A thesis submitted in partial fulfillment of the requirements of the Marymount Honors Program

HON 400 (or departmental equivalent) Grade:_____

____

Mr. Collin Chartier Student

____

Dr. Michael Nordvall, Thesis Supervisor

Date of Defense: 4/25/17

____

Second Reader

____

Honors Director or Designee

Hemoglobin, Hematocrit, and Body Composition Status of Collegiate Triathlon and Cross Country Athletes During the Competitive Season

Marymount University

Collin Chartier

Introduction

The purpose of this study is to investigate whether there are statistically relevant associations between the Marymount University Triathlon and Cross Country Teams' physiological status (Hemoglobin, Hematocrit, Anthropometrics) over the course of their competitive season. Marymount University is home of the first Varsity Intercollegiate male and female Triathlon Teams in the United States, and at present, there is no published data on blood parameters and body composition in these athletes. Although data on age-group triathletes and elite/professional triathletes exist, research on Varsity Collegiate Triathletes is needed to support this up-and-coming population. The National Collegiate Athletic Association (NCAA) Triathlon initiative is currently underway, giving grants to universities who commit to launching varsity triathlon programs, and several universities are starting varsity triathlon programs. The hope of this NCAA initiative is for triathlon to be a NCAA sport by 2020, which will require a certain number of universities to have fully funded varsity triathlon programs.

Physiological status will be measured for hemoglobin concentration, hematocrit, and body composition. These measures are known to be correlated with endurance performance, and limited information exists when tracked through the competitive season for the Cross Country Teams in the Fall semester and the competitive season for the Triathlon Teams in the Fall and Spring semesters. Generally Marymount's Triathlon and Cross Country teams begin the season with a lower racing volume and high aerobic volume leading to a performance peak at the end of the semester. This study attempts to investigate whether a correlation exists between physiological measures described above and performance over the course of the competitive season.

The implications of this study may better help athletes train and peak for athletic competition.

Literature Review

The sport of triathlon is relatively new, and is one of the fastest growing intercollegiate varsity sports. Current literature on triathletes is limited, and on varsity collegiate triathletes is virtually non-existent. Studies on triathletes have either focused on beginner triathletes or elite triathletes, with a significant gap in performance between these two groups. There is a distinction between collegiate club triathlon teams and intercollegiate varsity triathlon teams, such that intercollegiate varsity teams are supported under the athletic director and are financially backed by a University. USA Triathlon (USAT), the governing body for the sport of triathlon, holds a Collegiate Club National Championships annually, where all collegiate teams, both club and varsity, have an opportunity to compete. In 2015, the NCAA hosted the first varsity intercollegiate national championships, for women. There is no current varsity intercollegiate national championships for men, illustrating the early stages of development for this sport.

Collegiate triathlon and cross country are considered to be endurance endeavors, which consist of either sustained swimming, biking, running at sub-maximal to maximal intensities. For Marymount University's Cross Country Teams, running events range in distance from 5 kilometers to 8 kilometers. The physiological demands on the athletes for these events require muscular endurance, muscular strength, and speed to cover the initial anaerobic start of the race, having the ability the sprint at the end of the race, as well as aerobic power to sustain a running pace over varied terrain.

For Marymount University's Varsity Triathlon Teams, events range from 750-1500 meter swimming, 20-40 kilometer biking, and 5-10 kilometer running. The physiological demands on the athletes require extensive muscular endurance and muscular strength training, and high-intensity race-specific training. Many variables affect performance in these running and multi-disciplinary events.

Aerobic power, the most significant indicator of endurance performance in athletes, is the ability to consume, transport, utilize, and diffuse oxygen to actively working muscles. Oxygen flow from the lungs, to the blood, to the metabolically active tissues is essential in completing the aerobic process of breaking down lactic acid and producing ATP. Aerobic power, which is measured as the maximal volume of oxygen consumed (VO2max), is largely studied in the field of endurance sport, because there is a significant positive correlation between VO2max and performance (El-Sayed, 2009). Several studies have shown there to be a positive correlation between VO2max and hematocrit, albeit a weak one. It has been shown that increasing an individual's hemoglobin concentration levels beyond their normal values increases VO2max and enhances performance (El-Sayed, 2009; Bjorn, 2000).

There is scientific data that supports the fact that higher hemoglobin concentrations and higher hematocrit values are associated with enhanced performance. This assumption is being explored in this study. Several studies have shown that increased aerobic power is associated with diluted pseudo-anemia, which manifests itself in a lower hematocrit score (El-Sayed, 2005). This is counter to the popular belief that has presumably been instilled through the World Anti-Doping Agency's (WADA) arbitrary 50% hematocrit threshold in sport (WADA.org), which states an athlete cannot compete if their red blood cells constitute more than 50% of one's total blood volume. Athletes historically have artificially manipulated their hemoglobin and hematocrit levels beyond their normal values through 'blood doping' to enhance athletic performance. Increases in hemoglobin and hematocrit are associated with increased VO2max and oxygen carrying capacity (Jacobs, 2011). Nevertheless, there exists conflicting evidence among current bodies of research on the relationship between hemoglobin concentration, hematocrit, and performance in athletes.

Hemoglobin is an iron-containing protein molecule located within red blood cells (RBCs) that carries the majority of oxygen in the blood to muscle tissue (El-Sayed, 2005). The total number of hemoglobin molecules (tHb-mass) is very positively correlated with an increase in total oxygen carrying capacity, and thus VO2max. In trained endurance athletes, tHb-mass is markedly elevated when compared to the untrained population (Malczewska, 2013). Similarly hemoglobin concentration (Hb) is also positively correlated with an increase in oxygen carrying capacity, but is not as strongly correlated as tHb-mass. VO2max increases by approximately 1% for each 3 g/L increase in Hb over the Hb range (120 to 170 g/L) (Otto, 2013). Thus, the relationship between Hb and VO2max is important to athletic performance in intercollegiate varsity athletes because it can be measured, tracked, and utilized in planning for peak performance.

The hemoglobin concentration (Hb) levels in healthy adults is 157 +/- 17 g/L for males and 138 +/- 15 g/L for females (Jacobs, 2011). Levels below those of healthy adults are considered anemic, which is a condition of low red blood cells resulting in a decreased ability to transport oxygen in the blood. Anemia is a common problem among elite endurance athletes (Martinović, 2013), due to uncontrollable variables such as hemolysis, dilutional pseudo-anemia, nutrition, genetics, or other factors. Hemolysis, the breaking of red blood cells, in runners is common and is related to the impact of repeated foot strikes (Telford, 2003). Diluted pseudo-anemia, the phenomenon of a low percentage of red blood cells compared to the rest of the blood, is common in endurance athletes because aerobic exercise increases blood plasma volume (Allen,
1992), thus appearing as if the subject was anemic due to their low hematocrit score. Among several sports, athletes showed similar hemoglobin concentration (Hb) and hematocrit (Hct) values (Malczewska, 2013), showing that there may be an upper physiological limit.

Hematocrit (Hct) is related to hemoglobin concentration (Hb) and VO2max. Hematocrit is the ratio of red blood cells (RBCs) to the rest of the blood and plasma volume, and is expressed in a percentage normally. Hematocrit values in healthy adults are .40-.52 for males and .36-.48 for females (Clark, 1990). Values less than the lower end range are considered anemic. Values greater than the higher end range are considered polycythemia, which is a condition of elevated red blood cells and puts an excessive strain on the heart muscle. As the number of (RBCs) increases, Hb increases because there is a higher number of circulating hemoglobin molecules in the blood. If the number of RBCs increases without a corresponding increase in blood plasma volume (PV), then hematocrit increases. This is often seen when artificial methods of increasing RBCs are used. An elevated hematocrit is associated with a high blood viscosity, which may actually impair oxygen delivery to metabolically active tissue because the thicker blood will take longer to deliver oxygen. It has been shown by that there is actually an inverse relationship between cardiovascular fitness and hematocrit, where individuals with a higher aerobic capacity display lower hematocrit measures (Brun, 2000). This is converse to the common assumption that higher hematocrit equals improved performance. As above, normal adaptation to exercise includes an increase in RBCs and plasma volume (PV), where hematocrit remains relatively unchanged or even be lowered below normal untrained values (Brun, 2000).

Data on NCAA distance runners represented by the average body fat percentage among all Divisions indicates that males have a body fat percentage between 5-11%, and females between 10-15% (NCAA, 2015). These ranges differ among the recommendations for the general adult population, men between 10-22% and women between 20-32% (Pescatello, 2014). One study tested and compared body anthropometrics of male and female elite and junior triathletes, and showed that body fat percentage in elite males ranged from 5-10%, in junior males from 5-11%, in elite females ranged from 10-15%, and in junior females ranged from 9-21% (Ackland, 1998). Average body fat percentage ranges in elite triathletes were consistent with the average ranges of NCAA distance runners (NCAA, 2015, Auckland, 1998). Physiological data on NCAA triathletes and Varsity intercollegiate triathletes do not currently exist.

Training induced changes in body composition can effect exercise performance and are measured as body weight, body fat percentage, and lean muscle mass. Body composition can change by increasing energy expenditure less than energy consumption, which results in a decreased body mass. Body composition also changes by increasing or decreasing fat-free mass, which results in a lower body fat percentage or greater body fat percentage (Ackland, 1998). Decreases in body weight from fatmass can enhance endurance performance through an increase in efficiency. One study has shown a strong association between body fat percentage and performance in male triathletes, with a weaker association in female triathletes (Knechtle, 2010). Males with a lower body fat percentage had a quicker finishing time than those with a greater body fat percentage. This is consistent with other research that compared anthropometrics between male and female endurance athletes (Ackland, 1998; Knechtle, 2010). Studies on female triathletes showed a strong association between training parameters, such as volume, time, experience in years, and performance, in contrast to the body fat mass (Leake, 1991). These results appear to point to a gender difference in the importance of body composition among triathletes. Several studies have shown that body fat percentage is not as critical to race performance as training volume for triathletes, but is critical for elite runners (Knechtle, 2010). The training parameters for optimal performance in triathletes seem to be gender specific and sport specific, differing among athletes who compete solely in swimming, cycling, or running versus triathletes who train for all three disciplines.

We hypothesized that subjects' body composition will favorably alter over the course of the competitive season such that percentage of body fat will decrease and lean body mass will increase. In addition, we hypothesized that subjects' hemoglobin concentration will increase while hematocrit will decrease over the course of the season. Lastly, this study also compares various methods of body composition assessments.

Purpose

The purpose of this research project is to work with the coaches for both the Triathlon and Cross Country teams of Marymount University (MU) to periodically monitor the physiological status of current student athletes for changes in hemoglobin, hematocrit, and anthropometric data relative to the time in the competitive season. The triathlon team at MU represents the first varsity intercollegiate athletic team in this sport and results from this study may increase our understanding of the varsity intercollegiate triathletes.

Methods

Subjects

The 18 total subjects, comprised of 6 males and 12 females, were full-time students and variety collegiate athletes at Marymount University. All subjects were in between the ages of 18 and 22 years of age, ranging from incoming freshmen to graduating seniors. The varsity collegiate cross country and triathlon subjects were combined in this study because both programs were under the direction of a single coach. For the male subjects, four of them were on both cross country and triathlon teams, and two were solely on the cross country team. For the females, five of them were on both cross country and triathlon teams, and seven were solely on the cross country team.

The testing protocol for this study was consistent with the accepted practice in the field. The discomfort associated with exercise was not novel for these subjects. All subjects had considerable experience in each of the disciplines of triathlon and cross country running. The MU Triathlon and cross country coaches prescribed exercise as normal and as part of each team's normal training protocol. All exercise was self-paced by the subjects. All data collection, except for Hb and Hct analysis, was accomplished through non-invasive methods. All safety and disposal procedures were followed according to established OSHA standards. Institutional Review Board (IRB) approval was granted in April, 2015 and later renewed through April, 2017.

Procedures

Findings from this research study are presented individually and in aggregate form. Indirect identifiers such as individual subject’s age, class status, and years on the team were not be published. Since there were a limited number of subjects due to the size of the triathlon and cross country teams, certain individuals, upon reading the results of the study, may determine individual physiological results from the testing by past performances in competitive triathlon or cross country races. This is an accepted practice in exercise physiology data presentation because the data is purely physiological in nature. Anthropometric data was presented/described in aggregate. The identities of all subjects were kept confidential.

The schedule of competitions in the Marymount University’s Men’s Triathlon

Team was structured to occur over the Fall and Spring seasons. The USAT Collegiate Club National Championships event is the most prestigious and well attended event on the calendar, taking place at the end of the Spring academic semester. The Marymount University coach has structured a training program that prepared the triathletes for peak performance at this event. During the academic Fall semester, peak performance and physiological status was planned to occur around late October and early November, in preparation for the USAT Mid-Atlantic Collegiate Conference Championships. The hope of this study was to find a change in physiological measures from the beginning to the end of the racing season, where performance should have been at its peak. This study looked at the Triathlon and Cross Country Teams separately. The Cross Country

Teams were only tracked during the academic Fall semester, because their Capital Athletic Conference (CAC) championships was in late October. The Triathlon Teams were tracked from the beginning of the academic Fall semester through the end of the academic Spring semester, because their training regiments were planned for peak performance at the USAT Collegiate National Championships. The teams followed the NCAA mandated 20 hours of practice time per week rule. For the triathletes, two practice sessions per day were held five days of the week. Competitions were on weekend. There were three triathlon competitions scheduled during the Fall and three scheduled during the Spring. For the cross country athletes, one practice session per day was held five days of the week. Competitions were on the weekend. There were six competitions during the Fall.

Three times, twice in the Fall and once in the Spring, over the course of the competitive year each subject reported to the Kinesiology laboratory in Caruthers Hall

#2034 and underwent testing for height, body mass, body composition, and hemoglobin (Hb)/hematocrit (Hct). All subjects followed their normal training routine during the course of the study. Hb and Hct analysis were measured at the same time from a simple and single finger prick, from single-use lancets, where blood is collected using a sterile collection tube for insertion into the microhematocrit analyzer. The micorhematocrit analyzer used is the HemoPoint H2 by STANBIO, which is portable and provides accurate results with one simple test. The analyzer gives results within 3060 seconds, with a +/- 0.3g/dL error at 14.0 g/dL, and uses the azide methemoglobin method (hemopoint.com). The measuring ranges of the analyzer are limited to 36-54% hematocrit and 0-25.6g/dL hemoglobin mass. Body composition was measured using three methods, the seven site skinfold, the Omron Bioelectrical Impedance Analyzer (BIA), and the Tanita BIA. Procedures for the seven site skinfold method were followed according to the American College of Sports Medicine (ACSM) handbook (ACSM, 2013). A Lange skinfold caliper was used. Measurements were taken on the right side of the body. The caliper was aligned perpendicular to the skin fold and halfway between the crest and the base of the fold. The skinfold pinch was maintained while reading the caliper. Duplicate measures within 1 to 2 mm were taken at each site. The seven sites are tricep, chest, midaxillary, subscapula, suprailliac, abdominal, and thigh (ACSM, 2013). The bioelectric impedance analyzers, both the Omron and Tanita scales, measure the opposition to an electric current through body tissues to estimate total body water, which is used to estimate total body fat percentage. Procedures for each BIA scale were followed according to their manufactures' guidelines. The procedures for the Omron and the Tanita were similar enough that the subjects were instructed similarly, to stand on the scale, place their feet on the electrodes, and hold on to the hand-electrodes. The scan takes 30-60 seconds of scanning before reading the results. All safety procedures and OSHA standards for handling and discarding of medical waste will be followed during all Hb and Hct assessments described here. Subjects may have experienced moderate but very brief/temporary pain associated with the finger prick. Should a subject choose to not have a Hb and Hct analysis performed, or any other anthropometric assessment, they are in no way obligated to do so.

Subjects had the choice to end or refuse any physiological measurement on their own accord. Subjects could communicate with the investigator(s) at any time and vice versa to ensure the safety of subjects during data collection. Subjects were under no obligation from the investigators of this study to perform any exercise outside of their normal planned training schedule as prepared by the triathlon and cross country coaches.

Data Analysis

To determine the changes in body fat percentage, hematocrit, and hemoglobin mass over the course of the study, repeated ANOVA was used to determine differences in the means and standard deviations. In the cross-country groups, two sets of data points, (pre-season and championship season), were analyzed for means and standard deviations. In the triathlon groups, three sets of data points, (pre-season, mid-season, and championship season), were analyzed for means and standard deviations. To compare the precision between the three body composition methods used in the present study, repeated ANOVA was used to compare the means, standard deviations, and variance. A Pearson Correlation Coefficient was used to determine if there were any correlations between the different three methods of determining body fat percentage used in this study. Statistical significance was set at $p < .05$.

Results

Subject characteristics are presented in Table 1. The subjects were grouped in Fall season Cross-Country athletes and year-long Triathlon athletes. Subjects were then grouped by gender.

Table 1: Subjects	Female	Male
Age	19.6 (+/- 1.0)	19.6 (+/- 1.0)
BMI	21.1 (+/- 2.1)	22.7 (+/- 2.3)
Cross-Country Athletes	12	6
Triathlon Athletes	5	4

Body fat percentage increased from the beginning of the season to the end of the season, for Fall Cross-Country groups and for year-long Triathlon groups (See Table 2, Table 3, Figure 1, and Figure 2). Repeated ANOVA Analysis for Variance for seven site skinfold data was used to track changes in body composition. The average body mass across all groups increased (See Table 2 and Table 3).

Table 2: Male Cross Country and Triathlon	Pre-Season	End-Season
Body Fat Avg (%)	9.8 (+/- 6.4)	12.3 (+/- 6.2)
Body Mass Avg (kg)	68.2	68.9
Hematocrit (%)	42.1 (+/- 3.1)	43.1 (+/- 1.7)
Hemoglobin (g/dl)	14.4 (+/- 1.1)	14.7 (+/- 0.6)

Table 2 shows changes in body fat percentage, body mass, hematocrit, and hemoglobin mass from the 'Pre-Season' in September to 'End-Season' in November for male subjects on both the Cross-Country and Triathlon teams.

Table 3: Female Cross Country and Triathlon Athletes	Pre-Season	End-Season
Body Fat Avg (%)	21.6 (+/-5.5)	23.4 (+/-5.0)
Body Mass Avg (kg)	58.2	59.1
Hematocrit (%)	38.6 (+/-2.6)	39.1 (+/-1.2)
Hemoglobin (g/dl)	13.1 (+/-0.9)	13.3 (+/-1.2)

Table 3 shows changes in body fat percentage, body mass, hematocrit, and hemoglobin mass from the 'Pre-Season' in September to 'End-Season' in November for female subjects on both the Cross-Country and Triathlon teams.

Over the course of their variety intercollegiate season, male triathletes on average increased body fat percentage by 2.1%, from 6.8% to 9.6%, and gained on average 1.5 kilograms in body mass, from 67.8 to 68.3 kilograms (See Figure 1).

Figure 1: Male Triathlon Anthropometry Over the Course of a Year-Long Season

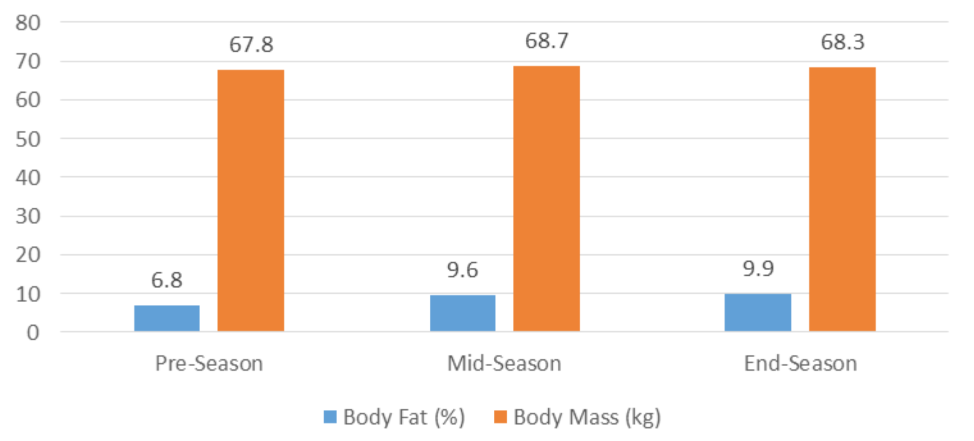

Figure 1 shows changes in body fat percentage and body mass for male triathletes over the course of their varsity intercollegiate season from September to May. Over the course of their variety intercollegiate season, female triathletes on average increased body fat percentage by 6.4%, from 19.5% to 25.9%, and gained on average

3.5 kilograms in body mass, from 59.0 to 62.5 kilograms (See Figure 2).

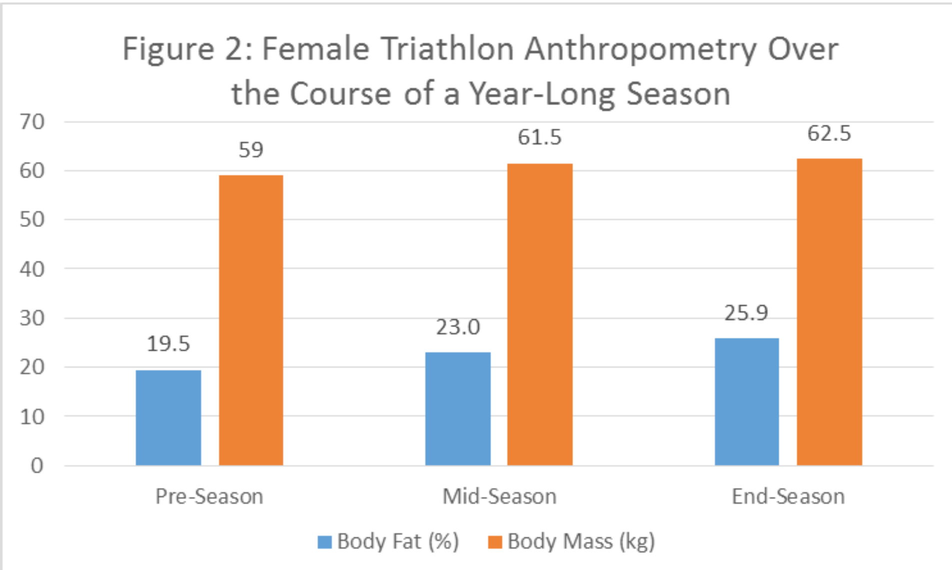

Figure 2 shows changes in body fat percentage and body mass for female triathletes over the course of their varsity intercollegiate season from September to May. Among all Fall Cross-Country and Triathlon groups there were small changes in hemoglobin mass but were not statistically significant, and hematocrit values increased slightly, but were not statistically significant. Between the male and female groups, females generally had lower hematocrit and hemoglobin mass values, and higher body fat percentages (See Table 2 and Table 3 above).

Although body fat percentage, body mass, hematocrit, and hemoglobin mass all increased slightly from Pre-Season to End-Season in the Fall Cross-Country and

Triathlon groups, both males and females, there were no statically significant correlations between each other (See Table 2 and Table 3 above).

In both male and female varsity intercollegiate triathlon teams, hematocrit and hemoglobin mass remained relatively the stable over the course of their seasons and were not significantly correlated with the time of their seasons (pre-season, mid-season, and end-season) (See Figure 3 and Figure 4).

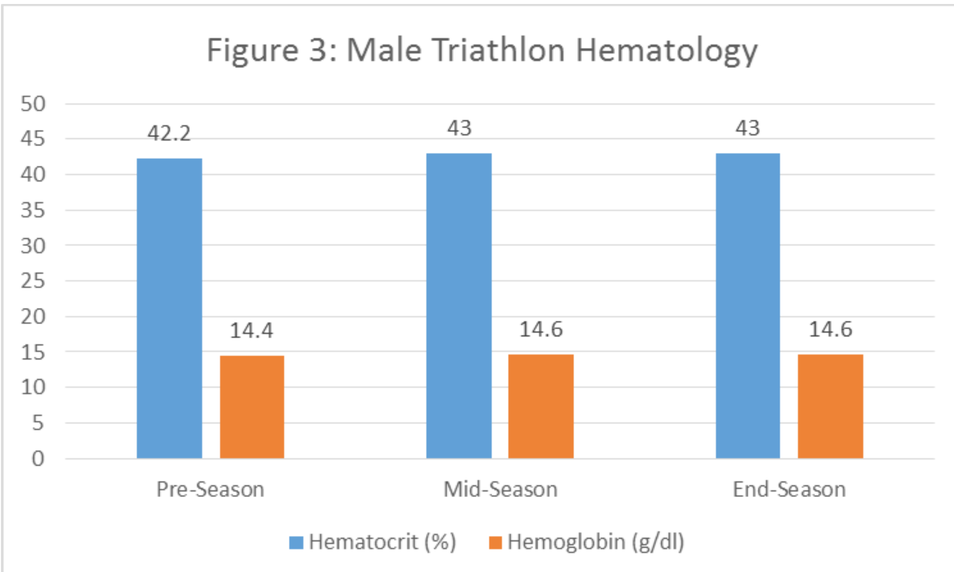

Figure 3 shows changes in hematocrit and hemoglobin mass for male triathletes over the course of their varsity intercollegiate season from September to May.

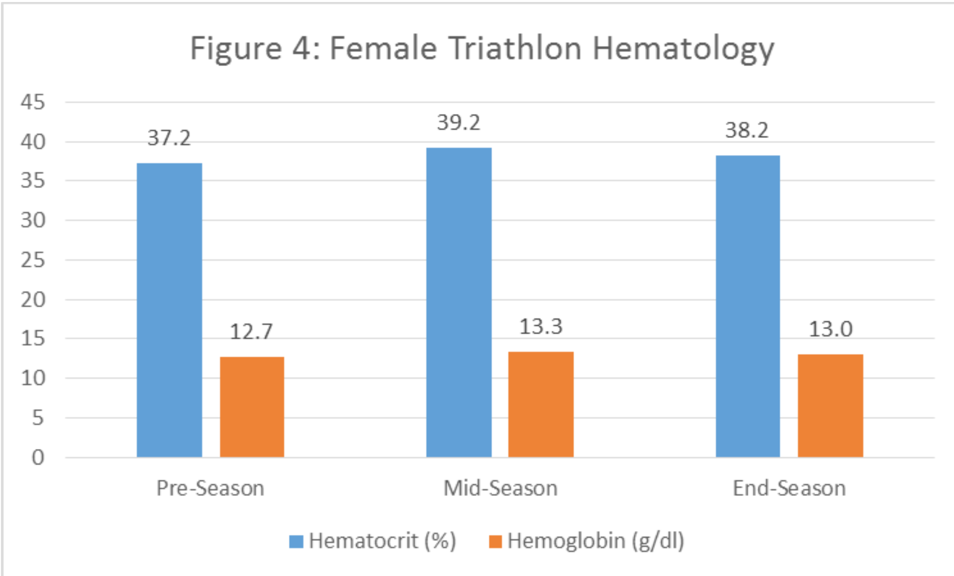

Figure 4 shows changes in hematocrit and hemoglobin mass for female triathletes over the course of their varsity intercollegiate season from September to May.

The seven site skinfold method was used as the standard in this study to track changes in body fat percentage in both groups. Using Pearson Correlation Coefficient to compare the measures between each of the three body composition methods used, the Tanita BIA scale had a strong correlation to the Omron BIA scale ($r=0.96$, $p<.01$). Using a Repeated ANOVA Analysis of Variance, the Tanita scale had the lowest variance, 35.8, and standard deviance, 6.0, for all data collections in both male and females combined over time (See Table 4).

Table 4: Body Composition Methods Comparison	**Tanita**	**Omron**	**7 Site Skinfold**
Combined Body Fat Means (%)	16.6	23.9	18.7
Standard Deviation	6.0*	7.8	7.7
Variance	35.8*	61.4	59.8

Table 4 shows the mean body fat percentage, the standard deviation, and the variance of all data collections in both male and females combined. (* marks significance $p<.01$)

There was a strong correlation between the Omron and Tanita BIA scales. There was no statistically significant correlation between the seven site skinfold method and either of the BIA scales used. Body composition values from the Tanita BIA scales expressed the lowest body fat percent averages, 16.6%, for male and female subjects combined, compared to averages from the Omron BIA scale and the seven site skinfold method (See Table 4 above).

Discussion

Endurance training has been show to increase fat oxidation as the body becomes more highly adapted to aerobic energy production systems for long events, however this was not observed in our study. Our results showed an increased body fat percentage in athletes over the course of their year-long season. This data was not in accord with our hypothesis that lower body fat percentage is associated with peak performance in athletes. The changes in body composition, increased body fat percentage and increased body mass, could be associated with the type of training prescribed, instead of the time in the season. Low and moderate intensity training is typical of pre-season or base season training regimes, and studies have shown that fat oxidation is greatest at this intensity, 65% to 70% of max heart rate (Ramijn, 2000). The increased body fat percentage and increased body mass could also be associated with changes in diet because some students were coming from their respective homes to the university campus and had access to cafeteria food and restaurants. Men and women had their lowest mean body fat percentages at the beginning of the Fall season, indicating that students may have had healthier dietary habits before coming to school. Our data reflects the possibility that the athletes came into the Fall season with an low aerobic base due to low to moderate intensity training, thus influencing fat metabolism. Endurance training and high intensity training, which were both prescribed over the course of the competitive seasons, can decrease total hematocrit scores because of an increase in blood plasma volume, however this was not observed overall, except in certain individuals. The drop in hematocrit is a sign of a very aerobically conditioned athlete. We noted that the hematological measures of hemoglobin mass and hematocrit showed no association with the progression of the season. The workouts at the beginning of the season were low to moderate intensities, and the workouts progressed to high aerobic intensities towards the end of the season, which corresponded with championship competitions. Research indicates that with both endurance and high intensity aerobic training, no significant changes in total blood volume, hemoglobin mass, or hematocrit occur (Helgerud, 2007). Our data was in accord with Helgerud (2007), in that hemoglobin mass did not change and hematocrit slightly increased with training, but remained statistically insignificantly. In contrast, it has been observed that a negative correlation exists between aerobic fitness and hematocrit (Brun, 2000, ElSayed, 2005), due to an increase in plasma volume. Although we did not see any significant changes in hematocrit in varsity collegiate endurance athletes, it may be worthwhile to monitor hematocrit in elite endurance athletes over the course of many seasons. Periods of lower hematocrit scores, while hemoglobin mass remains constant, may serve as a strong indicator of an athlete's aerobic fitness (El-Sayed, 2009). A lowered hematocrit score may also indicate anemia if it is a function of decreased hemoglobin mass, thus resulting in a decreased oxygen carrying capacity in red blood cells. Monitoring changes in hematocrit and hemoglobin mass in individuals may prove useful for determining the fitness and anemia status in athletes.

We observed that in varsity intercollegiate cross country and triathletes, increased body mass index was associated with increased body fat percentage. Our results are in accord with previous studies, that generally show increases in body mass are correlated with increases in body fat mass (Duernberg, 1998). However, there appears to be wide differences among ethnicities and age in the relationship between percent body fat and body mass index due to differences in energy balance and body build (Deurenberg, 1998). It would be difficult to determine an ideal percent body fat and body mass index ratio for optimal endurance performance because the relationship is interdependent on differences in race and age. It should be noted that as the course of the season progressed from more low to moderate intensity aerobic training to high intensity aerobic training and racing, body fat percentage increased. The demands for energy with high intensity aerobic training are fueled primarily by glucose and less through fat oxidation (Ramijin, 2000). Therefore, the increase in body fat percentage obtained in subjects could be a result of the shift in training type over the course of the season. In addition, the collegiate environment and lifestyle could have influenced the increase in body fat percentage over the course of the year. Students may be experiencing self-management and independence for the first time in their lives, and the lack of developed skills and/or education of portioning and selecting healthy foods may be a factor (NCAA.org). In several studies on nutrition practices and knowledge of NCAA varsity collegiate athletes, there was a small percentage of athletes who correctly identified the recommended intakes of dietary carbohydrate, protein, and fat, and about 50% of the athletes reported receiving nutritional advice from athletic trainers, coaches, or nutrition classes during their collegiate career (Jacobson, 2001). The athlete's use of alcohol was unknown in this study, but it too could play a significant role in the increased body mass and body fat percentage obtained in the present study. Alcohol inhibits fat oxidation, and thus it may be a detriment to the positive effects of endurance aerobic training (Shelmet, 1988).

Many of the hemoglobin scores we measured expressed signs of anemia for a normal population. Several male subjects had hemoglobin mass levels of 13.4 g/dL, and several female subjects had hemoglobin mass levels of 12.0 g/dL, both of which indicate anemia (MayoClinic), however these athletes were training and competing at a high level on daily basis. This phenomenon could be explained by genetics, diet, and hemolysis, which is the breaking down of red blood cells during the foot-strike among runners, and among many other factors (Telford, 2003). The prevalence of low hemoglobin scores in our study was surprising, especially considering the high level of exercise and class load that these athletes were managing. Similarly, certain studies have shown that anemia is a common problem among endurance athletes (Brun, 2000; Martinović, 2013; Telford, 2003). Although hemoglobin mass may not be a good indicator of peak performance during the varsity intercollegiate seasons in triathletes and cross-country runners, tracking an athletes' hemoglobin mass could be useful in monitoring the health of the athlete. Maintaining hemoglobin mass naturally at a healthy level will ensure the best oxygen carrying capacity for competition, and can be accomplished through specific nutrition, training, and monitoring programs.

In comparing body composition analyzers, the Tanita Bioelectrical Impedance (BIA) scale had the lowest standard deviation and variance for all measures of body composition in this study. The Omron BIA scale had the highest standard deviation and variance for reporting body fat percentage in our study. In study on the errors of BIA scales, a 2-4% error was observed with standardized conditions using accurate heights and weights, and the percent error increased depending on the subjects' prior exercise, dietary intake, and skin temperature status (Kushner, 1996). In one study, the seven site skinfold method had an average error of 4% for women and 1% for men (Barreira, 2013). The over all human error in this study was not calculated, but it is speculated that it was greatest during our seven-site skinfold testing procedures compared to the BIA scales. Prior to data collection, the seven site skinfold method was determined to be the standard in this study before data collection began, despite our results of it not being the most reliable among body fat measuring methods. The DEXA scan and underwater weighing are generally accepted as gold standards, however the methods used for this study were the most accessible and repeatable for varsity intercollegiate athletes. All three methods were susceptible to large degrees of error, such that the BIA scales may be influenced by the subject's hydration levels, exercise, and food consumption prior to testing, and the seven-site skinfold are influenced by estimation error and human error.

The subjects' testing occurred throughout certain times of the day, and some athletes may have consumed fluids or food, or had exercised prior to testing, which needs to be taking into consideration regard the accuracy in results for BIA scales. Future research should take into account these factors when scheduling data collection. This study recognizes that the variables being measured over the course of the competitive cross country season are not exhaustive.

Conclusions

In conclusion, our results indicate that lean body mass, hemoglobin mass, and hematocrit are useful measures in varsity intercollegiate cross country and triathlon athletes during their competitive seasons for tracking fitness and overall health. We also conclude that the Tanita BIA scale out-performed the Omron BIA scale and the seven site skinfold method in precision, meaning that consecutive measures varied the least. Our study did not measure the accuracy of each body composition method. DEXA imaging and underwater weighing are known as the gold standards in body composition methods because they have proven to be the most accurate. The Tanita BIA scale is a practical and useful tool for an athlete to track changes in body composition throughout the season. Based on the results of this study, collegiate cross-country and triathlon athletes should consider periodically tracking changes in their body mass and body composition during their competitive seasons for the purpose of maintaining a healthy weight and lean body mass. These conclusions must be viewed with caution when taking into consideration the limitations described above.

Our study was in part supported by Marymount University's Discover Program, providing financial support for undergraduate research, and by the Virginia

Foundation for Independent Research (VFIC), providing financial support and educational opportunities to students attending independent colleges in Virginia.

References

Ackland, T. R., Blanksby, B. A., Landers, G., & Smith, D. (1998). Anthropmetric profiles of elite triathletes. Journal of Science and Medicine in Sport, 1(1), 52-56.

Allen, M. E., Tully, B. S., & Bieling, A. M. (1992). Plasma volume expansion following mild aerobic exercise. Research in Sports Medicine: An International Journal, 3(3), 157-163.

American College of Sports Medicine. (2013). ACSM's guidelines for exercise testing and prescription. Lippincott Williams & Wilkins.

Barreira, T. V., Renfrow, M. S., Tseh, W., & Kang, M. (2013). The Validity Of 7-Site Skinfold Measurements Taken By Exercise Science Students. International Journal of Exercise Science, 6(1), 4.

Brun, J. F., Bouchahda, C., Chaze, D., Aïssa Benhaddad, A., Micallef, J. P., & Mercier, J. (2000). The paradox of hematocrit in exercise physiology: which is the “normal” range from an hemorheologist's viewpoint?. Clinical hemorheology and microcirculation, 22(4), 287-303.

Clark, V. L., & Kruse, J. A. (1990). Clinical methods: the history, physical, and laboratory examinations. JAMA, 264(21), 2808-2809.

Deurenberg, P., Yap, M., & Van Staveren, W. A. (1998). Body mass index and percent body fat: a meta analysis among different ethnic groups. International journal of obesity, 22, 1164-1171.

El-Sayed, M. S., Ali, N., & Ali, Z. E. S. (2005). Haemorheology in exercise and training. Sports Medicine, 35(8), 649-670.

El-Sayed, M. S., Ali, N., & Al-Bayatti, M. (2009). Aerobic power and the main determinants of blood rheology: is there a relationship?. Blood Coagulation & Fibrinolysis, 20(8), 679-685.

Helgerud, J., Hoydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., ... & Hoff, J. (2007). Aerobic High-Intensity Intervals Improve VO~ 2~ m~ a~ x More Than Moderate Training. Medicine and science in sports and exercise, 39(4), 665.

Jacobs, R. A., Rasmussen, P., Siebenmann, C., Díaz, V., Gassmann, M., Pesta, D., ... & Lundby, C. (2011). Determinants of time trial performance and maximal incremental exercise in highly trained endurance athletes. Journal of Applied Physiology, 111(5), 1422-1430.

Jacobson, B. H., Sobonya, C., & Ransone, J. (2001). Nutrition practices and knowledge of college varsity athletes: a follow-up. The Journal of Strength & Conditioning Research, 15(1), 63-68.

Knechtle, B., Wirth, A., Baumann, B., Knechtle, P., Rosemann, T., & Oliver, S. (2010). Differential correlations between anthropometry, training volume, and performance in male and female Ironman triathletes. The Journal of Strength & Conditioning Research, 24(10), 2785-2793.

Kushner, R. F., Gudivaka, R., & Schoeller, D. A. (1996). Clinical characteristics influencing bioelectrical impedance analysis measurements. The American journal of clinical nutrition, 64(3), 423S-427S.

Leake, C. N., & Carter, J. E. L. (1991). Comparison of body composition and somatotype of trained female triathletes. Journal of Sports Sciences, 9(2), 125-135.

Malczewska-Lenczowska, J., Sitkowski, D., Orysiak, J., Pokrywka, A., & Szygula, Z. (2013). Total haemoglobin mass, blood volume and morphological indices among athletes from different sport disciplines. Archives of medical science: AMS, 9(5), 780-787.

Martinović, J., Kotur-Stevuljević, J., Dopsaj, V., Dopsaj, M., Stefanović, A., & Kasum, G. (2010). Paraoxonase activity in athletes with depleted iron stores and irondeficient erythropoiesis. Clinical biochemistry, 43(15), 1225-1229.

NCAA - Body composition: What are athletes made of? (2015). Retrieved April 29, 2016, from http://www.ncaa.org/health-and-safety/sport-science-institute/bodycomposition-what-are-athletes-made

Otto, J. M., Montgomery, H. E., & Richards, T. (2013). Haemoglobin concentration and mass as determinants of exercise performance and of surgical outcome. Extreme physiology & medicine, 2(1), 1.

Romijn, J. A., Coyle, E. F., Sidossis, L. S., Rosenblatt, J., & Wolfe, R. R. (2000). Substrate metabolism during different exercise intensities in endurance-trained women. Journal of Applied Physiology, 88(5), 1707-1714.Pescatello, L. S.

(2014).

ACSM's guidelines for exercise testing and prescription. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health.

Shelmet, J. J., Reichard, G. A., Skutches, C. L., Hoeldtke, R. D., Owen, O. E., & Boden, G. (1988). Ethanol causes acute inhibition of carbohydrate, fat, and protein oxidation and insulin resistance. Journal of Clinical Investigation, 81(4), 1137.

Telford, R. D., Sly, G. J., Hahn, A. G., Cunningham, R. B., Bryant, C., & Smith, J. A. (2003). Footstrike is the major cause of hemolysis during running. Journal of Applied Physiology, 94(1), 38-42.

World Anti-Doping Agency (WADA). (n.d.). Retrieved April 29, 2016, from https://www.wada-ama.org/