ENERGY INTAKES OF FEMALE COLLEGIATE ATHLETES

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ENERGY INTAKES AMONG FEMALE COLLEGIATE

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CHAPTER I

INTRODUCTION

Research interest in the female athlete has increased over the last decade due to the increased number of competitive events available to females. Female participation is becoming equal to their male counterparts; therefore the desire to understand the dynamics behind what factors improve performance of female athletes is increasing**.**

It is not uncommon to trace the deterioration of an athlete's performance to poor nutrition (Economos, Bortz, & Nelson, 1993). Adequate energy intakes of athletes are important and may significantly influence athletic performance both physically and mentally (Economos, Bortz, & Nelson, 1993). Previous research has suggested that female athletes often restrict their energy intake despite having high energy demands during both training and competition (Manore, Kam, & Loucks, 2007; Ziegler & Jonnalagadda, 2006; Manore, 2002; Edwards, Lindeman, Mikesky, & Stager, 1993). Female athletes are vulnerable to low energy intakes for numerous reasons, including unrealistic body image, social pressure to look thinner, and a drive to increase performance by losing weight (Kerr, Berman, & Jane De Souza, 2006; Kirk, Singh, & Getz, 2001; Krane, Stiles-Shipley, Waldron, & Michalenok, 2001). The health and nutritional status of female athletes may suffer as a consequence of inadequate energy consumption over an extended period of time because low energy intakes are associated with serious health problems such as low bone mineral density, amenorrhea, nutrient deficiencies, and disordered eating (Manore, Kam, & Loucks, 2007; Deutz, Benardot, Martin, & Cody, 1999). To date, only a few studies have evaluated energy intakes and determined the prevalence of inadequate energy consumption among female collegiate athletes. Given the importance of adequate energy intakes for health and optimum performance, it is essential to determine whether female athletes consume a sufficient amount of energy to support their training regimen and competition schedule.

In regards to assessing energy requirements, one of the challenges of dietitians/nutritionists is to accurately determine an individual athletes' overall daily energy expenditure. Currently, nutrition professionals use a variety of prediction equations to estimate the resting metabolic rate (RMR) of athletes, coupled with physical activity factors to account for energy expenditure during exercise. Some of the most commonly used tools for estimating the RMR are equations such as the Harris-Benedict and Cunningham (Frankenfield, Muth, & Row, 1998; Thompson & Manore, 1996; Cunningham, 1980). While these equations provide a quick estimate of an individual's daily RMR, the appropriateness and accuracy of their use is questionable, especially with female athletes because equations were mostly derived using males and/or non-athletic populations (Thompson & Manore, 1996).

The main purpose of this study was to evaluate energy intakes of a sample of female collegiate athletes. Reported energy consumption of each athlete was compared to their calculated energy requirements determined using measured RMR plus an appropriate physical activity factor. The second purpose of the study was to determine whether differences between actual RMR and estimated RMR, using the Harris-Benedict and Cunningham equations, exist in this target population. The third purpose of the study was to identify the relationship between an athletes' energy intake and their body composition, including lean body mass (LBM) and fat mass (FM). Finally, the relationship between individual's reported energy intake and score on the EAT-26 test was explored.

Hypotheses of the Study:

Research hypothesis #1: Majority of the female athletes will consume significantly less amount of calories compared to their estimated overall daily energy expenditure.

Research hypothesis #2: The RMR of the female athletes as measured by indirect calorimetry will be significantly higher than the resting metabolic rate estimated by Harris-Benedict and Cunningham equations.

Research hypothesis #3: There will be a significant positive relationship between energy intake and lean body mass and a positive relationship between energy intakes and body fat.

Research hypothesis #4: There will be a significant negative relationship between EAT-26 score and reported energy intake.

Limitations

1. The sample size in this study was relatively small, with a total of 45 subjects. In addition, only 23 subjects completed all the measurements, including RMR, 24-h recall, and 3-day food record. This limits the degree to which the results can be generalized to other female athlete populations.

2. RMR was not measured for some subjects due to the length of time it takes to measure RMR in individuals. The RMR assessment takes approximately 20 minutes per subject and some of the subjects could not devote that much time due to other training and academic obligations.
3. The sample used in the study was a convenience sample and thus the findings of this study may not be generalized to other groups or populations of female athletes. In addition, the sample consisted of female athletes from only three sports.

Definitions of Terms and Equations Used

Basal Metabolic Rate- The lowest need of energy at rest in a postprandial state under thermoneutral conditions. It is the energy used to run basic cell functions in a large variety of organs and maintenance functions such as body temperature (Weibel & Hoppeler, 2005).

Dual X-ray Absorptiometry- Technique that has become the clinical standard to measure bone density which is based on the absorption of low-energy x-rays. Also used to measure lean body mass (Visser et al, 1999 &; Brunton, Bayley, & Atkinson, 1993).

Energy Balance- Dietary energy intake minus total energy expenditure (Loucks 2007).

Estimated Energy Requirements -Amount of dietary energy estimated to maintain life and engage in physical activity (Nieman, 2007).

Food Record- (Also known as a food diary) is an example of a prospective, quantitative method. The subject is required to record the daily amounts of all individual foods and beverages. The recording of dietary intake is usually conducted over a period of 3–14 days (Trabulsi & Schoeller, 2001).

Kilocalories- A unit of heat equal to 1000 calories–the heat required to raise the temperature of 1 kg of H_2O 1ºC (Taber's Cyclopedic Medical Dictionary, 2005, P.319).

Lean Body Mass– Primarily consists of protein, water, and includes smaller amounts of minerals and glycogen. Skeletal muscles are the main component of lean body mass. LBM is also known as the weight of the body minus the weight of fat mass (Nieman, 2007; Sawyer, Hypes, & Brown, 2003).

Multiple Pass 24-Hour Recall - A dietary recall that consists of different stages. First step, the interviewer asks the subject to recall all foods and beverages consumed during the past 24 hours. Second step, the interviewer asks the subject to explain details regarding responses in step one. This also helps the subjects remember anything they left out in step one. Final step, the interviewer asks about cooking methods used for food preparation. This helps the subjects recall any other added ingredients (United States Department of Agriculture (USDA), 1998).

Resting Metabolic Rate- The energy expended by the body to maintain life and normal body function, such as respiration and circulation (Nieman, 2007). In other words, the calories burned at rest.

Abbreviations

ADA- American Dietetic Association

DEXA- Dual X-ray Absorptiometry

EAT-26- Eating Attitude Test

FAO/WHO/UNU – Food and Agriculture Organization of the United Nations, World Health Organization, and the United Nations University

Kcals- Kilocalories

LBM- Lean Body Mass

RMR- Resting Metabolic Rate

BMR- Basal Metabolic Rate

TEF- Thermic Effect of Food

CHAPTER II

REVIEW OF LITERATURE

Definition of Energy Balance and Athletes' Energy Intake

The key to achieving energy balance is to obtain adequate energy intakes that meet the needs of an individual's resting metabolic rate (RMR), thermic effect of food (TEF), and physical activity level (Jeukendrup & Gleeson, 2004). Energy intakes will vary between individual athletes, types of sport, and between different seasons (Haskell, 2007). Thus, energy balance in athletes is achieved when the energy consumed meets the energy cost of daily living including, exercise training and competition, building and restoration of muscle tissue, menstrual function, additional energy related to illness or psychological stress, or the amount of energy required to achieve weight maintenance (Manore, 2002). Attaining energy balance is important for athletes in order to achieve good nutritional status, maintain lean body mass (LBM), and optimize overall athletic performance (Ziegler, 2001; Manore, Barr, & Butterfield, 2000). Energy intake is also a major determinant of weight management, including weight loss, weight gain, and weight maintenance (Westerterp-Plantenga, 2004). Thus, meeting daily energy expenditure represents a major key to optimal weight and physical performance among athletes (Manore, Barr, & Butterfield, 2000).

While some athletes are able to achieve energy balance on a regular basis, many athletes fail to consume adequate energy to support the extra physiological and mental cost of their training and competition schedules. It has been found that athletes (13.5%) are more likely than non athletes (4.6%) to show signs of subclinical or clinical eating disorders (Sundgot-Borgen, 2004). Although energy restricted diets are relatively common among both women and men engaged in weight-restricted and aesthetic sports, such as gymnastics, running, diving, and rowing (Ziegler, Nelson, Barrat-Fornell, Fiveash, & Drewnowski, 2001; Bishop, Blannin, Walsh, Robson, & Gleeson, 1999), female athletes have a higher tendency to restrict energy intake compared to male athletes in the same sports (Ziegler & Jonnalagadda, 2006; Sundgot-Borgen & Torstveit, 2004 Manore, 2002; Mullinix, Jonnalagadda, Rosenbloom, Thompson, & Kickligher, 2003; Ziegler, Nelson, Barratt-Fornell, Fiveash,& Drewnowski, 2001). Manore (2002) states that female athletes are preoccupied with their body weight and shape, thus it is not unusual for them to want to lose 5 to 10 pounds although they are often at a normal weight or even under weight by all assessment standards. Mullinix and colleagues (2003) indicate that female athletes from diverse sports can be sustaining high energy-demanding training schedules with energy intakes as low as 45 kcal/kg of body weight/day. Sundgot-Borgen (2004) conducted a study on the prevalence of eating disorders in elite athletes and found that elite athletes, both male and female, had a higher incidence of eating disorders compared to the general population. While both male and female athletes make up a population with a high prevalence of eating disorders, female athletes have a higher tendency to restrict energy intakes than their male counterparts (Sundgot-Borgen & Torstveit, 2004).

Energy Intakes, Macronutrients, Micronutrients and Optimal Performance

Athletes should view their energy intakes as an important aspect of a training program for adaption, performance improvements, and recovery (Burke, Kiens, Ivy, 2004). Adequate energy intake is essential for achieving good nutritional status and for optimizing athletic performance (Ziegler, Nelson, Barrat-Fornell, Fiveash, & Drewnowski, 2001; Economos, Bortz, & Nelson, 1993). Female athletes that practice restrictive energy intake and do not maintain energy balance may lack adequate amounts of macronutrients, as well as micronutrients, which can significantly influence performance, recovery, and life-long health (Burke, Kiens, & Ivy, 2004). The two macronutrients most important for providing the working muscle with fuel are carbohydrates and fat. Protein, the third macronutrient, is more important in recovery and repair of muscle tissue especially, after strenuous exercise. It is important to note that benefits of these three macronutrients are interrelated. There have been many studies done on specific macronutrients' role in improved performance and increased energy; however it is thought that the improvements are due to an overall increase in total daily energy, not an increase in a specific macronutrient (Loucks, 2007; Horvath, Eagen, & Ryer-Calvin, 2000; Pendergast, Leddy, & Venkatraman, 2000).

Current research suggests that carbohydrates become the main substrate for energy as exercise intensity increases (Burke, Cox, Cummings, & Desbrow, 2001; Burke, Kiens, & Ivy, 2004; Jeukendrup & Gleeson, 2004; Economos et al, 1999). This is relevant to most athletes given the intensity, duration, and frequency of their training. Current carbohydrate recommendations for athletes range from 5-10 grams/kilogram/body weight/day (Burke, Kiens, & Ivy, 2004; Burke, Cox, Cummings, & Desbrow, 2001). The recommendations increase with energy expenditure and may exceed 10 grams/kilogram/day for some athletes. Total daily carbohydrate intake may be lower when athletes are not involved in training programs, such as during the off-season (Burke, Kiens, & Ivy, 2004). In the Burke, Kiens, and Ivy (2004) study, total energy intake increased when energy from carbohydrates increased; suggesting that the increases in carbohydrates may not be the only contributing factor to increased performance and decreased recovery time. Findings from Pitsiladis and Maughan (1999) also suggest that moderate changes in diet composition during training do not affect the performance of high intensity exercise in trained individuals when the total energy intake is adequate. Once again supporting the idea that total energy intake may be the key to optimal performance and recovery.

A recent study of the link between fat and injuries in female runners found that females with lower fat diets had a higher rate of injuries (Gerlach, Burton, Dorn, Leddy, & Horvath, 2008). The study concluded that the females with low fat diets also consumed less energy overall and thus were at a higher risk for injuries. While conclusions about the role of fat in exercise needs further research (Horvath, Eagen, Ryer-Calvin, & Pendergast, 2000; Pendergast, Leddy, & Venkatraman, 2000; Horvath, Eagen, Fisher, Leddy, & Pendergast, 2000), it is known that fat is the preferred substrate for muscles during longer-lasting exercise because it provides 9 kilocalories/gram compared to only 4 kilocalories/gram that come from carbohydrates. Another advantage of fat as a substrate during exercise is that this macronutrient can be stored without the presence of water, unlike carbohydrates, which makes it a more efficient and lighter source of energy for the muscle cells (Berning & Steen, 1998). Because of the characteristics of fat mentioned above, the human body has a large fat storage capacity. An 80 kilogram-male can store approximately 414, 976 kilojoules (KJ) of fat compared to 8,320 KJ of carbohydrate (Berning & Steen, 1998). Research of low fat, medium fat, and high fat diets by athletes has shown that athletes on the high fat diet (increased to 44% of fat from total energy intake) had lower lactate levels after an endurance run, which may be interpreted as an increase in performance (Horvath, Eagen, & Ryer-Calvin, 2000). However, as fat intake of the athletes increased, so did their overall kilocalories and carbohydrate intake thus, the increased performance in this and other studies is likely to be attributed to an overall increase in energy intake rather than an increased intake of a specific macronutrient (Horvath, Eagen, Fisher, Leddy, & Pendergast, 2000).

Adequate energy intakes of athletes are also essential in order to consume a sufficient amount of protein, especially essential amino acids (Waterlow, 1986). Proteins are important to many metabolic processes such as red blood cell synthesis, aerobic enzyme synthesis, and myoglobin synthesis, all of which may be helpful in the recovery process (Coleman, 2003). Recently, studies have focused on the effects of protein consumption during exercise and for recovery purposes (Phillips, 2006; Burke, Kiens, & Ivy, 2004). Common proteins that are broken down in exercise are the branched chain amino acids (BCAA), specifically leucine, isoleucine, and valine. It is estimated that when muscle glycogen stores are low, approximately 15% of energy used is provided by protein (Coleman, 2003). Protein recommendations for athletes vary due to a variety of factors such as intensity, duration, season, total energy consumed, and gender. Current recommendations for protein include a variance between

1.2-1.8 grams/kg/day (Jeukendrup & Gleeson, 2004). Protein recommendations for endurance athletes range from 1.2-1.4 grams/kg/day (American Dietetics Association, 2009; Fink, Burgoon, & Mikesky, 2009; Jeukendrup & Gleeson, 2004; Berning & Steen, 1998). Protein recommendations for strength athletes range from 1.6-1.7 grams/kg/day (Jeukendrup & Gleeson, 2004). The Position of the American Dietetics Association, Dietitians of Canada, and the American College of Sports Medicine (2009) also state current protein recommendations for athletes ranging from 1.2-1.7 grams/kg/day. Research shows that excess protein intake greater than 2 g/kg/day does not lead to enhanced performance but can be harmful to health by increasing calcium loss, increasing the risk of cardiovascular disease, and increasing dehydration (Fink, Burgoon, & Mikesky, 2009; Berning & Steen, 1998). Because research studies often do not control for confounding variables, the current recommendations for dietary protein are not unified and often vary from one source to another. However, there is a clear link between total energy intake and adequate protein intake that ultimately leads to optimal athletic performance (Deutz, Benardot, Martin, & Cody, 1999).

Adequate energy intakes are also important for sufficient micronutrient consumption that indirectly contributes to energy production by playing a crucial role in energy metabolism as cofactors and coenzymes. Female athletes restricting energy may be deficient in micronutrients which can be detrimental to their performance and long-term health. Examples of these nutrients are niacin, riboflavin, vitamin B6, calcium, and iron (Holschen, 2004; Mullinix, Jonnalagadda, Rosenbloom, Thompson, & Kickligher, 2003).

Riboflavin, niacin, and vitamin B6, in their coenzyme forms, play a vital role in the metabolism of the macronutrients. Recommendations for these vitamins are based on total energy requirement (riboflavin and niacin) and protein requirement for vitamin B6 (Manore, 2000). Riboflavin is essential for the production of the coenzymes flavin mononucleotide (FMN) and flavin adenine dinucleotide (FAD). These coenzymes are important in the metabolism of glucose, fatty acids, glycerol, and amino acids for energy (Manore, 2000). Riboflavin is also important in converting vitamin B6 into its functional coenzyme (Manore, 2000). The major function of vitamin B6 is the metabolism of proteins and amino acids (Manore, 2000). The coenzyme forms of niacin serve as carriers of reducing equivalents in glycolysis, pentose shunt, TCA cycle, and electron transport chain (Lewis, 1997). The two active coenzymes are adenine dinucleotide (NAD) and NAD phosphate (NADP) which are required for approximately 200 enzymes in metabolic reactions following the formation of fatty acids and glycogen (Fink, Burgoon, & Mikesky, 2009; Lewis, 1997). Physical training may increase the need for vitamins but it is important to remember vitamins do not provide energy and the B vitamins are required in proportion to calories or protein consumed and active people require more calories and protein. Therefore, if a balanced diet is consumed there should not be a need for an athlete to consume a vitamin supplement (Fink, Burgoon, & Mikesky, 2009; Jeukendrup & Gleeson, 2004; Sawyer, Hypes, Brown, 2003; Coleman & Steen, 2000). However athletes that are restricting energy intake (distance runners, gymnasts, female athletes) are at risk for vitamin deficiencies (Coleman & Steen, 2000). Calcium and iron are two other micronutrients (minerals) that athletes are at risk for developing a deficiency, especially if following an energy restricted diet (Rodriguez, DiMarco, & Langley, 2009; Fink, Burgoon, & Mikesky, 2009; Coleman & Steen, 2000; Jeukendrup & Gleeson, 2004).

Mullinix and colleagues (2003) state that female athletes with diets low in energy intake only obtain about 30% of their recommended amounts of calcium and iron. Quintas and colleagues (2003) also found that calcium intakes are inadequate among female athletes and that consumption of meat and drinks providing phosphorus contribute to low calcium by disrupting the calcium/phosphorus ratio in the body. Calcium is important for female athletes' health because, in conjunction with weight bearing exercise, it can decrease the risk of osteoporosis development (Ziegler & Jonnalagadda, 2006). Similarly, low iron stores are associated with a decrease in aerobic capacity and approximately 80% of female athletes may be iron deficient (Holschen, 2004), which is a major limitation to training and performance.

Energy Availability

Energy availability is defined as the amount of dietary energy remaining for all other metabolic processes after exercise (Loucks, 2007). Low energy availability may compromise normal physical and metabolic processes in the body, including oxygen uptake (VO2), lactate metabolism, thermoregulation, and recovery (Burke, Kiens, & Ivy, 2004; Burrows & Bird, 2000). Female athletes, endurance runners, gymnasts, and athletes in other weight-focused sports are especially at an increased risk for low energy availability (Loucks, 2004; Hassapidou & Manstrantoni, 2001). A review of the metabolic adaptations suggests that individuals' resting metabolic rate (RMR) can decrease during periods of low energy intakes (Sjodin et al, 1995; Waterlow, 1986). Thus, female athletes that do not match energy intake with energy expenditure may experience signs of adaptive thermogenesis, where the body can maintain core temperature without adequate energy intake (Benardot, 2007; Dulloo & Samec, 2001). Inadequate energy availability can also lead to low bone mass (ADA reports, 2005; Quintas, Ortega, Lopez-Sobaler, Garrido, & Requejo, 2003) because low energy levels are unable to support appropriate bone turnover. Furthermore, female athletes may experience not only a decrease in performance but also a disrupted menstrual cycle and a decrease in LBM (Thompson 2007, Nichols, Sanbourn, & Essery, 2007; Punpilai, Sriareporn, Ouyporn, Teraporn, & Sombut, 2005; Estok & Rudy, 1996).

Female Athlete Triad, Eating Disorders, and Eating Attitudes

Low energy intakes, and corresponding low energy availability, among female athletes may often indicate a potential threat for eating disorders which, along with osteoporosis and amenorrhea, represent the three components of Female Athlete Triad (FAT) (Thompson, 2007). The FAT is commonly associated with female athletes that restrict energy intakes and do not maintain energy balance on a regular basis. The components of the FAT are closely related (Manore, Kam, & Loucks, 2007). The FAT was formally defined in the summer of 1992 due to the growing concern for female athlete's health status (Morgenthal, 2002). The FAT is not limited to elite athletes and is prevalent in other physically active women and girls (Morgentahal, 2002). Females that participate in sports where low body weight or appearance is emphasized are more likely to experience the FAT and/or symptoms of the triad (Manore, Kam, & Loucks, 2007). Disordered eating and restricting energy intake is reported more frequently in female athletes than in non athletes (Morgenthal, 2002). Sundgot-Borgen and Torstveit (2008) found that 13.5% of athletes compared to 4.6% of non-athlete controls had sub clinical or clinical eating disorders. Disordered eating can be defined as restrictive dieting, bingeing, purging, changing eating patterns for personal appearance, or in preparation for athletic competition (Milligan & Pritchard, 2006). In fact, Jeukendrup and Gleeson (2004) state that female athletes are 10 times more at risk to have or develop an eating disorder compared to male athletes. Milligan and Pritchard (2006) state that females are more likely to develop eating disorders than males by a 9:1 ratio. Sundog-Borgen and Torstveit (2008) also found that the occurrence of disordered eating among female athletes in aesthetic sports was 42%, endurance sports 24%, and ball game sports 16%. Johnson, Powers and Dick (1999) found that out of 1,445 college athletes, 9% of female athletes needed treatment for their eating disorders, and 58% were at high risk for developing eating disorder behaviors.

The two most common eating disorders in female athletes include anorexia nervosa and bulimia (Estok & Rudy, 1996). Anorexia nervosa is characterized by maintaining a body weight less than 15% of normal weight and height for age. Bulimia nervosa is characterized by binging followed by vomiting, laxative use, or fasting (Milligan & Pritchard, 2006). Eating disorders such as anorexia among females often lead to amenorrhea, which is defined as the absence of three to six successive menstrual cycles (Thompson, 2007). The better known long-term effects of low energy intakes in female athletes are menstrual irregularities, amenorrhea, and infertility (Estok & Rudy, 1996). Within the FAT context, the loss of menstrual function can also be termed as athletically induced amenorrhea (Edwards, Lindeman, Mikesky, & Stager, 1993; Manore, 2002). One of the detrimental side effects of amenorrhea, or athletically induced amenorrhea, is bone loss. Williams and colleagues (2002) found that six to twelve months without menstruation can lead to bone loss. Research suggests that amenorrheic athletes have 10-25% lower bone mineral density at the lumbar spine versus the eumenorrheic athlete (Nichols, Sanbourn, & Essery, 2007). The lumbar spine is just one example showing that amenorrheic athletes are at an increased risk for stress fractures, especially when compared to eumenorrheic athletes (Manore, Kam, & Loucks, 2007; Burrows & Bird, 2000; Jeukendrup & Gleeson, 2004; Cook et al, 1987). A long term effect of amenorrhea and bone loss is osteoporosis. Osteoporosis is a premature loss of bone quality and quantity and can become a problem if low energy intakes are maintained for a prolonged period of time. It is important to recognize that one of the benefits of exercise is increased bone density (Nochols, Sanbourn, & Essery, 2007; Jeukendrup & Gleeson, 2004). However, disordered eating often does not allow for proper mineral and bone reabsorption, as would exercise with proper energy balance. While the FAT consists of three conditions, it is apparent that all three components are influenced by dietary energy intakes and thus energy balance.

Being an athlete is not the only factor contributing to the increased risk of disordered eating and FAT among female athletes. The social pressures and ideal body images that exist in the Western society likely contribute to disordered eating among females due to the emphasis on thinness and beauty (Kirk et al, 2001). Society emphasizes a body size ideal to which female bodies are compared to, with thinness being the main focus (Krane, 2001). Research suggests that 15-62% of college females practice some kind of weight control behaviors (Kirk et al, 2001). Society as stated above creates and perpetuates these often unobtainable images of how the female body should appear, resulting in the manifestation of eating disorders much earlier in life than many may believe. This has been coined as social physique anxiety (SPA), which is a strong concern about the way others perceive one's body (Krane, 2001).

Self-presentation and the desire to impress others are strong in sports and exercise, especially when related to disordered eating. Krane's (2001) study showed statistical evidence for a stronger drive for thinness in female athletes compared to female non athletes. Society may not be the only factor affecting female athlete's eating habits. Certainly, personality traits such as low self-esteem and being overly self-critical may contribute to disordered eating (Jeukendrup & Gleeson, 2004). Despite the prevalence of obesity in the US (2/3 of the adult population is overweight or obese), the female athlete strives for the "ideal" body composition and weight (Weight Control Information Network, accessed 2006).

Research suggests that social pressures, self-presentation, beliefs, and eating attitudes can all be linked to eating disorders (Jeukendrup & Gleeson, 2004; Krane, 2001; Kirk et al, 2001). Self esteem and body dissatisfaction are predictors for negative eating attitudes in both females and males (Milligan & Pritchard, 2006). Smith and Petrie (2008) state that up to 20% of female athletes experience sub clinical or clinical disordered eating. There are many different assessment tools for determining disordered eating which include: eating disorder inventory (EDI), drive for thinness (DT), body dissatisfaction (BS), Bulimia (BUL) subscales, body shape questionnaire (BSQ), symptom checklist for eating disorders (EDI-SC), and the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV) (Beals & Manore, 2000). The goal of these tests is to increase awareness of characteristics associated with subclinical eating disorders. An eating attitude test (EAT) is another test used to gather information and assess risk for disordered eating habits in individuals. Lane and colleagues (2004) states that "the EAT-26 test has been used extensively in clinical psychology and now its use is spreading to other areas, for example sports nutrition". EAT-26 was validated against the EAT-40, restrained eating inventory (EI), and the EDI in 1986 by Berland, Thompson, and Linton. The original version of the EAT-26 proved reliability (alph =0.90) and validity (r=0.87, p < 0.001) (Garner & Garfinkel, 1979). Later, the abbreviated version of the EAT-26 which correlates with the original (r=0.98) was validated by Garner and colleagues (1982). The EAT-26 questionnaire records participant's attitudes toward energy intake in three different areas: dieting behavior, oral control, and bulimia nervosa practices (Garner, Olmsted, Bohr, & Garfinkel, 1982). Picard (1999) compared EAT-26 scores of athletes to non athletes and found that athletes had higher scores then the non athletes, especially high scoring were aesthetic athletes. Another study utilizing the EAT-26 method found that 26% of their athletic population surveyed scored above the cutoff for being at risk for a clinical eating disorder. Eighty-four percent of these athletes at risk for an eating disorder were female (Milligan & Pritchard, 2006).

Association between Body Composition and Energy Intakes

Body composition is made up of structural components of the body, including muscle, bone, and fat (Jeukendrup & Gleeson, 2004). Body composition is one of the best indicators of physical fitness because unlike total weight it separates fat mass from lean mass. Fat mass is simply the amount of fat one has, while lean body mass includes muscle, bone, and all other components excluding fat. Assessment techniques used to assess body composition include hydrodensitometry, or (underwater weighing), dual-energy x-ray absorptiometry, air displacement plethysmography, skinfold measurements, body mass index (BMI), and bioelectrical impedance. Typical assessment facilities are not equipped to use all of the above methods. The most accessible of those listed are the skinfold measurement, bioelectrical impedance, and BMI which are less invasive and less expensive.

Body mass index (BMI) is also a commonly used body composition assessment tool in large populations due to its easy accessibility; however, BMI does not serve as a good indicator of body composition in the athletic population because the equation used does not take LBM into account. The equation used for BMI is as follows: weight (kg) / [height (m)]^2 (Jeukendrup & Gleeson, 2004). The BMI categories established in previous research include the following categories: Below 18.5 underweight, 18.5 – 24.9 normal weight, 25-29.0 overweight, and 30 and above obese

(Jeukendrup & Gleeson, 2004). Although BMI is not a good indicator of body composition in athletes due to its accessibility it still used as a general measurement.

Another tool for assessing body composition, dual-energy x-ray absorptiometry (DEXA), has gained validity and is considered by many experts the gold standard for measuring body composition (Fields & Goran, 2000; Brunton, Bayley, & Atkinson, 1993; Morrison et al, 1994). DEXA is becoming one of the most frequently used methods to estimate body fat and lean body mass in the lab setting. The DEXA machine is a useful tool when assessing LBM in athletes because it can provide estimates of fat per region of the body (Schoeller, 2005). This is often a useful tool in order to compare LBM and fat mass between different types of athletes. DEXA houses two x-ray beams working at different frequencies inside one scanner (Visser et al, 1999; Brunton, Bayley, & Atkinson, 1993). As this total body scanner travels over the body, it records data on bone mineral content and soft tissue composition (Morrison et al, 1994). This scanner can pass over the entire body and provides detailed results in approximately three to four minutes (Visser et al, 1999). Studies show that DEXA may be a better predictor of FFM because it does not seem to be affected by hydration status as does hydrodensitometry and bioelectrical impedance, two other popular methods for measuring body composition (Kohrt, 1998). Also, many studies are validating DEXA against other methods of determining body composition, such as hydrodensitometry (Kohrt, 1998; Chen et al, 2007). These studies support the use of DEXA as a noninvasive and efficient method for measuring body composition that is also more accessible for research studies (Visser et al, 1999).

Body composition is one of the many aspects associated with optimal athletic performance; therefore it is essential that athletes consume sufficient energy to maintain appropriate body composition while training at competitive levels (Rodriguez, DiMarco, & Langley, 2009). Some female athletes assume that lower energy intake will lead to a lower amount of body fat, however energy imbalance can, in fact, lead to a higher percent body fat and a decrease in LBM (Zachwieja, 2001; Deutz, Benardot, Martin, & Cody, 1999). Yet many female athletes tend to consume low calorie diets (<1800-2000kcals/day) not matching energy intakes with energy expenditure in order to decrease their body fat and maintain a low body weight (Loucks, 2004). An athlete must maintain enough body fat to fulfill essential fat requirements and fuel the body. Essential fat is necessary in areas like the brain, nerve tissue, organs, etc (Sawyer, hypes, & Brown, 2003). Essential fat for women is 12-15%. In general, a healthy body fat percentage for women ranges from 20-30% (Armstrong, et al., 2006; Sawyer, Hypes, & Brown, 2003; Coleman, 2003). An acceptable range for female athletes is approximately 14-30% (American Counsel on Exercise, 2009). The ranges given for body fat are not necessarily *ideal*. The best body composition will vary between athletes, types of sports, as well as season. Thus, it is recommended that athletes consider their *ideal* body composition as a percentage that falls within the healthy range in order to achieve their best performance results (American Dietetics Association, 2009; Coleman, 2003).

Trying to achieve a lower body weight by restricting energy can lead to a decrease in LBM, especially in athletes that are not in a weight training program (Bryner et al., 1999). Zachwieja (2001) showed that on a short-term (2-week) energy restriction diet, athletes that lost weight tended to lose mostly LBM. The following studies indicated that energy restriction, especially long-term energy restriction, has many negative consequences that are harmful to athletic performance. Gerlach and colleagues (2008) found that diets limiting fat and/or overall energy resulted in more injuries in female endurance runners than diets that did not restrict fat and/or energy. Loucks (2004) also found that energy restriction methods place a female athlete's reproductive and skeletal health, along with performance, at risk. A study by Deutz (1999) showed that assuming that energy restriction leads to lower body fat and increased performance is misleading. His study of 42 female gymnasts and 20 female runners found that daily negative energy balance can lead to a higher percent body fat. Given the results of previous studies, female athletes should be encouraged to consume adequate energy and avoid limiting their energy intakes to achieve *ideal* body composition (Deutz, 1999).

Assessment of Energy Consumption

Energy intake is defined as the energy consumed in a daily diet that is available for metabolic and physiological processes of the body (Hill & Davies, 2001). Athletes should regularly match energy expenditure with energy intake. Adequate energy intake is crucial for maintaining energy balance. There are three popular methods used in determining energy intake which are: dietary recall, food record, and food frequency questionnaires (Hill & Davies, 2001). Food recalls gain information on recent energy intake, usually the last 24 hours. The food recall is normally done in an interview session and the researcher records the data. Food records are performed in order to gain information on habitual energy intake. The most accurate food records are collected 7-14 days (Schoeller, 1995). Some studies infer that 3 to 7 days of food records are considered accurate (Hill & Davies, 2001). This shorter time period is thought to deliver more compliance by the subjects. The food record differs from a food recall in that the food record is completed by the participant independently and the food recall is completed with the researcher. A three to four day dietary record is the most widely used for studies using the athletic population (Magkos & Yannakoulia, 2003). The food record is laborious which results in its biggest disadvantage when used for research purposes (Hill & Davies, 2001). Although laborious, dietary records are often used because they are inexpensive and noninvasive. Another method used to gain information on dietary intakes is a food frequency questionnaire. A food frequency questionnaire consists of questions regarding the kinds of foods one has eaten and how often they consume these foods (McKeown et al., 2001). These questionnaires can vary depending on country, economic status, etc. Studies show that food frequency questionnaires are an accurate report of energy intake habits, especially for generalizing a population, but not as accurate for individual recommendations (Hill & Davies, 2001; Schoeller, 1995).

Underreporting of energy intake poses a problem when gathering dietary data. Studies show that when self reported energy intake (food records) are compared to reported energy intake (doubly labeled water technique) evidence of under recording energy is strong (McKeown et al, 2001; Hill & Davies, 2001; Schoeller, 1995). The most common reasons for underreporting of dietary data are errors in recording quantities and descriptions of foods or altering dietary intake during periods of data gathering in order to improve the perception of what is consumed (Burke, Cox, Cummings, & Desbrow, 2001). Because female athletes tend to engage in weight loss practices, monitor their energy intake, and strive for the *ideal* body, it is likely that they underreport their energy intake when completing food records or dietary recalls (Schoeller, 1995). Underreporting overall energy intake is not the only limitation when studying dietary habits of athletes. Other limitations include imprecise recording of portion sizes, fluid intake, supplement use, weight control actions, and snacking (Magkos & Yannakoulia, 2003). The weight control practices can include not recording extra workout sessions, especially if the workout session was not a team scheduled event. Underreporting exercise is just as detrimental to research as underreporting energy intake.

Estimating Overall Energy Requirements for Athletes

Precise energy requirement assessments are essential in determining the efficiency of planned nutrition interventions for athletes, which are often set in place to improve performance. Athletes should strive to match energy intake with energy expenditure and meet their energy requirements on a regular basis (Ismail, Wan Nudri, & Zawiah, 1997). Because athletes are influenced by a variety of physical, metabolic, and environmental factors, estimating energy requirements of individual athletes can be difficult (Broeder, Burrhus, Svanevik, & Wilmore, 1992; Thompson & Manore, 1996). There are three variables included in overall energy expenditure that must be considered when estimating overall energy requirements. These variables include RMR, physical activity, and the thermic effect of food (TEF) (Jeukendrup & Gleeson, 2004; Schulz, Alger, Harper, Wilmore, & Ravussin, 1992; Owens et al, 1986). There are many techniques that exist to determine overall energy requirements including estimation equations, indirect calorimetry, and direct calorimetry (Ainslie, Reilly, & Westerterp, 2003; Liu, Woo, Tang, Ng, Ip, & Yu, 2001).

Resting Metabolic Rate

Resting metabolic rate (RMR) accounts for approximately 65-70% of daily energy expenditure. Thermic effect of food is the energy required for food to go through the biochemical processes of digestion and absorption within the body and accounts for approximately 10-15% of total daily energy expenditure (Schulz, Alger, Harper, Wilmore, & Ravussin, 1992; Crovetti, Porrini, Santangelo, & Testolin, 1997). The thermic effect of food is a small percentage of total energy expenditure; therefore the main variables in estimating energy expenditure are RMR and physical activity.

Given that RMR is the most important determinant in estimating daily energy expenditure; accuracy in predicting RMR is important (Kien & Ugrasbul, 2004). Resting metabolic rate can be measured by direct and indirect calorimetry as well as estimated by equations. Metabolic carts (indirect calorimetry) measure the exchange of gases via a ventilated hood (Lorenzo, Bertini, Puijua, Testolin, & Testolin, 1999). The gas exchange being measured is the amount of oxygen consumed versus the amount of carbon dioxide produced (Lorenzo, Bertini, Puijua, Testolin, & Testolin, 1999). Studies show that the metabolic cart is considered a reliable source for gathering information on resting metabolic rate and has been used to test the validity of other instruments and equations used to measure metabolic rate (Pinnington, Wong, Tay, Green, & Dawson, 2001; Peel & Utsey, 1993). The availability of the metabolic cart can limit its use in many counseling settings and athletic venues. The gold standard for testing resting metabolic rate is the doubly labeled water technique (Kien & Ugrasbul, 2004). This technique is an indirect way of measuring energy expenditure which consists of administering a subject a known amount of water (Broemeling & Wolfe, 1993). Although precise, these two methods of determining energy expenditure can be impractical (Schoeller, Colligan, Shriver, Avak, & Bartok-Olson, 2000).

A common method of estimating energy requirements of athletes is based on equations estimating RMR (Frankenfield, Roth-Yousey, & Compher, 2005; Lawrence & Ugrasbul, 2004; Thompson & Manore, 1996). Some of the most popular equations for estimating RMR are Harris- Benedict, Cunningham, Mifflin et al, and Owens et al equations (Thompson & Manore, 1996). Two of the most common equations used are the Harris-Benedict and the Cunningham equations. Equations are often used by nutritionists, registered dietitians, and other specialist because they are cheap, quick, and can be assessed in any situation.

Harris and Benedict Equation

The Harris-Benedict equation is the oldest equation still used in the clinical setting (Frankenfield, Roth-Yousey, & Compher, 2005). This equation estimates RMR and uses a coordinating physical activity factor to estimate total energy required per day. The Harris-Benedict equation estimates energy requirements based on height, weight, age, and gender (Harris & Benedict, 1919). The equation was established from a sample of 239 healthy individuals including males (136) and females (103) (Frankenfield, Roth-Yousey, & Compher, 2005; Cunningham, 1980). Of this population, 16 males were classified as athletes (Harris & Benedict, 1919). This equation was developed over a time frame of approximately 10 years (1907-1917) (Frankenfield, Roth-Yousey, & Compher, 2005; Harris & Benedict, 1919). The Harris and Benedict equation has been found to underestimate energy requirements of individuals with high LBM and overestimate energy requirements for those with high body fat or obese individuals (Harris &

Benedict, 1919; Thompson & Manore, 1996; Owens et al, 1986). Some studies have found the Harris-Benedict equation to have a precision rate of (+/- 14%) or (+/- 200 kilocalories) (Roza & Shizgal, 1985; Kien & Ugrasbul, 2004). The Harris-Benedict RMR is multiplied by an activity factor in order to estimate total daily energy requirements (Rodriguez, DiMarco, & Langley, 2009). Although the Harris-Benedict equation does not account for LBM, the original study does mention that LBM could be the determining factor for estimating RMR (Harris & Benedict, 1919).

Cunningham Equation

John Cunningham (1980) supported Harris and Benedict's idea that LBM may be the best predictable variable in estimating RMR. According to Cunningham, LBM can account for approximately 70% of RMR (1980). RMR differs from BMR because RMR is not always measured following an overnight fast prior to any of the days' activities (Kern, 2005). For the purposes of this study, RMR was measured because subjects participated in minimal daily activity through the process of arriving at the testing center. Cunningham's study used the data from Harris and Benedict's original study of 223 healthy subjects. Sixteen male subjects were dropped from the study because they were identified as well trained athletes (1980). The subject's sex, age, and weight were taken from the original study and a formula was created that estimated LBM (Lorenzo, Bertini, Puijia, Testolin, & Testolin, 1999). The estimated LBM was then plugged into what is now known as the Cunningham formula to estimate RMR. Some studies have concluded that when compared to measured values, the Cunningham equation is the most accurate equation in estimating RMR because it takes LBM into consideration (Lorenzo, Bertini, Puijia, Testolin & Testolin, 1999; Thompson & Manore, 1996; Cunningham, 1980).

Comparison of Harris and Benedict and Cunningham

Many studies conclude that LBM is the best predictor of resting metabolic rate (Thompson & Manore, 1996; Mifflin et al, 1990; Cunningham, 1982; Cunningham, 1980). The main difference in these equations is that the Cunningham equation uses LBM as a variable in predicting resting metabolic rate, whereas the Harris-Benedict equation uses height, weight, age, and gender as main variables. Because LBM is considered to be one of the best predictors of estimating resting metabolic rate, it may be better suited for estimating daily energy recommendations when compared to equations like Harris-Benedict which do not use LBM as a variable. Several previous studies have suggested the use of the Cunningham equation with various athletic populations (Smith, Dollman, Withers, Brinkman, Keeves, & Clark, 1997; Thompson & Manore, 1996; Broeder, Burrhus, Svanevik, & Wilmore, 1992; Cunningham, 1980).

Estimating overall energy requirements for athletes is difficult because the above formulas were not created for the athletic population; however they are the easiest universal method to use. Although not athletes, the populations used to create these formulas were considered relatively lean and active (Thompson & Manore, 1996; Cunningham, 1980). The sample population should be the determining factor for which equation is used to estimate RMR for approximating energy requirements. Recommendations for athletes based on equations alone require close monitoring of the athletes' energy intake and body composition due to the error rate of the equations.

Physical Activity Factors Used to Estimate Energy Requirements

Physical activity is the most variable component of daily energy expenditure, accounting for approximately 20-30% (Sjodin et al, 1995; Liu, Woo, Tang, Ng, Ip, & Yu, 2001). In fact, Jeukendrup and Gleeson (2004) state that physical activity in athletes can vary from 30% to 50% of daily energy expenditure. The physical activity factor is an integer multiplied by RMR to obtain an individual's total estimated daily energy requirements. The physical activity factor is based on the duration, frequency, and intensity of an individual's physical activity. The physical activity factor accounts for additional energy required for certain added activities, which is why it is an important assessment tool when estimating RMR. According to Zalcman (2007) an appropriate activity factor for an active individual is 1.7. Each individual athlete's physical activity factor will vary based on mode, season, and training schedule; thus estimating one's physical activity factor can be challenging for nutrition professionals. Alfonzo-Gonza´lez and colleagues (2004) state that the Food and Agriculture Organization of the United Nations, World Health Organization, and the United Nations University (FAO/WHO/UNU 1985) activity factor of low activity (1.55 and 1.56) and high activity

(1.82 and 2.1) for female and males, respectively, often overestimate energy requirements. Physical activity factors vary, for example Rabeneck (1998) uses activity factors as very light 1.3, light 1.6, moderate 1.7, and heavy 2.1. Studies show variations between 1.3 and 1.6 for estimating physical activity expenditure, however most support the lower range of activity factors compared to the higher range of the activity factors stated by FAO/WHO/UNU 1985 (Bauer, Reeves, & Capra, 2004; Nielsen, Kondrup, Martinsen, Stilling, & Wikman, 1993). While several factors influence physical activity level, a reasonable activity factor for healthy athletes in general training is considered to range from 1.6-1.8 (Zalcman, 2007; Zello, 2006). The position of the American Dietetic Association, Dietitians of Canada, and American College of Sports Medicine (2009) states that acceptable activities factors range from 1.8-2.3.

Summary

Energy balance is important for athletes in order to maintain a healthy nutritional status, LBM, and optimize their athletic performance (Manore, Barr, & Butterfield, 2000; Ziegler, 2001). Energy intake also plays a major role in weight management, including weight loss, and weight gain (Westerterp-Plantenga, 2004). Thus, meeting daily energy expenditure represents a major key to optimal weight and performance among athletes (ADA Reports, 2005).

Although energy restricted diets are relatively common among both women and men engaged in weight-restricted and aesthetic sports, such as gymnastics, track and field, diving, and rowing (Ziegler, Nelson, Barrat-Fornell, Fiveash, & Drewnowski, 2001; Bishop, Blannin, Walsh, Robson, & Gleeson, 1999), research shows that female athletes are at a particularly high risk for under consuming calories (Ziegler & Jonnalagadda, 2006; Ziegler et al, 2001) compared to male athletes in the same sports (Ziegler & Jonnalagadda, 2006; Mullinix, Jonnalagadda, Rosenbloom, Thompson, & Kickligher, 2003; Manore, 2002; Ziegler et al, 2001). Under consumption of energy puts female athletes not only at risk for decreased performance and LBM, but lack of energy may also have long term health and nutritional consequences, including amenorrhea, bone loss, and eating disorders (Nichols, Sanbourn, & Essery, 2007). Current research suggests that amenorrheic athletes have 10-25% lower bone mineral density at the lumbar spine versus the eumenorrheic athlete (Nichols, Sanbourn, & Essery, 2007).

Estimating energy intakes of athletes currently poses a challenge because existing methods of estimating energy requirements were not derived using the athletic population. The gold standard of estimated RMR is a doubly labeled water technique;

however this method is not always accessible and practical. This is true for DEXA as well, which is currently accepted as the gold standard for measuring body composition. Furthermore, no specific standards for ideal body fat percentage currently exist for athletes (Jeeukendrup & Gleeson, 2004). The ideal body composition is highly dependant on the particular sport and should be advised on an individual basis, taking genetics, body frame, and other factors into consideration. Another challenge in estimating athletes' energy intakes is the assessment of energy consumption by dietary recalls, food records, or food frequency questionnaires which all have limitations of underreporting and/or over reporting (Hill & Davies, 2001).

The main purpose of this study was to evaluate energy intakes of a sample of female collegiate athletes. Reported energy consumption of each athlete was compared to their calculated energy requirements determined using measured RMR plus an appropriate physical activity factor. The second purpose of the study was to determine whether differences between actual resting metabolic rate and resting metabolic rate estimated using the Harris-Benedict and Cunningham equations, exist in the target population. The third purpose of the study was to explore the relationship between reported energy intakes and body composition of the female athletes, including lean body mass (LBM) and fat mass (FM). Finally, the relationship between individual's reported energy intake and score on the EAT-26 test was explored.

CHAPTER III

METHODOLOGY

Research Design and Subject Selection

This exploratory study used a convenience sample of collegiate female athletes who were recruited from several sports teams at a large mid-western university in the United States. A written approval was obtained from the Athletic Director prior to the beginning of the study. Athletes were informed about the purpose, nature and details of the study using written informed consent forms and they were recruited for the study by athletic trainers. A written informed consent form was obtained from each athlete prior to data collection. Data collection days and times were scheduled and coordinated through each team's individual athletic trainers. Subjects were recruited from a variety of athletic teams and consisted of soccer players, cross-country and/or track and field athletes, and basketball players. The study was approved by the Institutional Review Board at Oklahoma State University.

Study Procedures

Subjects were asked to visit a metabolic lab in the Department of Nutritional Sciences in the morning hours on a previously scheduled day. Subjects were asked to fast over night and limit their physical activity on the night before and the morning of their visit to the lab. They were asked to arrive to the testing laboratory via motorized vehicle and instructed to take the elevator to the laboratory room. The information was collected from subjects within a 1.5 hour visit, except for the 3-day food records that were collected from athletes within 1-2 weeks after the lab visit. Each participant was assigned an ID number in order to maintain confidentiality of the subjects. The measure obtained from each subject included height, weight, resting metabolic rate (RMR), body composition, a nutrition questionnaire (NQ), a 24-hour recall, a 3-day food record, and an EAT.

Anthropometric Data

Height was measured to the nearest 0.10 cm using a wall mounted stadiometer (Harpenden, Holtain, Creymmich, Pembrookshire, United Kingdom). Weight was measured (while wearing only minimal clothing) to the nearest 0.10 kg using an electronic scale (Seca 664, Hamburg Germany). Body composition was measured by the (DEXA) (QDR 4500A Hologic Inc, Bedford, MA). DEXA is based on photon attenuation of fat mass, fat-free mass, and bone mineral density (Plank, 2005). DEXA houses two x-ray beams working at different frequencies inside one scanner (Visser et al, 1999 &; Brunton, Bayley, & Atkinson, 1993). As this total body scanner travels over the body, it records data on bone mineral content and soft tissue composition (Morrison et al, 1994). The scanner passes over the entire body and provides detailed results in approximately three to five minutes (Visser et al, 1999). Scrubs were provided for the subjects and all metal was removed before the DEXA scan. Subjects were positioned on the machine by a trained technician and informed to close their eyes as the x-ray scanner passed over their heads. The DEXA scan took approximately three to five minutes per athlete. Detailed printouts of body composition were obtained from the scan.

Resting Metabolic Rate

RMR was measured by indirect calorimetry using a metabolic cart (Vmax Encore, Viasys, Yorba Linda, CA). During this test, a clear canopy was placed over the head and shoulders of each subject to measure carbon dioxide produced and oxygen consumed for 20 minutes (VCO2/VO2). The metabolic cart was located in a private room to minimize any distractions. The room was kept at a temperature of approximately 73 degrees to ensure a relaxing atmosphere. All subjects were monitored during this time to ensure their comfort. In addition to using indirect calorimetry to measure metabolic rate, RMR was also estimated for each subject using the Harris-Benedict and Cunningham equations. The two equations are shown in table 3.1.

Table 3.1 Equations Used to Estimate RMR of Female Athletes

Name	**Equation**
Harris-Benedict	RMR=655.1+9.56(wt)[a]+1.85(ht)[b]-4.68(age)[c]
Cunningham	RMR =500+(22*LBM)[d]

[a] body weight (kg); [b] height (cm)
[c] Age in years; [d] Lean body mass +BMC

Physical Activity Level

Physical activity level of the subjects was determined using data from a combination of two research instruments used in the study. First, subjects were asked to complete the NQ that included questions related to their training regimen, including both the amount and intensity of exercise. Second, data on physical activity was recorded during a 24 hour food recall interview that was conducted by a trained research assistant with each subject. The subjects were asked what sport they were involved in and what position they played. In addition, detailed information about the amount and intensity of training was recorded for each subject. Data on physical activity from both the NQ and the 24-h dietary recall were used to determine an appropriate physical activity factor for each athlete that was then utilized to calculate their total daily energy expenditure. Activity factors used were sedentary (1-1.4), low active (1.4-1.5), active (1.6-1.8), and heavy active (1.9) or greater (Zalcman, 2007; Zello, 2006; & Rabeneck 1998). Given that all subjects participating in the study reported high levels of physical activity during the study (1.6-1.8) and none of them were sick or injured, a physical activity factor of 1.7 was used to estimate the RMR of every subject.

24 Hour Recall & 3-day Food Records

Reported dietary energy intakes of the subjects were assessed by a 24-hour recall and a 3-day food record. A multiple-pass method was used to conduct the 24 hour recalls. First, subjects were asked to recall all foods and beverages consumed during the previous 24 hours. Then, the subjects were asked to elaborate on and specify some of the reported foods or beverages while the interviewer helps the subjects recall whether they consumed any other foods/drinks not previously recorded. Finally, the subjects were asked about cooking methods used for food preparation and if any condiments or other ingredients were added (USDA, 1998; Moshfegh, Borud, Perloff, & LaComb, 1999; Lytle et al., 1993). In order to help stimulate memory of the subjects, plastic food models, real food examples, and household measuring tools (cups, tablespoons, glasses, bowls, etc.) were used during the 24-hour recalls. A 3-day food record was also completed by the subjects. Detailed instructions on how to complete the 3-day food records were provided to the subjects at the end of the 24-h recall interview. Subjects were asked to record the quantity of all foods and beverages consumed in 3 days (one weekend day and two week days) in household measurements, as well as to record brand names, methods of food preparation, and ingredients of recipes where possible. When food was eaten outside the home, a record of the description of the food, place of purchase, and amount eaten were requested. When possible, portion sizes and food comparisons were recorded from the food manufacture's website or corresponding foods were purchased by the researchers in order to determine the nutrient composition of the particular food/beverage. The Diet Analysis 8.0 software program was used to analyze all foods and beverages obtained from the 24-hour recalls (Thompson learning, Belmont CA). The analyzed food records included all four days of recorded dietary intakes (one 24 hour recall and one 3-day food record). Two trained research assistants entered and analyzed the dietary intakes independently and the correlation coefficient between the two research assistants was r=0.98 for total energy intake, r=0.96 for total carbohydrate intake, r=0.96 for total fat intake and r=0.95 for total protein intake. When substantial differences in data entry were identified between the two research assistants, the dietary records were examined by the primary investigator and corrections were made in the dataset.

Eating Attitude Test

Subjects also completed EAT-26 which is a 26-item questionnaire designed to detect potential signs and concerns of eating disorders (Lane, Lane, & Matheson, 2004; Garner, Olmsted, Bohr, & Garfinkel, 1982). The EAT score is based on responses to the

26 items as follows: Never, Rarely, Sometimes, Often, Very Often; and Always. The first three responses are scored zero, with the last three responses scored 1, 2, and 3 respectively (Lane, Lane, & Matheson, 2004). A score greater than 20 is considered to be an indicator of a possible disordered eating problem. Individuals who score 20 or above on the EAT-26 test are encouraged to seek clinical counseling, or in a research setting the data is reported as suggesting a possible eating disorder in some subjects (Lane, Lane, & Matheson, 2004).

Statistical Analysis

Descriptive statistics, including means and standard deviations, frequencies and percentages, were used to describe the sample. The RMR measured by Vmax metabolic cart was compared to the RMR estimated by the Harris-Benedict and Cunningham equations (Harris, & Benedict, 1919; Cunningham, 1980). These comparisons were assessed using Student's paired t-tests. The energy requirements determined from the Vmax Metabolic Cart and the appropriate physical activity factors were compared with the reported dietary energy intakes using Student's paired t-test. Bivariate correlations were utilized to explore relationships between energy intakes and body composition, including lean body mass and fat mass. Lastly, body composition (LBM and body fat) were compared between the subjects who met and who did not meet their daily energy requirement using the Mann-Whitney nonparametric test. Level of significance for all statistical tests was set at $p<0.05$.

CHAPTER IV

FINDINGS

Demographics

Forty-five female athletes participated in this study. Sixteen were from the track & field team, 18 were from the soccer team, and 11 were from the basketball team. Seventy one percent (n= 32) of the subjects were Caucasian, 24% (n=11) of the subjects were African American, and 4% (n=2) of the subjects were Hispanic. Mean age of the subjects was 20.0 ± 1.5 years. Mean weight was 144.0 ± 26.0 pounds and mean height was 67.0 ± 3.0 inches. Demographic characteristics of the athletes, including age, weight, height, and race are summarized in Table 4.1.

Table 4.1 Descriptive Characteristics of Female Athletes (n= 45)

Characteristic	**Mean ±SD***	**Minimum**	**Maximum**
Age (yrs)	20.0 ± 1.5	18	23
Weight (lb)	144.0 ± 26.0	104	219
Weight (kg)	65.0 ± 12.0	47	99
Height (in)	67.0 ± 3.0	60	73
Height (cm)	167 ± 8.0	153	185
Race	**n (%)**		
Caucasian	32 (71)		
African American	11 (24)		
Hispanic	2 (4)		

*(SD) = Standard Deviation

Body Composition

Body composition measurements using DEXA were completed with all subjects participating in the study. Percent body fat, LBM, and fat mass of the subjects are presented in Table 4.2. Twenty-one out of 45 athletes had a body fat percent between 20-30% which is considered healthy for the general population (Sawyer, hypes, & Brown, 2003; Coleman, 2003; Armstrong, et al., 2006). Four athletes had a body fat percentage under 14% which some classify in the range of essential body fat for women (12-15%) (Sawyer, Hypes, & Brown, 2003; Coleman, 2003; Armstrong, et al., 2006), and one athlete had a body fat percent that fell at the bottom of the essential fat range which was 12% (Rodriguez, DiMarco, & Langley, 2009; Jeukendrup & Gleeson, 2004; Sawyer, Hypes, & Brown, 2003). BMI of the subjects ranged from 18.8 to 31.3 kg/m^2 with an average of 22.7 ± 2.9 kg/m^2 which falls within the normal category. However, there were 8 subjects with a BMI greater than 25 kg/m^2 which classifies as overweight. No subjects had a BMI of less than 18.5 kg/m^2 which is the upper cut-off for the underweight category. However, 3 subjects had BMI lower than 19 kg/m^2, including BMI of 18.7 kg/m^2, 18.8 kg/m^2, and 18.9 kg/m^2. There were no significant trends between BMI and body fat percentages of the subjects. Table 4.3 shows a comparison of BMI and percent body fat.

Table 4.2 Body Composition of the Female Athletes Participating in the Study (n= 45)

Characteristic	Mean ±SD*	Minimum	Maximum
Body fat (%)	19.5 ± 4.0	12.0	28.0
Fat mass (kg)	52.7 ± 8.0	37.0	74.0
LBM (kg)	13.0 ± 4.0	6.4	26.6

*(SD) Standard Deviations

Table 4.3 Comparison of BMI and % Body Fat

BMI	Body Fat (%)	BMI Continued	Body Fat (%) Continued
18.77	14.7	22.32	18.2
18.8	13.6	22.48	23.7
18.95	18.7	22.61	22.9
19.06	17.3	22.62	23.7
19.1	16.7	22.66	13.7
19.2	21.6	22.92	14.8
19.64	19.0	23.11	18.2
19.66	17.6	23.34	16.2
19.74	21.5	23.55	17.6
19.97	13.6	23.56	16.9
20.36	11.9	23.89	19.8
20.4	16.8	24.46	20.9
20.77	15.9	24.47	22.3
21.01	21.6	24.54	22.2
21.22	20.1	25	22.9
21.26	20.8	25.17	18.5
21.37	17.6	25.35	22.7
21.55	18.3	25.83	24.8
21.6	17.7	26.73	25.3
22.04	20.2	27.46	21.1
22.14	15.0	28.09	27.8
22.31	22.5	29.07	26.6
		31.25	23.6

Resting Metabolic Rate, Energy Requirements, & Energy Intakes

A total of 33 subjects (73% of the original sample) participated in RMR measurements. The mean RMR of the sample was 1378.0 kcals. A comparison of RMR measured by metabolic cart (indirect calorimetry) and RMR estimated by Harris-Benedict and Cunningham equations is shown in Table 4.4. The estimated RMR using both Harris-Benedict and Cunningham equations was significantly higher compared to the measured

RMR ($p<0.001$). Also the difference between the two equations was significant. The Harris-Benedict equation was shown to estimate RMR significantly lower than the Cunningham equations ($p<0.001$). Harris-Benedict equation overestimated RMR, on average, by 116.5 kcals (92% accuracy), and Cunningham equation overestimated RMR by 280.4 kcals (83% accuracy). The Harris-Benedict equation estimated RMR within ±200 kcals for 28 of the 33 subjects (85% accuracy ± 200 kcals). The Cunningham equation estimated RMR within ± 200 kcals of measured RMR for 11 of the 33 subjects (33% accuracy ± 200 kcals).

Table 4.4 Resting Metabolic Rate of Female Athletes (n=33)

Method of Measurement	**Mean ±SD***	**Minimum**	**Maximum**
RMR (kcals/day)	1378.0 ± 217.6	859.0	1885.0
Harris-Benedict (kcals/day)	1490.8± 123.9[a]	1286.7	1845.7
Cunningham (kcals/day)	1658.2 ± 185.2[b]	1349.6	2118.1

*(SD) = Standard Deviation
Sources: Harris-Benedict, 1919, Frankenfield, Muth, & Row, 1998, Cunningham, 1980
***significant at ($p<0.001$)
[a] Significant difference between Harris-Benedict RMR estimation and measured RMR
[b] Significant difference between Cunningham RMR estimation and measured RMR

To determine the subject's total energy requirements, the measured RMR (V Max Encore), and RMR estimated by the Harris-Benedict and Cunningham equations were multiplied by a physical activity factor of 1.7 for all subjects (Bauer, Reeves, & Capra, 2004; Nielsen, Kondrup, Martinsen, Stilling, & Wikman, 1993; Rabeneck, 1998; Woo, Tang, Ng, Ip, & Yu, 2001).

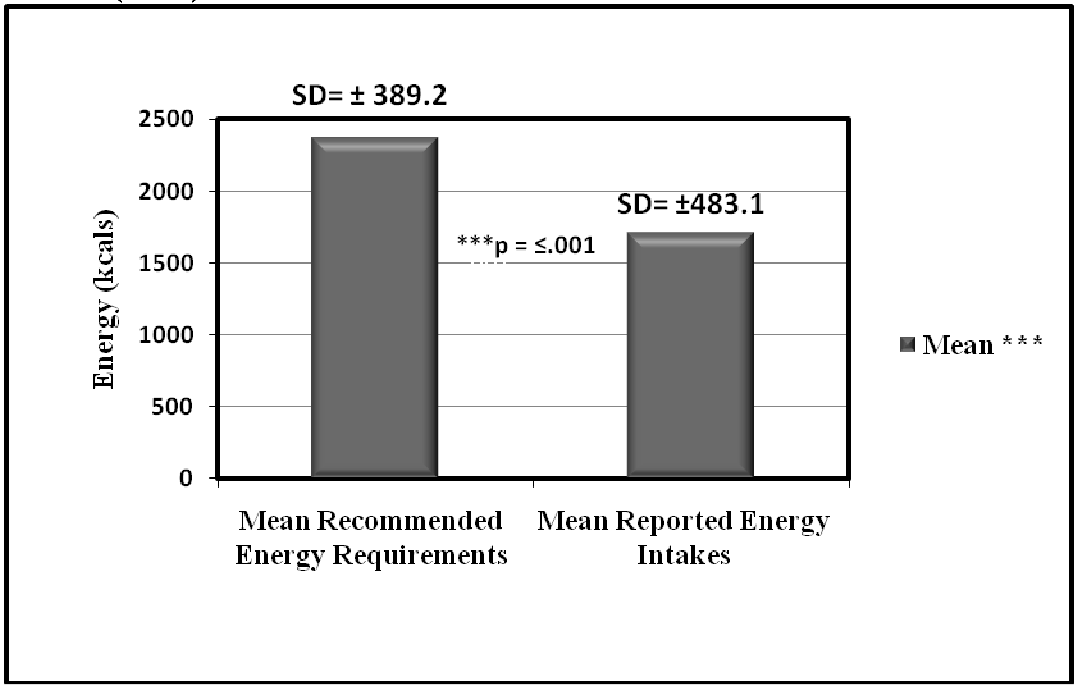
Table 4.5 Resting Metabolic Rate of Female Athletes with Added Activity Factor (n=33)

Method of Measurement	**Mean ±SD***	**Minimum**	**Maximum**
Metabolic Cart x PAF[a]	2342.7 ± 369.9	1460.3	3204.5
Harris-Benedict x PAF[a]	2535.7 ± 212.8	2187.4	3137.8
Cunningham x PAF[a]	2821.0 ± 311.6	2294.4	3600.8

*(SD) = Standard Deviation
[a] (PAF) = Physical Activity Factor of 1.7

The reported daily energy intake (a 4-day average) of the subjects was 1704.5 ± 483.1 kcals/day. Figure 4.1 compares the reported mean energy intakes to the recommended energy requirements of the athletes in this sample. Only 29 subjects (64% of the original sample) participated in both the metabolic cart measurements and the 4 day food record completion and are included in Figure 4.1. The mean recommended energy requirements for the entire sample of female athletes was 2364.0 kcals per day which was significantly lower compared to the athletes' mean reported energy intakes of 1704.5 kcals per day ($p<0.01$).

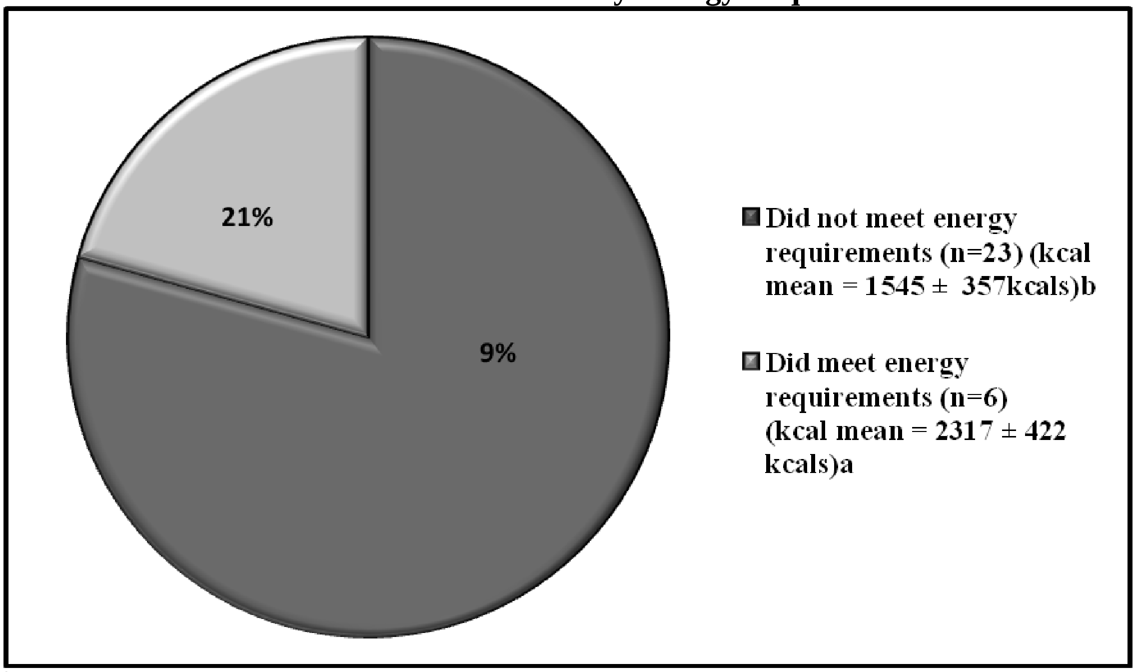
Figure 4.1 Recommended Energy Requirements Compared to Reported Energy Intakes (n=29)



Reported energy intake includes an average of 4-day food records

From the 29 subjects who completed both the RMR measurements and the dietary data collection (24-hour recall plus the 3-day food records), 23 did not meet their energy requirements within ±100 kcals a day. Figure 4.2 shows the percentage of the subjects who met and did not meet the recommended energy requirements. The average energy intakes of those who did not meet their energy requirements was 1545.0 kcals and the average energy intakes of those who did meet their energy intakes was 2317.0 kcals. The highest 4-day average energy intake from the 23 subjects who did not meet their enery needs was 1966.0 kcals. The lowest 4-day average energy intake was 835.0 kcals per day.

Figure 4.2 The Comparison of Mean Reported Energy Intakes between Subjects Who Met and Did Not Meet Their Total Daily Energy Requirements



[a]= Reported energy intake for the group of subjects who met their energy requirements (mean±SD)
[b]= Reported energy intake for the group of subjects who did not met their energy requirements (mean±SD)

Body composition, including LBM and body fat percentage, was also examined within the sample. A comparison of body composition was made between the subjects who met and who did not meet their energy requirements using the Mann-Whitney test. Figure 4.3 shows the LBM of the 6 subjects who met their recommended energy intakes compared to that of the 23 who did not meet their recommended energy intakes. Figure 4.4 also shows the comparison of body fat percentage between the 6 subjects who did meet their recommended energy intakes to the 23 who did not meet their recommended energy intakes.

Figure 4.3 Comparison of Body Composition Including LBM and FM (n=29)

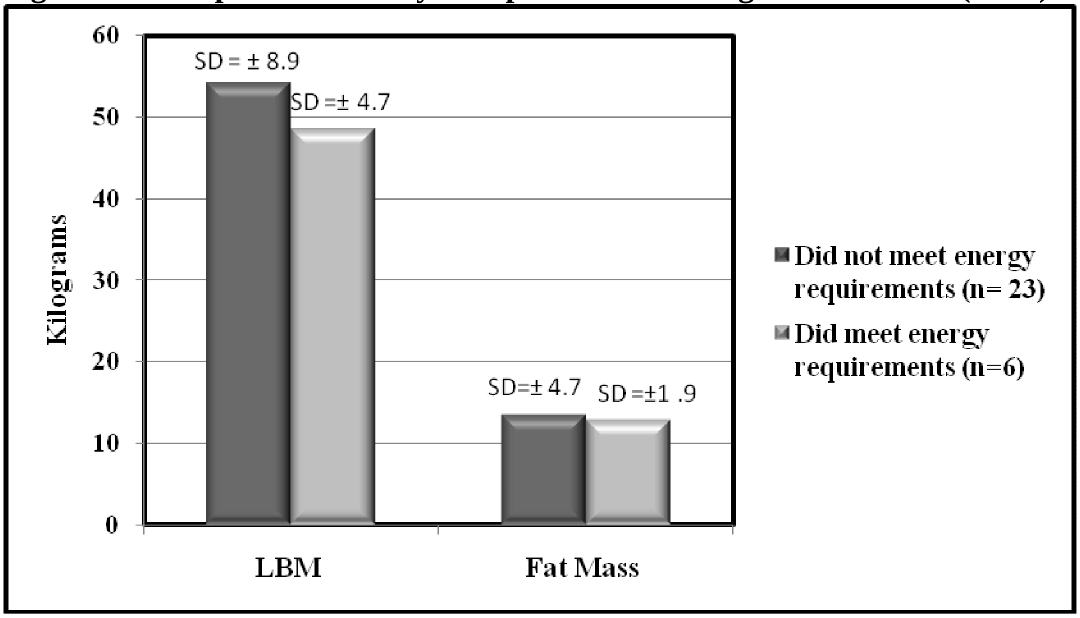
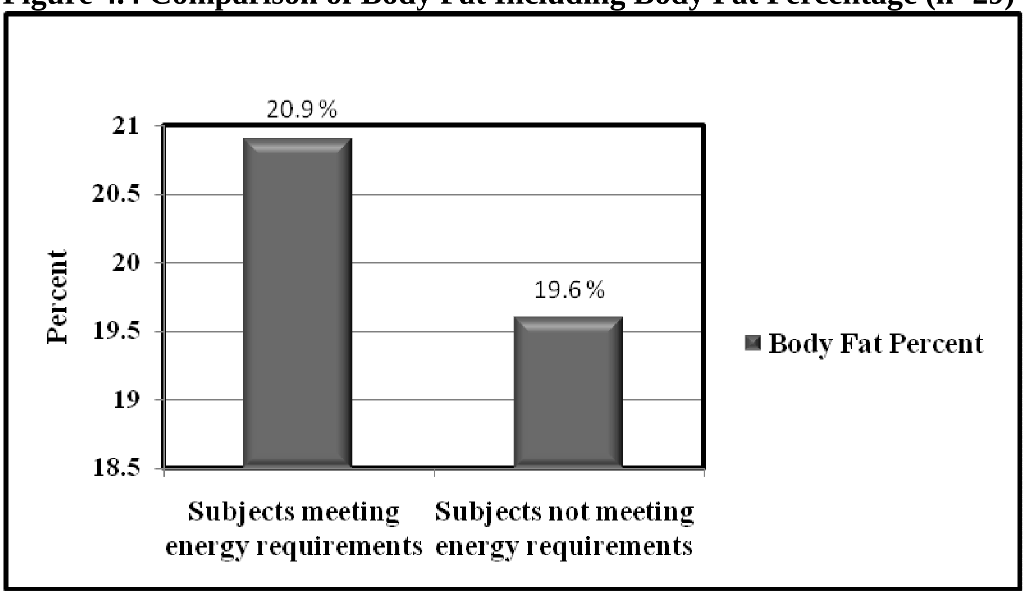
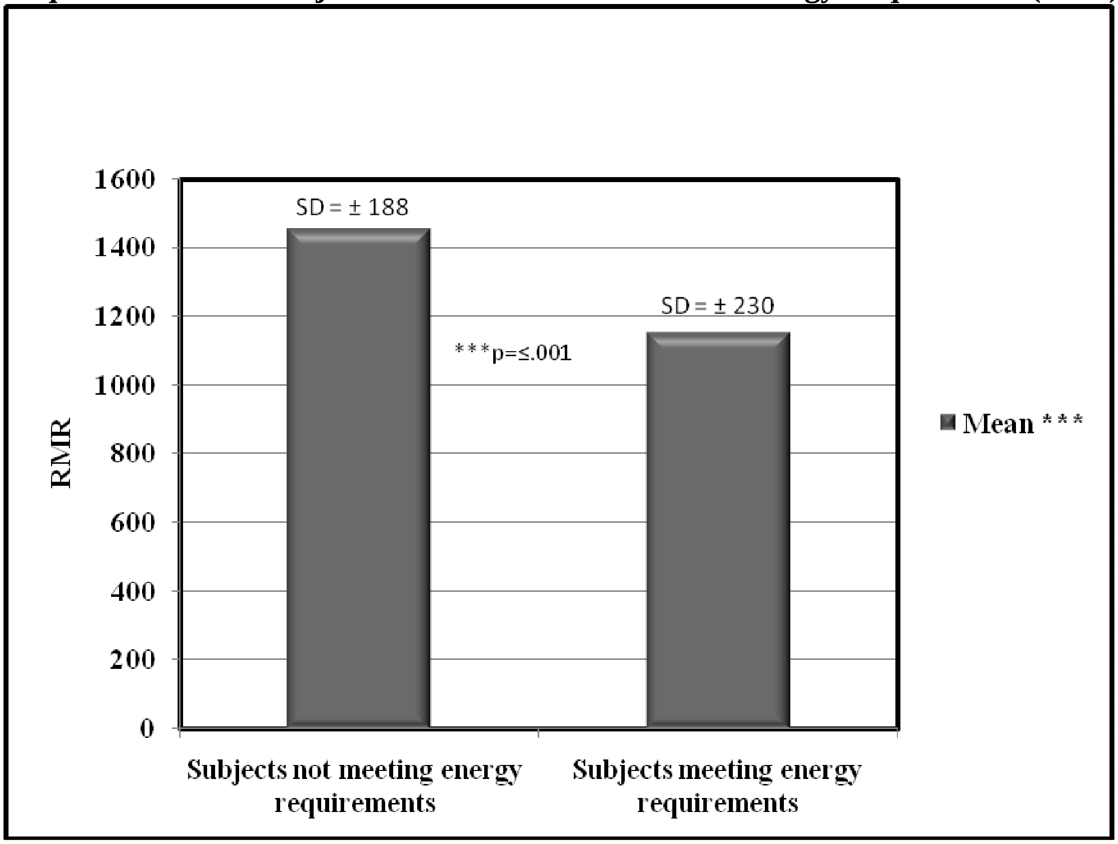


Figure 4.4 Comparison of Body Fat Including Body Fat Percentage (n=29)



The Mann-Whitney test showed there was not a significant difference between the two groups of athletes in categories including LBM, fat mass, and body fat percentage. The 6 female athletes who did meet their total energy requirments averaged LBM of 48.6 kg, fat mass of 12.9 kg, and body fat percent of 20.9%. The 23 female athletes who did not meet their energy recommendations averaged LBM at 54.2 kg, fat mass at 13.5 kg, and body fat percent at 19.6 %. The relationship between total energy intake and LBM was also not significant ($p = 0.732$). Similarly, the subjects' total energy intakes were not associated with total fat mass ($p = 0.720$). Resting metabolic rate measured by metabolic cart resulted in a mean RMR of 1453.0 ± 188 kcals for the group of athletes who met their energy requirements and in a mean RMR of 1154.0 ± 230 kcals for those who did not meet their energy requirements. There was a positive but non-significant relationship between RMR (measured by metabolic cart) and the reported energy intake in the group of athletes who failed to meet their estimated total daily energy needs ($r=0.21$). Among those who met their total estimated daily energy needs, RMR was also positively, but non-significantly, correlated with their energy intake ($r=0.25$).

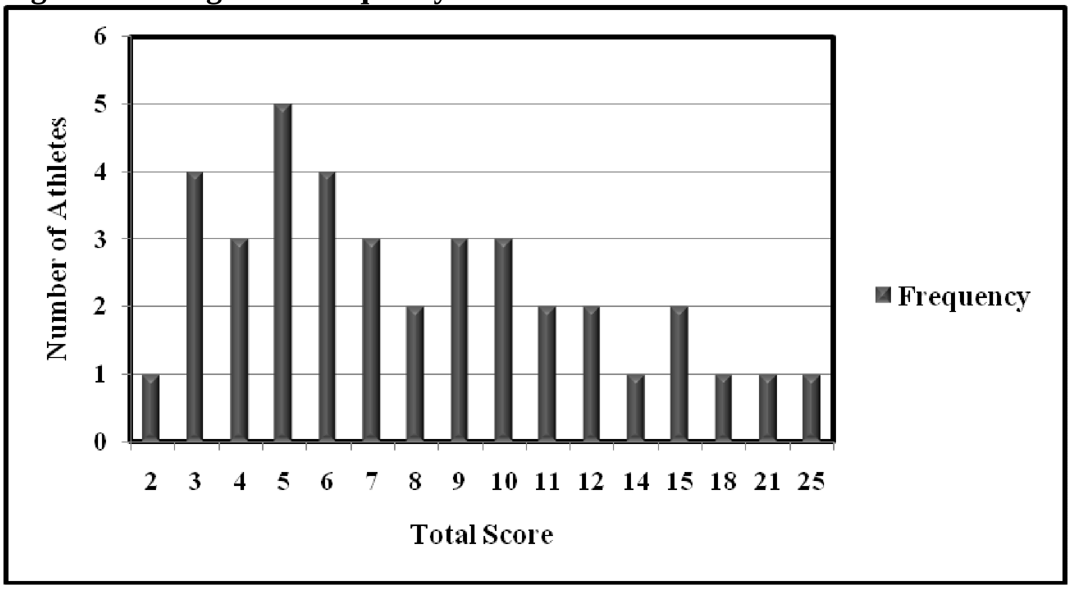
Figure 4.5 Comparison of Mean RMR Between Subjects That Met Their Energy Requirements and Subjects That Did Not Meet Their Energy Requirments (n=29)



Eating Attitude Test

The Eatting Attitude Test (EAT-26) was completed by 38 out of the 45 athletes. There were two athletes with a score over 20 which is indicative of potential signs and concerns of eating disorders. The highest scores were 25, 21, and 18. The subject with a score of 25 did not participate in the RMR measurements and therefore, it is unknown whether the athlete met her recommended energy requirements. However, the subjects with the scores of 21 and 18 failed to meet their recommended energy requirements. The subjects' 4-day food record averages were 1304.0 kcals/day and 1185.6 kcals/day, respectively while the recommeded energy intakes for these subjects were 2468.4 kcals/day and 2308.6 kcals/day. Figure 4.6 summarizes the frequency of the scores.

Figure 4.6 Range and Frequency of Scores on the EAT-26 Test



The average score on the EAT-26 test for the 23 athletes who did not meet their energy requirements was 9. The average score for the 6 athletes who did meet their energy requirements was 7. The questions most commonly scored the highest on were questions 1,6, and 12 (EAT-26 shown in Appendix C).

Table 4.6 Questions with the Highest Frequency (n=23)

Questions	**Always (%)**	**Often (%)**	**Usually (%)**
1. I am terrified about being overweight.	13% (n=5)	8% (n=3)	8% (n=3)
6. I am aware of the calorie content of the foods that I eat.	11% (n=4)	21% (n=8)	21% (n=8)
12. I think about burning up calories when I exercise.	3% (n=1)	16% (n=6)	11% (n=4)

Question 1: “I am terrified about being overweight.” Question 6: “I am aware of the caloire content of the foods that I eat”. Quesiton 12: “I think about burning up caloires when I exercise.” Thirteen percent (n=5) of the female athletes answered *always* to question one, “I am terrified about being overwieght”, and 8% (n=3) answered *often*

and *usually* to the same question. Approximately 21% (n=8) of the athletes answered *often* and *usually* to questions #6, “I am aware of the caloire content of the foods that I eat”, while 11% (n=4) answered *always*. Sixteen percent (n=6) of the athletes answered *often* to question 12, “I think about burning up caloires when I exercise”, and 11% (n=4) answered *usually* with only 3% (n=1) answering *always*. The total EAT score was negatively associated with reported energy intakes of the subjects (r=-0.34; p=0.09) and body fat % (r=-0.17; p=0.93). However to total EAT score was positively associated with LBM (r=0.08; p=0.69). None of these relationships were statistically significant.

CHAPTER V

DISCUSSION

The main purpose of this study was to compare female athletes' reported energy intakes to their recommended energy requirements. The second purpose of the study was to determine whether significant differences between measured RMR and estimated RMR by Harris-Benedict and Cunningham equations exist in a sample of collegiate female athletes. The third purpose of the study was to identify the relationship between reported energy intakes and body composition of the female athletes, including LBM, FM and body fat percentage. Finally, the relationship between individual's reported energy intake and score on the EAT-26 test was explored.

The majority of female athletes participating in this study failed to meet their energy requirements. When we compared the athletes' reported energy intakes with their recommended energy intakes, we found that the average recommended energy intakes for the sample was 2342.65 kcals per day, while the athletes in our sample reported consuming only an average of 1704.50 kcals per day. This study's results support research indicating that female athletes do not meet their recommended energy requirements and experience a negative energy balance on a regular basis (Mullinix et al, 2003; Hassapidou & Manstrantoni, 2001; Estok & Rudy, 1996; Estok & Rudy, 1996; Edward, Lindeman, Mikesky, & Stager, 1993). For instance, Manstrantoni (2001) found that all female athletes participating in their study, with the exception of volleyball players, were in negative energy balance during the competitive season.

Research shows that female athletes with negative energy balances may compromise their performance and their long-term health. Mullinix and colleagues (2003) state that female athletes who consume less than 2400 kcals per day often have inadequate intakes of calcium, magnesium, iron and zinc. Other micronutrients that can be inadequate with long term insufficient energy intakes are niacin, riboflavin, vitamin B6, calcium, and iron (Holschen, 2004; Mullinix, Jonnalagadda, Rosenbloom, Thompson, & Kickligher, 2003). Notably, these vitamins and minerals do not provide energy; they play important roles in the metabolism of macronutrients, which do provide energy. Therefore, athletes with low energy intakes risk a negative energy balance and inadequate stores of some micronutrients.

The second purpose of this study was to determine differences between measured RMR and RMR estimated by Harris-Benedict and Cunningham equations. Accuracy of estimated RMR is important in determining the precise daily energy requirements specific for individual athletes. This study found that the Harris-Benedict and Cunningham equations both estimated RMR significantly higher compared to the measured RMR by Vmax metabolic cart. These results do not support the hypothesis for this study which predicted RMR estimated using the Harris-Benedict equation will be lower than measured RMR. Nor do our findings support previous research which concluded that estimated RMR would be lower than measured RMR (Thompson & Manore 1996). Thompson and Manore (1996) tested other equations used for estimating RMR which included Mifflin et al. (1990) and Owens et al. (1986) (for male and females) and found that predicted values were significantly lower than measured values in all equations but the Cunningham. The Cunningham equation uses LBM as the only variable and several studies conclude LBM is the best predictor of resting metabolic rate (Thompson & Manore, 1996; Mifflin et al, 1990; Cunningham, 1980; Cunningham, 1982). However, our study indicates that the RMR estimated by the Cunningham equation was significantly higher than the RMR measured by the V Max metabolic cart and the RMR estimated by the Harris-Benedict equation. In this study the Harris-Benedict equation is more accurate for estimating RMR than the Cunningham equation. However, this study shows that the Harris-Benedict equation overestimated RMR of individuals considered lean, whereas the Harris-Benedict equation is actually known to underestimate RMR of lean individuals and overestimate energy requirements of obese individuals (Harris & Benedict, 1919; Thompson & Manore, 1996; Owens et al, 1986). Unfortunately, the validity of these equations in the athletic population has not been adequately studied.

In this study, the body fat percentages and BMI were gathered on all subjects. Body fat percentages conducive to peak performance vary among individual athletes. Current body fat percent classifications for the general population range from 20-30% (Sawyer, hypes, & Brown, 2003; Coleman, 2003; Armstrong, et al., 2006). In this study 27 out of 45 subjects fell into the general population's normal range. The average BMI and percent body fat of those with a BMI above 25 was 26.6 kg/m2 and 23%, respectfully. In this study 8 athletes were classified as overweight: measured BMI above 25. This shows that even though their BMI fell in the overweight category, their body fat percent was still within a healthy range. The average BMI and percent body fat of those with a BMI lower than 20 (underweight) were 19.3kg/m2 and 17.4%, respectfully. Once again, the BMI category classifies this group as underweight; however, their body fat percentage is still classified as healthy for female athletes (American Counsel on Exercise, 2009). BMI is an unsatisfactory assessment tool for athletes because it does not account for LBM. LBM (or muscle) weighs more than FM. Therefore, a lean athlete may classify as overweight or obese based on BMI measurements. The same is true with athletes who may be classified as underweight; a small athlete with a low BMI could still have a healthy body fat percentage.

The third purpose of this study was to determine the nature of the relationship between reported energy intakes and body composition between those who met their energy requirements and those who did not meet their energy requirements. This study's results showed that 23 of 29 female athletes (79%) did not meet their energy requirements as measured by Vmax metabolic cart with added physical activity factor. The 6 female athletes that met their total energy requirements averaged a LBM of 48.6 kg. This was less than the 23 female athletes who did not meet their energy requirements and averaged a LBM of 54.2 kg. Also the subjects who met their energy requirnments had a slightly higher, but not significant, amount of fat mass. Although previous research shows that inadequate energy intakes lead to lower LBM (Bryner et al., 1999; Benardot 1996), our findings do not support this argument. Deutz and colleagues (2000) found that energy deficits greater than 300kcals per day were significantly associated with higher body fat in both DEXA-derived and skin fold-derived body fat percentages. Our study also did not support the finding of Zachwieja and colleagues (2001) where short-term dietary energy restriction (2 weeks) resulted in weight loss with most of the loss coming from LBM. Our study did not measure energy deficits or weight loss over time, which could account for our results not supporting previous research by Duetz and colleagues (2000) and Zachwieja and colleagues (2001).

Although no differences in LBM and FM were detected between athletes who did consume their recommended energy requirements and those that did not, our findings support the argument that female athletes consume less energy than recommended and their nutritional status may suffer as a consequence of low energy availability. Inadequate energy intakes of athletes may also significantly influence their athletic performance not only physically but mentally as well (Economos, Bortz, & Nelson, 1993). Economos, Bortz, and Nelson (1993) state it is not uncommon for decreases in an athlete's performance to be traced back to poor energy intake. Previous research has suggested that female athletes often restrict their energy intake despite having high energy demands during training and competition (Manore, Kam, & Loucks, 2007; Edwards, Lindeman, Mikesky, & Stager, 1993). Research has shown that energy deficient individuals will often have a skewed (lower) measured RMR because of the body's ability to adapt to low energy intake (Deutz, Benardot, Martin, & Cody, 1999). This is known as adaptive thermogenesis and can dramatically affect estimated RMR which can lead to lower recommended energy intake in elite athletes (Benardot, 2007; Dulloo & Samee, 2001).

In our study the RMR of those that met their recommended energy requirements was 1154kcals which was lower than the group who did not meet their recommended energy requirements 1453kcal. Therefore the group who met their energy requirements consumed less energy in order to meet the requirement. There was a positive but non-significant relationship between RMR (measured by metabolic cart) and the reported energy intake in the group of athletes who failed to meet their estimated total daily energy needs and among those who met their total estimated daily energy needs, RMR was also positively, but non-significantly, correlated with their energy intake. The positive but non-significant correlation between reported energy intake and RMR shows the higher the estimated energy needs, the higher the reported kcal intake. This suggests that the higher the estimated energy needs, the harder it is to consume the recommended calories.

Previous research by Deutz and colleagues (1999) suggests that long term energy restriction may allow for the body to adapt to lower energy intakes thus lowering RMR. Recent research indicates that athletes should maintain frequent small meals along with adequate fluid intake to maintain body weight, body composition, and to maximize energy levels to decrease fatigue (Benardot, 2007).

The fourth purpose of this study was to determine the relationship between EAT-26 scores and reported energy intake. The total EAT scores were negatively associated with reported energy intakes of the subjects. This association was not significant but could show significance with a larger population.

Understanding the energy requirements of the female athlete is a relatively new research area. More research has been performed with male athletes due to confounding variables of female athletes such as menstruation. Research comparing female athletes and energy intake focuses mostly on eating disorders rather than body composition (Estok & Rudy, 1996; Kirk, Singh, & Getz, 2001; Kerr, Berman, & Jane De Souza, 2006). This study did not focus on eating disorders but did administer an EAT-26 test to identify signs and symptoms of eating disorders. The EAT-26 test is not a diagnostic indicator of eating disorders but subjects with a score greater than 20 are considered at high risk for disordered eating. This study only had one subject with a score greater than 20. The highest scores on the EAT-26 test were 21 and 18. Interestingly, these subjects did not meet their recommended energy requirements. These two subject's energy recommendations were among the average of the total group which does not fully support previous research by Benardot (2007) and Dulloo & Samee (2001) suggest that long term energy restriction can lead to lower RMR. This could be due to the fact that these specific subjects have not been practicing energy restriction long term, but short term during certain phases of their season. Although some studies found a very high prevalence of eating disorders among female athletes (Milligan and Pritchard, 2006), only 2% of the athletes in our sample scored at the cutoff for showing signs of clinical eating disorders. This study's results may be explained by the nature of the athletes in our study who were primarily from sports that are less susceptible to eating disorders than aesthetic or weight-restricted sports such as gymnastics.

Limitations

As mentioned above, underreporting energy intake could be a major limiation of this study. Underreporting of energy intake is often seen in those indivuals who are not satisified with their body. Studies show that when self reported energy intake is compared with the double labeled water technique; evidence of underreporting is strong (McKeown et al, 2001; Hill & Davies, 2001; Schoeller, 1995). Burke and colleagues (2001) state that the more dissatisfied a person is with their body, the more likely they are to underreport energy intake. Barbra and colleagues (2003) found that BMI and underreporting were positively correlated, as well as underreporting and participation in aesthetic sports. Female athletes also experience pressure from outside sources to have an *ideal* body which can also lead to underreporting. Another aspect that can lead to underreporting/overreporting is a knowledge deficit of food and nutrition when completing the 3-day food record. This knowledge deficit can lead to overreporting of some items, such as water intake, as well as underreporting of other items. Also contributing to underreporting can be a time delay. If a subject does not record foods eaten as soon as possible, their food record might not be as accurate as if they recorded foods eaten at the precise time that they were consumed. In this study, there was a delay in receiving some of the 3-day food records. This delay may have decreased the accuracy of food items recorded.

This study had a relatively small sample size (n=45) and only a subsample of subjects completed both the RMR measurement and returned a completed 3-day food record. This small sample size makes determining significant differences between LBM and FM of those that met energy requirments and those that did not meet energy requirments, difficult. Previous research by Zachwieja and colleagues (2001) took baseline measurements of body weight and body fat, then restricted energy intake for 2 weeks and re-measured body fat and body weight. Zachwieja and colleagues (2001) found that short-term energy restriction reduces LBM. Therefore, not having measurements of body weight and body fat over time is a limitation of our study. The results of this study also cannot be generalized to all female athletes due to a relatively small sample size. Also these results cannot be generalized for the entire population of female athletes becuase only three sports were represented in this sample.

According to previous research, chronic low energy intake can lead to an inaccurate measurement of RMR (Deutz, Benardot, Martin, & Cody, 1999). Therefore, it is possible that the measured RMR of some of our subject's could be metabolically lowered due to long-term energy restriction.

Lastly, it is important to gather accurate data on energy intake in order to compare energy intake to energy requirements. Ideally, food records would have been collected for a longer period of time than the 4 days used in this study. Future studies should compile a longer food record period (at least 7 days) and have the completed food records returned as soon as possible (Trabulsi & Schoeller, 2001; Schoeller, 1995). Also, nutrition education would improve the accuracy of the 3-day food records. In this study athletes were presented with directions on completing the 3-day food record and instructions on recording serving sizes. However subjects did not receive formal education on completion or serving sizes. Accuracy could be improved if athletes attended a session on measuring and recording serving sizes. In this study food records were not collected from all subjects for various reasons, such as lack of time, withdrawal from the sports team, and/or loss of contact with the athlete this decreased the number of athletes included in overall measurements comparing recommended energy requirements to reported energy intakes.

Conclusions

Based on the results of this study, the female athletes' energy intake in our sample was significantly lower than recommended energy requirements based on the indirect metabolic rate measurements. This study also found that the athletes' RMR estimated by the Harris-Benedict and Cunningham equations was significantly overestimated compared to the RMR measured by indirect calorimetry. Although further research is warranted in this area with large and representative samples of female athletes from various sports, our study suggests that the Harris-Benedict and Cunningham equations may not represent a reliable tool for estimating RMR within the female athletic population. Although not significant, there was a trend shown that the athletes who did not meet their recommended energy requirements scored slightly higher on the EAT-26 test compared to those who met their energy recommendation. The question that received the highest score on the EAT-26 test was "I am aware of the calorie content of the foods that I eat" suggesting pressure to consume a small number of calories, thus achieving a negative energy balance.

Implications for Practice

The results of this study support previous research indicating that female athletes tend to under consume energy and that equations such as Harris-Benedict and Cunningham may not represent accurate estimators of athletes' RMR. In an ideal setting, metabolic carts are the best method to measure RMR but if prediction equations are used, the Harris-Benedict may estimate athletes' RMR more accurately than the Cunningham equation, as shown in our study. One of the main goals of nutritionists and other professionals working with athletes should be to influence female athletes to consume the recommended amount of energy. While providing nutrition education in order to increase nutrition knowledge and make female athletes aware of the importance of adequate energy and nutrient intakes. Professionals should guide and encourage female athletes to increase energy intake throughout their days by eating small and frequent meals, with a special emphasis on carbohydrate-rich meals that are essential for optimal athletic performance.

The intention of athletic training is to maximize performance. However, athletes may not consider energy balance when trying to obtain this goal. Too often achieving maximum performance is centered on lowering body weight by decreasing energy intake. This strategy ignores that fact that body composition is could be more important to maximizing performance rather than overall weight. No specific standards currently exist for ideal body fat percentage or weight for athletes (Rodriguez, DiMarco, & Langley, 2009; Jeukendrup & Gleeson, 2004). Ideal body composition and weight is highly dependant on the particular individual and is based on individual characteristics such as genetic predispositions, body frame, training regime, and past performances. Athletes need specific, attainable, and measureable goals for body size and body composition based on their individual needs. Female athletes and coaches must understand attainable, healthy body sizes and body composition which should be accurately measured throughout an athlete's off-season, pre-season, and season.

Implications for Future Research

Further research is needed to compare reported energy intakes to recommended energy requirements among different types of female athletes, including aesthetic and weight-restricted sports. This study was initiated with a total of 45 subjects but only 29 subjects completed the entire study, including comparing reported energy intakes to recommended energy requirements. A larger sample size would give more precise results which could be generalized to the female athlete population.

Additional research is also warranted on the accuracy of various prediction equations used to estimate RMR with both male and female athletes. While several studies have been conducted on the validity of selected prediction equations in the past, the results are not consistent because these studies used different methodologies and diverse samples. Additionally, the accuracy of metabolic cart should be tested against other measures of RMR. Although the metabolic cart has been validated for accuracy in previous research (Pinnington, Wong, Tay, Green, & Dawson, 2001; Peel & Utsey, 1993), some still suggest the gold standard for testing resting metabolic rate is the double labeled water technique (Kien & Ugrasbul, 2004).

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APPENDIX

APPENDIX A
INFORMED CONSENT FOR PARTICIPANTS

Project Title: Nutrition-related Parameters, Dietary Intakes, and Food and Exercise-Related Attitudes among Collegiate Athletes
Project Leaders: Lenka Humenikova, PhD; Nancy Betts, PhD, RD; Brenda Smith, PhD

We are asking you to participate in a study measuring body composition, metabolic rate, food intake and attitudes about food and exercise in pre-season, season, and off-season. We are asking you to volunteer to participate because you are an OSU student athlete who is 18 years of age or older. The purpose of this study is to assess nutrition-related parameters, dietary intakes, and food- and exercise- related behaviors and attitudes among OSU collegiate athletes and monitor changes that occur throughout the year. The ultimate purpose of this research project is to make recommendations for dietary intakes that will optimize athletic performance of OSU male and female athletes. You must be 18 years old or older to be able to participate in this study.

You will be invited to make one visit to the Department of Nutritional Sciences during the pre-season, season, and off-season (a total of 3 visits). Each visit will take approximately 1.5-2 hours.
Your body composition and bone density will be measured using the Dual Energy X-ray Absorptiometry (DEXA). DEXA is currently the most accurate scan that measures body composition and bone density. You will be asked to dress in comfortable clothing (we will provide clothing if needed), removing any metal (excluding orthodontic braces). During the scan, you will lay on an examination table while a machine arm passes over his body. You will feel no discomfort. The X-ray exposure from DEXA is much smaller than exposure from a chest X-ray (approximately 10 times less). The scan will take approximately 10-15 minutes, including all the preparation procedures.

Your body composition will also be measured using standard skinfold thickness measurements. A trained researcher will measure your body fat using calipers in 7 different places on the body (arm, stomach, back etc.). This measurement will take approximately 10 minutes. Before the body composition measurement, we will measure your height and weight. Because body composition affects metabolic rate, we will measure your resting metabolic rate during each visit. You will sit in a semi-recumbent chair with a clear canopy placed over your head. You will be asked to rest as much as possible. We will measure the amount of oxygen you breathe in and the amount of carbon dioxide you breathe out with each breath for approximately 20-30 minutes.

In addition, during each visit, you will also be asked to remember what foods and beverages you ate during the previous day. This activity will take about 10-15 minutes. You will be also asked to complete two questionnaires that contain items related to your diet history, hydration, body weight, and other nutrition- and exercise-related topics. It will take approximately 10 minutes to fill out the questionnaires. Lastly, you will be instructed on how to complete a food record and you will be asked to complete a 3-day food record at home. To complete a 3-day food record, you will be asked to write down all foods and beverages you consume within the next 3 days immediately following your visit.

The measurements that will be completed are not medical procedures and no medical diagnoses will be made. However, you will benefit from the study by receiving results of the study through your athletic trainers. The results of these tests will be useful for determining the optimal nutrition for your sport. Your performance may be optimized as a result of this knowledge. If you are a male, there are no known risks associated with this research study which are greater than those ordinarily encountered in daily life. If you are a female, you must <u>not</u> be pregnant while participating in this study. Although the radiation dose from the DEXA scans is very low, there may be some risks to an embryo or fetus, including birth defects. If you become pregnant or suspect that you are pregnant during the course of this study, you will be asked to do a pregnancy test (urine test) prior to having a DEXA scan. The pregnancy test kit will be provided to any female athlete that requests it. If pregnancy is confirmed, you will not be allowed to have the DEXA scan performed, but may participate in the other assessment associated with the study.

We will protect your confidentiality during the project by assigning you an ID number. The list of all names and corresponding ID numbers will be kept in a locked drawer and only the project leaders will have access to the list. Your measurements will be obtained in a separate room without the presence of other individuals. Any reports we prepare from the study will be for grouped data and no individual will be identified. None of the results of the measurements will be shared with your coach.

The OSU Institutional Review Board has the authority to inspect consent records and data files to assure compliance with approved procedures. The participation in the study is voluntary. If you feel uncomfortable while reporting any information, you can choose not to answer any question, or to withdraw completely from the study at any time. A decision to withdraw from the study will not result in any loss of benefits to which you are otherwise entitled.

If you have questions about the project, please contact Lenka Humenikova at (405) 744-8285 or lenka.humenikova@okstate.edu or Nancy Betts at (405) 744-5040 or nancy.betts@okstate.edu or Brenda Smith at 744-3866 or bjsmith@okstate.edu. If you have any questions about your rights as a research participant, you may contact Dr. Sue Jacobs, Institutional Review Board Chair, 218 Cordell Hall, Oklahoma State University, Stillwater, OK 74078 at (405) 744-1676.

DOCUMENTATION OF INFORMED CONSENT

You are voluntarily making a decision whether or not to participate in the research study. Your signature certifies that you have decided to participate having read and understood the information presented. You will be given a copy of this consent form to keep.

I have read and fully understand the consent form.

I,____________________________(print name), agree to participate in the described research.

______________________________ ______________________________
Signature Date

____
I certify that I have personally explained this document before requesting that the participant sign it.

____ ______________
Signature of PI Date

INFORMATION RELEASE FORM

Your signature certifies that the project leaders have your permission to send the results of your measurements to your team athletic trainer(s) who will then share the results with you. If the measurements collected during the study indicate that you may have any potential nutrition-related problems, the project leaders will make nutrition recommendations through your athletic trainer(s) and suggest a referral to your team physician.

I fully understand the information release form. I, _____________________________(print name), give permission to the project leaders to share the results of my measurements with my athletic trainer(s).

___________________________________ ____________________

Signature Date

APPENDIX B
APPROVAL LETTER FROM OSU

AUG-15-2007 08:54A FROM: TO:41357 P.2/2

August 15, 2007

Oklahoma State University Institutional Review Board

RE: Nutrition-related Parameters, Dietary Intakes, and Food and Exercise-Related Attitudes among Collegiate Athletes

The Oklahoma State University Athletic Department has reviewed this purposed research study by the Nutritional Sciences Department. This study will be a benefit to us and we look forward to participating in it.

Through this research we hope to learn better nutritional information to provide to our athletes and coaches. The nutritional information should help our athletes and coaches to be more competitive in their athletic pursuits as well as help them to lead healthier lives when their athletic careers are over. Also, this information should help us to identify potential injury/illness risk factors and address these issues early before they become more serious problems.

We look forward to participating in this research project and hopefully others in the future.

Sincerely,

Dave Martin
Senior Associate Athletic Director
Oklahoma State University

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APPENDIX C

EATING ATTITUDES TEST

Please place an (X) under the column which applies best to each of the statements. Most of the questions directly relate to food or eating, although other types of questions have been included. All of the results will be **strictly** confidential. Please answer each question carefully. Thank you.	ALWAYS	USUALLY	OFTEN	SOMETIMES	RARELY	NEVER
1. I am terrified about being overweight.						
2. I avoid eating when I am hungry.						
3. I find myself preoccupied with food.						
4. I have gone on eating binges where I feel that I may not be able to stop.						
5. I cut my food into small pieces.						
6. I am aware of the calorie content of foods that I eat.						
7. I particularly avoid foods with a high carbohydrate content (e.g. bread, rice, potatoes, etc.).						
8. I feel that others would prefer if I ate more.						
9. I vomit after I have eaten.						
10. I feel extremely guilty after eating.						
11. I am preoccupied with a desire to be thinner.						
12. I think about burning up calories when I exercise.						
13. Other people think that I am too thin.						
14. I am preoccupied with the thought of having fat on my body.						
15. I take longer than others to eat my meals.						
16. I avoid foods with sugar in them.						
17. I eat diet foods.						
18. I feel that food controls my life.						
19. I display self-control around food.						
20. I feel that others pressure me to eat.						
21. I give too much time and thought to food.						
22. I feel uncomfortable after eating sweets.						
23. I engage in dieting behavior.						
24. I like my stomach to be empty.						
25. I enjoy trying new rich foods.						
26. I have the impulse to vomit after meals.						

APPENDIX D
NUTRITION QUESTIONNAIRE

Please write the requested information in the blank spaces. For some questions, answer by placing a check (X) in the appropriate space. **If you answer Yes to some of these questions, additional information is requested**.

Please print requested information.

Name:____ **ID# (office use only) ______**

Address:____
(street) (apt #) (city) (state) (zip code)

E-Mail:________________________________ **Phone: (   )** ____________________

Do you have Internet access? ___Yes ___No **Date of Birth:** ____________________

Height: _______feet ________inches Weight: ______pounds Event(s): ____________________

Nutrition Profile

How would you describe your eating habits? __ Good __ Fair __ Poor

I eat ____ meals and ____ snacks a day (*specify number*)

On average, how many times do you eat out per week? _____

When you go out to eat what are the three most common places you go?

1. ______________________
2. ______________________
3. ______________________

Do you avoid any of the following foods?

__ red meat	__ fruit	__ sweets
__ poultry	__ fried foods	__ alcohol
__ fish	__ breads	__ fat/oil (mayo, butter, salad dressing)
__ milk/milk products	__ grains(pasta/rice)	__ vegetables
__ fast food	__ other, please specify: ______________________	

Do you have any food allergies? __ No __ Yes: ____________________

Comments: ____

____

Fluid Intake

Do you monitor your body water level to find out if you are dehydrated? ___ Yes ___ No
If yes, how do you monitor it?

In a typical workout/practice, how many cups of fluid do you drink **before** exercise?
___ None ___ 3-5 cups
___ 1-2 cups ___ More than 5 cups

What fluids do you drink:____

In a typical workout/practice, how many cups of fluid do you drink **during** exercise?
___ None ___ 3-5 cups ___ According to my weight loss
___ 1-2 cups ___ More than 5 cups

What fluids do you drink:____

In a typical workout/practice, how many cups of fluid do you drink **after** exercise?
___ None ___ 3-5 cups ___ According to my weight loss
___ 1-2 cups ___ More than 5 cups

What fluids do you drink:____

Do you use a schedule for drinking fluid during competition? ___ Yes ___ No
If yes, what is it?

Do you ever experience muscle cramps during training or competition? ___ Yes ___ No
If yes, where and how often?

Menstrual History (if applicable)

At what **age** did you have your first menstrual period? _______ Years old

What is the **average number of menstrual periods** you have had during the past year? _______

What is the **average number of days your periods have lasted** during the past year? _______ Days

Are you currently using a birth control pill or implant? __ Yes __ No
If yes, what type and for how long?

Body Weight & Diet History

What is the most you have ever weighed as an adult? ______ pounds At what age? ______

What is the least you have ever weighed as an adult? ______ pounds At what age? ______

I presently think of myself as being:

__ Underweight __ Moderately overweight
__ At a healthy weight __ Very overweight

I would like to:

__ Maintain my present weight/body composition

__ Lose ___ pounds in ____ weeks or ____ months (please specify numbers)

__ Gain ___ pounds in ____ weeks or ____ months (please specify numbers)

__ Build muscle mass

__ Decrease body fat

Have you been on any diets in the past year? __ Yes __ No

If yes, please specify:

What are the reason(s) for this/these diet(s)?

___ Weight loss ___ Weight gain ___ Doctor's recommendation

___ Health reasons, explain: ____

___ Other:____

Are you following a special diet at this time? ___Yes ___No

If yes, place an X next to the appropriate diet or diets that best describe your present diet:

___ Low calorie ___ High protein

___ High calorie ___ High fiber

___ Low cholesterol ___ Low sodium (salt)

___ Low fat ___ Diet for allergy

___ High fat ___ Diet for high blood triglycerides

___ Low carbohydrate ___ Diet for high blood cholesterol

___ High carbohydrate ___ Diet for hypoglycemia

___ Vegetarian ___ Other:__________________

How easy or difficult is it for you to maintain your competition or in-season weight?

__ Very Easy __ Somewhat Difficult
__ Somewhat Easy __ Very Difficult

Additional Comments:

____

____

____

____

Dietary Supplement Use

Do you currently take any vitamin or mineral supplements? __ Yes __ No

If yes, please specify type, brand name, and amount:

Do you currently take any of the following dietary supplements? (Please place an X next to all that apply)

__ Creatine __ Pyruvate __ Protein shakes/bars

__ Amino Acids __ Herbs __ Stimulants (Ma Huang/Ephedra)

__ Ribose __ HMB __ "Andro" DHEA

__ Glycerol __ Other (please specify): ___________________________

__ Caffeine: *if so, how much* _________________________________*(cups,ounces)*

Do you know which supplements are banned or restricted by the USOC? __ Yes __ No

Do you take any "over the counter" medications? __ Yes __ No

If yes, list the names and schedule of what you take:

Do you take any prescription medications? __ Yes __ No

If yes, list the names and schedule of what you take:

Training Profile

How many days a week do you train? _____ Days

Below, please fill in the type of exercise you do, the time you spend doing it, and the intensity.

Exercise	**Duration (time)**	**Intensity (easy/moderate/hard)**

Have you had a serious illness or injury in the last year? __ Yes __ No

If yes, please describe the illness or injury:

List the foods, beverages, or supplements you consume **during** competition.

Time	Food	Beverage	Supplement

Do you have problems following your training and competition diet when traveling? ___Yes ___No

If yes, what problems do you have?

Rate the quality of your current dietary habits/plan for your Training Phases by putting the RATING SCALE number in the blanks before each Training Phase.

RATING SCALE: 1 = Excellent 5 = Poor

Training Phase	Diet Rating	Comments (if applicable)
Training	_______	____________________________________
Pre-competition	_______	____________________________________
During Competition	_______	____________________________________
Post-competition	_______	____________________________________

Additional Information

Do you have regular blood tests for iron status? __ Yes __ No

If yes, please specify: __ Ferritin

__ HCT

__ HGB

__ Other: _________________

Do you take iron supplements? __ Yes __ No

Please indicate the topics you would like to learn about by placing an X next to "Yes".

Changing body composition __ Yes
Optimal Nutrient Intake Timing __ Yes
Increasing energy __ Yes
Nutrition programs for peak performance __ Yes
Avoiding cramps and nausea __ Yes
Tips for eating out __ Yes
Tips on eating for injury recovery __ Yes
Tips of snacking __ Yes
Other, please specify: ____

If you have additional comments or question please indicate them below:

VITA

Gena Suela Crenshaw

Candidate for the Degree of

Master of Science or Arts

Thesis: **ENERGY INTAKES OF FEMALE COLLEGIATE ATHLETES**

Major Field: Nutritional Sciences

Biographical:

Personal Data: Born in Stillwater, Oklahoma, on September 5, 1984, the daughter of Gene and Carla Wollenberg.

Education: Graduated from Perkins-Tryon High School, Perkins, Oklahoma in May 2003; received Bachelor of Science degree in Nutritional Sciences with honors from Oklahoma State University, Stillwater Oklahoma May 2008. Completed the requirements for the Master of Science in Nutritional Sciences at Oklahoma State University, Stillwater, Oklahoma in May 2009.

Experience: Employed by Oklahoma State University, Colvin Center Recreation, Personal Trainer and Group Fitness Instructor from August 2006-present. Employed by Oklahoma State University, Department of Nutritional Sciences as a graduate teaching assistant from June 2008 to December 2008. Professional Memberships: American Dietetic Association (Student Liaison), Sports, Cardiovascular, and Wellness Nutritionists, Oklahoma Dietetic Association, North Central District Dietetic Association (President- Elect), Phi Kappa Phi National Honor Society.

Name: Gena Suela Crenshaw Date of Degree: May, 2009

Institution: Oklahoma State University Location: OKC or Stillwater, Oklahoma

Title of Study: **ENERGY INTAKES OF FEMALE COLLEGIATE ATHLETES**

Pages in Study: 79 Candidate for the Degree of Master of Science

Major Field: Nutritional Sciences

Scope and Method of Study:

The main purpose of this study was to evaluate energy intakes in a sample of female collegiate athletes and compare their reported energy intakes to the total daily energy needs. The second purpose of the study was to determine whether differences between RMR measured by indirect calorimetry and RMR estimated by the Harris-Benedict and Cunningham equations exist in the target population. The third purpose of the study was to explore the relationship between energy intake and body composition, including lean body mass and fat mass in the target population. Finally, the relationship between athletes' reported energy intake and eating attitudes was explored.

This exploratory study used a convenience sample of collegiate athletes and 45 female athletes were recruited from several teams including soccer (n=18), cross-country and/or track and field (n=16), and basketball (n=11). Athletes were assessed for body composition using a Hologic DEXA scanner. RMR for each athlete was measured using indirect calorimetry (Vmax Encore metabolic cart, Viasys) as well as estimated by the Harris-Benedict and Cunningham equations. Each athlete completed a 24 hour recall, 3-day food record, and eating attitude test. Measured RMR was compared to estimated RMR. Recommended energy intake based on measured RMR was compared to reported energy intake from a 4-day energy intake average.

Findings and Conclusions:

The results of this study indicated that subjects' consumed a significantly lower amount of energy compared to their daily energy recommendations. Only six out of 29 subjects who completed the dietary and metabolic measurements met their total daily energy needs. The Harris-Benedict and Cunningham equations were not reliable tools for estimating RMR within this athletic population, with both estimating RMR to be significantly higher than the RMR measured using indirect calorimetry. There was no significant difference in body composition between athletes who reported consuming the recommended amount of energy and those who failed to meet their total daily energy requirements.

ADVISER'S APPROVAL: Lenka Shriver Ph.D.