2012

EVALUATION OF THE BODY COMPOSITION OF FEMALE COLLEGIATE ATHLETES USING THE BOD POD

Adrienne Jennifer Glodt Baker
University of Kentucky, ajgl222@uky.edu

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Adrienne Jennifer Glodt Baker, Student

Dr. Janet Kurzynske, Major Professor

Dr. Kwaku Addo, Director of Graduate Studies

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THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Sciences in the
College of Agriculture
at the University of Kentucky

By

Adrienne Jennifer Glodt Baker

Lexington, Kentucky

Director: Dr. Janet Kurzynske, PhD, RD

Lexington, Kentucky

2012

ABSTRACT OF THESIS

EVALUATION OF THE BODY COMPOSITION OF FEMALE COLLEGIATE ATHLETES USING THE BOD POD

The body composition of female collegiate athletes was measured using the Bod Pod® device. The sample consisted of 75 student athletes, aged 18 to 22 years old. Five sports at the university level were represented, including basketball, gymnastics, soccer, swimming & diving, and soccer. Participants were measured at the preseason and postseason periods. Overall, participants in all five sports were not found to change significantly in total body mass, fat mass, fat free mass, percent body fat, or body mass index from the preseason period to the postseason period at the alpha = 0.05 level. On average, the members from each of the different teams were found to be significantly different from each other for one or more variables. In general, basketball and volleyball players were found to be similar in body composition. The average member on the swimming & diving, soccer, and gymnastics teams was found to vary from the average team member on each of the other teams.

KEY WORDS: Bod Pod, body composition, percent body fat, female, collegiate athlete

Adrienne Jennifer Glodt Baker
August 1, 2012

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By

Adrienne Jennifer Glodt Baker

Janet Kurzynske, PhD, RD
Director of Thesis

Kwaku Addo, PhD
Director of Graduate Studies

August 1, 2012
Date

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Chapter 1: Introduction

Maintaining a specific body weight and body composition are important requirements for optimal athletic performance. In order to achieve a body composition that promotes maximum physical ability, competitive athletes must train at a high level of intensity with great frequency. This level of intensity can vary by sport, and the timing of intense training can vary by age of the athlete. In certain sports, highly-focused training can begin as early as adolescence, whereas in other sports, this level of training does not occur until early adulthood. Elite athletes who are training their bodies to achieve athletic greatness typically aim to develop a highly-muscular, minimally-fat body composition as compared to the average person.

For the female athlete specifically, overly strenuous athletic training during adolescence and early adulthood can have a major impact on her level of health. There is the potential to cause permanent damage to internal body systems with lasting effects throughout adulthood. The majority of females who participate in athletics at a highly competitive level do so during their college years. This is a time when females are completing growth and development and must take care of their bodies. It is therefore critical for competitive athletes, especially females, to be able to learn about their body composition measurements as accurately as possible in order to maintain a sufficient level of health while training.

A primary goal of athletic trainers and sports nutritionists is to monitor the body composition of athletes before, during, and after the peak training season. Due to the increased muscle mass of a competitive athlete, it has been speculated that conventional methods for determining body composition are not accurate in this population (Ode, Pivarnik, Reeves, & Knous, 2007). Recording and tracking body weight alone cannot precisely illuminate body composition or level of fitness. A measurement of body weight shows only total body mass and cannot specify lean mass or fat mass as separate values. Similarly, another concept used to track body composition relies on using height and body weight to develop a numerical value that signifies density, referred to as the body mass index (BMI). The body mass index (BMI), also known as the Quetelet index, is defined as body weight divided by height squared, and is usually reported as kg/m^2 or without units. Athletes may be inaccurately represented when only using BMI to calculate body composition due to the contribution of increased muscle mass to the overall body weight (Jonnalagadda, Skinner, & Moore, 2004). In this manner, using BMI to represent an athlete's fitness level may falsely imply a certain amount of body fat. Research has indicated that it is not possible to connect a certain BMI value with precise body fat percentage in athletes (Garrido-Chamorro, Sirvent-Belando, Gonzalez-Lorenzo, Martin-Carratala, & Roche, 2009). If using only BMI, the misrepresentation of body fatness may lead to inappropriate training decisions, which may in turn affect the performance ability and overall health of the athlete. Knowing an accurate value for lean mass and fat mass can help athletic support staff make comparisons of an athlete's body composition across the season in order to correctly train the athlete while simultaneously maintaining her health. Thus other tools may be used in conjunction with the body mass index formula and provide more detailed information.

Air displacement plethysmography (ADP) uses air displacement to measure total body volume and calculate the muscle mass and fat mass of an individual. Within the last decade, this method of determining body composition has been found to be reliable and valid for the female collegiate athlete population (Ballard, Fafara, & Vukovich, 2004). The instrument used to measure ADP is called the Bod Pod®, created by COSMED USA, Inc., formerly Life Measurement, Inc.

The importance of knowing the female athlete's body composition measurements is of value to the athletic community. This study aims to describe and compare the body composition measurements of female collegiate athletes representing various sports teams by using typical composition calculations and calculations from the Bod Pod® instrument. The collection and analysis of this information contributes data to the body of knowledge regarding the body composition of collegiate female athletes and additionally allows these current female athletes to learn about their own level of health.

Chapter 2: Literature Review

Athletic Training Increases Muscle Mass and Decreases Fat Mass

Competitive athletes are extremely dedicated to their sport of choice and therefore invest many hours each week into actively improving their physical abilities and body composition. As a result of the time invested in training, the body composition of an athlete shows increased muscularity and decreased adiposity relative to a typical person. Skeletal muscle is a highly-adaptable tissue that is capable of increasing in strength and size based on the intensity, frequency, and volume of exercise (Coffey & Hawley, 2007). The two main types of exercise are endurance training and resistance training. Endurance training leads to increased muscle glycogen stores and better utilization of glycogen due to a higher rate of fat oxidation and other factors (Coffey & Hawley, 2007). Simply stated, the low level of body fat seen in athletes is largely a result of performing intense and frequent endurance exercises. Resistance training leads to hypertrophy of the targeted muscles caused by a greater amount of new muscle tissue creation than the amount of muscle tissue degradation (Coffey & Hawley, 2007). Basically, athletes show increased muscle mass due to performing resistance exercises that challenge their muscles to work harder.

Competitive athletes usually perform both endurance and resistance exercises as part of their training regimen. Current practices in athletic training prescribe sustained, distance running as a means of conditioning athletes (Elliott, Wagner, & Chiu, 2007). This type of conditioning is often added to the training of young athletes in their adolescence. In addition to endurance exercises, athletes must also spend time learning athletic techniques relevant to their sport and performing resistance exercises to improve their ability to execute said techniques. The combination of these training requirements has been documented to affect the body composition of competitive athletes, especially women (Elliott et al., 2007).

The Female Collegiate Athlete

The female athlete is a physiologically-complex being and has been less studied and even lesser understood than her male counterpart in the scholarly literature. As time progresses beyond the 20th century and further into the 21st century, there has been a steady increase in the number of women who are participating in competitive sports at a national or worldwide level. The need for research on the female athlete has become more relevant than ever before. It is important to understand the anatomy and physiology of the female athlete as she begins training in adolescence and continues training into adulthood. Before puberty, males and females are equal on an anatomical basis, with similar levels of body fat and muscle mass. As the female reaches puberty, her bone mass, lean body mass, circulation, and metabolism will change under the influence of female sex hormones (Holschen, 2004). By adulthood, females typically have smaller bones and significantly less muscle mass than males. Comparing a man and woman of the same body mass and level of athletic conditioning, the woman has been found to have a smaller heart and lung mass, lower stroke volume, and lower maximal cardiac output than the man; this causes the woman to be less effective in anaerobic and aerobic athletic activities. Due to the difference in the female's reproductive system as compared to the male's reproductive system, there are numerous unique conditions that are necessary to consider. Disorders related to the menstrual cycle can be related to intense training, low body mass, low body fat, nutrition that does not match needs, and other factors related to hormone levels (Holschen, 2004).

Along with the benefits of exercise, there are also dangers that may occur when adolescent females exercise excessively. These potential risks include an impact on growth, reproductive function, and bone mineralization (Warren & Shantha, 2000). The importance of monitoring the female athlete for changes in body composition remains paramount in her training program. The competitive female athlete aims to be the most efficient player she can be; however, the need to sustain certain body composition levels is critical to long-term health maintenance. In the literature, there are currently no accepted published body fat ranges, particularly for athletes, which makes it difficult to determine when to intervene with a female athlete's training plan (Gallagher et al., 2000). There are guidelines used by the American Council on Exercise (ACE) for classifying the body fat percentage of men and women (Muth, 2009). According to the guidelines for women, "essential" body fat is 10-13%, and body fat for "athletes" is 14-20%. Furthermore, the percentage of body fat for "fitness" is 21-24%, an "average" body fat is considered 25-31%, and a body fat of 32% or higher is classified as "obese." The manufacturer of the Bod Pod®, COSMED USA, Inc uses a different set of guidelines as displayed on the results printout available after testing a subject. The Bod Pod® guidelines give the following ranges for the body fat of a woman aged 18 years or older: "risky low body fat" is less than 15%, "ultra lean" is 15-18%, "lean" is 19-22%, "moderately lean" is 23-30%, "excess fat" is 31-40%, and "risky high body fat" is over 40% (COSMED USA, 2012). The "ultra lean" body fat classification is noted to be found in elite athletes. The document suggests that subjects who fall into the "risky high body fat" and "risky low body fat" ranges seek advice from a health care professional to modify their body composition. Examining these two sets of guidelines, it appears that the percent body fat range in which female athletes are predicted to suffer adverse health effects is below 14-15%. As a comparison, the known percent body fat averages for young women who are not competitive athletes are found to be much higher than this range; the average percent body fat for untrained women aged 15-19 years is 20-24%, and the average for untrained women aged 20-29 years is 22-25% (Carbuhn, Fernandez, Bragg, Green, & Crouse, 2010). These published averages do not imply any level of health status and are used only to show the range for the typical young woman in the United States of America. It has been the aim of other researchers, and is the aim of this study, to provide more information on the range of body composition measurements in the female athlete. After the critical period of adolescence, the health of the female athlete remains vulnerable in young adulthood as she transitions into collegiate athletics.

The female collegiate athlete is a young woman in her late teens or early twenties who has pursued a goal of competing in athletics on a national level while simultaneously working toward a college degree. As previously discussed, participation in competitive athletics has been found to cause changes in female body composition. Additionally, it has been found that women who participated in various sports had differences in their body compositions, with these differences most likely being dually attributed to the training required for that sport and having a body type that allows for success in the sport. Carbuhn and his associates at Texas A&M University (Carbuhn et al., 2010) described the body composition measurements of women collegiate athletes at three distinct times in the athletic season. These researchers used dual energy X-ray absorptiometry (DXA) to measure 67 athletes from the softball, basketball, volleyball, swimming, and track teams. The women were measured during the off-season, preseason, and postseason with the goal of tracking changes that may occur at different points in the training season. Generally, the data analysis showed that track jumpers and sprinters were lower in total body mass, fat mass and percent body fat as compared to the other athletes at all points in the season. Basketball and volleyball team members were found to have the highest total body mass, lean muscle mass, and leg bone mineral density, with these values usually being significantly higher than the members of the softball, swim, and track teams. As a whole, the data for softball athletes was found to fall between the values for all other sports. Additionally, the researchers found that all the female athletes demonstrated a significant change in the different parameters across the season, showing the effect of training for and competing in their sport. Based on their results, the authors concluded that the low fat mass and percent body fat of the track athletes were expected in order to maximize performance. The similarities in total body mass, fat mass and percent body fat among the basketball, volleyball, and softball athletes were thought by the authors to suggest that a similar body composition is required for optimal performance in these three sports. Although the study from Carbuhn and associates is one of the first to publish data related to the body composition of female collegiate athletes taken serially throughout the training season, it provides a general comparison for other studies that aim to describe the characteristics of this population at multiple times in the season. It also shows there are significant differences in female collegiate athletes when examined as a per sport subset. It remains necessary to consider whether certain sports innately promote thinness in female athletes as a means to succeed competitively. Several studies have shown that athletes in certain sports feel pressure to maintain a low weight, while other studies have shown that this pressure is not always present (Robinson & Ferraro, 2004). This pressure may lead female athletes to push themselves too far, leading to negative health effects.

The Female Athlete Triad

A typical athlete at the collegiate level has often been practicing a particular sport for several years prior to joining the college team. Throughout this time period, the athlete learns not only the finite details of how to play the game, but also how to condition her own body to achieve the correct technique. Although endurance exercises may not be the basis of her training, she will perform them frequently as a means of conditioning. She may also feel pressure to keep her body mass as low as possible in order to improve her performance.

The combination of three medical disorders known as the female athlete triad can be the result of young female athletes striving to achieve a particularly low body mass. The American College of Sports Medicine (ACSM) released an updated position stand on the female athlete triad (Nattiv et al., 2007). The updated document defined the female athlete triad as the interrelationship between low energy availability, amenorrhea, and osteoporosis. Each of these conditions alone is dangerous to the health, but the occurrence of all three together can be life-threatening (Beals, Brey, & Gonyou, 1999). In the original position stand on the female athlete triad by the ACSM, low energy availability was referred to as disordered eating (Otis, Drinkwater, Johnson, Loucks, & Wilmore, 1997). The ACSM adjusted this part of the triad to low energy availability citing evidence that "low energy availability may occur inadvertently without clinical eating disorders, disordered eating behaviors or even dietary restriction." The possibility still remains that female athletes may develop disordered eating or an eating disorder as a result of trying to achieve an unreasonably low body weight.

Disordered eating can include the spectrum of harmful eating behaviors practiced with the goal of losing weight or maintaining a low body mass. Anorexia nervosa and bulimia nervosa are the two eating disorders seen as the extreme ends of the spectrum. Anorexia nervosa is described as a fear of gaining weight and having the self image of being overweight when the person is at least 15% below expected weight for age and height (Nattiv et al., 2007). This leads the person to intentionally restrict caloric intake over a long period of time. Bulimia nervosa represents uncontrolled binging and purging behaviors, such as vomiting, exercising excessively, or using laxatives, diuretics, or enemas, with the goal of losing weight (Beals et al., 1999). People suffering from eating disorders can show evidence of the following medical complications: depleted glycogen stores, decreased lean body mass, chronic fatigue, micronutrient deficiencies, dehydration, anemia, electrolyte imbalances, acid-bases imbalances, gastrointestinal disorders, parotid gland enlargement, decreased bone density, and erosion of tooth enamel (Beals et al., 1999). Psychological disorders associated with disordered eating can include: decreased self-esteem, anxiety, depression, and acts of suicide (Beals et al., 1999). The second factor of the female athlete triad is amenorrhea, which is defined as the absence of three or more consecutive menstrual cycles. Amenorrhea can be classified as primary amenorrhea or secondary amenorrhea. Delayed menarche, or primary amenorrhea, occurs when a female aged 15 years or older with secondary sex characteristics has not started menstruation (Nattiv et al., 2007). Secondary amenorrhea occurs when a female who has reached menarche does not have a menstrual cycle for three or more consecutive months. Other menstrual dysfunctions can also affect the female athlete, such as complete cessation of menstruation or oligomenorrhea, the term for cycles lasting longer than 35 days (Nattiv et al., 2007). The two medical conditions that are associated with amenorrhea are decreased bone density and premature osteoporosis (Beals et al., 1999). The third factor of the female athlete triad is osteoporosis. In young female athletes, osteoporosis indicates early bone loss and insufficient formation of bone. Osteoporosis in the female athlete can result in decreased bone mineral density, bone deterioration, weakness of the skeletal bones, and increased risk of stress fractures. Bone mineral density that is lost in this way may be irreversible. The female athlete triad can cause long-term negative health effects in adolescents and young women who participate in competitive sports. With increased awareness of these conditions, screening and early detection can help young women avoid the dangers of the female athlete triad.

As the awareness of the female athlete triad continues to grow, more studies have been conducted to reveal the prevalence in different populations. Knowing the prevalence for all age groups and by sport can help tailor the screening efforts performed by coaching staff and health care professionals. In a study of 80 varsity athletes and 80 sedentary controls at an all girls' private high school, researchers sought to determine the prevalence of the female athlete triad (Hoch et al., 2009). All subjects were between the ages of 13 and 18 years. Data were collected through the use of several methods. The subjects recorded 3-day dietary recalls after receiving instruction from a registered dietitian, completed validated questionnaires related to medical history including menstrual status, provided blood samples, and were measured by DXA scans. Amongst the 80 high school varsity athletes, 36% were identified as having low energy availability, 54% had amenorrhea or oligomenorrhea, and 13% were found to have low bone mineral density. In the sedentary control group, 39% had low energy availability, 21% were found to have amenorrhea or oligomenorrhea, and 20% were classified as having low bone mineral density. Only one athlete and one control were found to have all three parts of the female athlete triad. The researchers found that the female high school athletes and controls had a high prevalence of one but not all of the components of the triad.

Other studies have focused on one part of the female athlete triad and found high prevalence rates as well. In Norway, researchers found that elite female athletes in sports where leanness is important for performance were more likely to have a clinical eating disorder (Torstveit, Rosenvinge, & Sundgot-Borgen, 2008). From a sample of 186 athletes and 145 controls, 46.7% of leanness sports athletes, 19.8% of non-leanness sports athletes, and 21.4% of controls were found to have eating disorders. A small study of 15 Greek and 30 Canada elite female gymnasts identified that 78% reported menstrual dysfunction in the form of oligomenorrhea or secondary menarche (Klentrou & Plyley, 2003). In a large study of 788 Iranian female elite athletes from various sports, researchers reported that 71 or 9.0% had amenorrhea or oligomenorrhea, with 11 of those 71 athletes having polycystic ovary syndrome as the known cause (Dadgostar, Razi, Aleyasin, Alenabi, & Dahaghin, 2009). The evidence on the female athlete triad shows that its components can be prevalent in female athletes from various age groups and competition levels. Knowing this prevalence can help in the promotion of increased attentiveness to accurately measuring the body composition of female athletes.

Determining Body Composition in Athletes

Throughout the competitive season, one of the main ways to track an athlete's training progress and health is through body composition measurements. While athletes often record this information on their own, trainers and sports nutritionists often help with documentation and analysis. Total body mass is an easy measurement to track and provides a quick indication of any rapid changes. For some sports, body mass must be used as part of grouping players for competition, whereas in other sports, weight is not a determinant. Regardless of whether total body mass is critical to the sport, it does not indicate the muscle mass or fat mass of an athlete, which are measurements that can signify training progress and health, respectively. Another method of examining body composition involves using the body weight in conjunction with the height of the athlete to allow the calculation of density via the body mass index (BMI) formula. BMI is the most often used measurement to classify body weight in athletes (Jonnalagadda et al., 2004). BMI is weight divided by height squared and can be written at kg/m^2 or with no units. The Centers for Disease Control (CDC) provides BMI levels to indicate an adult's level of health: below 18.5 is considered underweight, 18.5-24.9 is the normal range, 25.0-29.9 is deemed overweight, and above 30.0 is indicated as obese (how to reference PDF?). While BMI shows the density of a person, this measurement does not explain to what the density is attributed.

The body mass index (BMI) calculation is a convenient and popular measure of body density and is used as an indirect measure of body fatness, but several researchers have indicated that it fails to accurately describe body composition. A study conducted in the United Kingdom aimed to assess whether BMI is valid for determining adiposity in both athletic and non-athletic populations (Nevill, Stewart, Olds, & Holder, 2006). Using skin-fold measurements at eight locations, the researchers suggested that BMI was not able to accurately represent body fatness, especially in athletic populations. In an article by Jonnalagadda and associates, the authors state that using the standard BMI classifications incorrectly labels some athletes as overweight because of the increased density of muscle mass (Jonnalagadda et al., 2004). A large study that took place in Spain from 2000 to 2004 was conducted with the aim of determining the correlation between BMI and fat, muscle, and bone percentages in athletes (Garrido-Chamorro et al., 2009). The subjects of the study were 3,971 Caucasian competitive-level athletes who had participated in National, European, World, or Olympic competitions. There were 1230 females and 2741 males from the sports of soccer, basketball, handball, badminton, tennis, volleyball, swimming, rowing, cross country, gymnastics, judo, alpinism, triathlon, and others. The body compositions of these athletes were calculated using skin-fold thickness measures. The authors concluded that BMI is not an adequate method to determine body fatness in the elite athlete population. At Michigan State University, a study was conducted with the main purpose of describing the relationship between body mass index (BMI) and percent body fat and the secondary purpose of determining the accuracy of BMI as a measure of percent body fat in college athletes (Ode et al., 2007). Participants for this study included 226 collegiate athletes and 213 college-aged non-athletes. Percent body fat was measured by use of the Bod Pod®. The researchers found that BMI was not an accurate measure of fatness of college athletes and non-athletes. In a similar study using DXA to measure percent body fat, BMI was found to be invalid for measuring body composition in female elite athletes due to the errors in categorizing based on BMI classifications (Klungland Torstveit & Sundgot-Borgen, 2012). The mounting evidence that BMI cannot accurately assess the body composition of the athletic population signals the need for a more valid method of measurement.

Air Displacement Plethysmography and the Bod Pod

As the field of body composition research continues to advance, a new method of measurement based on air displacement plethysmography has been included in an increasing number of studies. The device called the Bod Pod® has been commercially available since 1995 and is produced by COSMED USA, Inc., formerly Life Measurement, Inc. (Baracos et al., 2012). The Bod Pod® uses the relationship between pressure and volume to determine a subject's body volume and ultimately calculate percent body fat (Dempster & Aitkens, 1995). In general, all plethysmographic methods for determining body volume are centered on subtraction; when a subject is placed in a chamber of known volume, the body volume of the subject is the measured reduction in volume of the chamber. Since the subject is a living, breathing organism, changes in temperatures and gas composition must also be considered because they can influence the measurement. The Bod Pod® is an instrument with two chambers, in which one is for measuring the subject and the other is a reference chamber that holds pressure transducers, electronics, the breathing circuit, valves, and the air circulation system

(Dempster & Aitkens, 1995). After the subject is seated in the front chamber, the door is closed and multiple electromagnets act to seal the chamber. The subject must be wearing minimal clothing that is tight to the skin and a swim cap to compress the hair on the head in order to minimize the non-body volume. As a measurement takes place, a diaphragm in between the measurement and reference chambers will cause small volume changes and thus small pressure changes. A complete test of a subject provides data on the uncorrected body volume, computation of a surface area artifact and measurement or prediction of thoracic gas volume. The surface area artifact and the thoracic gas volume are subtracted from the uncorrected body volume to result in the final body volume. Density can be calculated using body volume and body mass. Once density is known, percent body fat and percent fat-free mass can be determined by the Siri equation, which states that percent fat equals 495 divided by density minus 450 (Dempster & Aitkens, 1995). The function of the Bod Pod® was tested repeatedly on inanimate objects and later on human subjects. The general adult population and child population were measured in numerous studies that supported the validity, reliability, and ease of use of the Bod Pod® in these populations since the late 1990s (Ball, 2005; Baracos et al., 2012; Collins, Saunders, McCarthy, Williams, & Fuller, 2004; Fields, Hunter, & Goran, 2000; Noreen & Lemon, 2006).

Reliability of the Bod Pod in Athletes

In order to determine whether the Bod Pod® can be considered a good instrument for the on-going monitoring of athletes, the accuracy of measuring minute changes in body composition must be examined. A study done in France had the objective of determining the sensitivity of air displacement plethysmography (ADP) when evaluating changes in body composition (Secchiutti et al., 2007). The subjects were 30 healthy adults, with 10 of these acting at the control group. The subjects underwent standard Bod Pod® procedures with and without a bottle of oil or water in the chamber. The researchers found that the Bod Pod is accurately able to determine the difference when additional water is present in the chamber versus additional oil. With the additional oil, the Bod Pod® measured the subject as having an increased percent body fat. The researchers concluded that the Bod Pod® is a reliable and valid instrument for measuring small changes in an individual's body composition, which is useful for the changing body composition of an athlete.

When using the Bod Pod® as the standard equipment to measure the body composition of competitive athletes, it must first be determined to be valid and reliable in comparison to other methods and equipment. A study at South Dakota State University was conducted with the purpose of evaluating the reliability and validity of air displacement plethysmography (ADP) as compared to dual energy x-ray absorptiometry (DXA) (Ballard et al., 2004). The sample was described as 47 Division II collegiate female athletes from various sports and 24 female non-athletes as controls. The athletes were members of the following teams: basketball, fast-pitch softball, soccer, swimming, track, and volleyball. All subjects were non-Hispanic, Euro-American females, aged 18 to 21 years, and healthy. All participants were measured using a Hologic QDR 4500A software version 12.01 for DXA and a Bod Pod® for ADP within a 30-minute time period. Prior to testing, participants were instructed to fast and refrain from exercise for four hours at minimum. Immediately prior to testing, participants used the restroom and were then weighed on a calibrated electronic scale and had height measured on a stadiometer. The same technician performed all DXA scans. The Bod Pod® measurements used predicted thoracic volumes, and participants wore the recommended nylon swimming suits and nylon swimming caps with all jewelry removed. The researchers found that there were no differences in percent body fat or free fat mass in ADP when compared with DXA for the athlete group. For the control group, there were no differences between DXA and ADP for percent body fat. The results indicate that ADP is reliable and valid for measuring body composition of female collegiate athletes and non-athletes when compared with DXA.

A similar study to the one by Ballard and associates was performed at the University of New Mexico in 2008 aimed to examine the accuracy of the Bod Pod® as compared to three other methods (Bentzur, Kravitz, & Lockner, 2008). Hydrostatic weighing (HW) was used as the gold standard method, and dual energy x-ray absorptiometry (DXA) and skin-fold (SF) measurements were used for further comparison. The subjects of the study were 30 Division I collegiate female athletes from the track and field team. The sample was 60% Caucasian, 20% Hispanic, 10% Black, 3.3% Asian, and 6.7% other. Height was measured with a stadiometer and weight was measured with a digital scale. Subjects underwent the standard procedures for Bod Pod® measurement and thoracic gas volume was measured. Subjects also underwent standard procedures for DXA and HW measurements. Four sites were used for the skin-fold measurements, and all measurements were performed in triplicate by the same technician. The study found that percent body fat measured by the Bod Pod® was significantly higher than percent body fat measured by HW, significantly lower than percent body fat measured by DXA, and not significantly different than percent body fat measured by skin-fold technique. In conclusion, the authors suggested that skin-fold measurements were a quick and inexpensive alternative to using the Bod Pod® in the female athlete population. The opinion of the author suggested that the Bod Pod® may eventually be a good method of body composition analysis in the future after the accuracy is improved.

Summary

As result of training for competition, the scholarly literature shows that athletes commonly gain muscle mass and lower fat mass in variable amounts based on the type of sport. For female athletes, especially the young women participating in sports at the collegiate level, it is vital to monitor body composition at regular intervals. Keeping observations of specific values, such as percent body fat, can help members of the female athlete population be aware of their ongoing health status. It is when the female athlete has a low level of body fat and low energy availability that she can develop health problems related to the female athlete triad. A method of accurately measuring percent body fat is through air displacement plethysmography in the Bod Pod® instrument. The literature supports this device as being valid and reliable in the general population as well as the athlete population. This study is designed to measure the body composition of female collegiate athletes from five teams using the Bod Pod®.

Chapter 3: Methodology

Research Purpose

The purpose of this study was to examine the body composition measurements of female collegiate athletes recorded during the preseason and postseason periods and to compare and contrast the difference in measurements of the members of various teams. This investigation of data related to the body composition of female collegiate athletes adds to previous research conducted by others, and provides information to the individual female athletes regarding their personal health at specific points in the training season.

Research Objectives

Objective 1.1: Assess the body composition of female collegiate athletes using data provided by the Bod Pod®.

Objective 1.2: Assess the body composition of female collegiate athletes using data provided by the body mass index formula.

Objective 2: Compare and contrast the body composition measurements for members of the basketball, gymnastics, soccer, swimming & diving, and volleyball teams.

Objective 3: Compare and contrast the body composition measurements for members of the same team between the preseason and postseason periods.

Research Hypotheses

Hypothesis 1: Total body mass, fat mass, and percent body fat will significantly decrease in all teams from the preseason to postseason period.

Hypothesis 2: Fat free mass will increase significantly in all teams from preseason to postseason.

Hypothesis 3: Basketball and volleyball players will be similar in body composition.

Hypothesis 4: Swimming & diving and gymnastics members will be similar in body composition.

Study Design

The measurements analyzed for this study were a portion of a larger data set from a research project conducted by the Department of Dietetics and Human Nutrition at the University of Kentucky. The study was originally approved by the University of Kentucky Institutional Review Board (IRB) in August 2010 as a nonmedical research protocol. The full research project consisted of data collected via the Bod Pod® instrument, anthropometric measurements pertaining to height and waist circumference, the Block Dietary Data Systems 2005 Food Questionnaire, and the EDI-3 Eating Disorder Inventory Referral Form. The portion of data used in this study included only the Bod Pod® measurements and some of the anthropometric data.

Recruitment

The research project was a collaboration of a college athletic department and the University of Kentucky Department of Dietetics and Human Nutrition. The athletic department approached the researchers about determining body composition of various teams. An agreement was made that the researchers would assess the teams and in turn would have access to the teams for securing consent for the research project. Coaches were provided the body composition results only and were not present for the testing and thus were unaware of which athletes agreed to participate in the study. Subjects were provided an informed consent document in order to determine their individual participation. The subjects' consent to participate was obtained voluntarily. No incentive was provided to the participants other than the opportunity to help with a research project about collegiate athletes and the possible opportunity to learn about their own body composition on an individual basis, if their coaches chose to reveal it. Some of the team members chose not to participate in the study.

Participants

The study population consisted of female athletes on the basketball, gymnastics, soccer, swimming & diving, and volleyball teams. All participants were aged 18 to 22 years old. Race and ethnicity were not exclusionary factors. Participants were studying various majors and in various years of study.

The total population consisted of 75 female athletes. The distribution of athletes from the various teams showed 12 subjects from the basketball team, 17 subjects from the gymnastics team, 15 subjects from the soccer team, 18 subjects from the swimming & diving team, and 13 subjects from the volleyball team. Participants were evenly distributed by year of study with 34.7% reporting themselves as freshmen, 29.3% as sophomores, 22.7% as juniors, and 13.3% as seniors during the preseason.

Research Instrument

All measurements used for this study were completed in the Nutrition Assessment Laboratory at the University of Kentucky. The measurements used for this study included the data provided by the Bod Pod® instrument and the anthropometric measurement of height collected manually by the researchers.

Utilization of the Bod Pod® instrument was the main method of data collection. The instrument is manufactured by COSMED USA, Inc., formerly Life Measurements, Inc. of Concord, CA and is solely operated by researchers from the Department of

Dietetics and Human Nutrition. The Bod Pod® is serviced by a manufacturer representative once yearly following the company's maintenance protocol. Prior to each testing session, the instrument and attached scale were calibrated according to the manufacturer instructions.

Data Collection

Subjects who agreed to participate in the study and provided signed consent were tested in the Bod Pod® and measured for anthropometric data by a researcher in the Nutrition Assessment Laboratory. Prior to testing, athletes were instructed to follow a set of guidelines in order to allow accurate data collection by the Bod Pod®. Subjects were asked to refrain from exercise for the four hours before testing, refrain from eating and drinking for one hour before testing, and use the restroom immediately before testing. Each participant was required to wear a tightly-fitting swimsuit or exercise shorts with sports bra top, plus a swim cap made of Spandex® or similar material. All jewelry and eyeglasses were removed. Height was measured through the use of a standard floor stadiometer.

Researchers followed the operating procedures from the Bod Pod® manufacturer's manual (Life Measurement, 2004). At the beginning of a test, identification information and height of the subject were entered by the researcher. As part of the research protocol, the Bod Pod's® software was instructed to use the appropriate ADP formula and a predicted lung volume that varied per individual. For each subject, the Bod Pod® required a two-point calibration test. The first calibration established that the instrument could accurately measure an empty chamber. The second calibration established that the instrument could measure an object of known volume. This object was a closed, hollow cylinder provided by the manufacturer with a volume of approximately 50 liters. Following this two-point calibration, the total body mass of the subject was measured via the Bod Pod® scale and automatically recorded by the software. The last part of the testing procedure was the measurement of the subject in the Bod Pod® for two separate 50-second periods, with the Bod Pod® being opened between each period. The individual was asked to breathe normally, sit still, and remain quiet during the two periods. Data were available immediately for review, but were not provided to the subjects by the researchers.

Statistical Analysis

Data were downloaded into Microsoft Office Excel 2007 from the Bod Pod® software and subsequently analyzed using SAS (version 9.3, English). Data were divided into several subsets in order to allow for comparison and contrast. Initially, the observations were divided by preseason and postseason. It was determined that some subjects were tested more than once during the preseason or postseason periods; therefore, only the last observation during the preseason and postseason for each subject was kept for analysis. This data set was then divided by team for further comparison. Descriptive information was produced for each subset that included mean, standard deviation, minimum value, and maximum value. Tests for significant differences between the teams and between preseason and postseason were performed using analysis of variance (ANOVA). Further statistical analysis included the use of the paired t-test to determine the significance of change in the variables between preseason and postseason for each team. The dependent variables included total body mass, fat mass, fat free mass, percent body fat, body mass index (BMI), and height. The comparison type III error rate was set at $\alpha \leq 0.05$. Any statistical comparisons found to be at or below the $\alpha = 0.05$ level were considered to be significant in nature.

Chapter 4: Results

Demographics

The final sample for this study included 75 participants. All participants were female (n=75). Team make-up for the sample was 24.0% (n=18) from the swimming & diving team, 20.0% (n=15) from the soccer team, 17.3% (n=13) from the volleyball team, 16.0% (n=12) from the basketball team, and 22.7% (n=17) from the gymnastics team. At the time of the preseason measurement, the participants represented all four years of study at the university with 34.7% (n=26) of the participants reporting themselves as freshmen, 29.3% (n=22) as sophomores, 22.7% (n=17) as juniors, and 13.3% (n=5) as fourth or fifth year seniors. Participants had a mean age of 20.0 ± 1.2 years with 18.0 years as the lowest age and 22.9 years as the highest age.

Height

One characteristic that is known to vary among athletes of different sports is height. To allow for a more simplified and cohesive comparison, the height measurements from preseason and postseason were averaged together for each team to give one representative value. All heights are reported in centimeters (cm) as shown in Table 4.1. The swimming & diving team members had an average height of 171.6 ± 5.8 cm. These team members were significantly taller than both the soccer and gymnastics team members, but significantly shorter than the members of the volleyball team (soccer, $p = 0.0042$; gymnastics, $p < 0.0001$; volleyball, $p = 0.0001$; basketball, $p = 0.7971$). The soccer participants were 166.3 ± 5.8 cm in height. The members from this team were significantly shorter than the swim & dive, volleyball, and basketball players on average, and significantly taller than the gymnastics members (swimming & diving, $p = 0.0042$; volleyball, $p < 0.0001$; basketball, $p = 0.0047$; gymnastics, $p = 0.0004$). The volleyball team had a mean height of 179.1 ± 9.6 cm. The average height of the volleyball team was significantly taller than all other teams, making them the tallest of all the teams (swimming & diving, $p = 0.0001$; soccer, $p < 0.0001$; basketball, $p = 0.0010$; gymnastics, $p < 0.0001$). Members of the basketball team had an average height of 172.1 ± 8.8 cm. When examining the height of the basketball team in relation to the other teams, the members were significantly taller than the soccer and gymnastics members but significantly shorter than the volleyball players (soccer, $p = 0.0047$; gymnastics, $p < 0.0001$; volleyball, $p = 0.0010$; swimming & diving, $p = 0.7971$). The gymnastics participants were 159.6 ± 6.4 cm tall on average. The team was significantly shorter in height than all other teams, and was found to be the shortest team overall (swimming & diving, $p < 0.0001$; soccer, $p = 0.0004$; volleyball, $p < 0.0001$; basketball, $p < 0.0001$).

Table 4.1 below shows the demographic characteristics of the sample.

Table 4.1: Demographic characteristics for all sports (mean of preseason and postseason combined).

	n	Age (y)	Height (cm)	Total body mass (kg)	Body mass index (kg/m^2)
Total	75	20.0 ± 1.2 (18.0-22.9)	169.2 ± 9.7 (130.8-193.0)	67.7 ± 8.8 (51.1-95.5)	23.7 ± 2.4 (17.6-30.7)
Swimming & Diving	18	19.9 ± 1.3 (18.1-22.9)	171.6 ± 5.8 (158.6-183.5)	70.0 ± 9.7 (51.8-95.5)	23.7 ± 2.6 (18.6-30.7)
Soccer	15	19.6 ± 0.9 (18.3-21.4)	166.3 ± 5.8 (152.0-176.0)	65.7 ± 6.2 (56.6-84.0)	23.7 ± 1.7 (20.7-27.7)
Volleyball	13	20.4 ± 1.3 (18.0-22.6)	179.1 ± 9.6 (158.8-193.0)	71.5 ± 6.0 (62.7-85.3)	22.4 ± 2.1 (17.6-25.3)
Basketball	12	20.2 ± 1.2 (18.6-22.4)	172.1 ± 8.8 (159.0-189.2)	71.4 ± 10.3 (54.4-90.5)	24.1 ± 2.5 (20.4-28.6)
Gymnastics	17	19.9 ± 1.2 (18.1-22.3)	159.6 ± 6.4 (130.8-167.6)	61.6 ±7.1 (51.5-74.2)	24.2 ± 2.5 (19.0-30.3)

Note: Mean ± standard deviation with range in parentheses.

Comparisons

Several measurements of interest from the Bod Pod® data were selected for comparison as shown in Tables 4.2 through 4.6. Comparisons were made between teams and between preseason and postseason measurements within teams. The designated measurements included: total body mass, fat mass, fat free mass, and percent body fat. Body mass index (BMI) was calculated separately from the Bod Pod® data and also used for comparison. Fat mass, as measured by the Bod Pod®, is the weight of all adipose tissue, while fat free mass is the weight of all remaining tissue, which includes muscle, water, bone, and internal organs. All masses are reported in kilograms (kg).

Preseason Measurements

The swimming & diving team participants on average were found to weigh 70.3 ± 10.5 kg, with 18.2 ± 5.8 kg fat mass and 52.1 ± 5.7 kg fat free mass. The average percent body fat of the team members was 25.4 ± 4.5%. The mean body mass index was 23.5 ± 2.8 kg/m^2. The members of swim & dive had a significantly higher average total body mass than the gymnastics team (soccer, $p = 0.1064$; volleyball, $p = 0.8552$; basketball, $p = 0.7792$; gymnastics, $p = 0.0017$). On average, they also had significantly more fat mass than members of the soccer and gymnastics teams (soccer, $p = 0.0218$; volleyball, $p = 0.0954$; basketball, $p = 0.1800$; gymnastics, $p = 0.0001$). The swim & dive members were not significantly different than any team in fat free mass (soccer, $p = 0.5438$; volleyball, $p = 0.0702$; basketball, $p = 0.0939$; gymnastics, $p = 0.0763$). Examining the percent body fat comparisons, the swimming & diving team members had the highest average percent body fat of all the teams; this was the only team that was significantly different than the rest (soccer, $p = 0.0287$; volleyball, $p = 0.0204$; basketball, $p = 0.0476$; gymnastics, $p = 0.0002$). There was no significant difference in the team's average body mass index as compared to the other teams (soccer, $p = 0.9240$; volleyball, $p = 0.1901$; basketball, $p = 0.7800$; gymnastics, $p = 0.6266$).

On average, the participants from the soccer team weighed 65.5 ± 6.4 kg, and had 14.5 ± 3.7 kg fat mass and 51.0 ± 3.8 kg fat free mass. The mean percent body fat of the team members was 21.9 ± 4.0%, and the average body mass index was 23.4 ± 1.8 kg/m^2. The soccer members were not significantly different than the others teams in terms of total body mass, with their average falling between the other teams' averages (swimming & diving, $p = 0.1064$; volleyball, $p = 0.0964$; basketball, $p = 0.0850$; gymnastics, $p = 0.139$) . The soccer players had a significantly lower amount of fat mass than the swimming & diving members (swimming & diving, $p = 0.0218$; volleyball, $p = 0.5899$; basketball, $p = 0.4175$; gymnastics, $p = 0.1311$). The soccer team had significantly lower amount of fat free mass than both the volleyball and basketball teams (swimming & diving, $p = 0.5438$; volleyball, $p = 0.0228$; basketball, $p = 0.0322$; gymnastics, $p = 0.2683$). Similar to other teams, the soccer team on average had a significantly lower percent body fat than the swimming & diving team (swimming & diving, $p = 0.0287$; volleyball, $p = 0.8287$; basketball, $p = 0.9390$; gymnastics, $p = 0.1205$). The team's average body mass index was not significant differently than the other teams (swimming & diving, $p = 0.9240$; volleyball, $p = 0.82872410$; basketball, $p = 0.7228$; gymnastics, $p = 0.5766$).

The participants from the volleyball team on average had a total body mass of 70.9 ± 5.8 kg; the mean fat mass and fat free mass were 15.4 ± 4.3 kg and 55.5 ± 3.0 kg, respectively. The average percent body fat was 21.5 ± 4.6%. The mean for the body mass index was 22.3 ± 2.1 kg/m^2. The volleyball team members were significantly higher in total body mass than the gymnastics team members (swimming & diving, p = 0.8552; soccer, p = 0.0964; basketball, p = 0.9241; gymnastics, p = 0.0023). The volleyball team was also found to be significantly higher in fat mass than the gymnastics team (swimming & diving, p = 0.0954; soccer, p = 0.5899; basketball, p = 0.7830; gymnastics, p = 0.0466). The volleyball players had significantly more fat free mass than the gymnastics team and the soccer team and had the highest fat free mass of all the teams (swimming & diving, p = 0.0702; soccer, p = 0.0228; basketball, p = 0.9281; gymnastics, p = 0.0009). The volleyball players had a significantly lower percent body fat than the swimming & diving team on average (swimming & diving, p = 0.0204; soccer, p = 0.8287; basketball, p = 0.7804; gymnastics, p = 0.2020). There was no significant difference in this team's body mass index average as compared to the other teams; however the volleyball team had the lowest average body mass index (swimming & diving, p = 0.1901; soccer, p = 0.2410; basketball, p = 0.1477; gymnastics, p = 0.0835).

The basketball team participants on average were found to weigh 71.2 ± 10.8 kg, with 15.9 ± 4.6 kg fat mass and 55.3 ± 7.0 kg fat free mass. The average percent body fat of the team members was 22.0 ± 3.8%. The mean body mass index was 23.7 ± 2.7 kg/m^2. This team had the highest average total body mass and this value was significantly higher than the gymnastics team's value (swimming & diving, p = 0.7792; soccer, p = 0.0850; volleyball, p = 0.9241; gymnastics, p = 0.0021). Similar to the volleyball players, the basketball team players also had a significantly higher average fat mass than the gymnastics members (swimming & diving, p = 0.1800; soccer, p = 0.4175; volleyball, p = 0.7830; gymnastics, p = 0.0261). The basketball team had a higher fat free mass than both the soccer team and the gymnastics team members (swimming & diving, p = 0.0939; soccer, p = 0.0322; volleyball, p = 0.9281; gymnastics, p = 0.0016). The percent body fat of the basketball team was significantly lower than that of the swimming & diving team (swimming & diving, p = 0.0476; soccer, p = 0.9390; volleyball, p = 0.7804; gymnastics, p = 0.1242). The body mass index of the basketball team was not significantly different than the other teams (swimming & diving, p = 0.7800; soccer, p = 0.7228; volleyball, p = 0.1477; gymnastics, p = 0.8723).

On average, the participants from the gymnastics team weighed 61.0 ± 7.4 kg, and had 12.0 ± 3.9 kg fat mass and 49.0 ± 5.1 kg fat free mass. The mean percent body fat of the team members was 19.3 ± 5.1%, and the average body mass index was 23.9 ± 2.4 kg/m^2. The members of the gymnastics team had the lowest total body mass, fat mass, fat free mass, and percent body fat of all the teams. The gymnastics members were significantly lower in total body mass than the swimming & diving, volleyball, and basketball team members (swimming & diving, p = 0.0017; soccer, p = 0.1396; volleyball, p = 0.0023; basketball, p = 0.0021). The gymnastics team was found to be lower in fat mass on average than the swimming & diving, volleyball, and basketball teams (swimming & diving, p = 0.0001; soccer, p = 0.1311; volleyball, p = 0.0466; basketball, p = 0.0261). The gymnasts had significantly lower fat free mass than both the volleyball and basketball members (swimming & diving, p = 0.0763; soccer, p = 0.2683; volleyball, p = 0.0009; basketball, p = 0.0016). In terms of percent body fat, the gymnasts were significantly lower than the swimming & diving members (swimming &

diving, $p = 0.0002$; soccer, $p = 0.1205$; volleyball, $p = 0.2020$; basketball, $p = 0.1242$). On average, the gymnastics members were not significantly different than any other team in body mass index, but did have the highest value (swimming & diving, $p = 0.6266$; soccer, $p = 0.5766$; volleyball, $p = 0.0835$; basketball, $p = 0.8723$).

Postseason Measurements

The members of the swimming & diving team had an average total body mass of 69.7 ± 9.0 kg, with 17.1 ± 4.1 kg fat mass and 52.6 ± 5.5 kg fat free mass. The mean percent body fat was found to be 24.3 ± 3.1%. The team's average body mass index was 24.0 ± 2.3 kg/m^2. The swimming & diving team members were significantly higher in total body mass than the gymnastics team members (soccer, $p = 0.1678$; volleyball, $p = 0.3940$; basketball, $p = 0.5172$; gymnastics, $p = 0.0064$). The swimming & diving team was higher on average in fat mass than the gymnastics team, and had the highest fat mass of all the teams (soccer, $p = 0.1823$; volleyball, $p = 0.1131$; basketball, $p = 0.4774$; gymnastics, $p = 0.0018$). In terms of fat free mass, this team was significantly higher than the volleyball team (soccer, $p = 0.2839$; volleyball, $p = 0.0100$; basketball, $p = 0.1140$; gymnastics, $p = 0.0861$). The average percent body fat of the swimming & diving participants was significantly higher than that of the volleyball and gymnastics members (soccer, $p = 0.3195$; volleyball, $p = 0.0090$; basketball, $p = 0.1741$; gymnastics, $p = 0.0027$). This team was not significantly different than other teams for body mass index (soccer, $p = 0.8997$; volleyball, $p = 0.0685$; basketball, $p = 0.6238$; gymnastics, $p = 0.4836$).

The soccer team had an average total body mass of 65.8 ± 6.3 kg. The members' fat mass was found to be 15.1 ± 3.8 kg and the fat free mass was found to be 50.7 ± 3.9

kg. The percent body fat was 22.8 ± 3.9% on average. The mean body mass index of the soccer players was 24.1 ± 1.5 kg/m^2. The soccer team on average was significantly lower in total body mass than the volleyball team (swimming & diving, p = 0.1678; volleyball, p = 0.0385; basketball, p = 0.0637; gymnastics, p = 0.1957). The soccer players were found to be significantly lower in fat free mass than both the volleyball and basketball teams (swimming & diving, p = 0.2839; volleyball, p = 0.0007; basketball, p = 0.0142; gymnastics, p = 0.5531). There was no significant difference in the soccer players' average value for fat mass as compared to the other teams (swimming & diving, p = 0.1823; volleyball, p = 0.7663; basketball, p = 0.5987; gymnastics, p = 0.0805). The soccer team was not significantly different in percent body fat than the other teams (swimming & diving, p = 0.3195; volleyball, p = 0.1021; basketball, p = 0.6784; gymnastics, p = 0.0520). On average, the soccer team was not significantly different for body mass index as compared to all other teams (swimming & diving, p = 0.8997; volleyball, p = 0.0624; basketball, p = 0.7200; gymnastics, p = 0.5858).

The volleyball team participants on average were found to weigh 72.1 ± 6.3 kg, with 14.7 ± 4.1 kg fat mass and 57.4 ± 3.7 kg fat free mass. The mean percent body fat of the team members was 20.1 ± 4.2%, and the average body mass index was 22.5 ± 2.1 kg/m^2. The volleyball team had the highest total body mass and fat free mass of all teams. The mean value for total body mass was significantly higher than the mean value for the soccer and gymnastics teams (swimming & diving, p = 0.3940; soccer, p = 0.0385; basketball, p = 0.8625; gymnastics, p = 0.0010). Members of the volleyball team were not found to be significantly different than other teams for fat mass (swimming & diving, p = 0.1131; soccer, p = 0.7663; basketball, p = 0.4299; gymnastics, p = 0.1664).

The volleyball players' average fat free mass was significantly higher than the swimming & diving, soccer, and gymnastics participants' average fat free mass (swimming & diving, $p = 0.0100$; soccer, $p = 0.0007$; basketball, $p = 0.3612$; gymnastics, $p < 0.0001$). In terms of percent body fat, the volleyball team was significantly lower than the swimming & diving team (swimming & diving, $p = 0.0090$; soccer, $p = 0.1021$; basketball, $p = 0.2479$; gymnastics, $p = 0.8446$). This team had the lowest body mass index value and the value was significantly lower than that of the basketball and gymnastics teams (swimming & diving, $p = 0.0685$; soccer, $p = 0.0624$; basketball, $p = 0.0358$; gymnastics, $p = 0.0158$).

On average, the participants from the basketball team weighed 71.6 ± 10.2 kg, and had 16.0 ± 4.2 kg fat mass and 55.6 ± 7.2 kg fat free mass. The percent body fat of the team members was found to be 22.1 ± 4.0%. The mean body mass index was 24.4 ± 2.4 kg/m^2. The basketball players were significantly heavier in total body mass than the members of the gymnastics team (swimming & diving, $p = 0.5172$; soccer, $p = 0.0637$; volleyball, $p = 0.8625$; gymnastics, $p = 0.0023$). Additionally, the basketball players were also significantly higher in fat mass than the gymnasts (swimming & diving, $p = 0.4774$; soccer, $p = 0.5987$; volleyball, $p = 0.4299$; gymnastics, $p = 0.0304$). For the measurement of fat free mass, the basketball team was significantly higher than the soccer and gymnastics teams (swimming & diving, $p = 0.1140$; soccer, $p = 0.0142$; volleyball, $p = 0.3612$; gymnastics, $p = 0.0025$). Basketball team members were found to not be significantly different in percent body fat than the other teams (swimming & diving, $p = 0.1741$; soccer, $p = 0.6784$; volleyball, $p = 0.2479$; gymnastics, $p = 0.1573$). Examining the body mass index value, the basketball team was found to be significantly higher than the volleyball team (swimming & diving, $p = 0.6238$; soccer, $p = 0.7200$; volleyball, $p = 0.0358$; gymnastics, $p = 0.8853$).

The participants from the gymnastics team on average had a total body mass of 62.2 ± 6.9 kg; the mean fat mass and fat free mass were 12.6 ± 4.3 kg and 49.7 ± 4.2 kg, respectively. The mean percent body mass of the team members was 19.8 ± 5.5%. For the members, the average body mass index was found to be 24.5 ± 2.6 kg/m^2. The gymnastics team had the lowest average total body mass, fat mass, fat free mass, and percent body fat. The members were significantly lighter in total body mass than the members of the swimming & diving, volleyball and basketball teams (swimming & diving, $p = 0.0064$; soccer, $p = 0.1957$; volleyball, $p = 0.0010$; basketball, $p = 0.0023$). The gymnastics team was significantly lighter in fat mass than both the swimming & diving and basketball teams (swimming & diving, $p = 0.0018$; soccer, $p = 0.0805$; volleyball, $p = 0.1664$; basketball, $p = 0.0304$). In terms of fat free mass, the gymnasts had significantly less than the volleyball and basketball members (swimming & diving, $p = 0.0861$; soccer, $p = 0.5531$; volleyball, $p < 0.0001$; basketball, $p = 0.0025$). The gymnastics participants had a significantly lower percent body fat than the swimming & diving members (swimming & diving, $p = 0.0027$; soccer, $p = 0.0520$; volleyball, $p = 0.8446$; basketball, $p = 0.1573$). Of all the teams, the gymnastics team had the highest body mass index; the team was significantly higher than the volleyball team (swimming & diving, $p = 0.4836$; soccer, $p = 0.5858$; volleyball, $p = 0.0158$; basketball, $p = 0.8853$).

Preseason to Postseason Change

Data from each of the five teams were analyzed in order to investigate potential changes in body composition measurements from the preseason period to the postseason period. For all of the parameters, it was determined that none of the teams exhibited a significant change from the preseason to the postseason at the confidence level $\alpha \leq 0.05$; however, small changes in the measurements have been observed. All teams except for the swimming & diving team were found to have an increase in the average total body mass of the members from preseason to postseason. The swimming & diving and volleyball teams were the only two teams to have the members exhibit a decrease in both average fat mass and average percent body fat. On average, all teams' members except for the soccer team members increased in fat free mass. Mean body mass index was found to increase for all teams.

Tables 4.2 through 4.6 below show the body composition measurements for each team by preseason and postseason.

Table 4.2: Body composition measurements for the swimming & diving team.

	Seasonal Period	Total body mass (kg)	Fat mass (kg)	Fat free mass (kg)	Percent body fat (%)	Body mass index (kg/m^2)
Swimming & Diving	Preseason	70.3 ± 10.5 (51.8-95.5)	18.2 ± 5.8 (9.8-30.5)	52.1 ± 5.7 (42.0-65.0)	25.4 ± 4.5 (17.7-32.6)	23.5 ± 2.8 (18.6-30.7)
	Postseason	69.7 ± 9.0 (54.3-93.8)	17.1 ± 4.1 (11.0-29.0)	52.6 ± 5.5 (42.7-64.7)	24.3 ± 3.1 (19.8-31.0)	24.0 ± 2.3 (20.2-30.5)
	p-value for difference	0.5157	0.1696	0.9284	0.0813	0.4536

Note: Mean ± standard deviation with range in parentheses.

Table 4.3: Body composition measurements for the soccer team.

	Seasonal Period	Total body mass (kg)	Fat mass (kg)	Fat free mass (kg)	Percent body fat (%)	Body mass index (kg/m2)
Soccer	Preseason	65.5 ± 6.4 (56.9-83.4)	14.5 ± 3.7 (8.6-22.9)	51.0 ± 3.8 (43.7-60.5)	21.9 ± 4.0 (13.8-27.5)	23.4 ± 1.8 (20.7-27.7)
	Postseason	65.8 ± 6.3 (56.6-84.0)	15.1 ± 3.8 (8.9-24.7)	50.7 ± 3.9 (43.7-59.4)	22.8 ± 3.9 (13.6-29.4)	24.1 ± 1.5 (22.1-27.1)
	p-value for difference	0.9584	0.9684	0.9141	0.9708	0.5370

Note: Mean ± standard deviation with range in parentheses.

Table 4.4: Body composition measurements for the volleyball team.

	Seasonal Period	Total body mass (kg)	Fat mass (kg)	Fat free mass (kg)	Percent body fat (%)	Body mass index (kg/m2)
Volleyball	Preseason	70.9 ± 5.8 (63.4-83.4)	15.4 ± 4.3 (8.6-23.4)	55.5 ± 3.0 (50.0-60.2)	21.5 ± 4.6 (13.6-28.1)	22.3 ± 2.1 (17.6-25.3)
	Postseason	72.1 ± 6.3 (62.7-85.3)	14.7 ± 4.1 (8.2-22.9)	57.4 ± 3.7 (50.4-62.4)	20.1 ± 4.2 (12.1-26.8)	22.5 ± 2.1 (17.9-25.0)
	p-value for difference	0.8058	0.8457	0.4546	0.7566	0.9736

Note: Mean ± standard deviation with range in parentheses.

Table 4.5: Body composition measurements for the basketball team.

	Seasonal Period	Total body mass (kg)	Fat mass (kg)	Fat free mass (kg)	Percent body fat (%)	Body mass index (kg/m2)
Basketball	Preseason	71.2 ± 10.8 (54.6-90.5)	15.9 ± 4.6 (8.1-24.7)	55.3 ± 7.0 (44.4-65.8)	22.0 ± 3.8 (14.8-27.3)	23.7 ± 2.7 (20.4-28.6)
	Postseason	71.6 ± 10.2 (54.4-87.5)	16.0 ± 4.2 (7.8-21.3)	55.6 ± 7.2 (44.7-66.7)	22.1 ± 4.0 (14.3-27.3)	24.4 ± 2.4 (20.5-28.4)
	p-value for difference	0.8470	0.7203	0.9101	0.9415	0.6342

Note: Mean ± standard deviation with range in parentheses.

Table 4.6: Body composition measurements for the gymnastics team.

	Seasonal Period	Total body mass (kg)	Fat mass (kg)	Fat free mass (kg)	Percent body fat (%)	Body mass index (kg/m2)
Gymnastics	Preseason	61.0 ± 7.4 (51.1-73.4)	12.0 ± 3.9 (4.1-58.8)	49.0 ± 5.1 (40.1-58.8)	19.3 ± 5.1 (8.0-25.5)	23.9 ± 2.4 (19.0-27.0)
	Postseason	62.2 ± 6.9 (51.8-74.2)	12.6 ± 4.3 (3.7-21.1)	49.7 ± 4.2 (41.8-60.3)	19.8 ± 5.5 (7.0-28.4)	24.5 ± 2.6 (19.1-30.3)
	p-value for difference	0.7597	0.7473	0.4610	0.7827	0.6873

Note: Mean ± standard deviation with range in parentheses.

Figures 4.1 through 4.5 below illustrate the differences between the teams and the change from preseason to postseason for each body composition measurement.

Figure 4.1: Total body mass for each team, including preseason and postseason measurements.

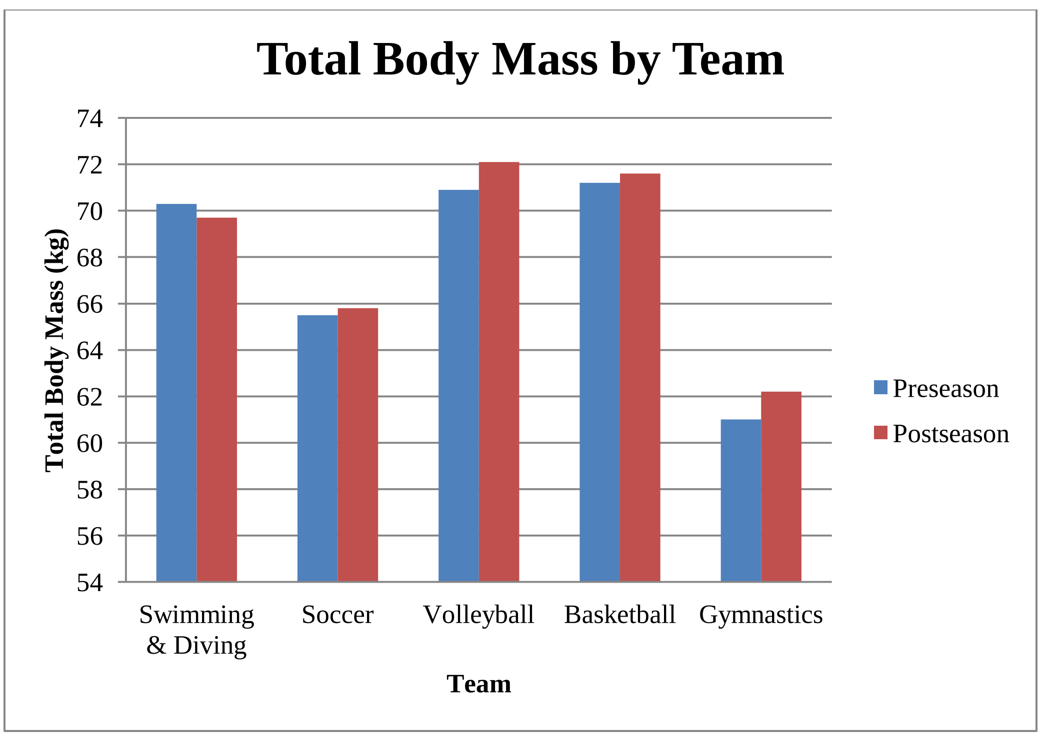


Figure 4.2: Fat mass for each team, including preseason and postseason measurements.

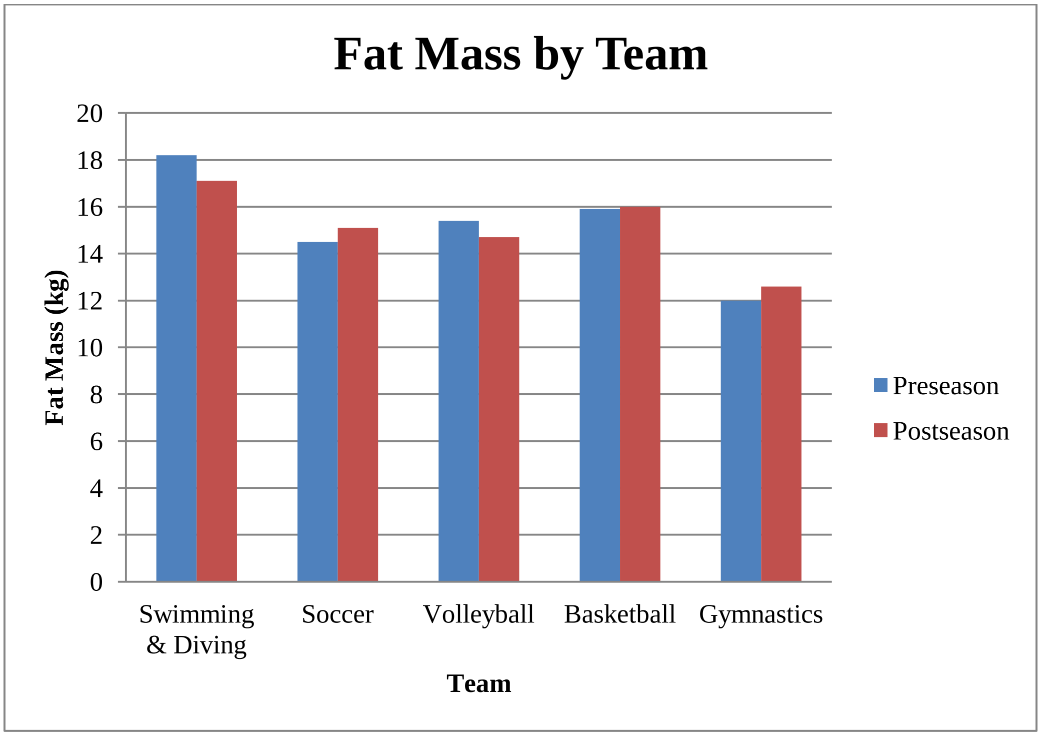


Figure 4.3: Fat free mass for each team, including preseason and postseason measurements.

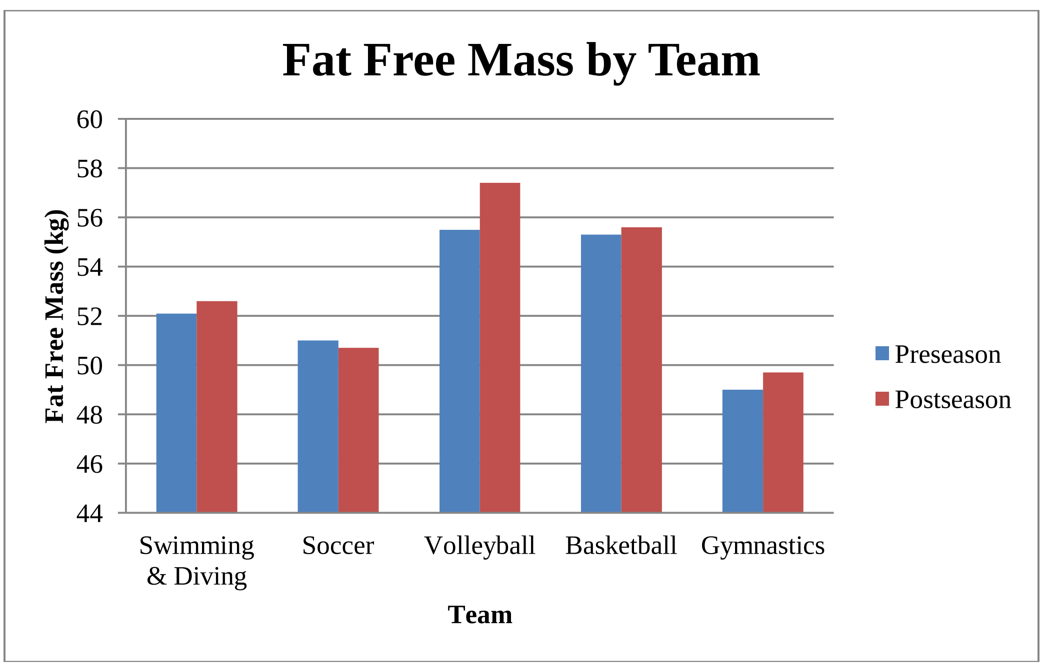


Figure 4.4: Percent body fat for each team, including preseason and postseason measurements.

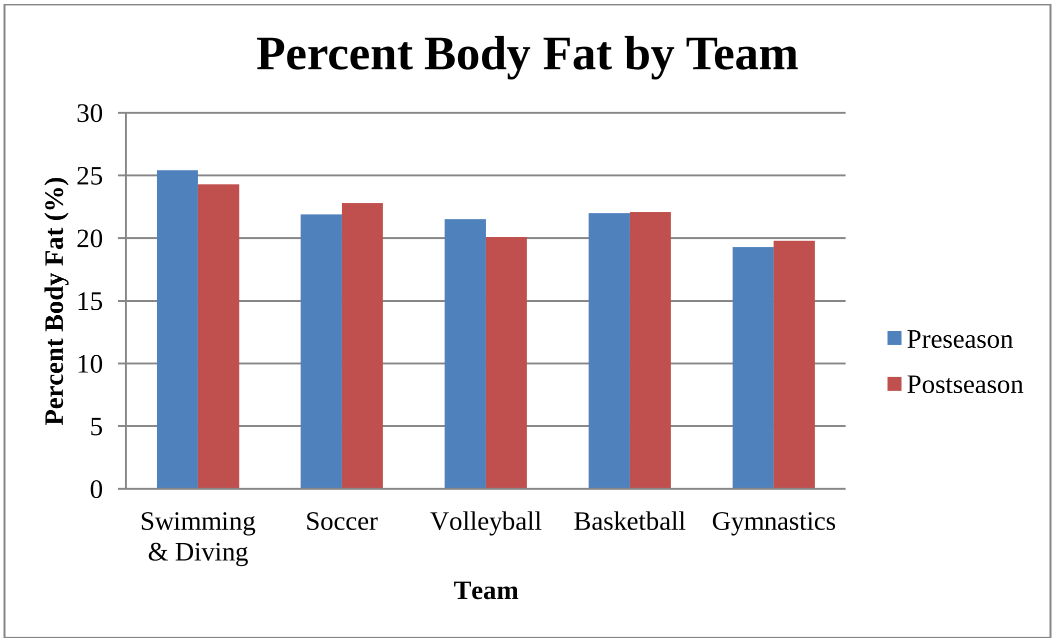
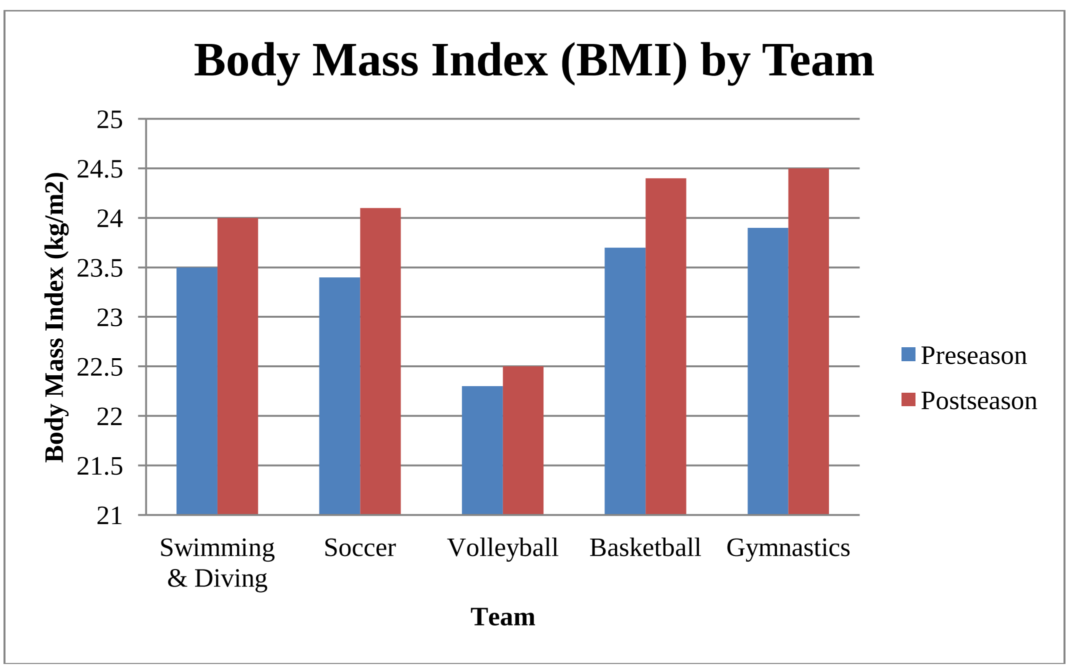


Figure 4.5: Body mass index for each team, including preseason and postseason measurements.



Chapter 5: Discussion

Findings

This study was conducted with the intent of measuring the body composition of the female collegiate athlete population in order to learn more about the general body composition and health status indicators of this group. A secondary goal of the study was to provide the young women with personalized health information that could be used for their benefit. The results indicated that this sample of the female collegiate athlete population was generally within a healthy range in regards to body compositions measurements. This was a positive find for the female athletic population because it supported the idea that participation in competitive sports at the collegiate level can be beneficial for young women depending on how training is performed.

One of the major objectives of the study was to compare and contrast the body composition measurements of the athletes from the preseason and postseason. Two of the hypotheses were related to this objective. After analysis of the data, it was discovered that none of the teams displayed significant changes in any body composition measurement from preseason to postseason at the $\alpha \leq 0.05$ level, which implies that the changes could be due to chance and may not be a result of athletic training over the course of the season. Hypothesis 1, which states that total body mass, fat mass, and percent body fat will significantly decrease in all teams from preseason to postseason, was not supported. Hypothesis 2, which states that fat free mass will increase significantly in all teams from preseason to postseason, was also not supported. There a several possible explanations for the lack of significant change from preseason to postseason on any team. Perhaps the reason is due to timing of the measurements; preseason was not early enough and postseason was not late enough. It is also possinle that training was not as intense as predicted, resulting in less dramatic changes in body composition across the season. Due to the lack of significance in the statistical analysis, potential trends can be noted but not substantiated by the data. Some teams seemed to show a small change in the expected direction each a particular measurement while other teams seemed to show a small change in the unexpected direction for some of the measurements. All teams showed an increase in total body mass, which is unexpected to be due to the predicted decreased contribution of adipose tissue. Of note, the soccer, basketball, and gymnastics teams showed a small increase in fat mass from preseason to postseason. Since the expected change is a decrease in fat mass, the changes in total body mass and fat mass are unexpected because the required endurance exercise conditioning for these sports would be thought to result in lower fat mass and thus lower total body mass (Elliott et al., 2007). One of the only published studies to record the body measurements of female athletes at more than one time during the season showed different results. Researchers found that female collegiate basketball, volleyball and swimming team members showed a decrease in total body mass from preseason to postseason, but only the swimming team showed a significant decrease (Carbuhn et al., 2010). Additionally, the three teams showed a decrease in fat mass, with the change for the basketball and volleyball players being significant. The reason for the difference in results between the two studies could be due to the use a different instrument for measurement. The researchers used DXA to measure the athletes, whereas this study used the Bod Pod®. When examining the change in fat free mass, also known as lean mass, the soccer team was the only team to show a decrease in fat free mass over the season, which is unexpected for athletes who are actively training due to the documented increase in muscle mass as a result of repeated exercise (Coffey & Hawley, 2007). The research by Carbuhn and associates regarding change in lean mass varied per team and supports the change seen in this study for only the swimming & diving team. The results show that both the soccer and gymnastics teams displayed the unexpected change of increased percent body fat from the preseason to the postseason; however the decrease in percent body fat achieved by the other teams is supported by the literature (Carbuhn et al., 2010).

The other major objective of this study was to compare and contrast the body composition measurements between athletes on different teams in order to provide information related to specific sport participation. There were two hypotheses related to this objective. The volleyball, basketball, and swimming & diving team members were found to be generally close in total body mass and heavier than soccer or gymnastics team members. Even though these three teams displayed similar exterior profiles, the volleyball players were the leanest of the three, and the swimmers and divers were the least lean. Basketball players seemed to fall in middle of the volleyball players and swim & dive members. Therefore, Hypothesis 3, which states that basketball and volleyball players will be similar in body composition, is supported by the results. The similarities of the three teams is also supported by the previously mentioned study that compared female collegiate athletes using DXA (Carbuhn et al., 2010). Possible explanations for these differences and similarities in the measurements are highly attributed to the nature of each sport. Basketball players require height due to the technique needed for offense and defense, but require more weight than the other tall athletes due to making physical contact with the opposing team. The basketball players need to be able to hold their ground and move through resistance applied by their opponents. The volleyball players similarly need height for technique related to offense and defense, but do not require as much weight because they are not in direct physical contact with their opponents. The reason for the difference in the body fat of swimmers & divers from the other tall players is unknown but it may be due to the need for body fat to maintain internal body temperature in the cold environment of the water. The swimmers need to keep their muscles warm to move efficiently, and shivering would interfere with muscle performance. Higher body fat may also help swimmers with buoyancy and aid in staying close to the surface of the water when competing. Another idea is that swimmers & divers should be measured separately because these two groups may have very different body compositions. It could be that swimmers are lower in total body mass and percent body fat than divers, or vice versa. The soccer players seemed to represent the medium weight and medium height athlete. Overall, the soccer players had less total body mass than the three taller and heavier teams' members, but had fat mass that was close to the range of that group. As a result, the soccer players have much less fat free mass than those three teams. Soccer players are required to perform ball handling techniques that frequently occur at the ground level, so it seems to be more efficient to not be very tall. In addition, the soccer players do have limited physical contact with their opponents, so increased body weight will help when working to maintain footing when being physically resisted. The gymnastics members were the smallest and shortest of all five teams. They had less total body mass and height, as well as less fat mass and fat free mass. This low weight and height allows a gymnast to require less effort to move her body for the various performance techniques. The gymnast can also be more aesthetically pleasing by having less adipose tissue and a more muscular appearance. After examining the data, Hypothesis 4, which states that swimming & diving and gymnastics team members will be similar in body composition, is not supported by the results. It is unknown whether the results are supported by the scholarly literature because no other studies comparing gymnasts to other athletes in the same study could be found. Interestingly, when using the BMI values to compare each of the teams' overall densities, athletes from the teams of swimming & diving, soccer, basketball, and even gymnastics showed similar densities, with volleyball being the only team to have a much lower density than the other athletes. No scholarly literature comparing female collegiate athletes from multiple teams in one study was located that could support or dismiss the relationships shown by these BMI results.

Using the data on body composition collected from this study, it is possible to construct the outline of how a typical participant on each of these five teams may appear. A swim & dive team member would be relatively tall for a woman at 172 cm (5'8") and of moderate weight at 70 kg (154 lbs). Her percent body fat of 25% would be considered "moderately lean" according to the Bod Pod® classification chart and "average" according to the American Council on Exercise chart (COSMED USA, 2012; Muth, 2009). This would be put her at the upper end of the published range for an untrained female in her twenties and most likely higher than many female athletes in other sports. Her BMI of 24 may be slightly misleading as too high but can be used as approximate estimate of her body fatness. Basketball and volleyball players would be similar in body composition. Both women would be tall at around 172 to 179 cm (5'8" to 5'10") and of moderate weight at 72 kg (157 lbs). With a percent body fat in the range of 21% to 22%, they would fall into the “lean” category for the Bod Pod® classifications and the “fitness” classification for the ACE chart. These young women would be at the lower end of the range for untrained females in their twenties. With a BMI of 22 to 24, this value may not be a good indicator of her level of body fatness because it implies more body fatness than was measured. A soccer player would be of medium height at 166 cm (5’5”) and below moderate weight at 66 kg (145 lbs). Her percent body fat of 22% would show her as “lean” on the Bod Pod® classification chart and “fitness” on the ACE chart. She would be at the low end of the range untrained women in their twenties. Her BMI of 24 may not be a good indicator of her level of body fatness because it would imply a higher amount of body fat than she has actually maintained. A gymnast would be relatively short for a woman at 160 cm (5’3”) and of a lower weight at 62 kg (136 lbs). Her percent body fat of 19.5% defines her as “lean” according to the Bod Pod® classifications and in the “athlete” category for the ACE chart. She would be well below the range for young untrained women in their twenties and at the low end of the range for young women in their late teens. Her BMI of 24 would not be a good indicator of her level of body fatness because her level of body fat is far below the level implied by that BMI value.

Implications

This collection of data related to body composition measurements of the female collegiate athlete population has the potential to be used as a reference for other scholarly works. Few studies focusing on the Bod Pod® data for female athletes currently exist for further comparison. While this study was unable to support a significant change in any of the teams' measurements from preseason to postseason using only Bod Pod® data, other studies using different instruments have been able to support that concept. What this study was able to do was show that female athletes in different sports are often significantly different in measurements of height, total body mass, fat mass, fat free mass, percent body fat, and body mass index. The significant differences in female athletes from various sports seems to suggest that the athletes train differently and utilize differing physical mechanisms in order to perform well in their respective sports. Depending on the sport, some athletes are found to not be significantly different, which may imply that athletes from those sports undergo similar training or perhaps require a similar, innate body composition in order to achieve success. Regardless of the reason for the diverse body composition of the female athletes, this data can be useful for future comparison by studies using the Bod Pod® for data collection.

The design of this study allowed for the added benefit of being able to share the measurements with the individual female collegiate athletes. Although the ultimate decision to share the body composition information with the female athletes was held by each team's training staff, it is expected that this information was shared. This would be especially important for females who displayed a low percent body fat for their age group. On each of the sports teams except swimming & diving, there were one or more female athletes who had a percent body fat in the 14-15% range. While researchers continue to develop guidelines related to specific percent body fat ranges for optimum health for various populations, this 14-15% zone is the potential danger zone that two classification systems seem to suggest (COSMED USA, 2012; Muth, 2009). It is important for women in competitive sports to be made aware that their current body composition could negatively impact their health in the present and in the future. By providing the female athlete with personal measurement information and teaching her knowledge about the lasting effects of maintaining certain compositional values on a long-term basis, she can be more prepared to make decisions about what is necessary for her health. There is the possibility that changing her level of body fatness specifically will impact her competitiveness, but she needs to be prepared to make that sacrifice if she wants to preserve her reproductive and osteopathic well-being.

In order to make a change in her level of body fatness, the female athlete would most likely need to alter her exercise training regimen and, perhaps more importantly, her nutritional intake. Knowing that one of the components of the female athlete triad is low energy availability, it is important for sports dietitians, and the athletes themselves, to monitor intake and support nutritional needs. By meeting the athlete's requirements for calories, protein, carbohydrates, and fat, plus other nutrients, she can preserve her long term nutrition status. It is equally important for athletes to continue to monitor their nutrition status after their competitive careers are over due to the changes in body composition that can occur from a decrease in repetitive exercise. Athletes should be educated as to the decrease in bone mass that results from performing less impact exercises, and prepare accordingly by consuming adequate amounts of nutrients that support bone health, such as calcium and Vitamin D. Athletes should also be taught about the decrease in caloric needs when no longer exercising with high intensity and frequency in order to maintain a healthy level of body fat. By knowing more about nutrition, athletes can continue to maintain their bodies in excellent condition and promote a high quality of life as they age. Sports dietitians and other dietitians can contribute to this effort by working with athletes to continue monitoring nutrition status and providing the necessary nutrition education.

Strengths, Limitations, and Future Research

There were multiple strengths to this study. Some strengths of this research were the use of the Bod Pod®, an instrument found to be valid and reliable in previous research, and the collection of objective data versus subjective data via the Bod Pod® instrument. Other strengths include the method of recruitment and obtaining informed consent. It was efficient to work with entire teams with the permission of the coaching staff because multiple participants from a team arrived in a large group at data collection times. Although not all members of the teams agreed to participate, this method allowed for a greater number of subjects from a particular sport to be available for potential recruitment. By asking training staff to not be present when informed consent was obtained from the participants, this eliminated any potential bias that the training staff may have caused.

Several limitations were encountered over the course of this study and the subsequent analysis. The major limitation to this study was the use of multiple of research assistants for data collection. When different assistants are involved with measuring participants, it is possible to encounter discrepancies in measurements performed manually. Specifically, the measurement of height performed using the floor stadiometer is of concern. It is difficult to discern whether slight differences were due to measurement error. A second limitation is that study participants were only available from those teams in which the coaches had requested Bod Pod® assessments. Of the numerous women's teams, only five could be included in this research.

The topic of female athlete body composition is one that is highly expandable into many different directions. While further research is needed to confirm the range of healthy body fat percentages for young female athletes, this type of study could contribute to that exploration by simultaneously comparing health records with percent body fat. This could help determine at which body fat percentage a female athlete's health is shown to be comprised. In another direction, the nutrient intake and eating disorder screening data of an athlete could be analyzed along with her percent body fat to examine correlations. By incorporating a variety of data types, the research can delve into numerous facets of the effect of athlete training on the health of young women.

This study made contributions to the overall project that includes the full data set and will help with future research efforts. As this is the first attempt to analyze any part of the data, there is an increased awareness of the need for greater consistency with measuring the subjects' height. Future researchers will know to look closely at the Food Frequency Questionnaire and other efforts related to the overall project, such as the training table. In addition, a potential topic for further analysis using the full data set is the comparison between the athlete's percent body fat and body mass index.

Final Conclusions

The female collegiate athlete accepts an enormous amount of responsibility when she decides to be a competitive athlete and a university student in her early adult years. Athletic training that promotes an ideal body composition for competition can be physically stressful on the female body. The college years are a time when it is important for a young woman to properly care for her body with the goal of maintaining an excellent level of health for the present and future. The female athlete specifically must be careful to avoid the components of the female athlete triad, defined as a combination of low energy availability, menstrual dysfunction, and osteoporosis. By following changes in body composition measurements, such as percent body fat, the athlete can monitor the effect of her training regimen and how her body is reacting. The Bod Pod® is a valid and reliable instrument for measuring body composition in the athlete population.

The research conducted for this study provided further information on the typical body composition of a female collegiate athlete competing at the national level. Basketball, volleyball, and swimming & diving team members were found to be taller and higher in weight than the other athletes, with swim & dive athletes showing increased body fatness. It was observed that soccer players were of medium height and weight as compared to the other athletes with an increased amount of body fat. Lastly, gymnastics participants exhibited short height and low weight in relation to the other athletes and had a low amount of body fat.

Data showed that some female athletes in each of the five sports displayed percent body fat amounts at a level well below the known range for the general female population. It is important for these athletes to be frequently monitored for body composition changes and educated on the potential health consequences that can occur. This research shows that screening and prevention is relevant for female athletes from all sports at the collegiate level.

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Vita:

Adrienne Jennifer Glodt Baker

Date and Place of Birth:
April 17, 1984
Rockville, Maryland

Education:

- Bachelor of Science in Biological Sciences
  University of Maryland, Baltimore County, May 2006

- ACEND-Required Coursework in Dietetics
  University of Kentucky, December 2010

- ACEND-Accredited Supervised Practice Program
  University of Kentucky, August 2011

Professional Positions:

- Teaching and Research Assistant, Department of Dietetics and Human Nutrition, University of Kentucky, January 2009 to May 2012
- Dietetic Technician, Lexington Country Place, Five Star Quality Care, Inc., August 2011 to July 2012
- Assistant Director of Dietary Services, Lexington Country Place, Five Star Quality Care, Inc., July 2012