anthropometry: Body composition, as well as body mass, was measured by the Bod Pod®, utilizing the Brozek equation (Dempster & Aitkens, 1995:1695). Stature was measured with a stadiometer to the nearest 0.1 cm (Marfell-Jones *et al.,* 2006:58-59).

Menstrual health questionnaire: Menstrual regularity was assessed with a questionnaire compiled from reviewed literature. The same questions, regarding menstrual-, dietary- and weight-history, as well as oral contraceptive use have been used by authors throughout literature (Vereeke West, 1998:68; Torstveit & Sundgot-Borgen, 2005:1450; Waldrop, 2005:214-215).

Eating Attitude Test-26: The EAT-26 is a standardised questionnaire to assess risk for disordered eating. It consists of three subscales (i.e. Dieting, Bulimia and Food Preoccupation and Oral Control) and a total score of ≥ 20 is considered a risk for disordered eating/ an eating disorder (Garner *et al.*, 1982).

Definitions:

Energy availability: Dietary energy intake minus exercise energy expenditure or the dietary energy remaining after exercise training for the metabolic processes.

Menstrual irregularity: Present primary amenorrhea (the failure to initiate menses by age 15, although the girl has experienced other normal developmental changes occurring during puberty), secondary amenorrhea (the absence of menses after menarche for a total of three cycle intervals) and oligomenorrhea (menstrual cycles of 35 days or more) were all defined as menstrual irregularities (Gremion *et al.*, 2001:16; Cobb *et al.*, 2003:712).

Statistical Analysis: Because this was a study regarding the prevalence of components of the Triad, only descriptive measures were calculated.

Results

Table 1: Descriptive statistics regarding body composition and energy availability for the total group of athletes

	Valid N	Mean (SD)	Median	Min	Max
Stature (cm)	32	159.98 (±5.43)	159.60	150.00	178.00
Body mass (kg)	32	54.67 (±12.04)	54.00	39.00	98.30
Body fat % (percentage)	32	25.62 (±9.681)	24.95	9.60	49.60
Lean body mass (LBM)	32	39.79 (±4.86)	38.80	30.20	49.60

Energy Intake (kJ/d)	32	8059.68 (±3496.20)	7745.23	2980.29	17633.71
Exercise Energy Expenditure (kJ)	19	4227.35 (±1487.41)	3917.49	2436.06	7800.83
Energy availability (kJ/kgLBM[1]/day)	19	124.16 (±94.93)	112.57	-16.27	334.57

[1] Although the terms lean body mass and fat-free mass are used interchangeably in literature, the term lean body mass will be used in this study.

Energy availability

The energy availability could only be calculated for a sub-sample (n=19) of athletes who completed both the 24 hour recalls and wore the Actical® physical activity monitors. The mean energy intake of this group was 8059.68 ± 3496.20 kJ/day and the mean activity energy expenditure for the subgroup of athletes was 4227.35 ± 1487.41 kJ per day. The subgroup consisted of nineteen athletes who were able to wear Actical® monitors, of which 15 athletes were those with regular menstrual cycles and 4 were those with irregular cycles.

Energy availability was firstly calculated for each individual athlete and then the mean of the nineteen athletes' energy availability was determined. The mean energy availability for the nineteen athletes was 124.16 ± 94.93 kJ/kgLBM/day. Figure 1 illustrates the individual energy availability of the entire group of athletes. As can be seen on the graph, even though the mean energy availability is sufficient, 11 of the athletes are below 125 kJ/kgLBM/day; the recommended daily energy availability to ensure menstrual health.

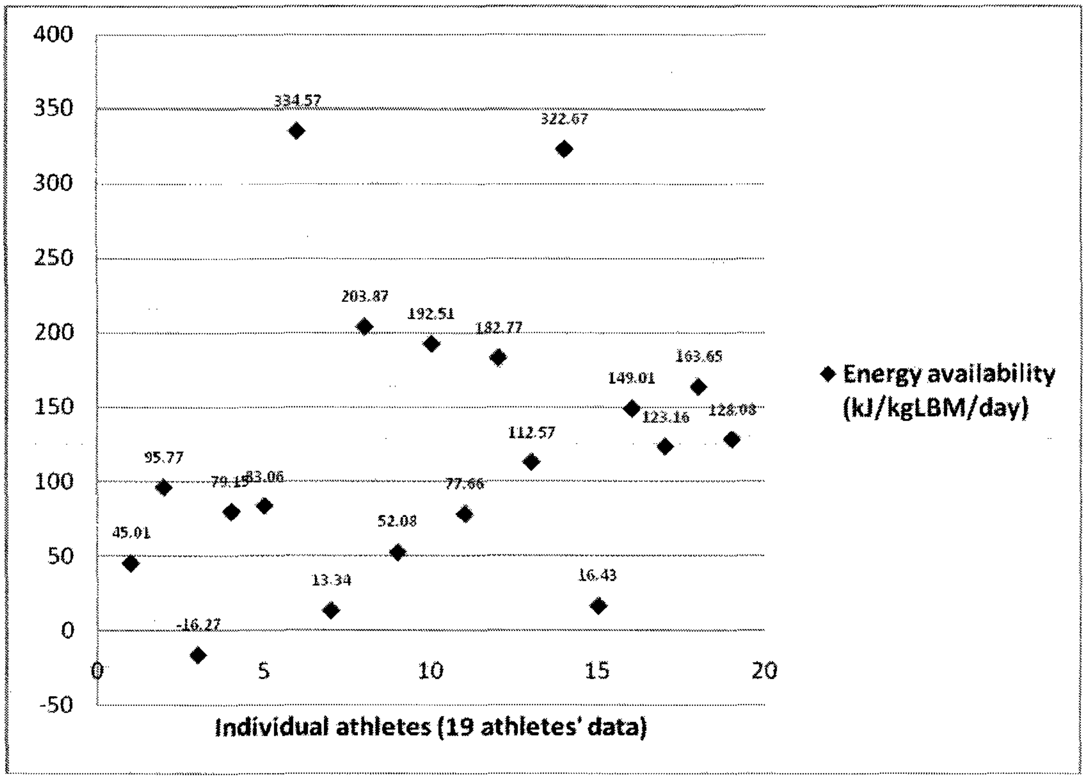

Figure 1: Energy availability (kJ/kgLBM/day) of the individual athletes

Menstrual regularity

The menstrual regularity of this group of athletes is outlined in Table 2.

Table 2: Menstrual regularity of the entire group of athletes

Menstrual status	Valid N (32)	Percentage of N (%)
Regular, no contraceptive use	22	68.8
Regular, using contraceptives	2	6.3
Regular, but did not state whether or not they use contraceptives	2	6.3
Irregular, no contraceptives	3	9.4

Irregular, using contraceptives	1	3.1
Unresponsive regarding menstrual status	2	6.3

As can be seen in Table 2, 68.8% of the participants reported regular menstrual patterns without taking any contraceptives. 9.4% of all the athletes, regardless of their menstrual status, reported using contraceptives, where the main reason for using contraceptives was indicated as being birth control. Irregular cycles were reported by 12.5% of the athletes, with or without contraceptive use. Regarding the association between menstrual irregularity and energy availability: two of the athletes, with energy availabilities of -16.27- and 52.08 kJ/kgLBM/day respectively, reported secondary amenorrhea. One athlete with an energy availability of 16.43 kJ/kgLBM/day reported oligomenorrhea, the other athlete that reported oligomenorrhea had an energy availability of 123.16 kJ/kgLBM/day.

Disordered Eating

Table 3: EAT-26 Questionnaire subscales for the total group

EAT-26	Valid N	Mean (SD)	Median	Min	Max
Dieting subscale	32	9.87 (±6.12)	9.00	0.00	23.00
Bulimia & Food preoccupation subscale	32	2.69 (±2.65)	2.50	0.00	11.00
Oral Control subscale	32	4.00 (±3.26)	3.00	0.00	11.00
EAT-26: Total score	32	16.47 (±8.50)	15.50	0.00	35.00

SD = standard deviation

Of the thirty two athletes participating in this study, thirteen (40.6%) had a score of twenty or more, indicating a risk for disordered eating. Of the thirteen, five had an energy availability below that recommended and two reported both menstrual irregularities and low energy availability.

Discussion

In this study it was shown that black South African athletes are also at risk for low energy availability, menstrual irregularities and disordered eating.

Loucks and Thuma (2003:297) found that energy availability, the dietary energy remaining after exercise training for the metabolic processes, below 125 kilojoules per kg fat-free mass per day (kJ/kgFFM/day) (30 kcal/kgFFM/day) were detrimental to menstrual health, a follow-up study in 2007 (Loucks, 2007:349) supports this finding. The athletes in this group reported a sufficient mean amount of energy availability to sustain menstrual health; a mean energy availability of 124.16 kJ/kgLBM/day. This may seem adequate, but if the athletes' individual energy availability is taken into account, we find that more than half of the athletes' energy availability was below par. The low level of energy availability found among some of the current study's athletes was expected, since both household food poverty and disordered eating had been reported among black South Africans (Le Grange *et al.,* 2000:452; Statistics South Africa, 2006:vi). Comparative data was difficult to obtain, as most energy availability studies (Loucks *et al.,* 1998:37; Zanker & Swaine, 1998:167; Kopp-Woodroffe *et al.,* 1999:70; De Souza *et al.,* 2003:337; Ihle & Loucks, 2004:1231) focused on cause and effect and not on reporting prevalence.

In this study we found a prevalence (12.5%) of menstrual irregularities. The prevalence of menstrual irregularity in other studies has been documented as ranging from 23.0% to 36.0% among the participants in the respective studies (Cobb *et al.,* 2003:713; Beals & Hill, 2006:8; Nichols *et al.,* 2006:137; Nichols *et* *al.,* 2007:364; Thompson, 2007:129). The athletes in this study's prevalence of menstrual irregularity was low in comparison.

Cobb *et al.* (2003:713) also studied female runners and reported that 36% met criteria for abnormal menses, 26% oligomenorrheic and 10% amenorrheic. Beals and Hill (2006:8) found that menstrual irregularity was significantly more prevalent among athletes in lean-build (32%; n=21) compared to non-lean-build sports (17%; n=8). A study by Nichols *et al.* (2007:364) also found that 26.7% of those athletes participating in lean-build sports reported menstrual irregularities compared to 16.6% that took part in non-lean-build sports. They report that even though athletes from lean-build sports were more susceptible to menstrual irregularities, they were not necessarily susceptible to disordered eating. In an earlier study among athletes representing 8 sports (including track and field, cross-country running, soccer, softball, swimming, softball, tennis, and lacrosse) they reported a 23.5% prevalence of menstrual irregularity (Nichols *et al.*, 2006:137-138). Of these, oligomenorrhea was the most common menstrual irregularity (17.1%), followed by secondary amenorrhea (5.3%) and primary amenorrhea (1.2%). Thompson (2007:129) also found that 23.0% collegiate cross-country runners reported menstrual irregularities.

It is difficult to compare results of *risk for disordered eating* in athletes between studies, since it is measured with various questionnaires. Nevertheless, Beals and Hill (2006:6-7) found no significant differences between lean-build (24.62%; n=16) and non-lean-build (25.53%; n=12) sports regarding disordered eating. Nichols *et al* (2006:137) found that 18.2% of athletes in a group of 170 measured with the Eating Disorder Examination Questionnaire (EDE-Q) reported disordered eating. They also found that 18.5% of the athletes (N=146) taking part in lean-build sports met the criteria for disordered eating when using the Eating Disorder Examination Questionnaire (EDE-Q) (Nichols *et al.*, 2007:370). Thompson (2007:130) assessed female cross-country runners' perceptions of previous or current eating disorders with one question, "Have you ever been told or perceived that you had an eating disorder". They found that 19.3% (N=300) confirmed the statement. In the present study, 40.6% of the athletes presented with a risk for disordered eating behaviour assessed by the EAT-26 questionnaire.

Le Grange *et al.* (2004:448-449) administered the EAT-26 questionnaire to a group of black high school students and found that the results for the EAT-26 in one high school indicated that 59 participants (38.3% of the total sample) scored above the cut-off point (i.e. a score of 20 or more). Upon interviewing them, it was found that in some students the EAT-26 resulted in a false positive score. For example, when respondents were asked whether they found themselves preoccupied with food, some of the interviewees indicated on the EAT-26 that this was always the case - indicative of someone exhibiting disordered eating symptoms. Instead, the reason given in two cases, as recorded by the interviewer, was that their "family is poor, there is not always food in the house; thus they are always hungry and thinking about food" (Le Grange *et al.*, 2004:449). Questions such as these, when asked within a population group with food insecurity and certain cultural beliefs led to a high score which was not due to disordered eating behavior *per se*. It is suggested by the researchers that these questions should allow for explanations of behavior. A limitation of the current study was that athletes that scored high on the EAT-26 were not followed up with an interview, thus these results should be interpreted with care.

Statistical analysis revealed that only the Dieting subscale showed reliability in this specific population, with a Cronbach Alpha value of 0.60. The other two subscales were not shown reliable and had Cronbach Alpha values of 0.32 and 0.34 respectively. Results were given for all the subscales as there is very limited information available regarding the prevalence of disordered eating in indigenous South African athletes. Ideally, future research should incorporate a two-stage methodology, where both an initial screening and a follow-up diagnostic interview are done.

Methodological issues that might be considered a limitation to this study include the use of 24-hour recall questionnaires to measure energy intake as well as Actical® physical activity monitors as supposed to weighed dietary records and exercise log books. Taking more than one 24-hour recall on non-consecutive days have been shown to be a reliable dietary assessment tool (Gibson, 2005). We also made use of a validated food photo book to aid athletes in estimating food portion sizes (Venter et al., 2000). Since athletes were from a previously disadvantaged group and had a low socio-economic status the diet was very monotonous and therefore using two 24-hour recalls on non-consecutive days was considered a true reflection of their daily energy intakes. Due to literacy concerns and compliance of these athletes it was decided to make use of the Actical® physical activity monitors to measure energy expenditure since it has a low respondent burden.

In conclusion, the findings of this study do indeed suggest that black female runners are also at risk of developing the Triad and that some already present with one of its components. Additionally, some are moving towards functional hypothalamic amenorrhea as end-point of one of the legs of the Triad, with current irregular menstrual cycles. Many also present with disordered eating behavior putting them at risk of developing low energy availability with or without an eating disorder as end-point to another leg of the Triad. It is thus recommended that these athletes and their coaches should be educated on the components of the Triad and their health-related consequences to prevent their development and refer those at risk for relevant intervention.

Suggestions for future studies include further studying of the influence of ethnicity on the components of the Triad. Assessment of bone density among different ethnicities could shed more light on the effects of low energy availability as well as the measurement of luteal phase deficiency and anovulation.

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Chapter 4

Menstrual regularity and its relationship with body composition and energy availability amongst a group of black South African runners

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Abstract:

Menstrual regularity has been linked to body composition in the past, though recent research highlights the link between menstrual status and energy availability. Research regarding the relationship between both these components and menstrual status is limited regarding black South African female athlete. **Method:** Thirty two (n=32) recreationally competitive black South African female distance runners, between ages 15 and 40 years (mean: 21.4 ± 6.7), were selected on the basis of availability. Menstrual regularity was assessed by means of a questionnaire compiled from reviewed literature. Body composition was measured with the Bod Pod®. Two 24-hour dietary recalls were used to assess the athletes' mean energy intake, and Actical® physical activity monitors were used to determine the mean exercise energy expenditure. **Results:** Percentage body fat, and energy expenditure had a visible effect (both effect sizes = 0.46) on menstrual regularity, and a practically significant relationship was observed between energy intake, energy availability (effect sizes (d) = 0.84 and 1.01 respectively) and menstrual regularity. Energy intake (9793 ± 3504 vs. 6862 ± 1906 kJ/d, d=0.84) and energy availability (146 ± 93 vs. 44 ± 60 kJ/kgLBM/day, d= 1.01) differed significantly between the regular and irregular menstruating groups. **Conclusion:** Both energy intake and energy availability had a practically significant relationship with menstrual regularity in a group of black South African female runners.

Key words: [menstrual regularity, female athlete triad, energy availability, body composition]

Introduction

Low energy availability with or without an eating disorder disrupts normal menstrual function (Loucks, 2004:1; ACSM, 2007:1868). Early data obtained by Frisch and McArthur (1974:949) suggested a "critical weight" or percentage body fat necessary for menarche. Current publications differ from this approach by stating that it is energy deficiency rather than body composition that directly influences amenorrhea (Di Carlo *et al.,* 1999; Kopp-Woodroffe *et al.,* 1999:70-88; Loucks, 2004:7; Loucks, 2007:349).

Wade and Schneider (1992) concluded that, during periods of low energy availability, there is a shift of metabolic fuels away from the costly function of reproduction and towards life-sustaining metabolic processes as this likely is a metabolic effort to conserve energy. This disruption can be prevented by dietary supplementation in compensation for exercise energy expenditure without any moderation of the exercise regimen (Loucks, 2004:6). Williams *et al.* (2001a:2381-2389) demonstrated that both the induction and reversal of amenorrhea was intimately related to energy availability in an exercise training a nonhuman primate model, and that this is not necessarily associated with weight loss.

The causal role of low energy availability was again highlighted by Williams *et al.* (2001b:5184-5193) in a study focusing on first, the induction and then, reversal of amenorrhea using a monkey model (*Macaca fascicularis*). This was done by gradually increasing their daily exercise, whilst their food intake was kept constant. To test whether amenorrhea is caused by low energy availability, 4 of the 8 amenorrheic monkeys were provided with supplemental kilojoules, while they maintained their daily training. All 4 monkeys re-established ovulatory cycles, with rapidity of recovery related to the amount of energy that was consumed during the period of supplemental feeding. These data provide strong evidence that low energy availability plays a causal role in the development of exercise-induced amenorrhea.

Ovarian function critically depends on luteinizing hormone (LH) pulsatility (Loucks, 2003:1551). Loucks *et al.* (1998:37) tested the hypothesis that LH pulsatility is disrupted by the stress of exercise and found that it is not affected by the stress of exercise, but that LH pulsatility in women depends on energy availability. Loucks (2007:349) corroborates this theory by adding that LH pulsatility is disrupted when energy availability is reduced below 125 kJ/kgFFM/day (~30 kcal/kgFFM/day) from energy balance at 190 kJ/kgFFM/day (~45 kcal/kgFFM/day).

In adult athletes with functional hypothalamic amenorrhea, estradiol and progesterone are severely suppressed and average energy availabilities ranging from 76 to 122 kJ/kgFFM/day (18 to 29 kcal/kgFFM/day)[4] have been reported (Loucks, 2007:349) in these athletes. However, energy availabilities below 125 kJ/kgFFM/day (30kcal/kgFFM/day) have also been reported in some eumenorrheic athletes, but 80% of them display sub-clinical ovarian disorders in which progesterone suppression may also impair fertility (Loucks, 2007:349). Loucks (2007:349) reports that menstrual cycles have been restored by increasing energy availability above 125 kJ/kgFFM/day (30kcal/kgFFM/day).

Zanker (2006:489) advises that female athletes should consume adequate energy and carbohydrate to balance energy expenditure and replace glycogen if they want to avoid reproductive dysfunction. They should avoid abrupt and rapid weight loss and maintain an "adequate" body fat content, which may be individually specific, but coincides with regular menses (Zanker, 2006:490).

[4]Although the terms lean body mass and fat-free mass are used interchangeably in literature, the term lean body mass will be used in this study.

Many studies (Johnston *et al.,* 1971:1148; Sanborn *et al.,* 1987:207; Loucks *et al.,* 1998:37; Williams *et al.*, 2001a:2381; Williams *et al.*, 2001b:5184; Swenne, 2004:1449) have made a contribution to the field of physical science by studying menstrual regularity and the relationship thereof with both body composition and energy availability, but none of these focused, specifically, on the black South African athlete.

Thus the aim of the study was to investigate menstrual status and its relationship with body composition and energy availability among a group of black South African runners.

Methodology

Subjects: Thirty two (n=32) black South African female distance runners, between ages 15 and 40 years (mean: 21.44±6.69), were selected on the basis of availability. The recreational competitive athletes were recruited from local running clubs in Potchefstroom and surrounding areas, including Klerksdorp and Randfontein. Details of the study, as well as testing procedures, were explained to each subject, where after written informed consent was obtained. Approval for this study was granted by the Ethics Committee of the North-West University (project nr 06M05).

24-Hour recall: 24-hour dietary recalls were used for assessment of energy intake (Waldrop, 2005:215). The recalls were completed by trained final-year dietetic students in accordance with the multiple pass method (Conway *et al.*, 2004). Each athlete completed two 24-hour recalls on two non-consecutive days, and 24-hour recalls of all subjects were taken on different days of the week to enable the researchers to obtain a representative sample of their dietary intake.

Measurement of energy expenditure with Actical® Physical Activity Monitors: A sub-sample of nineteen athletes each wore an Actical® monitor for a period of 3 consecutive training days during all waking hours, except while bathing. The monitors were initialized with the resulting data exportable as text files (Heil, 2006:66-67).

Body composition and anthropometry: Body composition, as well as body mass, was measured by the Bod Pod®, utilizing the Brozek equation (Dempster & Aitkens, 1995:1695). Stature was measured with a stadiometer to the nearest 0.1 cm (Marfell-Jones *et al.,* 2006:58-59).

Menstrual health questionnaire: Menstrual regularity was assessed with a questionnaire compiled from reviewed literature. The same questions, regarding menstrual-, dietary- and weight-history, as well as oral contraceptive use have been used by authors throughout literature (Vereeke West, 1998:68; Torstveit & Sundgot-Borgen, 2005:1450; Waldrop, 2005:214-215).

Definitions:

Energy availability: Dietary energy intake minus exercise energy expenditure or the dietary energy remaining after exercise training for the metabolic processes (Loucks, 2007:348).

Menstrual irregularity: Present primary amenorrhea (the failure to initiate menses by age 15, although the girl has experienced other normal developmental changes occurring during puberty), secondary amenorrhea (the absence of menses after menarche for a total of three cycle intervals), and oligomenorrhea (menstrual cycles of 35 days or more) were all defined as menstrual irregularities (Gremion *et al.,* 2001:16; Cobb *et al.,* 2003:712).

Statistical Analysis: Because this was an availability study, p-values were not relevant and effect sizes were calculated to determine whether or not the differences in means were practically significant. Data obtained from convenience sampling should be considered small populations for which statistical inference and *p*-values are not relevant (Ellis & Steyn, 2003:51-53).

Subjects were grouped in terms of menstrual regularity, where descriptive measures were calculated. Instead of only reporting descriptive statistics, standardized differences (effect sizes) as a measure of practical significance were also determined (Ellis & Steyn, 2003:51-53) where practical significance can be understood to be a large enough difference to have an effect in practice. As such, an effect size of 0.2 is described as small and not visible. Likewise, an effect size of approximately 0.5 is described as medium and visible to a researcher. An effect size of 0.8 is practically significant and can be understood to be a large enough difference to have an effect in practice.

Results

Subjects were grouped in terms of menstrual regularity, where regular cycles are defined as regular flow occurring every 21 to 45 days, with 10 to 13 cycles per year (Rome, 2003:359). Menstrual irregularities were defined as either present primary amenorrhea (the failure to initiate menses by age 15, although the girl has experienced other normal developmental changes occurring during puberty), secondary amenorrhea (the absence of menses after menarche for a total of three cycle intervals), or oligomenorrhea (menstrual cycles of 35 days or more) (Gremion *et al.,* 2001:16; Cobb *et al.,* 2003:712).

Body composition

Table 1 presents the means and standard deviations for athletes with regular and irregular menstrual cycles. In the irregular group two athletes reported secondary amenorrhea and two oligomenorrhea. One of the latter experienced oligomenorrhea even though she used oral contraceptives.

Table 1: Descriptive statistics of body composition for both the regular and irregular menstruating groups

	Regular cycles (n=26)	Irregular cycles (n=4)	Effect size
	Mean (SD)	Mean (SD)	
Stature (cm)	160.05 (±5.94)	160.10 (±2.93)	-0.01
Body Mass (kg)	55.98 (±12.62)	52.53 (±6.15)	0.27
Lean Body Mass (kg)	40.16 (±4.95)	40.70 (±1.56)	-0.11
% Body fat	26.54 (±10.24)	21.88 (±7.41)	**0.46 ***

[Effect size of 0.46* is of medium effect and visibly different]

As can be seen from Table 1, there is a visible difference (effect size = 0.46) between the regular (26.54%) and irregular group's (21.88%) percentage body fat, with the irregular group visibly leaner with regard to percentage body fat than the regular group.

Energy availability

Nineteen of the total group of athletes was randomly selected to wear an Actical® activity monitor. Of these, 15 athletes had regular menstrual cycles and 4, irregular cycles. The athletes were then classified in the two groups according to menstrual cycle regularity and it was found that energy intake differed practically significantly (effect size = 0.84) between the two groups. The energy intake of the regular group was 9793 ± 3504 kJ per day, significantly more than that of the irregular group, 6862 ± 1906 kJ per day. Also, a visible difference (effect size = 0.46) were found between the group's exercise energy expenditure (see Table 2).

Table 2: Descriptive statistics of energy availability for both the regular and irregular menstruating groups

	Regular cycles (n=15)	**Irregular cycles (n=4)**	**Effect size**
	Mean (SD)	Mean (SD)	
Energy Intake (kJ)	9793 (±3504)	6862 (±1906)	**0.84***
Exercise Energy Expenditure (kJ)	4003 (±1210)	5067 (±2293)	**0.46 ***
Energy availability (kJ/kgLBM[1]/day)	146 (±92)	44 (±60)	**1.01 ***

[1] Although the terms lean body mass and fat-free mass are used interchangeably in literature, the term lean body mass will be used in this study.

[Effect size of 0.46* is of medium effect and visibly different and effect sizes of 0.84 and 1.01 * are practically significant]

Athletes with irregular cycles had a practically significant lower energy availability compared to those with regular cycles (effect size > 0.8, Table 2 and Figure 1). The energy availabilities of individual athletes from the irregular cycle group varied between -16 and 123 kJ/kgLBM/day (Table 2).

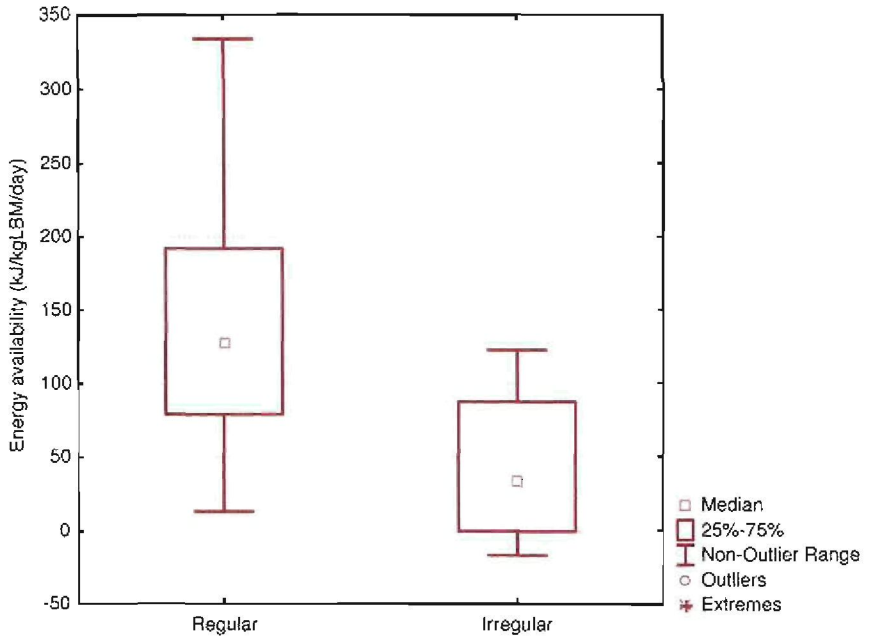

Figure 1: Energy availability grouped according to menstrual regularity

Discussion

This study investigated menstrual status and its relationship with body composition and energy availability. It was found that menstrual irregularity has a visible relationship with percentage body fat, but a practically significant relationship with energy availability.

Bronson and Manning (1991:946-948) though, stress that the issue here is not correlation, but cause and effect. They argue that the amount of energy stored in adipose tissue is an important component of energy balance, but there is no evidential basis on which to accord body fat a direct causal role in regulating ovulation in either the pre-pubertal or adult female (Bronson & Manning, 1991:948).

In the past, percentage body fat was thought to be correlated with amenorrhea and menstrual irregularities (Frisch & McArthur, 1974:949; Swenne, 2004:1449).

Early data obtained by Frisch and McArthur (1974:949) suggested a "critical weight" or percentage body fat necessary for menarche. This theory postulated that 19% of body fat was necessary to initiate menarche, with regular cycles maintained only when percentage body fat remained above 22%. In another study Swenne (2004:1449) found that the weight level required for return of menstruation is highly individual but can be predicted by the weight at which menstruation ceases.

Above-mentioned studies led to the assumption that a low percentage body fat (body composition) has a direct link with the occurrence of amenorrhea. Current literature differ from this approach by stating that it is rather energy deficiency that directly influences amenorrhea. Di Carlo *et al.* (1999) found that 8 severely obese women who underwent biliopancreatic diversion and eight healthy women of normal weight lost weight after surgery and became amenorrheic after 3 months. Amenorrhea occurred while they had lost 25% of their initial weight, but were still obese. The hormonal picture at that stage was one of hypothalamic amenorrhea with significantly reduced LH pulsatility frequency and amplitude – further adding weight to the argument of low energy availability, and not percentage body fat, playing a causal role. This study found a visible (medium effect) relationship between menstrual regularity and body fat percentage which support findings that body fat percentage is not a causal factor for menstrual irregularity. There is a lack of data on the relationship between body fat content and menstrual regularity amongst athletes from minority groups and especially from Africa which makes this study unique.

In another study by Kopp-Woodroffe *et al.* (1999:70-88), 4 amenorrheic athletes were submitted to a diet and exercise training intervention program where their energy intakes and balances were improved. Three of the participants resumed menstrual function when energy intake was increased above 127 kJ/kgFFM per day (approximately 30 kcal/kgFFM/day), despite the fact that their total minutes of exercise were not reduced. These results suggest that, as energy and nutrient balance improve, the body can support menstrual function.

The experimental evidence from animal studies argues even more strongly against the proposition that ovulation can be regulated by body fat (see Bronson & Manning, 1991 for a more comprehensive review). Williams and co-workers (Williams *et al.*, 2001a:2381-2389; Williams *et al.*, 2001b:5184-5193) readily demonstrated cause and effect in their work using a monkey model (*Macaca fascicularis*). They demonstrated that both the induction and reversal of amenorrhea were intimately related to energy availability in an exercise training a nonhuman primate model, and that this is not necessarily associated with weight loss.

Loucks *et al.* (1998:37) controlled subjects' energy intake and found that LH pulse frequency was reduced by low energy availability. Another study also found (De Souza *et al.*, 2003:337) that energy availability, the dietary energy remaining after exercise training for the metabolic processes, below 125 kJ/kgFFM/day (30 kcal/kgFFM/day) were detrimental to menstrual health in humans. Findings of the current study correspond with above-mentioned studies as the irregular menstruating athletes reported a low mean energy intake and high mean exercise energy expenditure resulting in a mean energy availability below 45 kJ/kgFFM/d thereby suggesting that menstrual regularity depends on energy availability. These results are again unique since no study to our knowledge have looked at menstrual regularity and energy availability in black African female runners.

Although energy availabilities below 125 kJ/kgFFM/day (30kcal/kgFFM/day) have been reported in some eumenorrheic athletes, 80% of them display sub-clinical ovarian disorders in which progesterone suppression may impair fertility (Loucks, 2007:349). A limitation of the current study was that blood sampling were not done, thus hormonal profiles of the athletes could not be evaluated. Since 11 of our athletes had an energy availability of < 125 kJ/kgLBM/day (cut off point for maintenance of normal menstrual function) (Loucks, 2007:349) of which only 4 presented with reported menstrual irregularities, it is possible that the remaining athletes might have had subclinical ovarian disorders like luteal phase deficiency or anovulation.

Methodological issues that might be considered a limitation to this study include the use of 24-hour recall questionnaires to measure energy intake as well as Actical® physical activity monitors as supposed to weighed dietary records and exercise log books. Taking more than one 24-hour recall on non-consecutive days have been shown to be a reliable dietary assessment tool (Gibson, 2005). We also made use of a validated food photo book to aid athletes in estimating food portion sizes (Venter et al., 2000). Since athletes were from a previously disadvantaged group and had a low socio-economic status the diet was very monotonous and therefore using two 24-hour recalls on non-consecutive days was considered a true reflection of their daily energy intakes. Due to literacy concerns and compliance of these athletes it was decided to make use of the Actical® physical activity monitors to measure energy expenditure since it has a low respondent burden.

In conclusion, the findings of this study provide strong evidence that menstrual irregularity is indeed linked with low energy availability rather than with body composition also in a group of black South African female runners. It is thus recommended that these athletes and their coaches should be educated on the components of the Triad and their health-related consequences as evidence of low energy availability have been found in these athletes.

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Chapter 5 Summary, Conclusions, Recommendations and Shortcomings

5.1 Summary
5.2 Conclusions
5.3 Recommendations
5.4 Shortcomings

5.1 Summary

The aim of this study was firstly to determine the prevalence of energy availability, menstrual regularity and risk for disordered eating among a group of black South African runners. The second aim was to determine menstrual status and it's association between body composition and energy availability among this group of black South African runners.

This dissertation was presented in four main parts, namely an introduction (Chapter 1), a literature review (Chapter 2) and two research articles (Chapters 3 and 4). The article format of the dissertation is approved by the Senate of the North-West University (Potchefstroom Campus), and the two research articles will be presented in accordance with the guidelines of appropriate and accredited journals.

Chapter 1 introduced the problem and stated the aims and hypotheses of this study. The literature review (Chapter 2) focused on the relationship between body composition, risk for disordered eating and menstrual irregularities.

Chapter 3 took the form of an article: The prevalence of energy availability, menstrual regularity and risk for disordered eating among a group of black South African runners. This article will be presented for publication to Medicine & Science in Sports & Exercise.

The second article, Chapter 4, consisted of the second research article titled "Menstrual status and its association with body composition and energy availability among a group of black South African runners." This article will be presented to the International Journal of Sport Nutrition and Exercise Metabolism.

5.2 Conclusions

The conclusions that are drawn from this research project are presented in accordance with the set hypotheses (Chapter 1).

Hypothesis 1: Low energy availability, menstrual irregularity, and risk for disordered eating are prevalent in this group of black South African runners.

The first hypothesis is partly accepted, based on the research findings that found the presence of both risk for disordered eating and menstrual irregularity in this group of athletes. The mean energy availability was, found to be in accordance with current literature, even though more than half of the athletes reported low energy availability. The hypothesis regarding the prevalence of low energy availability is, however, rejected, based on the sufficient mean energy availability of this group of athletes.

Hypothesis 2: Menstrual irregularity has an association with body composition and energy availability among this group of black South African runners.

The second hypothesis is accepted, based on the research findings that a visible relationship was found between menstrual irregularity and body composition (effect size = 0.46), and a practically significant relationship was found between menstrual status and energy availability (effect size = 1.01).

5.3 Recommendations

The results from this study contributed to the lack of data available on black South African athletes. Also, the importance of further research regarding menstrual status and energy availability among these African females must be emphasized. The findings of this study give support to the possibility of low energy availability and disordered eating being prevalent among some African women, even though they have traditionally been inclined towards a larger, fuller body shape. Ethnicity could, in the past, have been seen as a protective factor against underweight and disordered eating/eating disorders, but the results in this study show that this might not be the case in the athletic community.

5.4 Shortcomings

Certain shortcomings regarding this study can, however, be indicated:

First, analyses used cross-sectional data. Therefore our results do not establish a temporal relationship between menstrual status, body composition and energy availability. A longitudinal design where the subjects are randomly chosen to be included in the study would perhaps have been a more suitable approach. A longitudinal follow-up of the subjects and changes in menstrual status, along with changes in energy availability, would provide stronger evidence for a causal association between energy availability, body composition and menstrual status.

Secondly, the study consisted of a small number of subjects. As mentioned above, a longitudinal study design with larger numbers of participants would provide stronger evidence for causal associations. Also, the study's population sample was selected on the basis of availability from local clubs. The results can therefore not be generalized to the larger population of black runners, as certain discrepancies might occur.

Lastly, another limitation is that we did not measure hormone levels. That would have enabled us to take a look at the prevalence of all menstrual abnormalities, including luteal phase deficiency and anovulation.

Appendices

- Instructions for Authors: Medicine & Science in Sports & Exercise__89
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Brief Reviews
Brief review articles (maximum 25 double-spaced pages, including references—limit 75) will be screened by the Editor-in-Chief before entering the review process. Authors of review articles shall be established, recognized experts in the field. Literature reviews in conjunction with collegiate thesis work are not acceptable review articles.

Symposium Proceedings
Submission of ACSM Annual Meeting symposia papers is by Editor-in-Chief invitation only. Symposia papers from any ACSM Annual Meeting must be received in the Editorial Office before December 1 of the year of presentation. Previously stated submission requirements shall be followed; however, presentations should not exceed 15 typewritten, double-spaced pages. Authors who use previously published material shall obtain prior written permission to reprint from the publisher holding the copyright and provide a quality original for publication. (See "Previously Published Material.") All invited symposia manuscripts are subject to the peer-review process. Organizers of symposia concerned with new developments in sports medicine and exercise science are encouraged to contact the Editor-in-Chief regarding the possibility of publication.

Special Communications

Methodological Advances
Manuscripts that deal with new methods, important modifications of existing ones, or applications of new equipment will be considered for publication in a section titled Special Communications. Authors are strongly encouraged to familiarize themselves with the recently published articles in ***Medicine & Science in Sports & Exercise*®**, as the journal will not consider for publication those manuscripts that present results of articles previously published.

Rapid Communications
Authors are encouraged to submit manuscripts suitable to be considered as "Rapid Communication" articles for the purpose of releasing cutting-edge information expeditiously. There are two types of rapid communication articles:

1. Brand-new methodology
2. Revolutionary new findings

Authors must declare in writing the uniqueness of the paper at the time of submission. These papers are subject to the peer-review process and must follow *MSSE*® style.

Letters to the Editor-in-Chief
Letters addressed to the Editor-in-Chief will be considered for publication if they promote intellectual discussion of an *MSSE*® article published within the previous 12 months. Letters should contain an informative title and follow the submission requirements for manuscripts. Letters are limited to 500 words and a maximum of eight (8) references. If the letter is accepted for publication, a copy will be sent to the author of the original article with an invitation to submit a rebuttal that will be published with the letter. Letter responses will be held to the same length and number-of-reference requirements.

Books for Review
ACSM is pleased to provide readers with the most current reviews of just released publications from Doody Enterprises, Inc. and, therefore, does not accept books from publishers or authors for the purpose of independent review. Publishers or authors may still contribute books to ACSM's library by sending the materials to: ACSM National Center, Attn: Library, 401 West Michigan Street, Indianapolis, IN 46202-3233.

Manuscript Preparation

Text Guidelines

Language
English is the language of the publication. Authors who speak English as a second language are encouraged to seek the assistance of a colleague experienced in writing for English language journals. Authors of accepted manuscripts who cannot meet the journal's standard English usage are encouraged to seek assistance from the publisher, Lippincott Williams & Wilkins, who provides rewriting services for a fee.

Authors are encouraged to use nonsexist language as defined by the American Psychological Association (American Psychological Association. Guidelines for nonsexist use of language. *American Psychologist.* 1975;30:682–684) and to be sensitive to the semantic description of persons with chronic diseases and disabilities, as outlined in ***Medicine & Science in Sports & Exercise***® [Raven PR. Journal terminology: issues of sensitivity and accuracy. *Med. Sci. Sports Exerc.* 1991;23(11): 1217–1218.] as a general rule, only standardized abbreviations and symbols should be used. If unfamiliar abbreviations are employed, they should be defined when they first appear in the text. Authors should follow *Webster's Third New International Dictionary* for spelling, compounding, and division of words. Trademark names should be capitalized and the spelling verified. Chemical or generic names should precede the trade name or abbreviation of a drug the first time it is used in the text.

Previously Published Material
Medicine & Science in Sports & Exercise® will accept only original, unpublished

illustrations and tables, except in the cases of review articles, symposia, and meta-analyses. Authors of review articles, symposia, and meta-analyses papers who do use previously published material shall obtain prior written permission to reprint from the publisher holding the copyright and be able to provide a quality original to the Editorial Office for publication. It also is customary that written permission from the original authors be requested and received. The statement "used by permission" must appear in the caption of the figure or table with complete reference citation. Permission to reprint, if required, must accompany the manuscript at the time of submission.

Order of Manuscript

An original investigation should contain the following items and satisfy the given specifications.

- Title Page
    1. Title of no more than 85 characters, including spaces.
    2. Full names of the authors—Only those investigators who contributed substantially or who had a primary role in the research represented in the manuscript should be listed as authors. Manuscripts listing more than six (6) authors should provide justification. The Editor-in-Chief reserves the right to request that the author list be reduced.
    3. Institutional affiliation of each author clearly identified; linked to each author by use of superscript numbers
    4. Corresponding author name, mailing address, telephone, fax, and e-mail information
    5. Running title of no more than 45 characters, including spaces
- Abstract
    1. Limit of 275 words, including numbers, abbreviations, and symbols
    2. Structure states purpose, methods, results, and conclusion
    3. Reference citations are not permitted
- Key Words
    1. Four (4) to six (6) words following the abstract
    2. Should not repeat terms or phrases from the title
- Introduction
    1. State clearly the purpose and hypothesis of the study
    2. Provide relevant references
    3. Do not exhaustively review the subject
- Methods
    1. Present subject information
    2. Describe the experimental subjects and their controls
    3. Insert "written informed consent" statement or animal-use statement and ethics committee approval statement (required) (see "Human & Animal Experimentation Policy Statements")
    4. Identify the methods, apparatus, and procedures employed with sufficient details to allow others to reproduce the results
    5. Provide references for established methods and statistical procedures

6. Provide rationale for use and include a description of possible limitations for utilized methods not well known
7. Denote statistical significance when appropriate and include detailed statistical analyses, mathematical derivation, or computer programs in an appendix

- Results
  1. Present findings of the study in the text, tables, or figures
  2. Do not include the same data in tables and figures
- Discussion
  1. Emphasize the original and important features of the study and avoid repeating all the data presented within the results section
  2. Incorporate the significance of the findings and the relationship(s) and relevance to published observations
  3. Provide only those conclusions that are supported by the study
- Acknowledgments
  1. Identify funding sources
  2. Identify external reviewers, if any
- Conflict of Interest

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
2. State that the results of the present study do not constitute endorsement by ACSM

Failure to disclose such information could result in the rejection of the submitted manuscript.

- References

The title page must also include disclosure of funding received for this work from any of the following organizations: National Institutes of Health (NIH); Wellcome Trust; Howard Hughes Medical Institute (HHMI); and other(s).

The reference list shall be in alphabetic order (rather than in the order of citation) and numbered. There shall not be more than 40 references for original investigations. Review articles are limited to 75 references. All references shall appear in the text. The format for references is that which has been adopted by the United States National Library of Medicine [Patrias K. *National Library of Medicine Recommended Formats for Bibliographic Citation*. Bethesda (MD): The Library; 1991. Available from: NTIS, Springfield, VA; PB91-182030.] and employed in *Index Medicus*. For those not included in *Index Medicus*, adhere to the form established by the American National Standard for Bibliographic References. Examples of the types of references are as follows:

1. **Book**
   - Cohen J. *Statistical Power Analysis for the Behavioral Sciences.* 2nd ed. Hillsdale (NJ): Lawrence Erlbaum Associates; 1988. 567 p.
   - Paffenbarger RS, Hyde RT, Wing AL. Physical activity and physical fitness as determinants of health and longevity. In: Bouchard C, Shephard RJ, Stephens T, Sutton JR, McPherson BD, editors. *Exercise, Fitness, and Health.* Champaign: Human Kinetics; 1990. p. 33–48.
2. **Conference Proceedings**—Matthie JR, Withers PO, Van Loan MD, Mayclin PL. Development of a commercial complex bio-impedance spectroscopic (CBIS) system for determining intracellular water (ICW) and extracellular water (ECW) volumes. In: *Proceedings of the 8th International Conference on Electrical Bio-impedance*; 1992 Jul 28-31: Kuopio (Finland). University of Kuopio; 1992. p. 203–5.
3. **Doctoral Dissertation**—Crandall C. Alterations in human baroreceptor reflex regulation of blood pressure following 15 days of simulated microgravity exposure [dissertation]. Fort Worth (TX): University of North Texas; 1993. 100 p.
4. **Government Report**—U.S. Department of Health and Human Services. *Bone Health and Osteoporosis: A Report of the Surgeon General.* Rockville, MD: U.S. Department of Health and Human Services, Office of the Surgeon General; 2004. 436 p. Available from: U.S. GPO, Washington.
5. **Journal Article**—Blair SN, Ellsworth NM, Haskell WL, Stern MP, Farguhar JW, Wood PD. Comparison of nutrient intake in middle-aged men and women runners and controls. *Med Sci Sports Exerc.* 1981;13(5):310–5.
6. **E-Journal Article**—Vickers AJ. Time course of muscle soreness following different types of exercise. *BMC Musculoskeletal Disorders* [Internet]. 2001 [cited 2001 May 31];2(5). Available from: http://www.biomedcentral.com/1471-2474/2/5. doi:10.1186/1471-2474-2-5.
7. **Web site home page**—American Heart Association Web site [Internet]. Dallas (TX): American Heart Association; [cited 2006 Jan 1]. Available from: http://www.americanheart.org.
8. **Abstract**—An abstract can be cited when it is the only source of information.

Note: In-text reference citations shall be baseline in parentheses, not superscripts [e.g., (14,15), not [14,15]]. Personal Internet Web sites, Master of Science theses, personal communications, or other unpublished material are not acceptable as references. All book references require page numbers. Journal abbreviations should follow the abbreviations of *Index Medicus* published by the Library of Congress. Use of et al.—If fewer than seven (7) authors are listed, all should be mentioned. When seven or more authors are named, list only the first three.

- Figure Captions
  1. Provide a caption for each figure
  2. List captions together following references section

Technical Guidelines

Terminology and Units of Measurement
To promote consistency and clarity of communication, authors should use standard terms generally acceptable to the field of exercise science and sports medicine.

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. When expressing compound units of measurement, authors must locate the raised dot midway between lines to avoid confusion with periods; for example, $mL\cdot min^{-1}\cdot kg^{-1}$.

The basic and derived units most commonly used in reporting research in this Journal include the following:
mass—gram (g) or kilogram (kg); force—newton (N); distance—meter (m), kilometer (km); temperature—degree Celsius (°C); energy, heat, work—joule (J) or kilojoule (kJ); power—watt (W); torque—newton-meter (N·m); frequency—hertz (Hz); pressure—pascal (Pa); time—second (s), minute (min), hour (h); volume—liter (L), milliliter (mL); and amount of a particular substance—mole (mol), millimole (mmol). Selected conversion factors: 1 N = 0.102 kg (force); 1 J = 1 N·m = 0.000239 kcal = 0.102 kg·m; 1 kJ = 1000 N·m = 0.239 kcal = 102 kg·m; 1 W = 1 $J\cdot s^{-1}$ = 6.118 $kg\cdot m\cdot min^{-1}$.

Sample Size
Authors should justify the adequacy of their sample size by providing calculations regarding the power of their statistical tests. While there are different approaches that authors may take in performing these calculations, the book by Cohen is recommended as an appropriate starting point [Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale (NJ): Lawrence Erlbaum Associates; 1988. 567 p.].

Formulas and Equations
Simple in-text formulas and equations should be presented in a single line: $M = (a + b)/(x + y)$. More complex equations should be set displayed, and, if referenced in text, shall have an equation number:

$$\dot{V}O_{2(t)} = A_1(1 - e^{-(t-\delta_1)/\tau_1}) + A_2(1 - e^{-(t-\delta_2)/\tau_2})$$

[1]

All unusual characters must be accompanied by a definition or explanation.

Figures
Medicine & Science in Sports & Exercise® accepts electronic file artwork only. Captions are required for all figures and shall appear on a separate manuscript page.

Electronic Artwork Guidelines

- Each figure should be saved as a separate file without captions. Any figure with multiple parts should be sent as one file with each part labeled the way it is to appear in print.

- Files should be saved as and submitted in .tiff or .eps format—jpeg, .gif, or files downloaded from the Internet *are not* acceptable due to low resolution.
- Compression programs, such as WinZip, may be used to compress large .tiff or .eps files into a .zip file before uploading it to Editorial Manager®.
- Black-and-white line art should be saved at 900–1200 dpi (dots per inch) resolution with monochrome, 1-bit color mode.
- Photographs, CT scans, radiographs, etc. should be saved at a resolution of at least 300 dpi.
- Combination photo–line art and grayscale images should be saved at 600–900 dpi.
- Color images should be scanned in CMYK (cyan, magenta, yellow, black) mode. Do not submit any figures in RGB (red, green, blue) mode. Submit color figures only if color publication is intended. Color publication incurs additional charges.
- Lettering (symbols, letters, and numbers) should be between 8 and 12 points, with consistent spacing and alignment. Font face maybe serif (Times Roman) or sans serif (Arial).
- Line width should be ¾ point or greater.
- Any extra white or black space surrounding the image should be cropped. Ensure that subject-identifying information (i.e., faces, names, or any other identifying features) is cropped out or opagued.
- Artwork should be submitted in final size and should be cropped and rotated as it will appear in the final printed piece.

Tables

- Tables should be double-spaced and designed to fit a one-column width (3¼ inches) or a two-column width (7 inches).
- Each table shall have a brief caption; explanatory matter should be in footnotes below the table.
- The table shall contain means and the units of variation (SD, SE, etc.) and must be free of nonsignificant decimal places.
- Abbreviations used in tables must be consistent with those used in the text and figures. Definition symbols should be listed in the order of appearance, determined by reading horizontally across the table and should be identified by standard symbols.

International Journal of Sport Nutrition and Exercise Metabolism

Submission Guidelines

Manuscripts: Every manuscript must be in English, double-spaced with wide margins, and include an abstract of no more than 250 words. Include 3 to 6 key words that are not in the title. The abstract should contain a purpose/hypothesis statement, and a brief description of methods, results, and conclusions. Label clearly any tables and graphs, and include them on separate pages. Number all pages in the upper-right corner in this order: title page, abstract, text, references, acknowledgments if any, figure captions, tables, and figures. Include line numbers in the text. Disclose all funding sources.

Manuscripts may be submitted electronically via the IJSNEM ManuscriptCentral site at http://mc.manuscriptcentral.com/hk_ijsnem. The ManuscriptCentral system manages the electronic transfer of IJSNEM manuscripts throughout the article review process, providing step-by-step instructions and a user-friendly design.

Alternatively, submit two paper copies of the manuscript and either a disk containing the manuscript file or an e-mail attachment of the file to:

Dr. Emily M. Haymes (ehaymes@mailer.fsu.edu)
Department of Nutrition, Food & Exercise Science
Florida State University
Tallahassee, FL 32306-1493.

Carefully proofread the final revision, check the references, and keep a copy of the manuscript. Do not submit the manuscript to another journal at the same time.

Manuscripts are read by the editor and two reviewers; reviews will not be blind. The authors are invited to provide the names and addresses of at least 4 possible reviewers when they submit their manuscripts. The review process should take about 7 to 10 weeks. Each copy of the manuscript must have a separate cover sheet including title of manuscript, name(s) of author(s), institutional affiliation(s), running head, and mailing address and phone number of the author who is to receive the galleys. Only one copy of the manuscript will be returned to the lead author, whether it is accepted or rejected for publication. Authors of manuscripts accepted for publication are required to transfer copyright to Human Kinetics, Inc.

Copyright Assignment Form

Figures and Tables: Figures should be professional in appearance and have clean, crisp lines. Hand drawings and hand lettering are not acceptable. In graphs, use black and white only, no shading or color. Keep labels proportionate with the size of the figures on the journal page, which is 4.5 in. wide. Digital images should be 300 dpi at full size for photos and 600 dpi for line art. Format tables in the table function of your word-processing program rather than aligning columns in text with tabs and spaces or using text boxes. Figures can be submitted electronically in .TIF or .PDF file formats. Submit a copy of each figure with each copy of the manuscript. On each figure indicate figure number, author's name, and top side. Authors are encouraged to submit illustrations rather than tables. When tabular material is necessary, it should not duplicate the text. Tables should be double-spaced on separate sheets and include brief titles.

Use of Human and Animal Subjects: *IJSNEM* requires that all submitted studies using human or animal subjects conform to the policies established by the U.S. Department of Health, Education, and Welfare and the American Physiological Society.

UPDATE: With the first issue of 2008, Volume 18, *IJSNEM* is changing its editorial style. We will now follow the style laid out in the *Publication Manual of the American Psychological Association* (APA), 5th ed. The reference list will still be alphabetized but not numbered, and citations in text will include the authors' last names and the date in parentheses. Examples of the three most common forms of references are as follows. For other variations, please consult the APA manual.

Chisolm, D.J., Young, J.D., & Lazarus, L. (1969). The gastrointestinal stimulus to insulin release. *Journal of Clinical Investigation, 48,* 1453-1460.
Wadler, G.I., & Hainline, B. (1989). *Drugs and the athlete.* Philadelphia: F.A. Davis.
Haymes, E. Proteins, vitamins, and iron. (1983). In M.H. Williams (Ed.), *Ergogenic aids in sport* (pp. 27-55). Champaign, IL: Human Kinetics.

Dear Athlete

RESEARCH STUDY – PREVALENCE OF AMENORRHEA AND DISORDERED EATING PATTERNS AMONG LONG-DISTANCE AND MARATHON ATHLETES

The prevalence of amenorrhea (cessation of the menstrual cycle for at least 3 months) and disordered eating patterns among long-distance and marathon athletes is of prime importance for coaches, dieticians, and medical specialists, as it is important for the athletes' health, and thus her future performance. Both amenorrhea and disordered eating patterns, together with a lowered bone density (osteopenia/osteoporosis) are collectively known as the "Female Athlete Triad". The aim of this study is (1) to determine the prevalence of amenorrhea and disordered eating patterns among these athletes via a questionnaire, (2) to determine the relationship between body composition and amenorrhea, and (3) to determine the relationship between low energy intake and amenorrhea. This study is undertaken by the School of Biokinetics, Recreation and Sport Science (BRS) at the Northwest University (Potchefstroom campus).

Information regarding the study:

1. The aim of this study is (1) to determine the prevalence of amenorrhea and disordered eating patterns among these athletes via a questionnaire, (2) to determine the relationship between body composition and amenorrhea, and (3) to determine the relationship between low energy intake and amenorrhea
2. The prevalence of amenorrhea and disordered eating will be measured via a questionnaire. Every athlete will answer the questionnaire individually – but there will be opportunities to ask questions if there is any uncertainty. The second questionnaire, a 24-hour recall questionnaire, will be completed with the help of final year dietician students.
3. Privacy and confidentiality is essential.
4. Body mass and body fat percentage will be measured by way of the Bod Pod. Every athlete will be measured individually. The measuring procedure requires the athlete to wear swimwear, or a sportsbra and thigh-length "ski-pant" with no shoes, socks or jewellery for the duration of the measurement. Privacy is of prime importance and the individual will be measured by a female biokineticist.
5. Muscle mass will be determined via circumferences and skin folds. The circumferences that will be taken include the forearm, front thigh and calf circumferences. Skinfolds will be taken at the front thigh as well as the calf.
6. For any further enquiries please don't hesitate to contact Judy on 082 545 2972.

Thank you

Judy Prinsloo **(Biokineticist in training and M-student)**	**Professor Hans de Ridder** **(Promoter: School of BRS, NWU)**

I, ... (full name) declare that I have read the details with regards to the above-mentioned project and that I understand it.
I understand that I may ask any questions, or request further explanation or information, about the activities undertaken during the research project.
I understand that I take part in this project out of my own free will and hereby give permission to take part in this research project.
I hereby indemnify the University, as well as any of the employees or students from any accountability that may arise during the course of the project.
Also, I further declare not to sue the University for any damage or personal loss that I suffer due to the project, except if it is due to the negligence of the University, its employees or students.

(Signature of subject)

Signed in .... on ....

WITNESSES

1. ....

2. ....

Signed in .... on ....

Health, Weight, Dieting, and Menstrual History Questionnaire

Subject number: _______

Demographic Information

1. Birth date (mo/day/yr) ___/___/_____ 2. Age (yrs) _______
3. Ethnicity (check one): □ Black □ White □ Coloured □ Other
4. Primary sport you participate in: ______________________________
5. Years of participation in this sport: ___________
6. ***Primary*** source of nutrition information/education ***(check only one):***

□ Magazines □ Textbooks □ Peers □ Dietician □ Coach

□Physician □ Other Medical Profession □ Health Food Store □ Other (describe) _____________________

Musculoskeletal/Health History

1. Is there a history of osteoporosis (low bone density) in your family? □ YES □ NO
2. Have you ever been diagnosed with or treated for any of the following? (check all that apply)

   □ low bone density □ scoliosis □ anorexia nervosa □ bulimia nervosa
3. Have you ever suffered a ***stress fracture*** as a result of training or competition?

   □ YES □ NO

   * If you answered ***YES***, how many stress fractures have you had? _____
4. Have you ever suffered a soft-tissue (e.g., muscle, tendon or ligament) injury as a result of training or competition? □ YES □ NO

   * If you answered ***YES***, how many soft-tissue injuries have you had? ____
5. Do you smoke? ? □ YES □ NO

   * If you answered ***YES***, how many cigarettes do you smoke per day? _______
6. How many ***hours per week*** do you participate in your sport? ___________
7. How many ***km's per week*** do you spend on the road? _____________

Menstrual History

1. Have you ever had a menstrual period? □ YES □ NO
2. How old were you when you had your first menstrual period? ______________
3. When was your last menstrual period? _____/_____ (mo/yr)
4. How many menstrual periods have you had in the last 12 months? ____
   in the last 6 months? _____
5. Please describe the regularity of your cycle. (check one)

□ I am very regular (within 3 days) □ I am somewhat irregular (4-10 day variation)

□ I am very irregular (variation greater than 10 days)

6. Are there changes in your menstrual period during your athletic "season"

   □ YES □ NO

   * If you answered ***YES***, please describe the changes: ___________________

   ____

7. Do your periods change during your off-season? □ YES □ NO

   * If you answered ***YES***, please describe the changes: ___________________

   ____

8. Have you ever gone for 3 or more months without having a menstrual period?

   □ YES □ NO

   * If you answered ***YES***, how many times have you gone 3 or more months without having a period? ____

   * If you answered ***YES***, how many months did you go without menstruating? ___

9. Do you currently take birth control pills or hormones? □ YES □ NO

   * If you answered ***YES***, why are you using them?

   □ birth control □ regulate menstrual cycle □ both

   * If you answered ***YES***, how long have you been using birth control pills?

   (months) ____

Nutrition History

1. How many meals (i.e., breakfast, lunch, dinner) do you usually eat per day?

   (check one)

   □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ more than 6

2. How many snacks (chocolate bar, sports bar, piece of fruit) do you usually eat per day? (check one)

   □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ more than 6

3. Do you skip meals? □ YES, frequently □ YES, occasionally □ NO
4. Are you a vegetarian? □ YES □ NO

   * If you answered ***YES***, please indicate which type:

   □ vegan (no animal products, e.g., meat, eggs or milk- and milk products)

   □lacto/ovo (use eggs and milk- and milk products in your diet, no meat)

   □lacto (use milk- and milk products, no meat or eggs)

5. Do you limit/restrict the ***amount*** of food you eat to control your weight?

   □ YES □ NO

6. Do you limit/restrict the ***types*** of food you eat to control your weight?□ YES □ NO
7. Do you ever feel out of control when eating or feel that you cannot stop eating?

   □ YES □ NO

8. Have you ever eaten a large amount of food rapidly (i.e., binged) □ YES □ NO

   * If you answered ***YES***, how often have you engaged in this behaviour during the past year?

   □ < once a month □ ~ once/month □ 2-3 times/month □ ~ once/week

   □ > once/week □ daily

9. Have you ever purged after a binge? □ YES □ NO

   * If you answered ***YES***, what type of purging did you engage in? (check all that apply)

   □ laxatives □ vomiting □ diuretics □ extra exercise □ sauna/sweat suits

10. Do you think your diet is nutritionally adequate? □ YES □ NO
11. Have other people indicated that your eating habits are unusual or abnormal?

    □ YES □ NO

12. Do you think you might have an eating disorder? □ YES □ NO
13. Are you currently being treated for an eating disorder? □ YES □ NO
14. Do you take vitamin or mineral supplements?

    □ YES, daily □ YES, but not every day □NO

15. Please indicate the type(s) of supplement(s) you use ***(check all that apply)***

    □ multivitamin/mineral □ iron □ calcium □ vitamin C □ vitamin E

    □ B-complex vitamins □ zinc □ herbals □ other (describe)____________

16. Do you use nutritional supplements or sports products?

□ YES, daily □ YES, but not every day □NO

17. Please indicate the type(s) of supplement(s) you use ***(check all that apply)***

□ protein powder/drink □ sports bar (e.g., energy bar) □ amino acids

□ "fat burners" (ephedrine) □ sports drinks (e.g., energade) □ "glutamine

□ HMB □ hormones (androstendione, DHEA) □ chromium

□ creatine □ other (please specify)______________________

Weight History

1. What is your "ideal weight"? ________kg.
2. Have you ever been at your ideal weight? □ YES □ NO
3. Last time at your ideal weight? __________________(mo/yr)
4. How many times has your weight gone up and down by at least 2.5 kg in the last year? __
5. How often are you trying to control your weight ***during*** the season?

   □ never □ rarely □ sometimes □ often □ always
6. How often are you trying to control your weight in the "*off season*" or when you reduce your training?

   □ never □ rarely □ sometimes □ often □ always
7. When your season is finished and you stop or reduce your training do you (check one)

   □ Lose weight (amount:____) □ Gain weight (amount:_____)

   □ Maintain weight (amount:_____)
8. Which of the following are you currently trying to do about your weight? (check one)

   □ Lose weight □ Gain weight □ Maintain weight □ I am doing nothing
9. When I see myself in the mirror I see myself as...(check only one)

   □ Very underweight (>10 kg) □ Slightly underweight (2.5-5 kg)

   □ At an "ideal weight" □ Slightly overweight (<5 kg)

   □ Moderately overweight (5-10 kg) □ Very overweight (>10 kg)
10. How satisfied are you with your current body weight?

    □ very satisfied □ somewhat satisfied □ neutral

    □ somewhat dissatisfied □ very dissatisfied
11. Have you ever been diagnosed with anorexia nervosa? □ YES □ NO
12. Have you ever been diagnosed with bulimia nervosa? □ YES □ NO

13. Please indicate which of the following methods you have used in your ***lifetime*** **AND** ***within the past year*** to control your weight by checking the appropriate column:

METHOD	Lifetime		Past Year	
	YES	NO	YES	NO
Diet pills or “fat burning supplements				
Fasting				
Liquid diet supplements (e.g. Shape)				
Very-low-energy diet ($\leq$1000 kcal/day or $\leq$ 4000 kJ/day)				
Using laxatives				
Using diuretics				
Self-induced vomiting				
High protein/low carbohydrate diet				
Additional exercise beyond regular training program				
Other (please describe)				

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24-HOUR RECALL

Subject number: ________ Interviewer: ___________________
School: ____ Date: ____/ _____/ 200___

Height: _____cm Current Weight: _____kg Age: _____yrs

Tick what the day was yesterday:

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday

Would you describe the food that you ate yesterday as typical of your habitual food intake?

Yes	1	No	2

I want to find out about everything you ate or drank yesterday. Please tell me everything you ate from the time you woke up to the time you went to sleep. I will also ask you where you ate the food and how much you ate.

Time (approximately)	Place (Home, work, etc)	Description of food and preparation method	Amount	Amount in g (office use only)	Code (office use only)
From waking up to going to work, or starting day's activities					
During the morning at work or at home					

Time (approximately)	Place (Home, work, etc)	Description of food and preparation method	Amount	Amount in g (office use only)	Code (office use only)
Middle of the day (Lunch time)					
During the afternoon					
At night (dinner time)					
After dinner, before going to sleep					

Do you take any vitamins (tablets or syrup)?	Yes	1	No	2
Give the brand name and dose of the vitamin/tonic:				

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NORTH-WEST UNIVERSITY
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Anthropometry Proforma

Test number: ____________________ Test Date: ____________________

Examiner: ____

Name: ____

E-mail address: ____

Date of birth: ____________________

Mass (kg) ____________________ **Height (cm)** ____________________

	ID	*Site*	*Trial 1*	*Trial 2*	*Trial 3*	*Median*
Skinfolds	**1**	Front thigh				
(mm)	**2**	Medial calf				
Girths	**3**	Thigh				
(mm)	**4**	Forearm				
	5	Calf				

	% Body Fat	Body Fat Mass	Lean Body Mass
BOD POD			
BMI			