

Validity of Bioimpedance as a Measure of Body Fat in High School
Wrestlers

Jesse James Donnenwerth

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and
State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

In

Curriculum and Instruction

Richard Stratton, Chair
Delmas Bolin
Quinton Nottingham
Kerry Redican

July 28, 2006

Blacksburg, Virginia

Keywords: Bioelectrical Impedance, Wrestling, Weight Certification, Body
Composition, Hydration

Validity of Bioimpedance as a Measure of Body Fat in High School Wrestlers

Jesse James Donnenwerth

ABSTRACT

Background: In recent years several state high school athletic association have investigated methods to ensure the health and safety of high school wrestlers. One method implemented by the National Collegiate Athletic Association requires the prediction of minimum weight (MW) prior to the competition season. This weight certification program requires the assessment of body composition and hydration status. Results from those assessments place wrestlers in their lowest allowable wrestling weight class. There are a variety of measurement devices that have proven to be effective in measuring body composition. However, several considerations must be taken into account when choosing a device such as affordability and reliability. Of those devices leg-to-leg bioelectrical impedance analysis (BIA) has been suggested for use with wrestlers.

Purpose: To test the validity of bioelectrical impedance as an instrument of body composition and minimum wrestling weight compared to three-site skinfold using the Lohman-Brozek formula and the Bod Pod[®] among hydrated high school wrestlers.

Methods: Criterion for this study was the Bod Pod[®]. Subjects included 98 high school wrestlers taking part in the pre-season wrestling weight certification program implemented by the Virginia High School League. Hydration was assessed and a urine specific gravity (USG) ≤ 1.020 was assigned as the level of hydration.

Results: In order to investigate the validity of BIA in this study a repeated measure ANOVA with between-subjects factors was used to assess the equality of means between the three measurement devices. Also, in order to investigate hydration affect subjects were divided into two categories (hydrated and dehydrated). Finally, prior to analysis subjects were placed in weight categories based on their assigned wrestling weight class. Results of this study demonstrated that the three measurement devices did not produce similar results and it was concluded that hydration level had no affect on the measurements. Therefore, at this time BIA should not be considered as an alternative method for assessing body composition in high school wrestling weight certification programs.

ACKNOWLEDGMENTS

I would like to first thank my committee: Dr. Richard Stratton, Dr. Delmas Bolin, Dr. Quinton Nottingham, and Dr. Kerry Redican, their insight and encouragement guided me throughout the process of completing this degree. Each of these individuals has selflessly contributed to my education at Virginia Tech.

I would also like to thank the Virginia College of Osteopathic Medical School for their contribution to this research project. Without their continued support of research and the health and safety of high school wrestlers this study would not have been conducted. I specifically want to thank Dr. Bolin for believing in this project and providing excellent medical care for the athletes of Virginia Tech.

I also wish to thank each member of the Virginia Tech Sports Medicine staff for their support and encouragement. I especially want to thank Mike Goforth for giving me the opportunity to be a member of his staff and his guidance during my career at Virginia Tech. I also want thank Amy Freel for her contribution to this project.

DEDICATION

I dedicate this dissertation to the family and friends who have motivated and encouraged me throughout my life, without their continued support this goal would not have been attained.

TABLE OF CONTENTS

	Page
ABSTRACT	ii
ACKNOWLEDGEMENTS	iv
DEDICATION	v
TABLE OF CONTENTS	vi
LIST OF TABLES	viii
LIST OF GRAPHS	ix
LIST OF FIGURES	x
CHAPTER 1- INTRODUCTION	
Introduction	1
Statement of Purpose	5
Research Questions	6
Significance of Study	6
Limitations of Study	7
CHAPTER 2- REVIEW OF LITERATURE	
History of Rapid Weight Reduction	8
Effects of Rapid Weight Reduction	11
Minimum Wrestling Weight Programs	15
Methods of Body Composition Assessment	18
Methods for Assessing Minimum Wrestling Weight	23
Assessment of Hydration Status of Wrestlers	30
CHAPTER 3- METHODOLOGY	
Subjects	33
Study Protocol	33
Instrumentation	34
Data Analysis	40
CHAPTER 4- RESULTS	
Introduction	44
Percent Body Fat Analysis	47
7% Minimum Wrestling Weight Analysis	55
CHAPTER 5- DISCUSSION, CONCLUSIONS, RECOMMENDATIONS	
Discussion	63
Conclusion	66

Recommendations for Future Research	68
REFERENCES	70
APPENDIX A	75
CURRICULUM VITAE	79

LIST OF TABLES

	Page
TABLE 1- Wrestling weight categories defined by assigned wrestling weight classes	41
TABLE 2- Subject Characteristics	46

LIST OF GRAPHS

	Page
GRAPH 1- Mean percent body fat of light weight category	50
GRAPH 2- Mean percent body fat of light weight category with hydration	50
GRAPH 3- Mean percent body fat of middle weight category	52
GRAPH 4- Mean percent body fat of middle weight category with hydration	52
GRAPH 5- Mean percent body fat of heavy weight category	54
GRAPH 6- Mean percent body fat of heavy weight category with hydration	54
GRAPH 7- Mean minimum wrestling weight of light weight Category	58
GRAPH 8- Mean minimum wrestling weight of light weight Category with hydration	58
GRAPH 9- Mean minimum wrestling weight of middle weight category	60
GRAPH 10- Mean minimum wrestling weight of middle weight category with hydration	60
GRAPH 11- Mean minimum wrestling weight of heavy weight category	62
GRAPH 12- Mean minimum wrestling weight of heavy weight category with hydration	62

LIST OF FIGURES

FIGURE 1- View of hydration level through urine refractometer	35
FIGURE 2- Urine refractometer	35
FIGURE 3- Height stadiometer	36
FIGURE 4- Tanita [®] scale	36
FIGURE 5- Triceps skinfold measurement	38
FIGURE 6- Abdominal skinfold measurement	38
FIGURE 7- Subscapular skinfold measurement	38
FIGURE 8- Bod Pod [®]	40

CHAPTER ONE

Introduction

Background

The sport of wrestling has a strong tradition that precedes the first Olympic festival in 776 B. C., when Zeus wrestled Kronas for the possession of the earth (Gallagher, 1951). Since then the sport of wrestling continues to grow in popularity because of the discipline and mental toughness it requires to be successful in the sport. Unfortunately, the sport has also been associated with the stigma of “cutting weight” and the practices that accompany the process of competing at designated weight classes. Like the sports of judo, boxing, and competitive weight lifting, wrestling requires its athletes to compete at specific weights or weight classifications. Typically, these weight classifications differ by approximately 7-11 pounds depending on age and style of wrestling. It is common knowledge in present day wrestling that wrestlers compete in weight classes below their “normal” weight. The purpose of this practice is to gain advantages in strength, speed, and leverage over their opponents (Steen & Brownell, 1990).

In order for wrestlers to weigh-in at their designated weight classes prior to competition, they typically have to reduce their body weight. This is what the wrestling community refers to as “cutting weight” or “making weight.” In order to accomplish this weight reduction athletes use a variety of methods. These techniques can be divided into two categories, gradual and rapid weight reduction. Gradual weight reduction requires the athlete to not restrict caloric intake, however, consume enough calories to facilitate the loss of body fat through exercise and metabolic activity. This practice may also

include minimal body water weight loss that accompanies physical activity. The second category, rapid weight reduction, consists of a variety of practices that allows wrestlers to lose large amounts of weight in a small amount of time. These methods commonly combine caloric and fluid restriction with dehydration practices. Rapid dehydration can include: wearing plastic suits while exercising and sauna use (Horswill, Scott, Dick, & Hayes, 1994; Scott, Horswill, & Dick, 1994; Steen & Brownell, 1990; Utter & Kang, 1998; Wroble & Moxley, 1998). Other practices associated with rapid weight reduction include the use of diuretics, laxatives, and self-induced vomiting. It has also been reported that an athlete donated a pint of blood in order to make weight (Hursh, 1979). Often times a wrestler using rapid weight loss methods can lose 3-7% of their body weight in 2-3 days (Doscher, 1944; Kiningham & Gorenflo, 2001; Lakin, Steen, & Oppliger, 1990; Steen & Brownell, 1990; Tipton & Tchong, 1970).

During the past century, several health concerns relating to the sport of wrestling have been well documented and researched. One of the first documents addressing these concerns was written by an Illinois wrestling coach in 1930 (Kenney, 1930). In 1967 the American Medical Association issued a position statement addressing potential health risks associated with “cutting weight.” They stated that any form of dehydration will impair the performance of a wrestler, because water deficiency causes premature fatigue, and eventual clinical sickness (Association, 1967). Then in 1976, another important document from the American College of Sports Medicine pointed out specific health concerns related to making weight (American, 1976). Since then Oppliger et al. updated the position stand of the ACSM on weight loss in wrestlers (Oppliger, Case, Horswill, Landry, & Shelter, 1996). In that article the ACSM recommended that either state or

national governing bodies should require wrestlers to weigh-in immediately prior to competition. That paper also stated that wrestlers 16 years of age and younger with a percent body fat less than 7% and wrestlers older than 16 years of age with a percent body fat less than 5% would not be able to compete without medical clearance. Several other studies have shown the health consequences of cutting weight such as poor nutrition intake (Steen, Oppliger, & Brownell, 1988), renal function and electrolyte balance (Zambraski, Foster, Gross, & Tipton, 1976; Zambraski et al., 1975), thermal regulation (Steen et al., 1988), testosterone levels (Strauss, Lanese, & Malarket, 1985), and strength (Houston, Marrin, & Green, 1981).

Despite recommendations from the AMA and ACSM, the wrestling community received its greatest blow when in 1997 when three collegiate wrestlers tragically died while attempting to make weight (CONTROL, 1998). In order to address these traumatic events the National Collegiate Athletic Association (NCAA) developed and implemented a wrestling weight certification program. The primary outcome of the program is what is referred to as a “wrestler’s minimum wrestling weight” (MW). This value represents the lowest possible weight a wrestler can reach throughout the season while maintaining a percent body fat of at least 5 percent. Similarly, several state high school athletic governing bodies have developed wrestling weight certification programs that set the MW at a 7 percent body fat minimum (Perriello & Johnson, 2003). In the 2005-06 wrestling season the NCAA implemented an on-line certification process in conjunction with the National Wrestling Coaches Association. This on-line system provides the NCAA and over 21 high school governing bodies the capabilities of certifying athletes and provides individualized nutrition and weight loss programs. In order to gain a better

understanding of the MW certification process, it is necessary to identify the specific components involved, body composition and hydration assessment.

Body composition has been thoroughly researched among several populations such as adults, adolescents, elderly, and athletes (Kyle, Genton, & Pichard, 2002; Wagner & Heyward, 1999; Wagner, Heyward, & Gibson, 2000). During the past thirty years, research has focused its efforts to address anthropometric equations and measurement devices used to determine body density within specific populations. It is important to understand that body composition takes into account age, height, weight, and level of activity in order to accurately predict body composition within specific populations. This has led to extensive research pertaining to wrestlers and wrestling weight certification. Measurements obtained by using anthropometrics or a variety of body density measurement devices have shown to be valid in predicting fat mass, fat free mass, and minimum wrestling weight of wrestlers. Currently, the NCAA accepts the use of three instruments to determine body composition. These instruments include the three-site skinfold (SF) using the Lohman-Brozek equation, hydrostatic weighing (HW), and air displacement plethysmography (ADP) Bod Pod[®] (Life Measurement Inc., Concord, CA). The Virginia High School League (VHSL) and several other interscholastic governing bodies only allow three-site skinfold, based on prior research that indicated bioelectrical impedance (BIA) and Bod Pod[®] were “standardized only for adults” (Perriello V A, 2003).

The second component of the wrestling weight certification process is the assessment of each wrestler’s hydrated weight. As indicated earlier, rapid weight reduction is a common practice among wrestlers. Therefore, it makes sense to assess

hydration status prior to wrestling weight certification. In a study conducted by Bartok et al. it was suggested that a wrestler could hypothetically dehydrate prior to weight certification in order to lower his MW (C. Bartok, Schoeller, Randall Clark, Sullivan, & Landry, 2004). In order to address this potential problem both the NCAA and several high school state governing bodies use urine specific gravity (USG) to assess levels of hydration. An $USG \leq 1.020$ is commonly accepted as the level of hydration (Casa, Armstrong, & Hillman, 2000). Research also supports the fact that acute dehydration can impact the precision and validity of body composition assessment (C. Bartok, Randall Clark, & Schoeller, 2004). Data also suggests that USG testing is sensitive to the ingestion of fluids prior to hydration assessment (Oppliger & Bartok, 2002). Thus, prior to hydration analysis, the athlete ingest fluids in order to attain a $USG \leq 1.020$. This practice gives a false reading of hydration status and affects the estimation of a wrestlers' minimum wrestling weight. Therefore, it is important to assess the effects hydration status has on predicting MW.

Statement of the Purpose

The implementation of the wrestling weight certification programs has brought about several areas of concern, especially at the interscholastic level. Primarily because the process of collecting measurements and calculations needed to determine MW require time, specific equipment, and experienced personnel. These factors bring about poor inter and intra reliability to the process of MW certification. Previous research has shown tester reliability can influence assessment of body composition using skinfold calipers (Oppliger, Harms, Herrmann, Streich, & Clark, 1995). The VHSL has addressed these concerns by implementing training courses and instructional materials. Despite those

efforts there has been no validation of the VHSL MW certification process. Currently, no research has addressed the relationship between the validity of bio-impedance and levels of hydration among high school wrestlers. The validation of bio-impedance in this setting would provide a safe, cost effective, and reliable method of obtaining MW in high school wrestling. This current research proposes to validate bio-impedance among high school wrestlers.

Research Questions

Question: Is bioelectrical impedance with wrestler mode a valid index of body composition among high school wrestlers?

Purpose 1: To test the validity of bioelectrical impedance as an instrument of body composition compared to three-site skinfold using the Lohman-Brozek formula and the Bod Pod[®] among high school wrestlers.

Purpose 2: To compare the inter reliability of body composition assessment with levels of hydration.

Purpose 3: To evaluate the accuracy of bioelectrical impedance as an instrument of minimum wrestling weight assignment compared to three-site skinfold using the Lohman-Brozek formula and the Bod Pod[®].

Significance of the Study

Current research specifically involving high school wrestlers has thoroughly investigated the accuracy between skinfold calipers with Lohman-Brozek equation and bioelectrical impedance using the Tanita[®] Scale in predicting percent body fat and minimum wrestling weight. However, this study will use the Tanita[®] TBF- 300A with the high school wrestling retrofit which is new to bioelectrical impedance research.

Another factor contributing to the strength of this study is the number of subjects involved. Several studies investigating wrestling weight certification are typically limited to less than 50 subjects per study. This study will contain upwards of 100 subjects. This study will also incorporate the Bod Pod[®] as “gold standard” in assessing body composition in high school wrestlers during official MW certification. Collecting data during official weight certification is a major strength of this study because the subjects will be in realistic state of hydration. Levels of dehydration have shown to impact body composition assessment. This research will investigate both inter reliability of hydration status in order to identify variables that impact MW assessment.

Limitations of the Study

This research could be improved by implementing hydrostatic weighing into the study. However, due to lack of facilities and funding at this time it will not be included. This project could also provide greater generalizability by including females in the study. These individuals have been excluded from this study because a lack of subjects in the area. Another limitation of the study involves geographical location. This project could be improved by including wrestlers from other areas of the country. Each of these issues will be addressed in larger studies with external funding.

CHAPTER TWO

Review of Literature

History of Rapid Weight Reduction

The history of rapid weight reduction and the related health concerns of wrestlers have been well documented throughout the past century. Starting in 1930 when coach Kenny of Illinois wrote in Research quarterly about his concerns and recommendations for wrestlers making weight. From his account of these practices, he states that wrestlers commonly consume one half and up to one quarter of a normal diet in order to lose as much as ten pounds to compete at a specific weight class. Following this practice of limited caloric and fluid intake the wrestlers regain that weight following the match and repeat the cycle the following Saturday. He states the reason athletes perform this rigorous cycle is to gain a size and strength advantage over their opponents. In his recommendations to the National Collegiate Athletic Association, Coach Kenny recommends that each school's health department should examine each wrestler four to five times per season and make determinations about what weight each wrestler should wrestle. He then states that each wrestler should weigh-in five hours before wrestling and again at ringside. If at that time a wrestler has gained more than three pounds, he will be barred from competition (Kenney, 1930).

In order to address the concern of voluntary weight loss by dehydration and food restriction, Dr. Tuttle investigated how these practices affect performance. During the study each subject was instructed to lose up to 5% of their body weight prior to a variety of physiologic tests. Wrestlers used food and water restriction along with on the mat

workouts and sat in sweat boxes incorporated with towels and a heat lamp to lose their body weight. Following tests of strength, accuracy of movement, and reaction time it was concluded that rapid weight reduction had no affect. Along with performance testing five cardiovascular tests were performed and showed weight reduction had no effect on systolic blood pressure, diastolic blood pressure, resting heart rate, heart rate following exercise, and recovery time. The study also investigated several respiratory and oxygen requirement tests. All of these tests showed that rapid weight reduction had no affect. The author concluded that it was safe for a wrestler to lose up to 5% of their body weight and not have a negative affect on performance (Tuttle, 1943).

Another early account of concerns about rapid weight loss and its effect on performance was written by Nathan Doscher in 1944. In this document Doscher described stories about wrestler and boxers who used extreme methods to lose body weight. One story described that “boys are kept in steam baths for a week before a contest and are literally cooked down.” He also recalls a story about withholding food from athletes in order to make him angry, tough, and a better fighter. In order to address these concerns the author sent out a questionnaire to several collegiate wrestling and boxing coaches. From the questionnaire, he found that the majority of coaches were aware that rapid weight loss practices and they were also aware of possible health problems that could occur from those methods. However, those same coaches believed that a certain amount of weight loss was not detrimental to health. The coaches on average stated that a weight loss of 5-10% was not unhealthy (Doscher, 1944).

Despite the best efforts of researchers, the health concerns related to rapid weight reduction among wrestlers did not become apparent until 1967 when a county in Iowa

wanted to abolish interscholastic wrestling because of the unhealthy practices being used by high school wrestlers. Months of debate among delegates from the state medical society took place to determine the direction of interscholastic wrestling. It was determined that there was a lack of studies that address the magnitude and frequency of weight loss practices (Vaughan, 1968). In order to address those concerns Tipton et al. performed a series of studies to investigate the issue. In 1970, Tipton found the average weight loss of 747 high school wrestlers was 3.1 kg of initial body weight within a 17 day period of time (Tipton & Tchong, 1970). From a second study in 1973, Tchong and Tipton determined that wrestlers should not be allowed to wrestle if their percent body fat was less than 5% (Tchong & Tipton, 1973).

In a paper written by Brownell et al., data from a questionnaire given to 69 collegiate wrestlers showed that on average wrestlers' weight 7.6 kg less than their off-season weight. In terms of most amount of weight lost for a competition, the mean was 7.2 kg. Another interesting point made in this paper was that repeated weight cycling can lead to increased food efficiency. When a wrestler repeatedly loses and regains weight, their body will then require greater caloric restriction for each successive weight loss cycle (Brownell, Steen, & Wilmore, 1987). In a second questionnaire written by Steen and Brownell, sixty-three college wrestlers and 368 high school wrestlers were asked a variety of questions pertaining to "cutting weight." The athletes from the study showed the mean for most weight lost at any one time was 7.2 ± 3.2 kg for college wrestlers and 5.4 ± 3.3 kg for high school wrestlers. Among the college wrestlers, 89% stated that they had to lose an average of 4.4 ± 2.1 kg in 3 days. The high school wrestlers, 68% of the subjects reported they had to cut an average of 3.3 ± 1.8 kg in 4½ days (Steen &

Brownell, 1990). In contrast to these studies, Kiningham et al. surveyed 2532 high school wrestlers in the state of Michigan. They found that varsity high school wrestlers lose 1.6 to 2.3 kg 6-8 times throughout a season (Kiningham & Gorenflo, 2001). These numbers appear to be significantly lower than those reported by Steen and Brownell. This can be attributed to the Minimum Wrestling Weight program.

Effects of Rapid Weight Reduction

Since the possible health concerns related to rapid weight reduction were introduced, several researchers have thoroughly investigated the effects incurred by wrestlers. One of the main questions asked by researchers is how rapid weight loss affects the physiology of wrestlers. One study by Ribisl and Herbert looked at how physical work capacity of wrestlers was affected by rapid weight reduction and rehydration. The study studied the physical working capacity of eight wrestlers under three different states hydration. For this study physical working capacity was measured PWC-170 on a Monarch bicycle ergometer and body weight. First, measurements were taken when the wrestlers were in a state of normal hydration. Then the wrestlers were tested follow a 5% decrease in body weight within 48 hours. Finally, the athletes were tested after five hours of rehydration. The results of the study showed that after five hours of recovery and rehydration the wrestlers' physical working capacity was not diminished. Therefore, coming to the conclusion that 5% decrease in body weight from dehydration has no effect on physical working capacity (Ribisl, 1970).

A paper by Norman Hansen in 1978 compiled a variety of possible health concerns associated with wrestling. The first concern addressed was the possibility of growth stunting among wrestlers. An example was given of three brothers, two of which

started wrestling when they were in the seventh grade and the third brother who chose to play football. Following high school, the two brothers who wrestled were 5 ft 8 in tall and weighed 155 lb. as opposed to the third brother who was then 6 ft 2 in and weighed 195 lb (Hansen, 1978). This example could be mere coincidence; however, it paints a clear picture of the possible long term side effects cutting weight can have on a wrestler. This paper also addressed possible metabolic changes that could potentially harm a wrestler. Hansen references a study by Dr. William Herbert, who stated that if a wrestler were to rapidly lose over 4% of their body weight their carbohydrate stores in the liver would become depleted resulting in the body seeking energy needs else where in the body.

In order to determine the specific effects rapid weight loss has on energy needs of wrestlers, Tarnopolsky et al. investigated muscle glycogen concentrations of collegiate wrestlers. The study measured muscle glycogen by taking a biopsy of the wrestlers' dominant biceps brachii. The study found that muscle glycogen was significantly decreased following a 5% decrease in body weight through rapid weight reduction practices. It was also concluded that glycogen stores could be completely restored following a 17 hour recovery period (Tarnopolsky et al., 1996). It should be noted that during the time of this study collegiate wrestling weigh-ins occurred the evening prior to competition. Therefore, wrestlers had at least 17 hours of recovery time which included significant fluid and caloric intake. Meaning muscle glycogen stores could be replenished prior to competition.

One of the primary implications of decreased glycogen concentrations is anaerobic capacity. In a study by Webster et al. involving seven collegiate wrestlers, the

effects of rapid weight loss were investigated in terms of maximal strength, anaerobic power, anaerobic capacity, lactate threshold, and aerobic power. The wrestlers were given 36 hours to reduce their body weight by 5%. The athletes were then put through a series of physiological tests. The results from those tests were compared to testing results when the athletes were in a state of normal weight. It was noted that prior to both protocols, the athletes were not allowed to consume food 12 hours prior to testing. The study found that anaerobic power and anaerobic capacity was significantly decreased. The study also showed that wrestling weight loss techniques affect strength, lactate threshold, and aerobic power (Webster, Rutt, & Weltman, 1990). The results of this study indicate that rapid weight loss can dramatically decrease the performance of a wrestler.

Another area of concern regarding the weight reduction practices of wrestler's, is the effect on nutritional status. It has been hypothesized that recurrent cycling of weight along with caloric restriction can impact essential nutrients that bodies need to grow and develop. Of those nutrients that play a significant role in growth, protein is labeled as the building block of the human body. In a study by Horswill et al. different markers used to establish protein nutritional status were measured throughout a wrestling season. Measurements were taken prior to the beginning of the wrestling season and again at the end of the season. Each subject was required to give a blood sample in order to investigate concentrations of albumin, prealbumin, retinol binding protein, blood urea, nitrogen, hemoglobin, hematocrit, and 23 amino acids. Along with the blood sample, the athletes' body composition, height, and weight were assessed. The study found that on average wrestlers lost 6.6% of their body weight throughout the season. It also showed

that all markers used to measure protein nutritional status decreased throughout the season. Despite the diminished protein nutritional status, the author indicated that the athletes were not malnourished. This study could indicate that continuous decreases in protein nutritional status can lead to a suppression of lean tissue growth (Horswill, Park, & Roemmich, 1990).

In a similar study by Roemmich and Sinning, several aspects of energy and nutrient needs of high school wrestlers were shown to be related to growth and maturation. Subjects included nine high school wrestlers and seven active adolescent males. Each subject gave a sample of blood, had body composition assessed using underwater weighing, and strength was assessed by isokinetic testing with a Cybex. Results of the study showed that the wrestlers' mean weight loss during the season was 4.5 kg. In terms of body composition changes, there was a decrease in fat free mass of 1.1 kg during the in-season accompanied with a postseason increase of 3.0 kg. The authors found that there was a direct correlation between decreases in FFM with prealbumin levels. During the preseason the subjects' prealbumin levels were 26.0 ± 1.9 vs. 20.2 ± 0.9 mg/dl at the end of the season. Findings from this data also showed that the wrestlers' isokinetic strength decreased throughout the wrestling season. This study is consistent with Horswill et al., however, this study does show that there is a positive relationship between prealbumin levels and rate of lean tissue accrual (Roemmich & Sinning, 1997).

Several other studies have investigated possible health concerns related to rapid weight reduction. In a study by Strauss et al. showed that wrestlers who lose significant amounts of body fat throughout a season resulted in a decrease in serum testosterone

(Strauss et al., 1985). Other studies have attempted to determine if the weight loss practices used by wrestlers is associated with eating disorders. In 1998, Dale et al. concluded that wrestlers were concerned about their weight. However, the authors attributed their weight concerns to the demands of wrestling and noted that wrestlers in the study did not meet the criteria for diagnosis of bulimia nervosa (Dale & Landers, 1998). Another interesting study by Klinzing and Karpowicz used performance testing to measure the effects of rapid weight reduction. It was concluded that wrestlers who rapidly lose 5% of their body weight and undergo performance testing one hour later; there is a significant decrease in performance. However, if wrestlers are given five hours to replenish fluids and energy stores, performance was unaffected (Klinzing & Karpowicz, 1986).

Minimum Wrestling Weight Programs

The first wrestling organization to implement the recommendations of the AMA and ACSM was the Wisconsin Interscholastic Athletic Association. In 1989 the WIAA developed what was known as the Wrestling Minimum Weight Project. The project consisted of two major components. First, a standard was established to predict the body fat of wrestlers. In order to provide a protocol that was valid, reliable and cost effective the WIAA decided to use SF caliper measurements in conjunction with prediction equations from Lohman and modified by Thorland et al. to determine percent body fat. Based on recommendations from the ACSM, wrestlers in the project were not allowed to wrestle if their percent body fat was less than seven percent. The second component of the program implemented standardized testing protocols that included an educational program for testers who were assigned to access body fat. The reasoning for tester

training was based on research from Oppliger et al. that indicated high reliability among testers who have received training (Oppliger, Looney, & Tipton, 1987). The success of the project was portrayed in a follow-up study by Oppliger et al. in 1998. The study found wrestlers had decreased weight cutting, weight loss, and extreme weight cutting practices (Oppliger, Landry, Foster, & Lambrecht, 1998).

In 1998 the NCAA wrestling rules committee on competitive safeguards and medical aspects of sports developed recommendations to address concerns regarding wrestling weight loss and weigh-in procedures. The rules established a pre-season assignment of a wrestler's lowest allowable wrestling weight. This lowest weight was determined by first assessing a wrestler's hydrated body weight followed by assessment of body composition. Hydrated body weight was determined by using USG to measure levels of hydration. A USG less than 1.020 was considered hydrated and thus acceptable to proceed with body composition assessment. The NCAA approved HW and three-site SF with the Lohman-Brozek equation as the two acceptable methods for assessing body composition. It was determined that a wrestler's lowest allowable weight would be set at 5% body fat. In order to control the rate at which wrestlers lose weight to reach their lowest weight. The NCAA developed a weight loss plan that allowed wrestlers to lose 1.5% of their body weight per week during their weight descent. Along with the weight certification program the NCAA changed the time between weigh-ins and competition from five hours to one hour. There was also a complete reconfiguration of the ten weight classes in order to decrease the amount of weight between each weight class (Bubb, 1998).

In 1989 the Sports Medicine Advisory Committee of the Virginia High School League began investigating the harmful effects of rapid weight loss. Through a collaboration of efforts among states that have addressed the concerns related to rapid weight loss, task forces in the state of Virginia were organized to develop a wrestling weight control program (Perriello V A, 2003). Several pilot studies investigated the Virginia high school wrestling programs in order to address the feasibility of a weight control program in the state. Then the National Federation of State High School Associations mandated that all states must have a weight management program in place no later than 2004. Prior to the implementation of the weight control program, members of the VHSL provided instructional workshops for health care professionals in the state. The workshops reviewed the procedures of the program and established responsibilities for the individuals who wanted to take part in the program. Following the workshop, attendees were considered Certified Measurers for the weight control program.

The components of the VHSL wrestling weight control program are similar to the program established by the WIAA. Prior to the beginning of the wrestling season a certified measurer establishes each wrestler's MW which is established at 7% for males and 12% for females. Prior to testing each wrestler's hydrated body weight is assessed. Each athlete provides a urine sample that is placed on a urine refractometer which measures level of hydration by way of USG. A USG less than 1.025 is considered hydrated. A USG greater than 1.030 is not acceptable for weight certification and the athlete must return on another date for certification. If the USG is between 1.024 and 1.030, a specific percentage is added to the athlete's actual weight. After hydration is assessed, a baseline weight is taken on a calibrated scale. Finally, body composition is

assessed by way of three-site SF measurement with the Lohman-Brozek equations of males and the Slaughter, Lohman, Boileau equation for females. Athletes are then assigned their lowest allowable wrestling weight class and a weight loss program. Wrestlers are allowed to lose a maximum of 1.5% of their body weight per week until they reach their wrestling weight according to the weight loss program. If an athlete or coach is not in agreement of the lowest allowable weight established by the certified measurer, a protest can be filed for a re-test. If following the re-test, there is no agreement, a final test is performed by a state master tester (Perriello V A, 2003). This presents financial and logistical problems for the state and the athlete's trying to prepare for a competitive season. For this reason the methods for assessing body composition and hydration are constantly being researched.

Methods of Body Composition Assessment

Several methodologies exist in assessing body composition. Early concepts of body composition suggests the theory of the human body being made of fire, water, air, and earth (Schultz, 2002). Modern research can be traced back to the early 20th century. A major breakthrough in the field occurred in 1921 when J. Matiegka reported an anthropometric model for estimating total body muscle mass (Heymsfield, Lohman, Wang, & Going, 2005). Another advancement was when Behnke et al. introduced underwater weighing in 1942 (Heymsfield et al., 2005). This provided researchers a simple way of measuring FM and FFM. Since 1942 several methodologies and measurement devices have been developed and researched. For example dual-energy x-ray absorptiometry (DXA), near-infrared (NIR) light interactance, bioelectrical impedance (BIA), ultrasound, and magnetic resonance imaging have all shown to be

effective in assessing body composition. However, another significant breakthrough was developed during the 1990's when ADP became commercially available (Dempster & Aitkens, 1995). The validity and reliability of ADP has been established through comparative testing with reference methods such as HW, DXA, and multicompartement models (Fields, Goran, & McCrory, 2002). In regard to methods investigating minimum wrestling weight HW and ADP have been considered the "gold standards" for body composition assessment. However, considerable research has investigated BIA and SF as valid and reliable substitutes for determining a wrestlers' minimum wrestling weight. In order to fully understand the significance of these methods it is important to review their operational principles.

Hydrostatic weighing measures body composition through the estimation of body volume. The science behind this method is that body density is equivalent to the ratio of its mass (MA) and volume (V): $D_b = MA/V$ (Heymsfield et al., 2005). To make sense of this equation, think of body density as two components fat (F) and fat-free (FFM). Where body mass, set equal to unity, divided by body density (D_b), and are proportions of the fat and fat-free masses divided by their respective densities (Heymsfield et al., 2005). Fat-free mass can then be divided into water (W), protein (P), and mineral (M). These components can then be used to in a variety of models to predict body composition. The device itself consists of stainless steel or Plexiglas enclosed tank that is no smaller than 3m x 3m x 3m in size. The tank is equipped with heating and filtration systems in order to maintain a water temperature of 32-35 degrees Celsius. The subject is then seated on a chair that is suspended in the water by a spring loaded autopsy scale. Accuracy of weight measurement is dependant on the subject not moving while under

water. Next, the subjects' residual lung volume is measured by maximally exhaling while bending forward and submerging the head and shoulders under water. There are several variations of HW procedures which are described by Heymsfield et al. in *Human Body Composition 2nd edition* (Heymsfield et al., 2005).

Plethsmography refers to the measurement of volume. ADP is a method for measuring whole body volume. In order to make these measurements, the ADP uses two chambers of air to measure volume displacement (Fields et al., 2002). The test chamber is where a subject sits during testing. The second chamber is referred to as the reference chamber. Between the two chambers is a volume-perturbing element that oscillates producing sinusoidal volume perturbations (Utter et al., 2003). Those perturbations are measured by transducers and are analyzed for pressure at the frequency of oscillation. Thus, the relationship between pressure and volume is assessed by using Boyle's and Poisson's Gas Laws (Heymsfield et al., 2005; Utter et al., 2003). In order to accurately measure these volumes, it is essential that isothermal effects are controlled. Isothermal effects include the interactions of clothing, hair, surface area, and air in the lungs. In order to control for these effects each subject is required to wear minimal clothing and a swim cap. Air in the lungs is accounted for by either measuring each subject's lung volume or by using predicted measurements. Finally, the surface area of each subject is accounted for by using body surface area software (Fields et al., 2002). It should also be noted that subjects should not exercise or consume food and drink two hours prior to testing.

Bioelectrical impedance technology has been around since the late 1930's. However, BIA models used to assess body composition were not available until the mid-

1980's (Heymsfield et al., 2005). The basic concept behind BIA is that impedance is a function of resistance and reactance. This is measured by estimating total body water (TBW) from impedance because electrolytes in the body's water are good conductors of electrical current (Heyward & Wagner, 2004). To put this in perspective, biological tissues act as either conductors or insulators and the flow of a current will follow the path of least resistance. Therefore, body tissues such as body fat slow down or resist the flow of current. On the other hand FFM acts as an electrical conductor which allows current to pass through the body with little resistance and little impedance. There are several BIA models that measure resistance from different areas of the body by sending a low level electrical current from one area of the body and measures the impedance of that current as it travels to another part of the body. For example, upper body (hand-to-hand), lower body (leg-to-leg), and whole body where resistors are arranged in a series on the body. Other variations of BIA include different frequencies. After measurements of impedance are assessed a prediction equation is used to estimate FFM, TBW, and BF%. The equations used are taking into account age, height, weight, and activity level. Like ADP, the manufactures of BIA systems recommend for accurate readings that subjects should not consume food or liquids two hours prior to testing and subjects should avoid strenuous activity 12 hours before testing. It should be noted that equations for determining %BF and D_b are proprietarily developed.

Anthropometry has a history dating back to early forms body composition assessment. The traditional variables relevant to anthropometrics include: lengths, breadths, circumferences, SF thickness, area, volume, and weight. The variable relevant to minimal wrestling weight assessment is SF thickness. The techniques used to measure

SF thickness vary according to the population and prediction model being used. For example the Lohman equation for calculating D_b includes the sum of the triceps SF, subscapular SF, and abdominal SF. When obtaining each measurement, anatomical landmarks are determined by measuring with a tape measure and marking each location with a pen. Next, the measurer pinches the skin and subcutaneous tissue of each landmark between their thumb and pointer finger. Note that finger placement is 1 cm above the caliper landmark. The measurement is then obtained by placing the SF caliper perpendicular to the long axis of the SF. The caliper should be applied midway between the body skin surface and the bulbous crest of the SF. Caliper reading should occur within 2-4 second of caliper placement. Each measurement should be repeated three times and all measurements should be taken on the right side of the body (Perriello V A, 2003). After D_b is determined by the Lohman equation, either the Siri (Siri, 1961) or Brozek (Brozek, Grande, Anderson, & Keys, 1963) equation is used to predict percent body fat. The same recommendations prior subject testing applies when assessing SF thickness measurements.

In order to predict percent body fat and or body composition several methods can be used. The methods that have proven to be the “gold standard” for estimating body composition and body density of an individual are hydrostatic weighing or air displacement plethysmography. Hydrostatic weighing has been the standard for measuring body density since Behnke et al. introduced the concept in 1942 (Heymsfield et al., 2005). Another method, which is non-invasive, is bio-electrical impedance. This method uses impedance values of resistance and reactance within a prediction equation to estimate composition. A third method is to use anthropometric measurements such as

skinfold thickness or girth measurements. These measurements are then used within an equation to determine body density. Within the population of high school and collegiate wrestler the most acceptable anthropometric equation is the Lohman Equation (Lohman, 1981).

Despite the fact that HW and ADP are considered the “gold standards” for estimating body composition and body density it is unrealistic for these methods to be available to everyone because of the drawbacks each method presents. For example, HW is extremely invasive and requires subject compliance in order to be accurate. Subjects state that a full expiration of air followed by submersion underwater is uncomfortable. For this reason, it can take between 20-30 minutes to test a subject. To counteract these downfalls, Bod Pod[®] offers a testing environment that is comfortable for subjects and requires less time to make its measurements. Despite the benefits that ADP offers, the cost to purchase a system is extremely high. It would be impractical for a state interscholastic governing body like the VHSL to purchase a Bod Pod[®], let alone each school within the Commonwealth of Virginia. This is why research continues to investigate convenient and affordable methods like SF and BIA for MW assessment (Clark, Bartok, Sullivan, & Schoeller, 2005).

Methods for Assessing Minimum Wrestling Weight

In 1985, Williford et al. investigated four different anthropometric models for high school wrestlers. The models investigated were developed by Tchong and Tipton (Tchong & Tipton, 1973), Michael and Katch (Michael & Katch, 1968), Forsyth and Sinning (Forsyth & Sinning, 1973) and were compared to HW using D_b formula of Goldman and Buskirk and percent body fat according to Siri. The study involved fifty-

four high school wrestlers during a wrestling season. The results showed that the Michael and Katch formula overestimated D_b and underestimated percent body fat. The Forsyth and Sinning model underestimated D_b and overestimated body fat. The best formula estimation for minimum wrestling weight was the Tchong and Tipton equation even though it underestimated MWW when compared to HW (Williford, Smith, Mansfield, Conerly, & Bishop, 1986). This study was important in determining the direction of MWW equations even though the results were somewhat inconclusive.

In a study conducted in 2000, seven anthropometric regression equations were investigated in order to determine appropriate weight classes for collegiate wrestlers. The seven equations included Lohman (Lohman, 1981), Thorland et al. (Thorland, Johnson, Tharp, & Houch, 1984), Katch and McArdle (Katch & McArdle, 1973), Durnin and Wommersley (Durnin & Wommersley, 1974), Tipton and Oppliger (Tipton & Oppliger, 1984), Jackson and Pollock (Jackson & Pollock, 1978), and Sinning (Sinning, 1974). The study also compared both the Siri (Siri, 1961) and Brozek (Brozek et al., 1963) equations for estimating percent body fat. All methods were compared to HW using predicted residual volume according to Wilmore (Wilmore, 1987). There were twenty-two collegiate wrestlers involved in the study. Results showed that the Jackson and Pollock equation underestimated %BF thus showing that age, sex, and activity level are significant factors of regression equations. The Lohman, Katch and McArdle, and Tipton and Oppliger equations were validated by this study. All three of these equations tended to over predict percent BF at low values and under predict percent BF at high values. The conclusion of this study supports the Lohman equation as the best equation for predicting percent body fat in wrestlers (Carey, 2000).

In a study following the implementation of the WIAA wrestling weight control program, Clark et al. investigated four methods for assessing body composition in order to predict MW. Those methods included SF using the Lohman equation that was modified by Thorland to predict percent body fat, NIR, BIA, and DXA. The study included 95 high school wrestlers during a summer wrestling camp. The criterion method used was HW to determine residual volume as described by Behnke and Wilmore. Results showed that there was a statistically significant difference between HW and the other four methods in predicting MW. However, the mean difference using SF was 0.6 kg which is considered to be within acceptable limits (Clark et al., 1993). One of the explanations of variability within this study is that hydration status was not assessed prior to the measurements.

In an article by Oppliger et al. in 1991, anthropometry, bio-impedance, and hydrostatic weighing were compared for the purpose of determining wrestlers' minimal wrestling weight. The study involved fifty-seven high school wrestlers. Body density was established by HW and percent body fat was then calculated using the Siri equation. Anthropometric measurements were assessed with SF calipers. The authors then used the Tcheng and Tipton equation to estimate percent body fat and the Oppliger and Tipton formula to calculate minimum wrestling weight. The third assessment of minimum wrestling weight used three different bio-impedance models. The results of the study showed that all three bio-impedance models under predicted minimum wrestling weight. However, when one of the BIA models incorporated SF measurements into its prediction equation, the results were similar to hydrostatic weighing (Oppliger, Nielsen, & Vance, 1991). One of the drawbacks of this study was that the subjects were tested during a

summer wrestling camp. During that time of the year, the subjects were not representative of the population of wrestlers.

In a study by Clark et al. in 2002, body composition methods were cross-validated among ninety-three collegiate wrestlers in order to determine MW. The Study took place at two different testing sites and occurred over a six year period. Body density was determined by HW and residual volume based on descriptions from Behnke and Wilmore. Percent body fat was estimated using the Brozek et al. equation. Other measurements included height, weight, and nine SF measurements were taken from three sites. Results from SF testing were then placed in the Lohman-Brozek equation to determine D_b and %BF. Results were represented in the form of Standard Error Estimate and Total Error. The author noted that these methods of comparison have become the standard when cross-validating methods of estimating body fat (Lohman, 1981). The author also cited from an article by Lohman in 1992 that TE values below 3.0% are “very good to ideal” when cross-validating methods (Lohman, 1992). Results from this study showed TE for the NCAA method was 2.49% placing it in the ideal category. This indicates that the NCAA equation using the Lohman equation accurately predicts %BF in collegiate wrestlers (Clark, Oppliger, & Sullivan, 2002). In another study by Clark et al. in the same year HW and the Lohman SF equation was cross-validated against a four component model (4C). The 4C model consists of analyzing bone mineral content (BMC), total body water (TBW), and D_b . The results of this study concluded that the Lohman equation accurate for predicting %BF when cross-validated against the 4C method (Clark, Sullivan, Bartok, & Schoeller, 2003).

In a more recent study, Clark et al. cross-validated DXA, BIA, HW, and SF for predicting MW using 4C criteria. Subjects included 53 Division I athletes. SF measurements were taken using the Lohman equation to predict D_b and the Brozek equation to predict %BF. Hydrostatic weighing was used to measure residual volume and D_b as described by Behnke and Wilmore. Percent body fat was then estimated using the Brozek et al. equation. The Norland XR-36 whole body densitometer was used for DXA measurements of %BF. Next, the TBF-305 GS was used to measure bioelectrical impedance and the Tanita[®] systems proprietary equations were used to estimate %BF. Finally, TBW was quantified by using the deuterium dilution, isotope ratio mass spectrometry technique and equations from Schoeller (Schoeller, 1996). The results of this study showed that when measurements were cross-validated against the 4C model. In terms of precision from SEE and PE values, HW and SF using the Lohman equation were the best methods for predicting MW.

In 2005 Clark et al. published another study that evaluated leg-to-leg BIA against the 4C criterion for predicting MW among wrestlers. The study measured D_b from HW, BMC from DXA, and TBW from deuterium dilution for calculating the 4C criterion. Bioelectrical impedance was measured using the leg-to-leg TBF-305. Subjects included 57 collegiate wrestlers whose hydration status was assessed prior to testing by using a $USG \leq 1.020$ as the limit for hydration status. Results of the study showed a significant correlation between BIA and the 4C criteria in predicting %BF; however, BIA underestimated MW in leaner wrestlers and overestimated MW in wrestlers who had more body fat. Further results showed that the SEE and PE values were ± 3.4 kg and \pm

3.5 kg respectively. Therefore, it was determined that leg-to-leg BIA was unacceptable for prediction of MW of collegiate wrestlers (Clark et al., 2005).

One of the first studies to validate ADP for assessing body composition of wrestlers was by Utter et al. in 2003. This study included sixty-six collegiate wrestlers who competed at three different institutions. Each subject was tested twice during a 48-h period of time. Prior to the first testing time hydration status was assessed using urine refractometry. Hydration status was established at the $USG \leq 1.020$ criteria for hydration. For the second test, athletes were asked to dehydrate 2-3% of their body weight. The dehydration of 2-3% was confirmed by reduction in body mass or by a $USG \geq 1.020$. Next, three-site SF measurements were assessed according to NCAA guidelines and D_b was determined by the Lohman equation. Percent BF was when determined using the Brozek equation. Residual lung volume was assessed using HW procedures used followed those of Wilmore et al. It should be noted that not all three testing sites used the same HW systems. Finally, ADP was used to measure body volume and D_b . All three measurements were taken in both hydrated and dehydrated states. The results of the study showed the SEE values for HW and ADP were 2.12% (hydrated) and 2.16% (dehydrated.) When HW was compared to SF for predicting percent BF, results indicated that SF overestimated BF % in both hydrated and dehydrated states. It was determined that ADP was as acceptable method for estimating % BF among collegiate wrestlers (Utter et al., 2003).

A second study by Utter et al. evaluated leg-to-leg BIA in assessing body composition of high school wrestlers. The study was conducted prior to the wrestling season and included 129 wrestlers. Prior to testing hydration status was assessed using

refractometry. Proper hydration levels were established at USG readings ≤ 1.025 . Three-site SF measurements were assessed using the Lohman equation to determine D_b and the Brozek equation was used to estimate % BF. Residual lung volume was assessed using procedures described by Wilmore et al. Next, the TBF-WA leg-to-leg BIA system was used to assess % BF. The results of the study showed standard error of estimates for BIA and HW as 3.64 kg and 1.97 kg respectively. Recommendations from this study suggest that BIA should only be considered as an assessment tool for high school weight certification if trained SF testers are not available for testing (Utter et al., 2005).

A study conducted by Dixon et al. in 2005 evaluated Bod Pod[®] and leg-to-leg BIA in estimating percent BF among Division III collegiate wrestlers. The study included twenty-five wrestlers and took place prior to the competitive wrestling season. Prior to testing hydration status was established using urine refractometry to measure USG. A USG ≤ 1.020 was the criteria for hydration and was a requirement for inclusion in the study. BIA measurements were assessed using the TBF-300A model and %BF was calculated using the “Athletic Mode” supplied by the manufacturer. Three-site SF measurements were taken according to the NCAA guidelines. Body density and %BF were calculated using the Lohman et al. and Brozek equations. Next, D_b was determined using residual lung volume from HW. Finally, ADP was used to D_b and %BF was estimated using the equation from Brozek et al. Results showed that BIA underestimated % BF when compared to HW and SF. The standard errors of estimates for SF, ADP, and BIA were 1.87%, 1.68%, and 3.60% respectively. Results also indicated that ADP and NCAA approved SF procedures accurately estimate % BF when compared to HW.

However, it was determined that BIA was not appropriate for predicting % BF of collegiate wrestlers (Dixon, Deitrick, Pierce, Cutrufello, & Drapeau, 2005).

Assessment of Hydration Status of Wrestlers

There are several methods available for assessing hydration status of athletes. In a paper by Oppliger and Bartok several of those methods were reviewed. One of the most common methods for hydration testing is monitoring body weight stability. This is achieved by assessing pre and post exercise body weights. Other methods of hydration assessment include urine volume, colour, osmolality, and specific gravity. Urinary volume consists of quantitative assessment of normal volumes and frequency of urination. Urine colour can be assessed by comparing actual urine colour to a six-point Likert scale which indicates level of hydration. Osmolality is assessed by using a freezing point osmometer. This instrument measures the amount of osmoles of solute particles per kilogram of solution. This method is uncommon for most practices of hydration assessment. Urine specific gravity on the other hand has become the easiest and most reliable method of measuring hydration status. USG can be assessed either by hygrometry, refractometry, or reagent strips. Hygrometry uses a weighted glass float to determine the density of urine relative to pure water. This is no longer considered an accurate or practical method of USG. The second way to assess USG; refractometry, involves passing a beam of light through a sample of urine and measuring how much the beam is refracted. The third USG method involves reagent strips. These strips estimate USG based on the release of hydrogen ions. These changes result in color changes on the reagent stripe. For example the strip changes from a blue color to yellow-green color. Usually a color chart is provided by the manufacturer. The standard for assessing

hydration status is blood osmolality. This method is expensive and invasive to the subject (Oppliger & Bartok, 2002).

In a study by Bartok et al. in 2004 the effect of dehydration was assessed on minimum wrestling weight assessment (C. Bartok et al., 2004). The study included twenty-five collegiate wrestlers. Prior to testing each athlete was injected with bromide and deuterium solution in order to measure ECW and TBW. Throughout the study all urine output was collected and measured for volume and loss of bromide and deuterium. Residual lung volume was then measured using HW, bone mineral density was measured by DXA, and SF measurements were taken. Next, the athletes gave a sample of blood for bromide and deuterium measurements and hydration status. Finally, BIS and BIA measurements were assessed. These measurements were referred to as euhydrated testing. Following these procedures the athletes were asked to dehydrate 2-5% of their body weight. Blood samples were then collected for a second time. Next, all body composition measurements were assessed for a second time. These measurements were referred to as dehydrated testing. The results of the study showed that in a euhydrated state the TE for HW and SF was 1.75 kg and 2.15 kg respectively. However, the TE for BIS and BIA was 3.68 kg and 3.77 kg. In the dehydrated state the TE for all methods increased significantly. The conclusions of this study indicate that acute dehydration can violate the assumptions necessary for accurate and precise prediction of MW using SF, BIA, and BIS.

In a second study by Bartok et al. hydration testing was evaluated when wrestlers were dehydrated. The purpose was to determine the accuracy of hydration testing methods. Twenty-five athletes were involved in the study. Like the previously described

study, athletes underwent the same protocol of euhydrated and dehydrated testing. However, this study included data involving SG-10 type USG dipsticks and an IRIS automated urinalysis system (IRIS). The results of the study compared measurements of urine protein, osmolality (Osm), USG-IRIS, USG-dipstick. From the blood samples plasma Osm, sodium, potassium, chloride, arginine vasopressin were investigated. The final measurement was the BIS relationship between ECW: ICW. The results showed that hypertonic dehydration produced significant decreases in most plasma, urine, and BIS hydration tests. This study also concluded that the acceptable cutoff for USG hydration should be 1.020 (C. Bartok, Schoeller, Sullivan, Clark, & Landry, 2004). This was one of the first comprehensive studies that investigated the effect of hypertonic dehydration on hydration assessment.

From a practical approach, Stuempfle and Drury investigated three methods of assessing hydration status of collegiate wrestlers. The study consisted of collecting a sample of urine from twenty-one subjects. Each sample was then evaluated twice by four different measurers. The three methods used to assess hydration included urine refractometry, hydrometry, and reagent strips. The standard criterion was determined by urine refractometry. The results of the study showed there was a strong relationship between trials and among testers. The final recommendations from this study suggest that only the urine refractometer should be used to determine USG in collegiate wrestlers (Stuempfle, 2003).

CHAPTER THREE

Methodology

Subjects

The subject pool for this study consisted of male high school wrestlers participating in the Virginia High School League. Female subjects were not included in the study due to anthropometric differences associated with gender. Subjects' age ranged from 14 to 18 years. Subjects were recruited from high schools within the surrounding area of Montgomery County Virginia. Ten area high school wrestling programs participated in this study.

Study Protocol

Data collection occurred during official dates of wrestling weight certification mandated by the Virginia High School League (VHSL). Prior to data collection, the study was approved by the Virginia Osteopathic Medical Schools' Institutional Review Board. All measurements and data collection were observed and recorded by licensed athletic trainers. Subjects were transported to the Virginia Tech Performance and Sports Medicine Laboratory from area high schools by either coach or guardian. Upon arrival at laboratory, both parental informed consent and student consent forms were obtained from the subjects. Assessment of body composition and minimum wrestling weight (MW) were within guidelines of the VHSL Wrestling Weight Control Program and were performed by a certified measurer of the VHSL.

Following the consent process the subjects provided date of birth, projected wrestling weight class, and expected weight class. Subjects were then asked to provide a urine sample. Collection of the urine sample was not directly observed by an

investigator. However, an investigator was present during the urine collection process in order to control for tampering with or diluting the specimens. After the subject produced a urine sample, a group of four testers independently assessed the level of hydration using the Atago[®] Urine Refractometry and Multistix[®] UG 10 reagent strips. Results were then recorded independently and attached to a data entry card. Next, the subject's height was assessed using a height stadiometer.

The subjects were then asked to stand on the Tanita[®] scale to measure their body fat and weight. The Tanita[®] scale uses low-level electrical charges to measure body fat and weight. Next, the subjects were asked to stand quietly while a researcher took three skinfold measurements using a caliper. This was the second way of measuring body composition. The subjects do feel a series of mild pinches during this process.

Finally, the subjects were placed in the Bod Pod[®]. This device uses air displacement to assess body composition. Before entering the Bod Pod[®], the subjects were instructed to sit quietly for approximately 1 minute per assessment for a total of three assessments.

They were reminded that should they become claustrophobic or uncomfortable during the test, they could stop the test by pressing a stop button located in the machine.

Instrumentation

Hydration

Hydration status of each subject was evaluated through urine specific gravity (USG) measurements. Instrumentation used to obtain USG values included the Atago[®] Urine Refractometer (Atago USA Inc.) (Figure 1 and 2) and Bayer Multistix[®] 10 SG reagent strips (Bayer Corporation USA). Prior to each data collection session the Atago[®] urine refractometer was calibrated according to manufacturer recommendations.

The Multistix[®] measurements were also assessed according to manufacturer recommendations which consist of recording measurements forty five seconds after the Multistix[®] is placed in the urine sample. In order to control for tester reliability two independent measurements were assessed by two different measurers for each measurement of USG. Following hydration assessment subjects were asked to dispose of the remaining urine sample in a toilet and place the collection container in biohazard container.



Figure 1: View of hydration level



Figure 2: Urine refractometer

Height and Weight

Height of each subject was assessed using a Seca[®] Road Rod height stadiometer (Invicta Plastics Limited) (Figure 3). Prior to height assessment each subject removed both shoes and socks. Subjects were asked to stand with their back facing the stadiometer and their feet placed on the stadiometer foot placement markers. Each measurement was recorded to the nearest centimeter. The weight of each subject was measured using the Tanita[®] TBF-300A body composition analyzer (Tanita Corporation) (Figure 4) which was set up and calibrated according to manufacturer recommendations. Each subject was asked to wear minimal dry clothing which consisted of a wrestling singlet. Subjects were asked to clean and dry their feet prior to stepping onto the scale

portion of the Tanita® TBF-300A body composition analyzer. Each measurement was recorded to the nearest kilogram.



Figure 3: Height Stadiometer

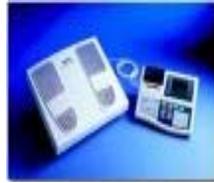


Figure 4: Tanita® Scale

Bioelectrical Impedance

The Tanita® TBF-300A foot-to-foot body composition analyzer with wrestler mode retrofit was used to assess bioelectrical impedance (BIA) of the subjects. This instrument consists of a weighing platform that has two anterior electrodes and two posterior electrodes on its surface. Those electrodes indicate proper foot placement for testing and represents the means for measuring BIA. Measurements of BIA are accomplished by inducing a low energy, high frequency, electrical current (50 kHz, 500 microamp) from the foot electrodes into the body (Corporation). This provides a baseline resistance to the flow of electrical current. As the current is passed from the anterior electrodes, the voltage drop is then measured on the posterior electrodes. The instrument also consists of a control box that is used to enter information specific to the population being tested. That information includes height, age, gender, and body type. Body type is categorized into male standard or athletic and female standard or athletic. These body types or modes represent the different mathematic equations used to predict body composition from BIA analysis. It should be noted that these different modes do not change or affect the actual analysis of BIA; however, they represent anthropometric differences of different populations. For the purpose of this study a Tanita® scale with a

mode specific to the high school wrestling population was used. Prior to testing date each subject was given a pre-test protocol to ensure optimal conditions that have been recommended by the manufacturer (Table 1). Each subject wore a wrestling singlet while measurements were taken by the BIA system. The weight of each singlet was accounted for by entering the weight of each singlet into the control unit before each measurement. Measurements obtained from this instrument included: fat mass (FM), fat-free mass (FFM), body mass index (BMI), basal metabolic rate (BMR), percent body fat (BF), impedance (BIA), and seven percent body fat minimum wrestling weight (MW).

- Avoid intense exercise 12 hours before test
- Avoid eating or drinking (especially caffeinated products) 4 hours before the test
- Empty bladder 30 minutes before test
- Avoid all diuretics for 7 days before test

Three-site skinfold

Another body composition assessment instrument used in this study included Lange calipers Beta Technology Inc. The calipers were used to measure the thickness of three anatomical skinfold sites of each subject. Prior to collection of data the Lange caliper was calibrated per the manufacturer's recommendations. The location of the three skinfolds used for this study included the triceps (Figure 5), abdominal (Figure 6), and subscapula folds (Figure 7), and. Each anatomical landmark was properly identified and marked using the skinfold assessment protocol mandated by the VHSL wrestling weight control program. These three skinfolds were chosen based on the specific anthropometric

equation developed by Lohman (Lohman, 1981). The Lohman equation takes into account age, weight, and the mean skinfold thickness measured by the skinfold calipers. With this information the Lohman equation predicts FM and FFM. That information is then placed into the Brozek et al. equation for the purpose of calculating %BF (Brozek et al., 1963). After the following equations have estimated body composition, each subjects FFM is divided by 0.93 in order to predict the subject's lowest allowable weight at 7% body fat. These equations and conversions represent those used by the VHSL wrestling weight control program.



Figure 5: Triceps Skinfold



Figure 6: Abdominal Skinfold



Figure 7: Subscapular Skinfold

Air Displacement Plethysmography

The third body composition assessment device used was the Bod Pod[®] (Figure 8). The components of the Bod Pod[®] consist of a weighing scale, computer, and air displacement chamber (Life Measurement, 2004). This study also used measured lung volume as opposed to predicted lung volume. Measured lung volumes require each subject to perform a series of expirations into a breathing tube. Information from those expirations are then measured by the device and used as that subject's lung volume. Following each test a new breathing tube was placed into the air displacement chamber. Measured lung volumes were recommended by the manufacturer because the measurements from this study were being used for research purposes.

Prior to data collection the device was turned on 45 minutes before data collection. Because the Bod Pod[®] consists of an external software system located in a computer and the actual measuring device that represents the hardware of the system, a warm-up process is required. Following the warm-up process a system test was conducted to ensure that the unit was properly calibrated. The unit was found to be within 46ml of standard deviation, which is considered to be within acceptable values as recommended by the manufacturer. Next, the software was set to use the Brozek equation to establish body composition. After the appropriate software was selected the weighing scale was calibrated. Calibration of the scale consisted of taking a scale weight when the scale was clear of any weight and then two 10 kilograms weights were placed on the scale and weighed. The weights were then removed and scale weight was taken again with a cleared scale.

Based on manufacturer recommendations the pre-test protocol indicated earlier was established prior to Bod Pod[®] testing. Another recommendation from Bod Pod[®] was that the subjects should wear minimal dry clothing for example spandex shorts. In order to meet those recommendations the subjects wore a wrestling singlet and swim cap and removed any jewelry, watches or eyeglasses. After those conditions were established each subjects height, age, gender, and numeric code were entered into the computer. Next, weight was assessed using the weighing scale. Prior to entering the air displacement chamber the subjects were instructed on how to use the breathing tube and the proper expiration sequence was explained.

The subjects were then asked to enter the air displacement chamber. After the chamber door was closed the subjects were asked to place a breathing tube into their

mouths. The subjects then performed the measured lung volume sequence which consisted of breathing normally and then expiring three easy puffs into the breathing tube. The participants were asked to repeat this portion of the test until an acceptable value was achieved. After lung volume was measured the subjects were asked to relax and breathe normally while remaining motionless until the test was completed. A normal test takes 3-5 minutes. After the Bod Pod[®] measures air displacement the FM and FFM of each subject can be determined. Finally, percent body fat is calculated using the Brozek equation.



Figure 8: Bod Pod[®]

Data Analysis

In order to investigate the validity of bioelectrical impedance using the Tanita[®] TBF-300A with wrestler retrofit in assessing body composition among high school wrestlers it was determined that the wrestlers would be divided into three categories based on wrestling weight class. The three categories included light, middle, and heavy (Table 2). In order to assess the interaction of hydration levels the subjects were further divided into groups of hydrated and dehydrated. Hydration was assessed using urine refractometry and used an USG ≤ 1.020 as the cutoff for hydration. That is, if a subject had a USG > 1.020 then they were classified as being hydrated; otherwise, they were classified as dehydrated.

Wrestling Weight Categories

Wrestling Weight Category	Wrestling Weight Class (lb)
Light	103, 112, 119, 125, 130
Middle	135, 140, 145, 152, 160
Heavy	171, 189, 215, 275

Table 1: Wrestling weight categories defined by assigned wrestling weight classes

Based on the fact that this study investigated the measurements of three different dependant variables bio-electrical impedance (BIA), three-site skinfold (SF), and Bod Pod[®] (BP). Each subject is exposed to the same three trials of body composition assessment. Along with this with-in subject's factor, a factor also exists between the subjects based on hydration status. This is created by the hydrated group and the dehydrated group of subjects. Therefore, when investigating the differences between means of the three dependant variables a repeated measure ANOVA with between-subjects factors is the most appropriate test. Statistical analysis of both percent body fat and 7% minimum wrestling weight estimates will include the calculation of mean differences, standard errors of estimate, and a comparison of means for percent body fat and 7% minimum wrestling weight estimates. For all analyses, a significance level 0.05 was used.

To assess the validity of BIA in measuring BF and MW it was necessary to create three wrestling weight categories and test the relationships of the three devices when the subjects were divided into hydrated and dehydrated groups. The design of this study was intended to rigorously investigate the validity of BIA in hydrated high school wrestlers. For that reason each hypothesis was tested to determine the equality of means instead of comparing the correlations and standard errors of estimate that typically represent how previous studies present research findings.

To the knowledge of the author, no previous studies have compared the three factors of BIA, BP, and SF across three wrestling weight categories. Along with this no previous studies have compared hydration affect across weight classes. In a study by Oppliger et al. (1991) high school wrestlers were placed into four weight categories.

However means were not compared across each of the weight categories. It should be noted that all previous studies have used hydrostatic weighting (HW) as the gold standard for predicting body composition. Perhaps one of the limitations of this study is that the Bod Pod[®] used as the gold standard instead of hydrostatic weighing.

CHAPTER FOUR

Results

Introduction

In order to address the results of the two research questions stated in this study, it is important to separate the questions into two sets of analyses. The first research question addresses the validity of bioelectrical impedance in measuring percent body fat (BF) among high school wrestlers. However, the second research question investigates the validity of bioelectrical impedance in assessing the seven percent minimum wrestling weight (MW) of high school wrestlers. Although these two questions can not be directly linked in terms quantifiable comparisons, an important relationship exists between the two questions in placing wrestlers in appropriate wrestling weight classes. In other words percent body fat is a component used to determine a wrestler's seven percent minimum wrestling weight in that a wrestler can not compete below the seven percent body fat marker. However, the equation for estimating the seven percent minimum is derived from an athlete's fat free mass not their percent body fat. This is why a direct relationship can not be compared between the two questions. Also when investigating the results of the two questions the percent body fat analysis is represented as a percent whereas the seven percent minimum wrestling weight results represent body weight in pounds and subsequently wrestling weight classes. These wrestling weight class assignments are arranged in approximately five-pound intervals.

The measurement devices used to address both research questions included comparing the Tanita[®] scale (BIA), three-site skinfold (SF) and the Bod Pod[®] (BP). The

analysis of those measurements used repeated measures ANOVA with between-subjects factors to compare means. Therefore, percent body fat of all subjects was measured by these three dependent variables creating a set of conditions called a within-subjects factor also referred to as trials. Another set of conditions were created by dividing the subjects into two hydration groups: Hydrated (HD) and dehydrated (DHD). Those conditions created a between-subjects factor which is considered as groups. In order to thoroughly investigate the proposed research questions it was determined that the analysis of the trials between groups be divided into three weight categories: Those included light (L), middle (M), and heavy (H) categories which represent respective wrestling weight classes. The characteristics of each category are addressed in (Table 1). This allows for comparisons to be made among different weight classes. All statistical analyses were performed using SAS software (SAS Institute, 2005).

Subject Characteristics

	Light (n = 23)	Middle (n = 48)	Heavy (n = 27)
Age	15.09± 0.95	15.77± 1.24	16.15± 1.20
Height (lb)	64.24± 1.8	67.81± 1.9	70.38± 2.1
Weight (in)	111.99± 11.3	145.11± 7.71	202.26± 33.97
Hydration (USG)	1.022± 0.01	1.021± 0.01	1.024± 0.02

Table 1: Subject Characteristics: Values are displayed as group means ± SD

Percent Body Fat Analysis

The research question addressed in this section of the analysis is the validity of bioelectrical impedance using the Tanita[®] TBF-300A with wrestler retrofit in measuring body composition among high school wrestlers. To test the validity of bioelectrical impedance as an instrument of body composition the measurements from the Tanita[®] scale were compared to three-site skinfold using the Lohman-Brozek formula and the Bod Pod[®] among high school wrestlers.

Percent Body Fat Hypotheses:

This null hypothesis proposes that all means are equal among the measurements of percent body fat across wrestling weight categories. The alternative hypothesis states that at least one of the means is different among the measurements of percent body fat across wrestling weight categories.

$$H_0: \mu_{BP(L)} = \mu_{SF(L)} = \mu_{BIA(L)}$$

H_a : at least one is different

$$H_0: \mu_{BP(M)} = \mu_{SF(M)} = \mu_{BIA(M)}$$

H_a : at least one is different

$$H_0: \mu_{BP(H)} = \mu_{SF(H)} = \mu_{BIA(H)}$$

H_a : at least one is different

This null hypothesis states that all means are equal among the measurements of percent body fat taking into account hydration status across weight categories. The alternative hypothesis states that at least one of the means is different among the measurements of percent body fat taking into account hydration status across weight categories.

$$H_0: \mu_{BP(DH)} = \mu_{BP(DHD)}$$

$H_a: \mu_{BP(DH)} , \mu_{BP(DHD)}$

$H_o: \mu_{SF(HD)} = \mu_{SF(DHD)}$

$H_a: \mu_{SF(HD)} , \mu_{SF(DHD)}$

$H_o: \mu_{BIA(HD)} = \mu_{BIA(DHD)}$

$H_a: \mu_{BIA(HD)} , \mu_{BIA(DHD)}$

Analysis of Percent Body Fat in Light Wrestling Weight Category

The first portion of this analysis investigated the mean percent body fat among the three measurement devices across wrestling weight categories using a repeated measures analysis of variance. There were 23 subjects used in this portion of the analysis. Of the twenty three subjects 17 were classified as dehydrated while 6 were considered hydrated.

The repeated measures analysis of variance resulted in a significance level of 0.0003.

Therefore, a significant difference was observed among the BP, BIA, and SF

measurements of percent body fat. In order to further investigate the differences among

measurement devices the analysis of variance of contrast variables was used to compare

means of the Tanita[®] scale and three-site Skinfold a significance level of 0.0001 was

observed. However, when the same analysis compared the three-site Skinfold to the Bod

Pod[®] a significance level of 0.3097 was found. These results indicated that of three

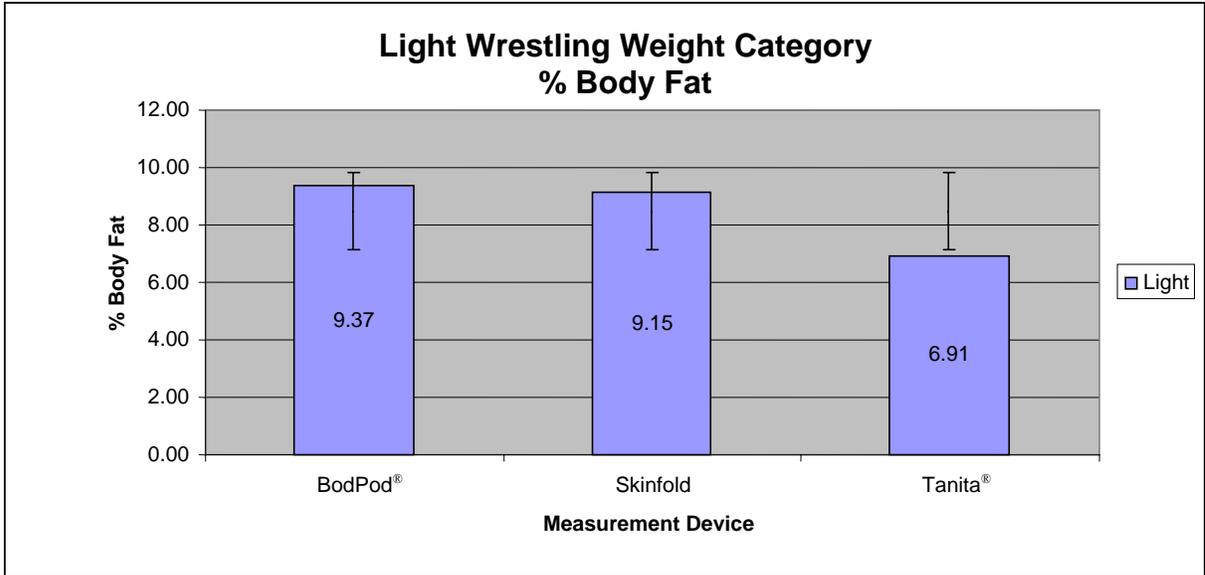
measurement devices, BIA did not produce similar results for measuring percent body

fat. This is supported by looking at the means presented in (Graph 1), in which the

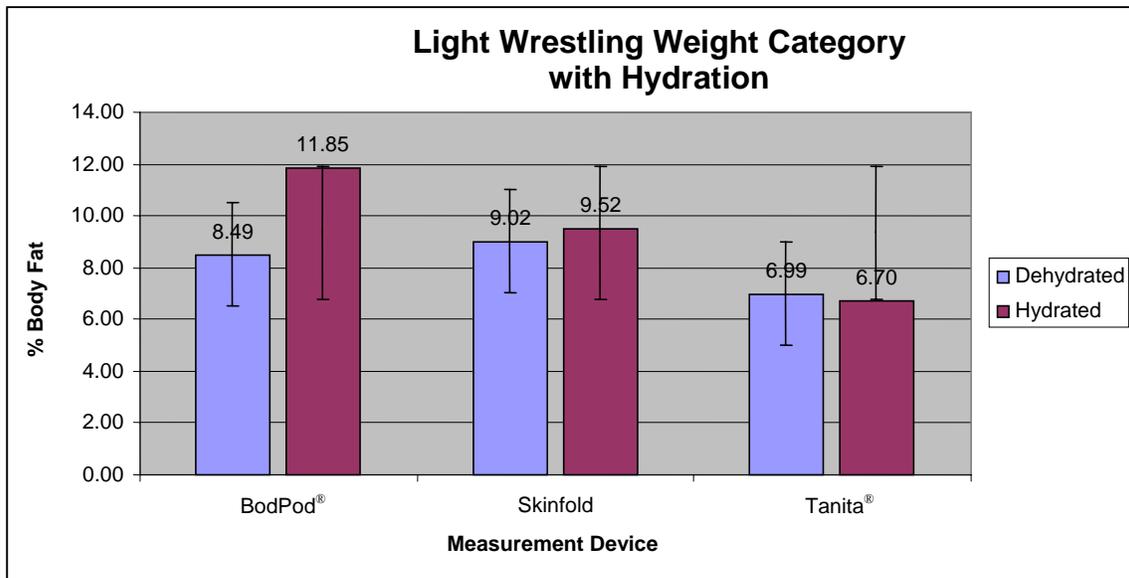
Tanita[®] scale seemed to underestimate percent body fat when compared to SF and BP

In addressing the second hypothesis of hydration effect on percent body fat in the light wrestling weight category the repeated measures ANOVA resulted in a significance level of 0.2440. Thus it was concluded that change in percent body fat is not a function

of hydration level. These findings were further supported by looking at (Graph 2) where the mean percent body fat between the two hydration groups differed by less than one percent. The slightly larger differences between means from the BP were found to be not significant. These results are important because it is hypothesized that light weight wrestlers typically use methods of rapid weight reduction frequently.



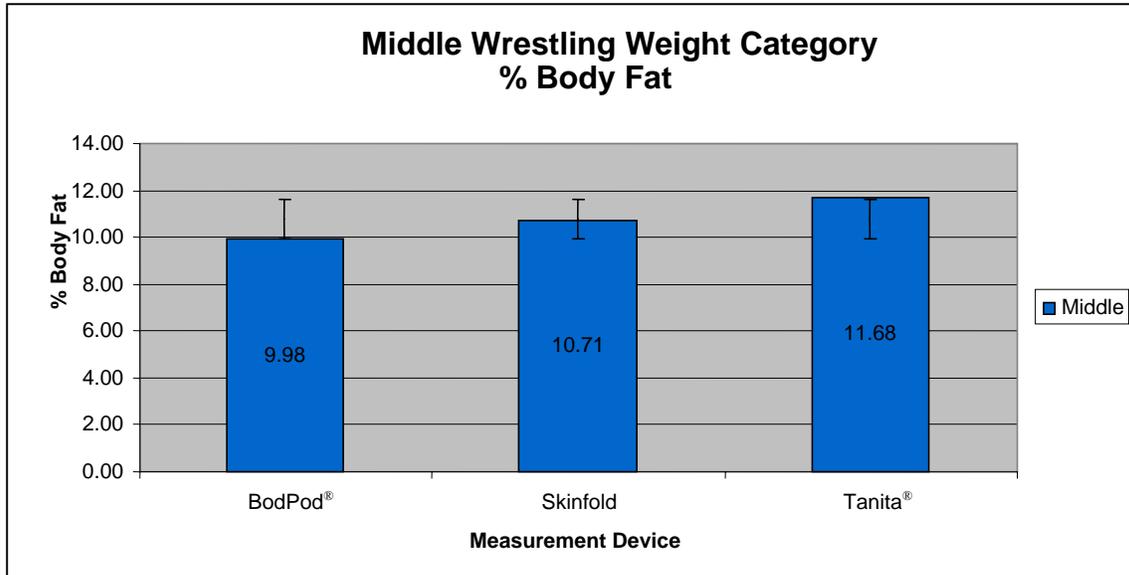
Graph 1: Mean percent body fat of light wrestling weight category



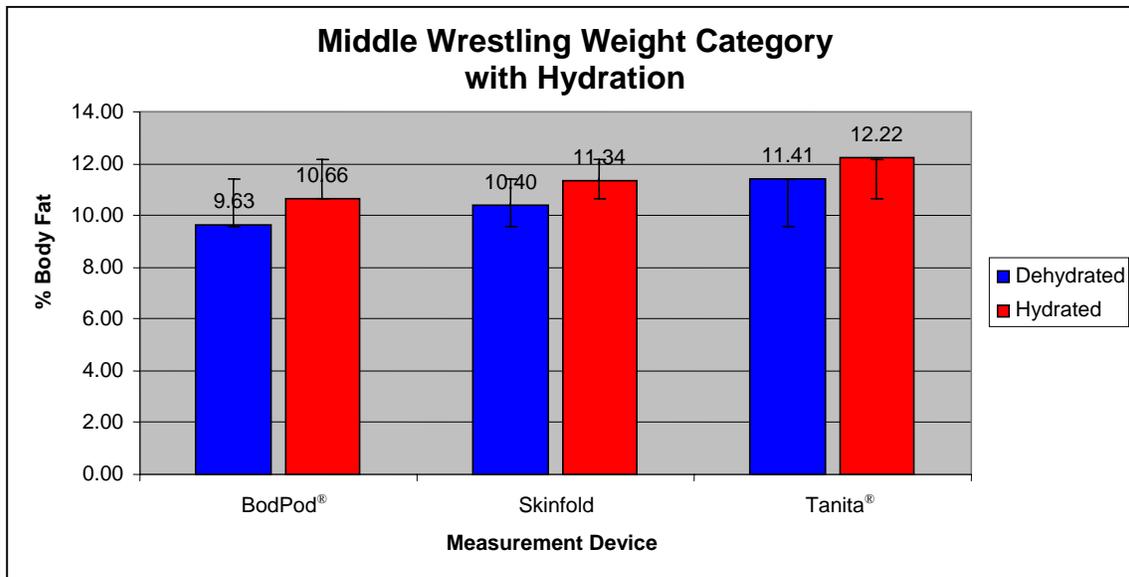
Graph 2: Mean percent body fat of light wrestling weight category with hydration

Analysis of Percent Body Fat in Middle Wrestling Weight Category

In the second portion of this analysis the equality of means of percent body fat were compared within the middle wrestling weight category. For this analysis 48 observations were made composing of 32 subjects considered dehydrated and 16 hydrated. The repeated measures analysis of variance for the three measurement devices in the middle wrestling weight category, a significance level of 0.0195 was observed. This p-value indicates that the null hypothesis was rejected and it was concluded that there is a difference in ability of the three measurement devices when measuring mean body fat. Further investigation of the means from (Graph 3) indicated that BIA overestimated percent body fat when compared to SF and BP. Results from the analysis of contrast variables support this finding by showing that there was not a significant difference in mean percent body fat when SF was compared to BP. However, there was a significant difference observed when BIA was compared to SF. When looking at the significance level of 0.9808 for hydration effect in this wrestling weight category, level of hydration had no affect on measuring percent body fat (Graph 4).



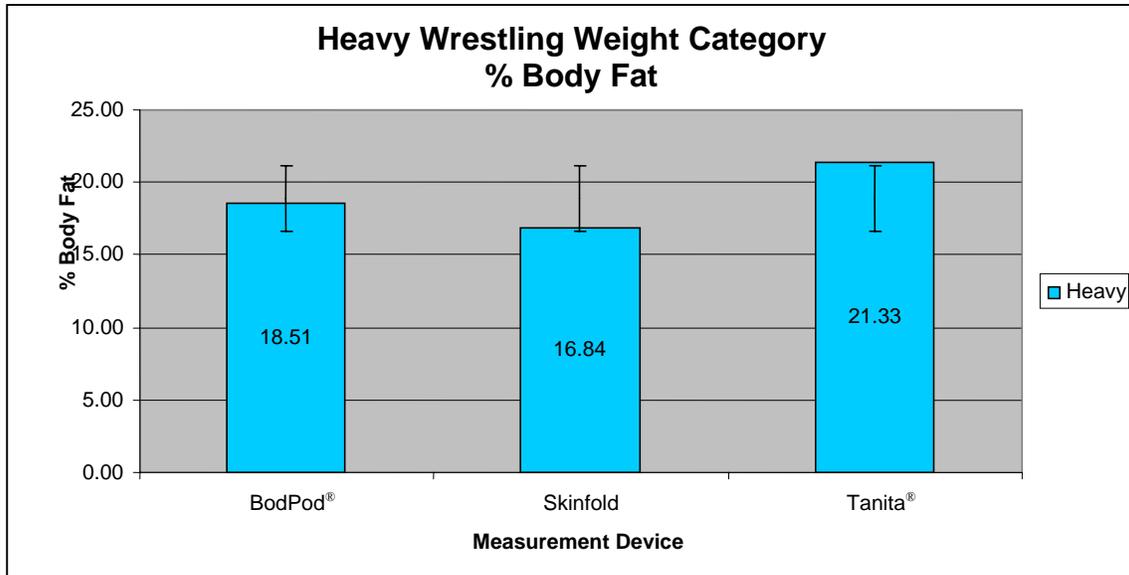
Graph 3: Mean percent body fat of middle wrestling weight category



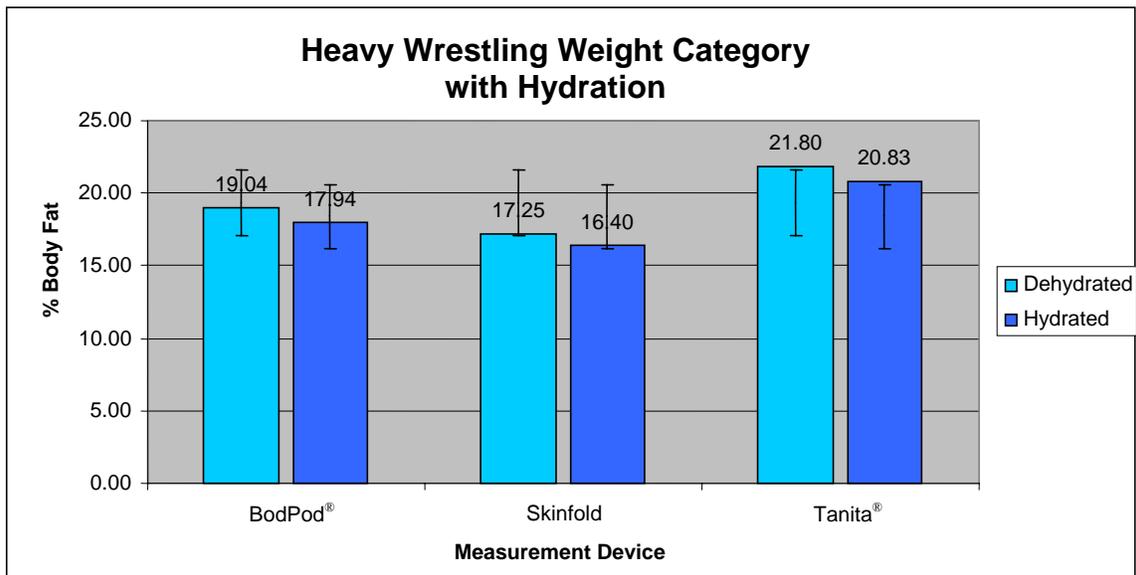
Graph 4: Mean percent body fat of middle wrestling weight category with hydration

Analysis of Percent Body Fat in Heavy Wrestling Weight Category

The final portion of the percent body fat analysis included the heavy wrestling weight category. Twenty seven observations were made during this part of the analysis where 14 were found to be dehydrated and 13 were hydrated. When the changes in percent body fat were examined among this weight category, the repeated measures ANOVA resulted in a significance level of 0.0001. This indicated that there was a significant difference among the means across the measurements of percent body fat. Like the other sections of this analysis it was determined that for this wrestling weight category the three devices did not produce similar results in measuring percent body fat. Similar to the results from the middle weight category, the means represented in (Graph 5) indicate that BIA over-estimates present body fat in the heavy weight category when compared to SF and BP. Results from the analysis of contrast variables also showed that similar measurements of body fat were obtained between BP and SF on the other hand BIA did not yield similar results when compared to SF. As for hydration effect on this weight category, the repeated measures ANOVA significance level of 0.9929 demonstrated that hydration was not a factor in estimating percent body fat in this category. Resulting means from (Graph 6) compare the hydrated and dehydrated groups. As the graph demonstrates there is little difference between the two hydration groups



Graph 5: Mean percent body fat of heavy wrestling weight category



Graph 6: Mean percent body fat of heavy wrestling weight category with hydration

7% Minimum Wrestling Weight Analysis

In this portion of the analysis, the validity of bioelectrical impedance was investigated in predicting a high school wrestlers' 7% minimum wrestling weight. Like the previous analysis the Tanita[®] TBF-300A with wrestler retrofit was compared to three-site skinfold using the Lohman-Brozek formula and the Bod Pod[®] among high school wrestlers. However, in order to measure a wrestler's MW, FFM was the primary measurement assessed as opposed to percent body fat. In order to make comparisons among the three devices FFM was assessed and that figure was then divided by 0.93. The result of the calculations represented the lowest allowable weight in which a wrestler can participate or the wrestler's MW. Keep in mind that the means and standard deviations presented in this data represent weight in pounds. This is important because weight classes are separated by approximately five pounds. Therefore, a difference in means greater than 4-5 pounds represents either an overestimation or underestimation of a wrestling weight class.

7% Minimum Wrestling Weight Hypotheses

This null hypothesis proposes that all means are different among the assessments of 7% minimum wrestling weight across wrestling weight categories. The alternative hypothesis states that at least one of the means is different among the assessments of 7% minimum wrestling weight across wrestling weight categories.

$$H_0: \mu_{BP(L)} = \mu_{SF(L)} = \mu_{BIA(L)}$$

H_a : at least one is different

$$H_0: \mu_{BP(M)} = \mu_{SF(M)} = \mu_{BIA(M)}$$

H_a : at least one is different

$$H_0: \mu_{BP(H)} = \mu_{SF(H)} = \mu_{BIA(H)}$$

H_a : at least one is different

This null hypothesis states that all means are the same among the assessments of 7% minimum wrestling weight taking into account hydration status across the three weight categories. The alternative hypothesis states that one of the means is different among the assessments of 7% minimum wrestling weight taking into account hydration status across the three weight categories.

$$H_a: \mu_{BP(DH)} = \mu_{BP(DHD)}$$

H_0 : one is different

$$H_a: \mu_{SF(HD)} = \mu_{SF(DHD)}$$

H_0 : one is different

$$H_a: \mu_{BIA(HD)} = \mu_{BIA(DHD)}$$

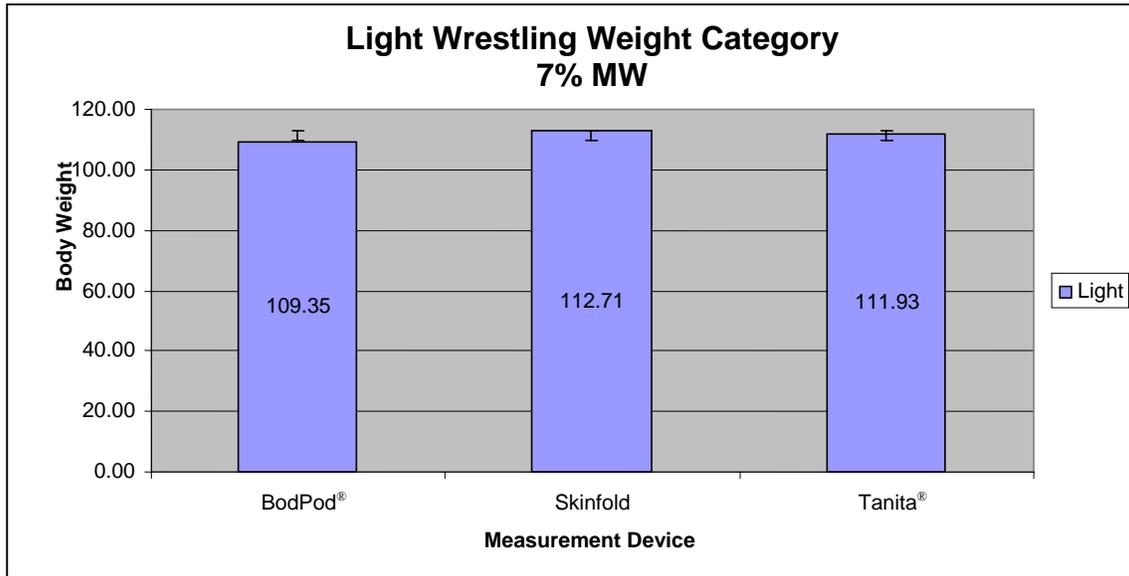
H_0 : one is different

Analysis of 7% MW in Light Wrestling Weight Category

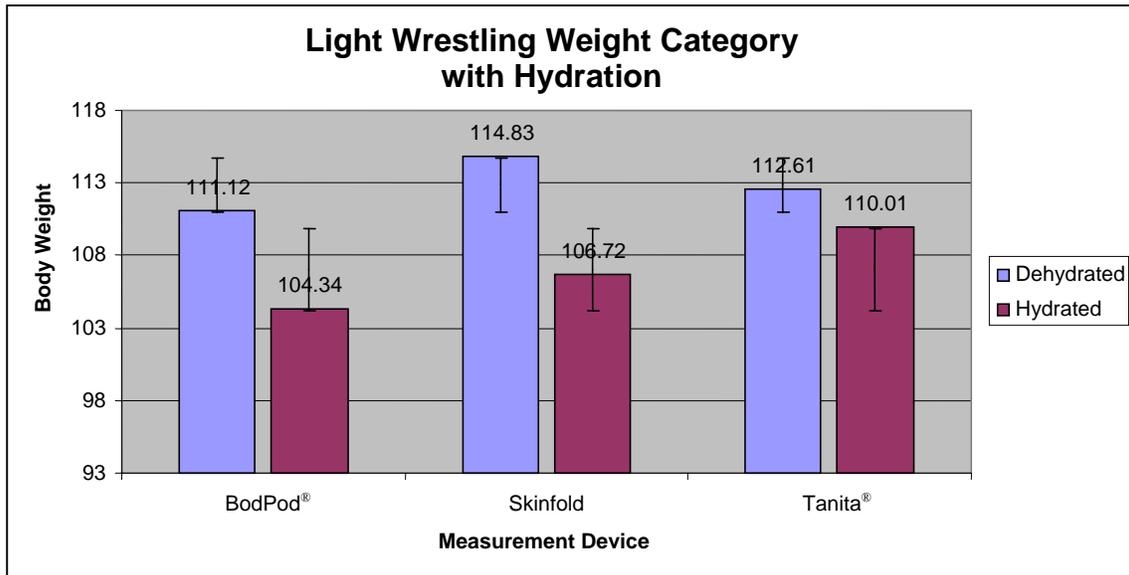
The first part of this analysis compared the equality of means of the three measurement devices in assessing MW in the light wrestling weight category. There were 23 observations in this analysis. This repeated measures analysis of variance resulted in a significance level of 0.0300, which indicated that there was a significant difference among the three measurement devices in assessing MW. However when looking at the means in (Graph 7) the difference between means represent less than one wrestling weight class. This means that on average, the three measurement devices placed the light weight wrestlers in similar weight classes when using BIA. This is supported by the analysis of variance of contrast variables comparing the BIA to the SF

in assessing MW a significance level of 0.6257 was observed, indicating that the two devices produced similar results in assessing MW. In contrast when the BP was compared to SF a significance level of 0.0340 indicated that those two devices did not produce similar results in assessing MW in the light weight category. This indicates that despite under-estimating percent body fat, BIA accurately predicts MW when compared to BP. Therefore, on average light weight wrestlers were placed in the appropriate wrestling weight class.

The second analysis of variance investigated the function of hydration on 7% minimum assessment. The resulting repeated measures ANOVA significance level of 0.0502 demonstrated that hydration status was not factor in assessing 7% minimum wrestling weight in the light category. When looking at (Graph 8) it is interesting to see that the dehydrated light wrestlers have higher MW as opposed to hydrated wrestlers. Typically the unethical theory behind weight certification includes rapid weight reduction prior to certification. This hypothetically places a wrestler in a lower weight class. This set of results seems to contradict that theory.



Graph 7: Mean percent body fat of light wrestling weight category

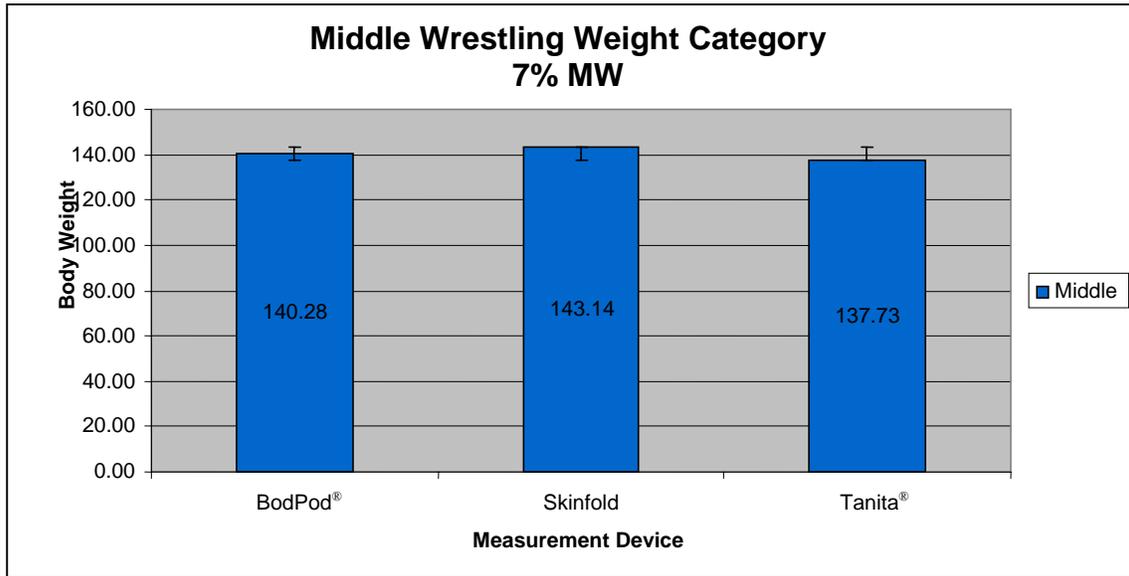


Graph 8: Mean percent body fat of light wrestling category with hydration

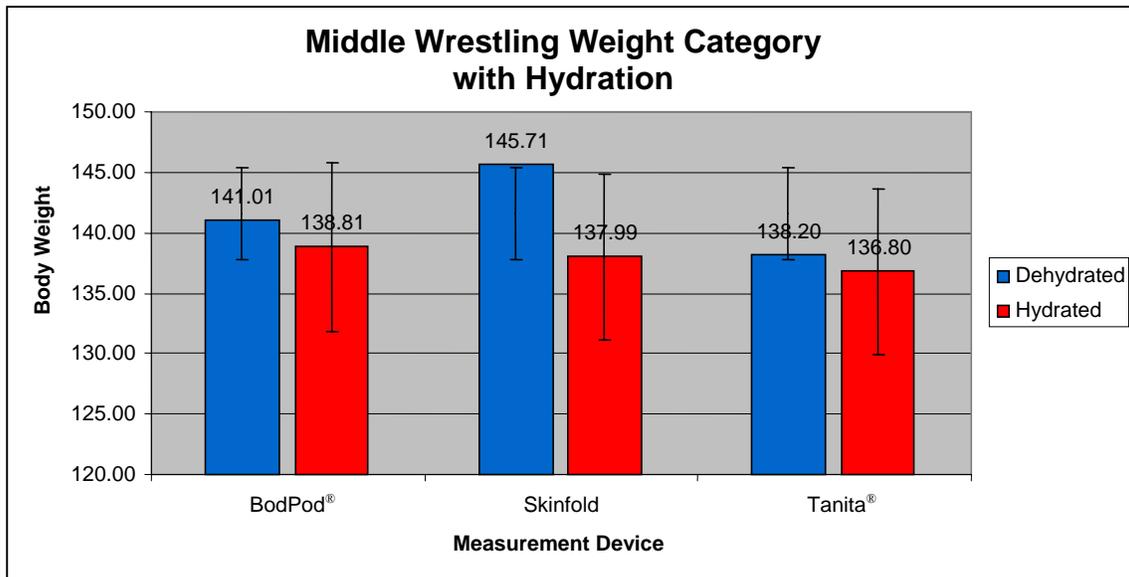
Analysis of 7% MW in Middle Wrestling Weight Category

This portion of the analysis compared the means of the three measurement devices in assessing the MW of the middle wrestling weight category. There were 48 observations in this analysis. A significance level of 0.0001 was observed from the repeated measures analysis of variance when investigating the equality of means of MW from the three measurement devices. Therefore, there was a significant difference among the BP, BIA, and SF in assessing MW. Despite the significant differences (Graph 9) shows that on average the three devices placed wrestlers within one wrestling weight class of each other. It seemed that MW was over-estimated by SF and under-estimated by BIA when compared to BP. When the analysis of variance of contrast variables compared BIA to SF a significance level of 0.0001 was observed, meaning the two devices did not produce similar results. The same test comparing BP to SF had a significance level of 0.0254 which also indicated that those devices did not yield similar results. A possible explanation for the variability in this portion of the analysis could be the uneven distribution of subjects within the weight classes of this weight category.

When investigating the repeated measures ANOVA for the middle weight category with hydration effect a significance level of 0.0001 was observed. This indicated that hydration did have an effect on assessing MW in the middle weight category. When looking at (Graph 10) it seems obvious that hydration affected measurements obtained from SF. There was a difference in MW between hydrated and dehydrated groups greater than one weight class, as apposed to less than one weight class difference observed from BIA and BP. Also within the SF results it seems that dehydrated athletes MW was over-predicted when compared to BIA and BP.



Graph 9: Mean percent body fat of middle wrestling weight category

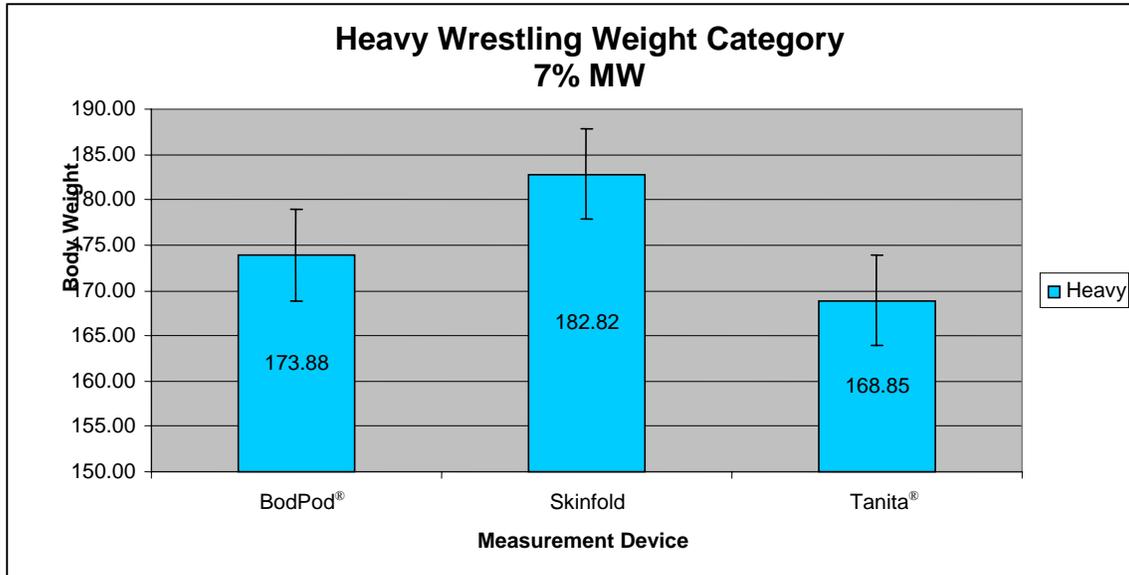


Graph 10: Mean percent body fat of middle wrestling category with hydration

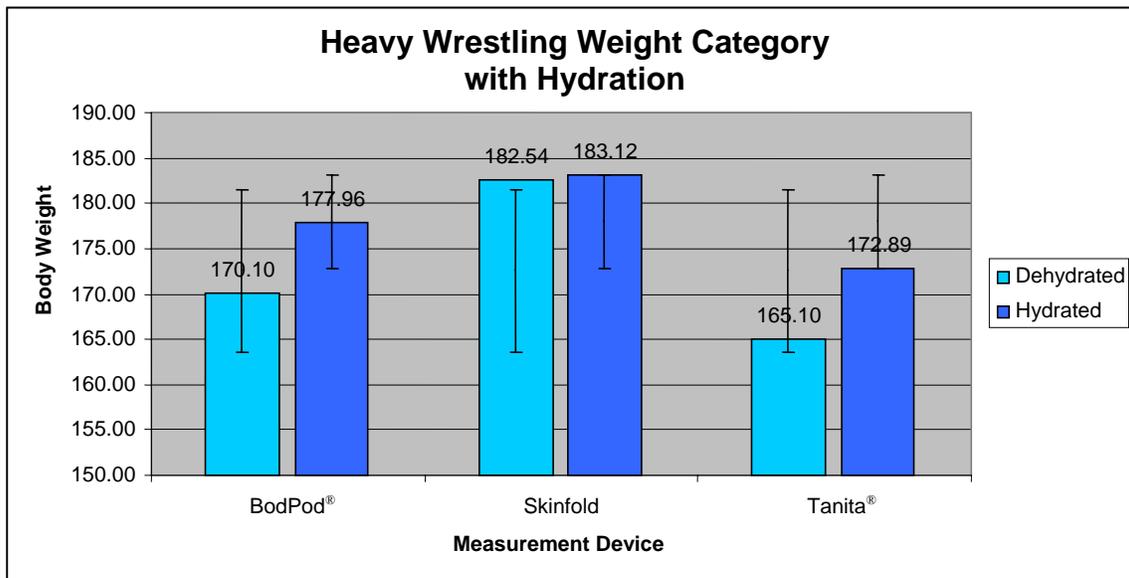
Analysis of 7% MW in Heavy Wrestling Weight Category

In the final part of the analysis the means of the three measurement devices were compared in assessing the MW of the heavy wrestling weight category. There were 27 observations in this section of analysis. The repeated measures ANOVA significance level of 0.0001 indicated that there was a significant difference among the three measurement devices in assessing MW. When looking at (Graph 11) a considerable amount of variability is demonstrated. This can be explained by the large range of body weight within the heavy weight category. Following the analysis of variance of contrast variables a significance level of 0.0001 was seen when BIA was compared to SF once again showing that the two devices did not produce similar results. The comparison of SF and BP yielded similar results with a significance level of 0.0091 indicating that the results for assessment of MW are not similar between the two. These results along with (Graph 11) seem to indicate that measurements from SF over-estimated MW when compared to the measurements from BP and BIA.

When the three devices were compared taking into account hydration affect a significance level of 0.3823 was produced. Therefore, it was concluded that hydration level was not a function of MW assessment in the heavy wrestling weight category. Therefore, the only explanation for the variability in this weight category is the large discrepancy in body weight between each weight class. The range of body weight within this weight category is 171 pounds to 275 pounds. Also if you look at (Table 1) in this chapter you will see that the average weight and standard deviation for this weight category is 202.26 ± 33.97 pounds. Aside from that it also seems that BIA underestimated MW when compared to SF and BP.



Graph 11: Mean percent body fat of middle wrestling weight category



Graph 12: Mean percent body fat of heavy wrestling category with hydration

CHAPTER FIVE

Discussion

Introduction

As stated in previous chapters rapid weight reduction and the potential health concerns that accompany the sport of wrestling have been well documented and thoroughly researched (Horswill et al., 1994; Oppliger, Steen, & Scott, 2003; Scott et al., 1994; Steen & Brownell, 1990). In an attempt to address those concerns wrestling weight certification programs have been developed to ensure the health and safety of wrestlers in all levels of competition. With these certification programs came the need to validate reliable and cost effective methods for measuring body composition and assessing minimum wrestling weight (Carey, 2000; Clark et al., 2005; Oppliger et al., 1998; Oppliger et al., 1991; Utter et al., 2005).

The present study examined the relationship between bioelectrical impedance using the Tanita[®] scale, Bod Pod[®], and Three-site Skinfold using the Lohman-Brozek equations to measure body composition high school wrestlers. In addition the three devices were compared in assessment of the seven percent minimum wrestling weight. In both instances hydration level was investigated in order to determine the relationship between levels of hydration and measurements obtained by the three devices.

In this study the observed levels of significance investigating the equality of means stated in the first hypothesis testing the validity of bioelectrical impedance in measuring body composition of high school wrestlers all fell below the significance level of 0.05. This indicated that across the three wrestling weight categories the three

measurement devices did not produce similar results. Therefore, it was concluded that the mean percent body fat does change across measurements obtained by BIA, BP, and SF. The levels of significance observed from the analysis of variance of contrast variables comparing BIA to SF indicated there was significant difference between the two devices across all three weight categories. However, when SF was compared to BP it was concluded that the two produce similar measurements for percent body fat across the three weight categories. From these results we concluded that measurements of percent body fat from BIA were significantly different than those of BP and SF across the three weight categories. In the analysis of body composition the basic finding was that BIA over-estimated percent body fat in lighter wrestlers and over-estimated percent body fat in heavier wrestlers when compared to BP and SF.

In practical terms the underestimation of percent body fat in light weight wrestlers could potentially limit them from wrestling in their desired weight class and even force wrestlers to obtain medical authorization for having a percent body fat below the minimum seven percent. The over-estimation of body fat via BIA could be expected given that the subjects in the heavy weight category have more body fat. With excess body fat comes increased resistance of the BIA current, which affects the scales ability to accurately measure body fat.

When investigating the second set of results testing the equality of means between measurement devices taking into account hydration status, no significant differences were observed. This demonstrated that hydration status did not have an interaction effect with assessing body composition. This could be predicted due to the variability in the distribution of the subjects by hydration status. Of the ninety-eight subjects involved in

the study sixty-three of the subjects were considered dehydrated. The failure to reject this hypothesis indicated that the change in percent body fat was not a function of hydration status. Therefore, by demonstrating that hydration had no effect on assessment of percent body fat, light weight wrestlers have no reason for severely lowering their body weight using dehydration practices.

In addressing the validity of bioelectrical impedance in assessing 7% minimum wrestling weight of high school wrestlers across the three wrestling weight categories a significant difference was observed between the three measurement devices. The analysis of variance of contrast variables comparing SF to BP resulted in differing results across the three weight categories. The two devices did not agree when the middle and heavy weight categories were investigated. When the means were looked at closer in the middle weight category the SK seemed to over predict MW when compared to BP. However, the difference in means represented less than one weight class. Results comparing BIA to SF all indicated that the two did not produce similar results across all weight categories. With this said it should be noted that the difference of means between BP and BIA across the light and middle weight categories did not differ by more than one wrestling weight class. This finding is important from the standpoint that on average BIA placed wrestlers in their appropriate weight classes in the light and middle weight categories. These findings were opposite of those stated by Utter et al. where the Tanita[®] scale seemed to under-predict FFM in lighter athletes and over-predicted FFM in heavier athletes (Utter et al., 2005).

The portion of this analysis investigating the effect of hydration level on assessing MW showed that hydration level was not a factor in the light and heavy weight

categories. However, the opposite was observed in the middle weight category. A possible explanation for hydration effect in the middle weight category is the distribution of hydrated and dehydrated subjects. There were twice as many dehydrated athletes as hydrated athletes in this weight category. This may help explain the variability associated with the repeated measures ANOVA comparing the three devices in assessing MW. It should be noted that on average the assessment of MW in the dehydrated group resulted in a higher MW as opposed to the hydrated middle weight wrestlers. This means that wrestlers who report to weight certification in dehydrated state are not assigned lower minimum wrestling weights. This information helps to dispel the practice of rapid weight reduction prior to weight certification.

Conclusion

In summary the design of this study proved to comprehensively test the validity of BIA in measuring body composition and assessment of MW in high school wrestlers. When the results of this study were examined it became obvious that the distribution of subjects in dehydrated and hydrated groups proved to add a considerable amount of variability to this study. However this study was designed to investigate a group of wrestlers in a setting that realistically represents the population. With this in mind the results showed that the three measurement devices did not produce similar results in measuring body composition or assessing seven percent minimum wrestling weight across the three wrestling weight categories. Because this study did investigate the measurement devices across weight categories, the variability attributed to weight differences across all of the weight classes was accounted for. Therefore, by testing each weight category the measurements obtained reflect the body type and composition

associated with each weight class. Even though this study did demonstrate that the three measurement devices did not produce similar results it was difficult to make direct comparisons to previous studies due to the fact that this study used a different gold standard to make measurement comparisons. Despite this possible limitation of the study the results support findings from previous studies investigating BIA in the wrestling population (Oppliger, 1997; Oppliger et al., 1991; Utter et al., 2005).

Furthermore these findings indicate that hydration status had no overall effect on measurement results. This is an important statement because this study used a $USG \leq 1.020$ as a cutoff for hydrated status as opposed to a $USG \leq 1.025$ which is typically used for testing hydration status of high school wrestlers. Because hydration level was shown not to affect the three measurement devices in measuring BF and assessing MW several harmful theories associated with weight certification should be dispelled. For example, some athletes may think that lowering their body weight by dehydration will allow them to reach the lowest possible weight class (C. Bartok et al., 2004). This study showed that on average dehydrated wrestlers had higher minimum wrestling weights as opposed to hydrated athletes. However, results from this study did not indicate which level should be preferred for high school wrestling weight certification.

Unlike a previous study by (Utter et al., 2005) that indicated BIA over-estimated the FFM of lighter wrestlers and under-estimated FFM of heavier wrestlers this study found that BIA seemed to underestimate percent body fat in lighter wrestlers and overestimate percent body fat of heavier wrestlers. An interesting finding regarding BIA was that the observed standard deviations were less than those observed by the other measurement devices. Despite these findings this study supports the findings of (Utter et

al., 2005) in that SF should continue to be the method of choice for assessing body composition during high school wrestling weight certification . This conclusion was reached because of the inability to demonstrate that there was not a significant difference between the three measurement devices in predicting percent body fat and assessment of seven percent minimum wrestling weight.

Recommendations for Future Research

Results from this study demonstrated the variability that exists across wrestling weight classes when measuring body composition and assessing MW. By investigating these results in this manner future research could possibly identify factors within wrestling weight categories that account for the variability between measurement devices. Also future projects should investigate the effect of hydration status on measuring body composition and MW. This will provide continued reasoning for hydration testing prior to wrestling weight certification. Future research should also include hydrostatic weighing as a measurement device. This would provide more information when making comparisons with past research projects. Also, because wrestlers use unique and at times unhealthy methods of losing body weight it is important that research evaluates their body composition during times of the year that truly reflect the population. Finally, the sport of wrestling has a long history of being both physically and psychologically demanding. These two characteristics of the sport teach its athletes discipline and accountability. These great aspects of wrestling should not be overlooked while research continues to ensure the health and safety of its participants. Hopefully with these ideas in mind wrestling can dispel the negative stigma associated with the

sport and continue to have a positive impact on the wrestlers and fans that care for the sport so much.

REFERENCES

- American, C. o. S. M. (1976). Position stand on weight loss in wrestlers. *Med Sci Sports Exerc*, 8, xi-xiii.
- Association, A. M. (1967). Committee on the Medical Aspects of Sports. Wrestling and weight control. *J.A.M.A.*, 201, 541-543.
- Bartok, C., Randall Clark, R., & Schoeller, D. (2004). The effect of dehydration on wrestling minimum weight assessment. *Med Sci Sports Exerc*, 36(1), 160-167.
- Bartok, C., Schoeller, D. A., Randall Clark, R., Sullivan, J. C., & Landry, G. L. (2004). The effect of dehydration on wrestling minimum weight assessment. *Med Sci Sports Exerc*, 36(1), 160-167.
- Bartok, C., Schoeller, D. A., Sullivan, J. C., Clark, R. R., & Landry, G. L. (2004). Hydration testing in collegiate wrestlers undergoing hypertonic dehydration. *Med Sci Sports Exerc*, 36(3), 510-517.
- Brownell, K. D., Steen, S. N., & Wilmore, J. H. (1987). Weight regulation practices in athletes: analysis of metabolic and health effects. *Med Sci Sports Exerc*, 19(6), 546-556.
- Brozek, J., Grande, F., Anderson, J. T., & Keys, A. (1963). Densitometric analysis of body composition: Revisions of some quantitative assumptions. *Annals of the New York Academy of Science*, 110, 113-140.
- Bubb, R. G. (1998). 1998 Wrestling Rules and Regulations (Vol. 3, pp. WR-23): The National Collegiate Athletic Association.
- Carey, D. (2000). The validity of anthropometric regression equations in predicting percent body fat in collegiate wrestlers. *J Sports Med Phys Fitness*, 40(3), 254-259.
- Casa, D., Armstrong, L. E., & Hillman, S. K. (2000). National Athletic Trainers' Association position statement: fluid replacement for athletes. *Journal of Athletic Training*, 35, 212-224.
- Clark, R. R., Bartok, C., Sullivan, J. C., & Schoeller, D. A. (2005). Is leg-to-leg BIA valid for predicting minimum weight in wrestlers? *Med Sci Sports Exerc*, 37(6), 1061-1068.
- Clark, R. R., Kuta, J. M., Sullivan, J. C., Bedford, W. M., Penner, J. D., & Studesville, E. A. (1993). A comparison of methods to predict minimal weight in high school wrestlers. *Med Sci Sports Exerc*, 25(1), 151-158.
- Clark, R. R., Oppliger, R. A., & Sullivan, J. C. (2002). Cross-validation of the NCAA method to predict body fat for minimum weight in collegiate wrestlers. *Clin J Sport Med*, 12(5), 285-290.
- Clark, R. R., Sullivan, J. C., Bartok, C., & Schoeller, D. A. (2003). Multicomponent cross-validation of minimum weight predictions for college wrestlers. *Med Sci Sports Exerc*, 35(2), 342-347.
- CONTROL, C. F. D. (1998). Hyperthermia and dehydration-related deaths associated with intentional rapid weight loss in three collegiate wrestlers-North Carolina, Wisconsin, and Michigan. *MMWR*, 47(6), 105-108.
- Corporation, T. Tanita Body Composition Analyzer Technical Notes (pp. 79). Tokyo, Japan: Tanita Corporation.

- Dale, K. S., & Landers, D. M. (1998). Weight control in wrestling: eating disorders or disordered eating? *Med Sci Sports Exerc*, *31*(10), 1382-1389.
- Dempster, P., & Aitkens, S. (1995). A new air displacement method for the determination of human body composition. *Medicine and Science in Sports and Exercise*, *27*, 1692-1697.
- Dixon, C. B., Deitrick, R. W., Pierce, J. R., Cutrufello, P. T., & Drapeau, L. L. (2005). Evaluation of the BOD POD and leg-to-leg bioelectrical impedance analysis for estimating percent body fat in National Collegiate Athletic Association Division III collegiate wrestlers. *J Strength Cond Res*, *19*(1), 85-91.
- Doscher, N. C. (1944). The Effects of Rapid Weight Loss Upon The Performance of Wrestlers And Boxers, and Upon The Physical Proficiency of College Students. *Res Q*, *15*, 317-324.
- Durnin, J. V., & Wommersley, J. (1974). Body fat assessment from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged 16-72 years. *British Journal of Nutrition*, *32*, 77-97.
- Fields, D. A., Goran, M. I., & McCrory, M. A. (2002). Body-composition assessment via air-displacement plethysmography in adults and children: a review. *Am J Clin Nutr*, *75*(3), 453-467.
- Forsyth, H. L., & Sinning, W. E. (1973). The anthropometric estimation of body density and lean weight of male athletes. *Medicine and Science in Sports*, *5*, 174-180.
- Gallagher, E. C. (1951). *Wrestling* (Revised Edition ed.). New York: The Ronald Press Company.
- Hansen, N. C. (1978). Wrestling With 'Making Weight'. *THE PHYSICIAN AND SPORTSMEDICINE*, *6*, 105-111.
- Heymsfield, S. B., Lohman, T. G., Wang, Z., & Going, S. B. (2005). *Human Body Composition* (2nd ed.). Champaign, IL: Human Kinetics.
- Heyward, V. H., & Wagner, D. R. (2004). *Applied body composition assessment* (2nd ed.). Champaign, IL: Human Kinetics.
- Horswill, C. A., Park, S. H., & Roemmich, J. N. (1990). Changes in the protein nutritional status of adolescent wrestlers. *Med Sci Sports Exerc*, *22*(5), 599-604.
- Horswill, C. A., Scott, J. R., Dick, R. W., & Hayes, J. (1994). Influence of rapid weight gain after the weigh-in on success in collegiate wrestlers. *Med Sci Sports Exerc*, *26*, 1290-1294.
- Houston, M. E., Marrin, D. A., & Green, H. S. (1981). The effect of rapid weight loss on physiological function in wrestlers. *Phys Sports Med Exerc*, *9*, 73-78.
- Hursh, L. M. (1979). Food and water restriction in the wrestler. *Jama*, *241*, 915-916.
- Jackson, S., & Pollock, M. L. (1978). Generalized equations for predicting body density of men. *British Journal of Nutrition*, *49*(497-504).
- Katch, F. I., & McArdle, W. D. (1973). Prediction of body density from simple anthropometric measurements in college-age men and women. *Human Biology*, *45*, 445-454.
- Kenney, H. (1930). The Problem of Weight Making for Wrestling Meets. *The Journal of Health and Physical Education*, *1*(1), 24-25, 49.
- Kiningham, R. B., & Gorenflo, D. W. (2001). Weight loss methods of high school wrestlers. *Med Sci Sports Exerc*, *33*(5), 810-813.

- Klinzing, J. E., & Karpowicz, W. (1986). The effects of rapid weight loss and rehydration on a wrestling performance test. *J Sports Med Phys Fitness*, 26(2), 149-156.
- Kyle, U. G., Genton, L., & Pichard, C. (2002). Body composition: what's new? *Curr Opin Clin Nutr Metab Care*, 5(4), 427-433.
- Lakin, J. A., Steen, S. N., & Oppliger, R. A. (1990). Eating behaviors, weight loss methods, and nutrition practices among high school wrestlers. *J Community Health Nurs*, 7(4), 223-234.
- Life Measurement, I. (2004). Bod Pod Customer Training Manual (Vol. 2102948, pp. 66).
- Lohman, T. G. (1981). Skinfold and body density and their relation to body fatness: a review. *Hum Biol*, 53, 181-225.
- Lohman, T. G. (1992). *Advances in body composition assessment*. Champaign, IL: Human Kinetics.
- Michael, E. D., & Katch, F. I. (1968). Prediction of body composition from skinfold and girth measurements. *Journal of Applied Physiology*, 25, 747-750.
- Oppliger, R. A. (1997). Validation of Bioimpedance Prediction Equations Among High School Wrestlers 1059. *Medicine and Science in Sports and Exercise*, (29)(5 Supplement), 186.
- Oppliger, R. A., & Bartok, C. (2002). Hydration testing of athletes. *Sports Med*, 32(15), 959-971.
- Oppliger, R. A., Case, H. S., Horswill, C. A., Landry, G. L., & Shelter, A. C. (1996). American College of Sports Medicine position stand. Weight loss in wrestlers. *Med Sci Sports Exerc*, 28(6), ix-xii.
- Oppliger, R. A., Harms, R. D., Herrmann, D. E., Streich, C. M., & Clark, R. R. (1995). The Wisconsin wrestling minimum weight project: a model for weight control among high school wrestlers. *Med Sci Sports Exerc*, 27(8), 1220-1224.
- Oppliger, R. A., Landry, G. L., Foster, S. W., & Lambrecht, A. C. (1998). Wisconsin minimum weight program reduces weight-cutting practices of high school wrestlers. *Clin J Sport Med*, 8(1), 26-31.
- Oppliger, R. A., Looney, M. A., & Tipton, C. M. (1987). Reliability of hydrostatic weighing and skinfold measurements of body composition using a generalizability study. *Hum Biol*, 59, 77-96.
- Oppliger, R. A., Nielsen, D. H., & Vance, C. G. (1991). Wrestlers' minimal weight: anthropometry, bioimpedance, and hydrostatic weighing compared. *Med Sci Sports Exerc*, 23(2), 247-253.
- Oppliger, R. A., Steen, S. A., & Scott, J. R. (2003). Weight loss practices of college wrestlers. *Int J Sport Nutr Exerc Metab*, 13(1), 29-46.
- Perriello V A, A. J., Johnson L. (2003). Virginia High School League Wrestling Weight Control Program Manual for Certified Measures (Vol. 803, pp. 1-47).
- Perriello, V. A., & Johnson, A. J. (2003). Virginia High School League Wrestling Weight Control Program *Manual for Certified Measures*, 803, 1-47.
- Ribisl, P. M. (1970). Effects of rapid weight reduction and subsequent rehydration upon the physical working capacity of wrestlers. *Res Q*, 41, 536-541.

- Roemmich, J. N., & Sinning, W. E. (1997). Weight loss and wrestling training: effects on nutrition, growth, maturation, body composition, and strength. *J Appl Physiol*, 82(6), 1751-1759.
- SAS Institute, I. (2005). Cary, NC.
- Schoeller, D. A. (1996). *Human Body Composition*. Champaign, IL: Human Kinetics.
- Schultz, S. G. (2002). William Harvey and the circulation of the blood: Birth of a scientific revolution and modern physiology. *News in Physiological Science*, 17, 175-180.
- Scott, J. R., Horswill, C. A., & Dick, R. W. (1994). Acute weight gain in collegiate wrestlers following a tournament weigh-in. *Med Sci Sports Exerc*, 26, 1181-1185.
- Sinning, W. E. (1974). Body composition assessment of college wrestlers. *Medicine and Science in Sports Exercise*, 6(2), 139-145.
- Siri, W. E. (1961). Body composition from fluid spaces and density: In J Brozek and A Henschel. *National Academy of Sciences*, 223-244.
- Steen, S. N., & Brownell, K. D. (1990). Patterns of weight loss and regain in wrestlers: has the tradition changed? *Med Sci Sports Exerc*, 22(6), 762-768.
- Steen, S. N., Oppliger, R. A., & Brownell, K. D. (1988). Metabolic effects of repeated weight loss and regain in adolescent wrestlers. *Jama*, 260(1), 47-50.
- Strauss, R. H., Lanese, R. R., & Malarket, W. B. (1985). Weight Loss in Amateur Wrestlers and Its Effect on Serum Testosterone Levels. *Jama*, 254(23), 3337-3338.
- Stuempfle, K. J., Drury, D. J. (2003). Comparison of 3 Methods to Assess Urine Specific Gravity in Collegiate Wrestlers. *Journal of Athletic Training*, 38(4), 315-319.
- Tarnopolsky, M. A., Cipriano, N., Woodcroft, C., Pulkkinen, W. J., Robinson, D. C., Henderson, J. M., et al. (1996). Effects of rapid weight loss and wrestling on muscle glycogen concentration. *Clin J Sport Med*, 6(2), 78-84.
- Tcheng, T. K., & Tipton, C. M. (1973). Iowa Wrestling Study: Anthropometric measurements and the prediction of a "minimal" body weight for high school wrestlers. *Med Sci Sports*, 5(1), 1.
- Thorland, W. G., Johnson, G. O., Tharp, G. D., & Houch, T. J. (1984). Estimation of Body density in adolescent wrestlers. *Annals of Biology*, 56, 439-438.
- Tipton, C. M., & Oppliger, R. A. (1984). The Iowa wrestling study: lessons for physicians. *Iowa Med*, 74(9), 381-385.
- Tipton, C. M., & Tcheng, T. K. (1970). Iowa Wrestling Study: weight loss in high school students. *Jama*, 214, 1269-1274.
- Tuttle, W. W. (1943). The Effect of Weight Loss by Dehydration and the Withholding of Food on the Pysiologic Responses of Wrestlers. *Res Q*, 14, 158-166.
- Utter, A. C., Goss, F. L., Swan, P. D., Harris, G. S., Robertson, R. J., & Trone, G. A. (2003). Evaluation of air displacement for assessing body composition of collegiate wrestlers. *Med Sci Sports Exerc*, 35(3), 500-505.
- Utter, A. C., & Kang, J. (1998). Acute weight gain and performance in college wrestlers. *J. Strength Cond. Res*, 12, 157-160.
- Utter, A. C., Nieman, D. C., Mulford, G. J., Tobin, R., Schumm, S., McInnis, T., et al. (2005). Evaluation of leg-to-leg BIA in assessing body composition of high-school wrestlers. *Med Sci Sports Exerc*, 37(8), 1395-1400.

- Vaughan, W. R. (1968). Report of the Committee on Sports Medicine. In H. f. t. H. o. Delegates (Ed.) (pp. 77): Iowa Medical Society.
- Wagner, D. R., & Heyward, V. H. (1999). Techniques of body composition assessment: a review of laboratory and field methods. *Res Q Exerc Sport*, 70(2), 135-149.
- Wagner, D. R., Heyward, V. H., & Gibson, A. L. (2000). Validation of air displacement plethysmography for assessing body composition. *Med Sci Sports Exerc*, 32(7), 1339-1344.
- Webster, S., Rutt, R., & Weltman, A. (1990). Physiological effects of a weight loss regimen practiced by college wrestlers. *Med Sci Sports Exerc*, 22(2), 229-234.
- Williford, H. N., Smith, J. F., Mansfield, E. R., Conerly, M. D., & Bishop, P. A. (1986). Validation of body composition models for high school wrestlers. *Med Sci Sports Exerc*, 18(2), 216-224.
- Wilmore, J. H. (1987). A formula for the prediction of residual volume in males *Medicine and Science in Sports and Exercise*, 19(2).
- Wroble, R. R., & Moxley, D. P. (1998). Acute weight gain and its relationship to success in high school wrestlers. *Med Sci Sports Exerc*, 30(6), 949-951.
- Zambraski, E. J., Foster, D. T., Gross, P. M., & Tipton, C. M. (1976). Iowa wrestling study: weight loss and urinary profiles of collegiate wrestlers. *Med Sci Sports*, 8(2), 105-108.
- Zambraski, E. J., Tipton, C. M., Tchong, T. K., Jordon, H. R., Vailas, A. C., & Callahan, A. K. (1975). Iowa wrestling study: changes in the urinary profiles of wrestlers prior to and after competition. *Med Sci Sports*, 7(3), 217-220.

APPENDIX A

Virginia Tech Performance and Sports Medicine

Informed Consent for Participants in Research Involving Humans

Project Title: In euhydrated high school wrestlers, is bioelectrical impedance a valid index of body composition?

Principle Investigator: Jesse Donnenwerth, MS, ATC

Co-investigator: Delmas Bolin, MD

Purpose of this Study

You are being asked to participate in a research study. The purpose of this study is to examine different methods of determining body composition.

High school wrestlers participating in the Virginia High School League (VHSL) are being asked to participate in this project. You are invited to participate as one of those individuals. Your commitment to the project will occur during the 2004-2005 wrestling season. If you choose to participate, study personnel will take body fat measurements during your wrestling weight certification.

Procedures

Because you are a high school wrestler participating in the VHSL and consider yourself to be non-claustrophobic, you have been contacted by, and spoken with the principle investigator of this project. Please read this consent form, and discuss it with him. He will explain the project to you and answer any of your questions. If you are willing to participate, you will be asked to sign this form. Your participation is completely voluntary; you will not be penalized if you do not participate in this study.

For the official VHSL weight certification, your coach will drive you to the Virginia Tech campus. At that time your official wrestling weight class will be determined and other measurements of body fat will be taken. Measurements will include:

- Standard weight measurement. This is needed to determine your minimum wrestling weight for the VHSL.

- A urine sample will be taken to measure your level of hydration. This test requires that you provide a small sample of urine in a collection cup. This is needed to determine your minimum wrestling weight for the VHSL.
- Three site skin fold measurements for body fat assessment. For this procedure you will be asked to stand in a relaxed position while the primary investigator performs the three-site measurements. You will feel a mild pinch when the investigator takes the measurements. This is also needed to determine your minimum wrestling weight for the VHSL.
- Body fat assessment from Tanita[®] Scale. The Tanita[®] scale looks similar to a standard scale. The difference being that it measures body fat by measuring bioelectrical impedance. For this measurement you will simply be asked to stand on the scale while the device takes its measurements.
- Body fat assessment from Bod Pod[®]. The Bod Pod[®] measures body fat by using air displacement. You will be placed in the device and will be asked to sit still and breathe normally while the device takes its measurements. If at any point during test you begin to feel uncomfortable, you can ask for the test to stop.

Following the collection of these measurements, the research staff will examine the data for, 1) the effects of hydration on the three body composition measurement devices, 2) the relationship of body composition measurements between three-site skin folds, Tanita[®] scale, and Bod Pod[®].

Risks

If you choose to participate in this study, your risk of injury due to the procedures is similar to those typically involved with the current VHSL weight certification process. The Bod Pod[®] and the Tanita[®] scale are the only components not currently being used by the VHSL for wrestling weight certification.

Benefits

No guarantee of benefits has been made to encourage your participation. Your participation helps us gain knowledge about the most effective methods of body composition measurement. This information may help to develop a more practical and cost effective method of determining minimum wrestling weight for high school wrestlers.

Compensation

You will receive no compensation for participating in this study. Should you be injured in any way or experience a worsening of a disease, directly or indirectly, as a result of your participation, neither the investigators nor the Virginia Polytechnic Institute and

State University (Virginia Tech), will provide medical care or pay for such care. However, by signing this consent, you do not give up any of your legal rights. You may use this information to determine whether you wish to participate in this study.

Should you sustain injury as a direct result of participation in this research, please promptly contact the investigators and/or the Virginia Tech Institutional Review Boards. Contact information is provided at the end of this consent form.

Confidentiality

All information collected from this study will be kept confidential. You will be assigned a number which will identify your information. All records will be kept in a secure location accessible only to study personnel. Publications or presentations of the results of this study will not include information that would identify individuals. All information will be reported as a group.

Freedom to Withdraw

Your participation in this study is completely voluntary. You are free to withdraw from this study at any time without penalty. You are also free at any time to state that you refuse to complete any portion of the procedures.

The investigators may terminate your participation at any time without your consent.

Approval of this Study

This study has been approved, as required, by the Institutional Review Board for Research involving Human Subjects at the Virginia Polytechnic Institute and State University.

IRB Approval Date

Approval Expiration Date

Participant's Responsibilities

I voluntarily agree to participate in this research study. I have the following responsibilities:

- I have read this consent form and asked all questions I have about this project.
- I will notify the study personnel if I have any unusual symptoms at any time during the study.
- I will report any changes in my medical condition or new treatments.

Agreement to Participate

I have read and understand the informed consent and conditions of this research study. I agree that all known risks to me have been explained to my satisfaction and I understand that no compensation is available from Virginia Tech and its employees for any injury resulting from my participation in this research. I agree to undergo all procedures described above. I understand that it is my right to withdraw from the study at any time without penalty and that I can be removed from the study by the investigators without my consent.

I have had the opportunity to ask questions. Any questions that I have asked have been answered to my complete satisfaction. By signing this consent, I understand that I do not give up any of my legal rights. I have used all of the information in this document to determine whether I wish to participate in this study. I acknowledge that I have been provided a copy of this consent form. I hereby acknowledge the above and give my voluntary consent for the participation in this study.

_____ Participant's Name (Print)	_____ Signature	_____ Date
_____ Legal Guardian's Name (Print)	_____ Signature	_____ Date
_____ Witness' Name (Print)	_____ Signature	_____ Date

Contact Information

Should I have any questions about this research or its conduct, research participants' rights, and whom to contact in the event of a project-related injury, I may contact:

- Virginia Tech Research Study Office
Office: (540) 231-4991
- Jesse Donnenwerth, MS, ATC
Office: (540) 231-6410 Email: trainer57@msn.com
- Delmas Bolin, MD, PhD
Office: (540) 231-7741 Email: techmd@vt.edu
- Amy Freel, MS, RDN
Office: (540) 231-9919 Email: aefreel@vt.edu

CURRICULUM VITAE

Jesse Donnenwerth, MS, ATC/L

1440 Monroe St. Madison, WI 53711

Cell: (608)219-2550 Office: (608)262-8036 E-mail: jjd@athletics.wisc.edu

Education:

2003-Present

Doctorate in Health Philosophy- ABD

Virginia Polytechnic Institute and State University- Blacksburg, VA

2003

Master's of Science in Education

Virginia Polytechnic Institute and State University- Blacksburg, VA

2002

Bachelor's of Science in Exercise Science- Athletic Training Curriculum Program

University of Iowa- Iowa City, IA

Professional

Positions:

2005-Present

Assistant Athletic Trainer

Virginia Polytechnic Institute and State University- Blacksburg, VA

- Provide athletic training services for: wrestling and football
- Supervise graduate assistants and student athletic trainers
- Developed ACC wrestling championship medical check standards
- Regional tester for Virginia High School League wrestling certification

2002-2005

Graduate Assistant Athletic Trainer

Virginia Polytechnic Institute and State University- Blacksburg, VA

- Provided athletic training services for: wrestling, football, men's soccer, and Blacksburg high school
- Developed and implemented sport specific rehabilitation programs
- Assisted physical therapist at University Physical Therapy

Research:

- **Senior Student Project: Treatment of Recurrent Outbreaks of Herpes Simplex-II Virus**
- **Co-investigator: Brain Injury Evaluation in Real-Time of Sports Trauma research project**
- **Primary investigator: Evaluating the Validity of the Tanita® Scale in Euhydrated High School Wrestlers research project**
- **Co-investigator: An Antimicrobial Evaluation to Manage and Control Communicable Skin Infections**

Related

Experiences:

- **US Open Wrestling Championships**
- **US Olympic Wrestling Trials**
- **Cadet and Junior National Wrestling Championships**
- **World Championship Wrestling Trials**

Certifications and Memberships:

- **Licensed to practice as an athletic trainer in the Commonwealth of Virginia**
- **Certified professional rescuer by American Red Cross**