Order Number 9310406

# The effects of chronic dehydration using bioelectrical impedance on isokinetic strength and endurance in college wrestlers

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Middle Tennessee State University, 1992



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# The Effects of Chronic Dehydration Using Bioelectrical Impedance on Isokinetic Strength and Endurance in College Wrestlers

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A dissertation presented to the
Graduate Faculty of Middle Tennessee State University
in partial fulfillment of the requirements
for the degree Doctor of Arts
in Physical Education

December 1992

THE EFFECTS OF CHRONIC DEHYDRATION USING BIOELECTRICAL IMPEDANCE ON ISOKINETIC STRENGTH AND ENDURANCE IN COLLEGE WRESTLERS

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**ABSTRACT**

**The Effects of Chronic Dehydration Using Bioelectrical Impedance on Isokinetic Strength and Endurance in College Wrestlers**

**Herbert K. Amato**

The objective of this study was to determine what changes in body water occurred in wres' lers from preseason to season's end and whether these changes affected muscle strength and endurance of the dominant quadricep. A bioelectrical-impedance analyzer (BIA) yielded actual body water measurements as the means of determining dehydration.

Nineteen subjects (age = 18.9 years) participated in a pretest, followed by two post tests four-and-one-half months later. Data were collected for physical characteristics, quadricep strength and endurance, and perceived exertion.

The wrestlers in this study lost an average of 2.88 pounds prior to the start of the season to the first testing session (post test A, chronic dehydration). The average amount of water loss measured by the BIA was 0.05 liters.

A multivariate analysis of variance (MANOVA) revealed a significant difference ($p > .05$) between tests measuring changes in body water. Tukey's test indicated a significant difference did not exist between the pretest and post test A. This post-hoc test showed the significant differences were between the pretest and post test B and between

post tests A and B (acute dehydration). These results indicated the wrestlers' body water levels remained relatively constant throughout the season, except just prior to making weight.

A MANOVA showed that no significant difference existed in muscle strength and endurance of the quadriceps between any of the independent variables. These findings are in agreement with 62 percent of the studies reviewed pertaining to dehydration and muscle strength and endurance.

As total body water decreased, wrestlers' rating of perceived exertion increased. No significant difference between tests comparing perceived exertion and changes in body water was found. Further research may show if wrestlers are not losing strength through dehydration they may be mentally less ready to compete in the later minutes of their match due to lower levels of body water.

## ACKNOWLEDGMENTS

I would like to thank Dr. A. H. Solomon for his supervision of this research project and his support throughout my doctoral program. By his example, I believe I have much more to offer my profession as a teacher and as an administrator. Additional thanks are given to the other members of my committee, Dr. J. Arters and Dr. P. McClellan, for their suggestions, encouragement, and advice. I am very thankful to have had such cooperation and flexibility from the members of this committee.

Bruce Matthias and I are not only linked by this dissertation, but also by friendship. My thanks to him for his time and effort in the typing and computer graphics for this project.

Special thanks and appreciation go to Dr. D. Wenos for all of his help in the design, hours of data collection, and statistical expertise given to this project. Not only did he help me as a colleague, but most importantly as a friend.

I would also like to give my thanks and love to my wife's parents who apparently knew when Lori and I needed help and support. Taking care of the children at times was a big help; however, just listening and caring made the past several years much easier.

It is impossible to adequately thank my parents for everything they have given me throughout my life. The love they have shown me is something I will never forget.

Finally, this study and degree could not have been accomplished without the support and sacrifice of my wife, Lori. Her encouragement and love kept me motivated.

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# CHAPTER 1

## Introduction

A major health concern in the sport of wrestling is the amount of weight athletes lose from preseason to the postseason competition. Studies conducted in the 1970s indicated that the majority of wrestlers are not overweight during the wrestling preseason (American College of Sports Medicine [ACSM], 1987b; Zambraski, Foster, Gross, & Tipton, 1976). As reported in the position stand on weight loss in wrestlers (ACSM, 1987b), average preseason body fat is approximately 8 percent for individuals weighing less than 190 pounds. Body fat for these athletes ranges from 1.6 to 15.1 percent. However, this population loses between 3 and 20 percent of their preseason body weight (Tipton & Tcheng, 1970; Zambraski et al., 1976). In a recent study of the amount of weight lost during wrestling season (Steen, Opplinger, & Brownell, 1988), 20 percent of the wrestlers studied lost more than 9 percent of their total preseason body weight. Postseason weight gain by wrestlers also suggests considerable amounts of weight loss during the season. Questionnaires sent out to wrestlers upon the completion of their season indicate they will gain between 4.5 pounds and 45 pounds postseason (Brownell, Steen, & Wilmore, 1987; Hursh, 1979; Steen & Brownell, 1986).

At the beginning of each season, there are many reasons a wrestler believes to be valid for reducing body weight. The majority of reasons are based on myth and are passed down from one grappler to another. Wrestlers learn the art of "cutting weight" from teammates (Tipton, 1980). In sports, such as gymnastics and swimming, appearance is a motivation for losing weight. However, in wrestling, cutting weight is perceived as a necessity by the wrestler in order to win matches (Committee on Medical Aspect of Sports [CMAS], 1967). Psychologically, this weight loss gives the wrestler a competitive edge. These athletes believe that losing large amounts of weight during the wrestling season allows them to compete against smaller opponents without strength loss (Serfass, Stull, & Alexander, 1984). In theory, a wrestler tries to lose as much weight as possible in the hopes of outweighing his opponent at match time. He does this by rehydrating his body in the time between when he weighs in prior to the match, but before the actual competition (CMAS, 1967). Another belief passed down from one wrestler to the next is that weight loss does not affect performance. Most wrestlers believe their preseason muscle strength and performance capacities are not diminished by weight reduction (ACSM, 1987b; Tipton & Tcheng, 1970).

What is not passed down by the wrestling community about weight reduction is information concerning the harmful effects cutting weight and weight cycling have on the body. Cutting weight by wrestlers is accomplished through a combination of food restriction, fluid deprivation, and dehydration. As shown in Table 1.1, there are a variety of routes a wrestler may use to reach his competitive weight.

Table 1.1

Methods of Weight Reduction Used by Wrestlers

| Food restriction | Fluid deprivation | Dehydration |
|---|---|---|
| Restrict food intake | Restrict fluid intake | Sweating through hyperthermia<br>a. Sauna<br>b. Rubber suits |
| Appetite suppressants | Restrict salt intake | Sweating through exercise |
| | | Diuretics |
| | | Laxatives |
| | | Induced vomiting |
| | | Spitting |
| | | Donating blood |

Sources: Serfass, Stull, and Alexander, 1984; Steen, Opplinger, and Brownell, 1988; Tipton, 1980; Yarrows, 1988.

The method most widely used by a wrestler to make his competition weight is acute dehydration (ACSM, 1987b; Tipton, 1980). The ACSM reports the following side effects as the ones most often resulting from the combined methods wrestlers use to lose weight:

1. A reduction in strength of the working muscles (Bosco, Terjung, & Greenleaf, 1968; Houston, Marrin, Green, & Thomson, 1981; Konin, Perrin, & Denegar, 1990; Webster, Rutt, & Weltman, 1990);

2. A decrease in work performance times (cardiovascular endurance) during maximal exercise (Saltin, 1964a; Saltin, 1964b; Taylor, Buskirk, Brozek, Anderson, & Grande, 1957);

3. A decrease in plasma and blood volume as total body water decreases, causing an increase in blood viscosity (Costill & Fink, 1974; Saltin, 1964b). The thickening of the blood augments the resistance of blood flow through the vessels, causing an increase in blood pressure (Fox & Mathews, 1981);

4. A reduction in cardiac function affecting heart rate during activities of submaximal work, stroke volume, and cardiac output (Ribisl & Herbert, 1970; Saltin, 1964b);

5. A greater negative effect on oxygen consumption as a result of food restriction than would occur as a result of the loss of total body water (Taylor et al., 1957);

6. An impairment of the heat regulatory system located in the hypothalamus of the brain (Tipton, 1980);

7. A reduced amount of blood moving to the kidneys (therefore a decreased clearance of waste products from the blood) as a result of a decrease in total body water;

8. The depletion of liver glycogen stores, limiting the amount of potential glucose to the working muscles; and

9. A decrease in electrolytes found in the body (in 1964b, Saltin reported that as body water and electrolytes are depleted, there is a reduction in the performance of the muscles).

An additional side effect of maintaining a body weight lower than the off-season weight is the reduction of the serum testosterone level. In a study of weight loss over a period of two months (Strauss, Lanese, & Malarkey, 1985), a decrease of 2.5 percent body fat resulted in significantly lower serum testosterone levels in wrestlers. The average testosterone level in a male ranges from 3.5 to 10 ng/mL. They also demonstrated that body fat in wrestlers lower than 5 percent reduced the testosterone level below the normal range. Testosterone controls the production of ribonucleic acid (RNA), which has an effect on the amount of muscle protein that is produced. With a reduction of testosterone, there is general muscle weakness, loss of weight, and a decrease in appetite (Strauss, 1987).

Dehydration has unique side effects which differ from the other forms of weight reduction. Water is a valuable nutrient that is needed for normal body functions. There is a link between the amount of body water lost and the rate of fatigue, chronic illness, and the body's ability to retain other nutrients (CMAS, 1967). In a study of aerobic and anaerobic work capacities, Saltin (1964a) found significant changes in cardiac output with water losses of as little as 2 percent of the initial body weight. This change in cardiac output is largely due to the decrease in total blood and plasma volumes, causing additional work for the heart. As the workload of the heart and the viscosity of the blood increase, the core temperature of the body rises (Saltin, 1964a). This increase in core temperature increases the likelihood of heat illness.

The second harmful effect associated with weight reduction in wrestlers is weight cycling. This occurrence includes fasting-eating-fasting. Repeated weight loss, or cycling, may be undertaken by a wrestler in excess of 30 times during any one year (ACSM, 1987b). Steen and Brownell's study (cited in Steen et al., 1988) indicated that 41 percent of wrestlers lose 11 to 20 pounds each week of the season. Of the college wrestlers questioned, 21 percent reported losing 11 to 20 pounds more than 50 times in their careers.

Weight cycling may lead to an increase in food efficiency and a decrease in the body's metabolic rate (Brownell et al., 1987; Steen et al., 1988). Steen et al. found that wrestlers who had a history of weight cycling had significantly lower metabolic rates than non-weight cyclers. The lower the body's metabolic rate, the harder it is for a wrestler to achieve his weight loss and control his weight gain each time he participates during this continuous cycle of weight fluctuation.

As weight cycling continues throughout a wrestling season or a wrestler's career, the body adapts to the changes in caloric intake. This adaption enhances the body's ability to use calories. The body perceives this change as a threat to its lean body mass and its needed energy stores. An atmosphere is created that causes normal body functions to slow or shut down (Brownell et al., 1987). The slowing down of body functions is ideal for periods of famine (Brownell et al., 1987; Steen et al., 1988). However, this defense mechanism due to increased food efficiency can be negative to a wrestler trying to maintain a reduced weight. A lower caloric intake is then needed to maintain past weight levels. Additionally, there are reasons to believe future weight loss will be more difficult for people with a history of weight cycling (Brownell et al., 1987; Steen et al., 1988).

The American Medical Association, the American College of Sports Medicine, and the National Collegiate Athletic Association discourage weight reduction by food deprivation, fluid deprivation, or dehydration. In their position statements, recommended guidelines are addressed for safe weight loss (American College of Sports Medicine [ACSM], 1987a; ACSM, 1987b; CMAS, 1967; National Collegiate Athletic Association [NCAA], 1991). Position statements alone are not enough to convince wrestlers that continuously cutting weight has long- and short-term side effects. These athletes look around and see very few teammates who are not cutting weight. In studies conducted after the finals of state and national wrestling championships, the winners have reported losses of 9 to 15 percent of their preseason body weight (ACSM, 1987b; Zambraski et al., 1976). As long as successful wrestlers continue to drop to lower weight classes, educating the wrestling community on the consequences of weight cycling is difficult. Coaches, athletic trainers, and physicians need to take active roles in changing weight-loss practices in the sport of wrestling (Tipton, 1980). The primary way to change wrestlers' attitudes toward cutting weight is to provide them with objective information showing that there are significant decreases in muscle strength and endurance as a result of this practice.

## Purpose of the Study

The purpose of this study is divided into two components: (1) to investigate whether total body water in wrestlers decreases from preseason to midseason and (2) to determine the effects changes in total body water have on muscle strength and muscle endurance of the dominant quadricep.

## Statement of the Problem

The problems investigated in the study are: (1) the hydration level of wrestlers during the preseason and midseason, (2) the muscle strength of the dominant quadricep, and (3) the muscle endurance of the dominant quadricep.

Data were collected with regard to the following variables associated with the study: (1) age, (2) dominant leg, (3) weight, (4) height, (5) percent body fat, (6) perceived exertion, (7) expected weight class (pretest only), (8) number of times the wrestler made this weight during the current season (post test B), and (9) number of times the wrestler cut more than 10 pounds in his wrestling career.

## Hypotheses

The following null hypotheses were tested in this study:

Hypothesis 1: The practice of intentional dehydration and weight loss over a four-and-one-half-month period will not cause a decrease in total body water.

Hypothesis 2: The practice of intentional dehydration and weight loss over a four-and-one-half-month period will not cause a decrease in the strength of the quadricep muscles.

Hypothesis 3: The practice of intentional dehydration and weight loss over a four-and-one-half-month period will not cause a decrease in the endurance on the quadricep muscles.

## Significance of the Study

The significance of this study is the determination of the effect of cutting weight by wrestlers by reducing total body water and the measurement of its relationship to the muscle strength and endurance of the quadriceps. Other studies have attempted to show the effect of dehydration on muscle strength (Ahlman & Karvonen, 1961; Bosco, Greenleaf, Bernauer, & Card, 1974; Bosco et al., 1968; Houston et al., 1981; Konin et al., 1990; Ribisl, 1974; Saltin, 1964a; Saltin, 1964b; Serfass et al., 1984; Singer & Weiss, 1968; Taylor et al., 1957; Torranin, Smith, & Byrd, 1979; Tuttle, 1943, Webster et al., 1990). However, these previous studies have looked at dehydration as a percentage of weight loss, not as a percentage of total body water.

Another factor in earlier studies which differs from this study is acute versus chronic dehydration. The typical wrestler loses weight several times during the season. No previous study considered the effects of weight cycling and water loss over a period of several months. Preseason strength and endurance levels have not been considered in acute dehydration studies.

The final factor which differentiates this study from previous studies on related topics is the use of isokinetic muscle testing. The use of isokinetic testing equipment is limited to three previous studies (Houston et al., 1981; Konin et al., 1990; Webster et al., 1990). Houston et al. stated that a major problem with assessing muscle strength and endurance is the selection of reliable testing equipment.

In view of the absence of clear and definitive results pertaining to total body water loss and its effect on a wrestler's strength and endurance, objective information is needed. Looking at the effects over time may provide valuable information for the medical community to outline the effects of weight cycling by wrestlers.

In summary, this study is unique and significant because it looks at total body water and weight loss over a period of more than four months. Previous studies have looked only at short-term dehydration using weight loss as the method of determining water loss. The use of bioelectrical impedance gives the researcher the ability to look at actual water loss associated with weight loss from preseason to the end of the regular season. The use of isokinetic testing equipment has been shown to give reliable measurements pertaining to muscle strength and endurance (Perrine & Edgerton, 1978; Thorstensson, Grimby, & Karlsson, 1976).

## Delimitations of the Study

1. The subjects were volunteers obtained from the James Madison University wrestling team.

2. The sample size included 36 varsity wrestlers who ranged in age from 18 to 22 years old.

3. The independent variable (pretest) included bioelectrical-impedance measurements for total body water conducted over a two-week period before the start of the wrestling preseason.

4. The post test included two separate measures of the independent variable.

5. A setting of 90 degrees-per-second on the Orthotron KT2 was used to measure muscle strength and endurance.

6. Orientation on the Orthotron KT2 prior to testing allowed for a practice session of one set of 15 repetitions.

7. All testing during the study was done using one set of 15 repetitions on the Orthotron KT2.

## Limitations of the Study

1. Visual reading of the Orthotron KT2 was used in measuring muscle strength and endurance.

2. The prior Orthotron experience for each subject was not the same.

3. Day-to-day fluctuations in total body water were not considered.

4. The number of wrestlers dropping out of the study over the four-and-one-half-month time frame of the study was not anticipated.

5. No consideration was given to wrestlers gaining weight during the season.

6. The weight loss of the non-starters was not controlled as the researcher was led to expect from the first coaches' meeting.

7. No control group pertaining to seasonal dehydration was included in the study.

## Basic Assumptions

1. The wrestlers from James Madison University were representative of all college wrestlers.

2. The speed of contraction, sets, and repetitions selected for the study were appropriate for measuring muscle strength and endurance.

3. Each wrestler gave a maximal effort on each muscle contraction.

## Definition of Terms

Accommodating variable resistance--at a fixed speed during a muscle contraction, the resistance of the lever arm adapts to the force applied by the working muscle throughout the range of motion.

Acute dehydration--sudden weight loss of $\geq 3$ percent of body weight (CMAS, 1967).

Bipolar--two-electrode technique for sending low-level electrical signals into the body.

Body composition--"quantification of the various components of the body, especially of the fat, water, protein, and bone mineral" (Thomas, 1989, p. 231).

Body fat--measured as a percentage of the weight of fat cells (adipose tissue) divided by total body weight.

Chronic dehydration--gradual body water loss over time due to rapid weight loss and weight cycling.

Cutting weight--slang term used in the sport of wrestling for a person losing weight over a short period of time in order to compete in a lower weight class.

Deuterium-dilution technique--non-radioactive isotopical water tracer (mass two isotope of hydrogen).

Fat-free mass--expressed in pounds and percent of total body weight.

Food efficiency--the need for less calories in maintaining body weight due to the lowering of the body's metabolic rate (ratio of weight change to ingested calories).

Grappler--slang term for a person participating in the sport of wrestling.

Impedance (Z)--frequency-dependent opposition of a conductor to the flow of an alternating electric current; expressed in Ohms.

Midseason--anytime during the season after the halfway point and before the final regular season wrestling match.

Muscle endurance--expressed as the amount of foot-pounds of pressure exerted by the working muscles on the Orthotron at a setting of three (90 degrees-per-second) on the fifteenth repetition (Amato, 1992).

Muscle strength--expressed as the amount of foot-pounds of pressure exerted by the working muscles on the orthotron at a setting of three (90 degrees-per-second) on the third repetition (Amato, 1992).

Postseason--Two- to three-week period following the last wrestling match (Amato, 1992).

Preseason--an approximately six-week period prior to the first wrestling match (Amato, 1992).

Resistance (R)--the ability of the body to conduct an electrical current; equals the opposition of the conductor to the current flow.

Tetrapolar--a four-electrode technique for sending low-level electrical signals into the body.

Total body water--expressed in liters and percent of total body weight.

Tritium-dilution technique--radioactive isotopical water tracer (mass three isotope of hydrogen).

Weight cycling--a method used by wrestlers to continuously reduce body weight in order to compete at lower weight classes (fasting-eating-fasting).

## CHAPTER 2

## Review of Related Literature

The purposes of this chapter are to review previous research and information pertinent to this study and to demonstrate the extent of the effect a decrease in body water has on the ability of a muscle to perform. Specifically, literature was reviewed in the following areas: (1) bioelectrical impedance, (2) validity and reliability of bioelectrical impedance in determining total body water, (3) dehydration, (4) the effect of dehydration on muscle strength, (5), the effect of dehydration on muscle endurance, and (6) isokinetic muscle testing.

### Bioelectrical Impedance

#### Equipment

Bioelectrical impedance is a relatively new method of measuring total body fat, fat-free mass, and total body water in the human (Cohn, 1985). There is a consensus among researchers who have used the method that bioelectrical impedance is a safe, simple, and non-invasive way to determine body composition. With its portable makeup, it is ideal for hospitals, field studies, and the collection of research data (Caton, Molé, Adams, & Heustis, 1988). The equipment requires little tester training or subject cooperation (Lukaski, 1990; Lukaski, Johnson, Bolonchuk, & Lykken, 1985; Oppliger, Nielsen, & Vance, 1991). An additional advantage of this device is its ability to provide quick information on nutritional status; obesity; and, indirectly, electrolyte balance (Kushner & Schoeller, 1986; Shizgal, 1990). Hoffer, Meador, and Simpson (1969) found that bioelectrical-impedance measurements were within an acceptable range for all adults, as well as for healthy and diseased children.

### Early Studies

Nyboer's studies (cited in Lukaski et al., 1985) were the pioneering work in the United States using the tetrapolar method of bioelectrical impedance. The purpose of these studies was to view pulse waves and blood flow to various organs. Studies based on these bioelectrical principles are found in the literature as early as the late nineteenth century. A good deal of research using bioelectrical impedance was done between the 1930s and 1950s on animals, as well as on humans. During that time, the physiological variables of the studies dealt with thyroid function, basal metabolic rate, and hormone levels (Baumgartner, Chumlea, & Roche, 1990). These early studies had many problems accurately calculating the impedance in biological tissue. One of the faults of early impedance units was that the current used surface conduction, rather than deep conduction as do the units of today (Baumgartner et al., 1990).

## General Information Pertaining to Bioelectrical Impedance

The basic principle of bioelectrical impedance is based on the fact that body water behaves as an electrical conductor. Cell membranes act as electrical condensers (Lukaski et al., 1985). Ionic distribution of the biological system is a second factor which influences the ability of the body to act as an electrical conductor (Lukaski et al., 1985). By introducing a constant, low-level, alternating electrical current to the body, there is frequency-dependent resistance to the flow of the current (Lukaski, 1990). The researcher then has the capability of determining the body composition of the patient.

## Ohm's Law

The determination of total body water, fat-free mass, and body fat through the use of bioelectrical impedance is based on the voltage drop of an electrical current between the wrist and foot (Fuller & Elia, 1989). This principle is based on Ohm's law. This law states that resistance (R) is equal to voltage (V) divided by current (I), which is R = V/I (Baumgartner, Chumlea, & Roche, 1987; Baumgartner et al., 1990; Miller, 1972). Lukaski (1987) stated that by using Ohm's law the electrical impedance (Z) of the body can also be measured in terms of voltage and current (Z = V/I). By definition, the terms impedance and resistance are not totally interchangeable; however, studies show that body resistance and body impedance are closely correlated (Lukaski et al., 1985).

The premise that bioelectrical-impedance measurements can be used to determine total body water is based on the conductor length, the height of the individual, the configuration of the body's frame, the cross-sectional area of the body, and the signal frequency of the impedance analyzer (Hoffer et al., 1969; Lukaski et al., 1985). By using a constant signal frequency with the electrical impedance unit, the impedance of a conductor with similar properties can be related to the volume of water in the body. In studies by Hoffer et al. (1969) and Lukaski et al. (1985), it was demonstrated that as long as the signal frequency and conductor configuration remain constant, the impedance of the flow of the current is related to the volume of water in the conductor.

Lean Tissue and Fat Tissue

Lean tissue contains the major portion of the body's total water and electrolytes. As shown in Table 2.1, the high concentration of water and electrolytes in fat-free tissue allows alternating electrical current (AC) to pass through with greater ease than in adipose tissue (Baumgartner et al., 1987). Body fluids and electrolytes are responsible for electrical conduction throughout the body (Baumgartner et al., 1987; Lukaski, 1987; Lukaski, 1990; Lukaski et al., 1985). The higher the amount of lean

**Table 2.1**

**Movement of Electrical Current Through the Body**

---

Lean tissue (fat-free tissue)

---

Large amount of water and electrolytes

LEAN TISSUE | LEAN TISSUE

Electrical
Current---(fast movement through the body)--->Low Impedance

Low Resistance
Low Impedance
Good Conductor

LEAN TISSUE | LEAN TISSUE

The less time it takes for electrical current to move from the wrist to the ankle, the lower the Ohms.

---

Adipose tissue (triglycerides)

---

Small amount of water and electrolytes

ADIPOSE TISSUE | ADIPOSE TISSUE

Electrical
Current--(slow movement through the body)--->High Impedance

High Resistance
High Impedance
Poor Conductor

ADIPOSE TISSUE | ADIPOSE TISSUE

The more time it takes for electrical current to move from the wrist to the ankle, the greater the Ohms.

---

ti...ue in the body, the better the body will act as a conductor for electricity (Baumgartner et al., 1987). The cell membrane somewhat hinders the flow of electrical current through the body (Lukaski, Bolonchuk, Hall, & Siders, 1986; Lukaski et al., 1985). This impedance of the current is directly related to the frequency of the current.

As illustrated in Table 2.2, data collected by Baumgartner et al. (1990), Thomasset (1962), and Nyboer (1970) in separate studies indicated that at low frequencies (1 kHz-5 kHz) cell membranes will not allow electrical current to pass through them. The current only passes through extracellular fluid (Baumgartner et al., 1990; cited in Lukaski, 1990; cited in Lukaski et al., 1985). Considering that there is a normal balance of fluid between the inside and the outside of the cells, measuring the resistance of extracellular fluid and factoring stature (height) squared divided by the resistance will show a high correlation to total body water (Delozier et al., 1988; Hoffer et al., 1969; Hoffer, Meador, & Simpson, 1970; Jenin, Lenoir, Roullet, Thomasset, & Bucrot, 1975; Lukaski et al., 1985). Baumgartner et al. (1990) looked at previous studies showing that bioelectrical impedance has an error measurement of 2 to 3 percent in comparison to deuterium and tritium dilution tests. However, after viewing several studies, he concluded the error rate of 2 to 3 percent seems

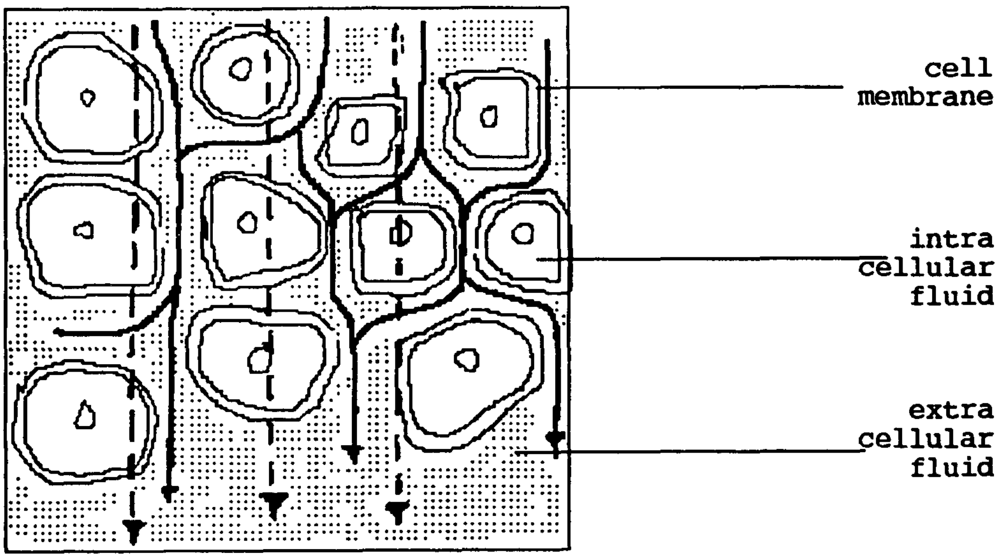
Table 2.2

Electrical Current Needed to Pass Through the Cell Membrane

Body water \
Ionic distribution ---> Electrical Conductor
within the body /

Cell Membrane ---> Electrical Condenser

low frequency current ________ high frequency current _ _ _ _ _




| 1kHz 5kHz | 50kHz | 100kHz 500 Khz 800kHz 1MHz |
|---|---|---|
| | | Penetrate Cell Wall |
| Low Frequency | | High Frequency |
| kHz = 1000 Cycles/sec. | | MHz = 1 million cycles/sec. |

Source: Kanai, Haeno, and Sakamoto, 1987.

to be within normal limits of estimating changes in total body water (Gray, 1988; Kushner & Schoeller, 1986).

Separate studies by Kanai (cited in Kanai, Haeno, & Sakamoto, 1987) and Settle (cited in Settle, Foster, Epstein, & Mullen, 1980) demonstrated that the frequency of 50 kHz is best suited for use with skeletal muscle tissue. As demonstrated in Table 2.2, when the radio frequency approaches 500 to 800 kHz, the current then has the ability to penetrate the cell wall and pass through the intracellular fluid (Baumgartner et al., 1990; cited in Lukaski, 1990; cited in Lukaski et al., 1985). Higher frequencies would theoretically reduce the 2 to 3 percent error in measurement of total body water; however, potential patient risks and technical problems of the machine would increase (Ackmann & Seitz, 1984). In a recent study comparing total body water measurements using a bioelectrical-impedance analyzer with the ability to change frequencies to isotope dilution, Segal et al. (1991) found a slightly higher correlation at 100 kHz versus 50 kHz or 5 kHz. However, due to the safety factor of the electric current through the body and the suitability of current to skeletal muscle tissue, 50 kHz has been set as the standard for commercially available bioelectrical-impedance body-composition analyzers (Bohm, Odaischi, Beyerlein, & Overbeck, 1990; P. S. Davies, Preece, Hicks, & Halliday, 1988; Kanai et al., 1987; Lukaski, 1987; Lukaski et al., 1985; Settle et al., 1980; Van Loan, 1990).

Lukaski (1990) reviewed the differences in conduction properties of fat-free tissue and tissue containing bone or triglycerides. A primary difference in the makeup of the tissues is the amount of water and electrolytes found in each and the higher metabolic activity of the lean tissue (Hamilton, Whitney, & Sizer, 1991). The fat-free tissue contains a larger portion of water and electrolytes than does the fatty material. As shown in Table 2.1, fat-free tissue has a very low resistance and is highly conductive to electrical current, allowing fast movement through the body. On the other hand, electrical current is hindered by fatty tissue, causing a decrease in the speed of the electrical current throughout the body. Bones and triglycerides are poor conductors of electricity with a high impedance pathway through the body.

The conduction properties of fat and fat-free tissues are the basis for determining the amount of total water in the body. As fat-free tissues increase, there is a decrease in Ohms with a fixed electrical current as it passes through the body (Fuller & Elia, 1989). By measuring the voltage drop between the wrist and the foot, calculation of total body water is possible through the use of the bioelectrical-impedance analyzer (Fuller & Elia, 1989).

## Validity and Reliability of Bioelectrical Impedance in Determining Total Body Water

In 1962, Thomasset conducted the first studies which determined an index for total body water using bioelectrical impedance. Studies by Thomasset from 1962 to 1965 utilized the bipolar method of electrical impedance. These studies did not make a major impact on the scientific community due to the low patient acceptability from the adverse side effects of the invasive needle electrodes (Baumgartner et al., 1990). Fellow researchers believed further studies in this area using the two-needle electrode technique would be difficult.

In later studies, total body electrical impedance measurements using a four-surface electrode approach were used to predict total body water (Hoffer et al., 1969; Hoffer et al., 1970). Hoffer et al. (1969) was a landmark study dealing with the validity of electrical impedance and total body water. These researchers used 20 volunteers and found a high level of correlation ($r = 0.92$) between measuring total body water with the bioelectrical-impedance and tritium-dilution techniques.

The use of an isotopical water tracer (isotope-dilution technique) is considered the "gold" standard for determining actual total body water (Gregory, Greene, Scrimgeour, & Rennie, 1991; Lukaski, 1987; Lukaski & Johnson, 1985). This determination of total body water is done by ingesting or intravenously injecting a specific quantity of the tracer into the body. The isotope-dilution is similar to water in its distribution volume and its manner of exchange (Lukaski, 1987). With these similar properties and accounting for the urinary loss of the tracer, total body water can be determined by the amount of tracer given divided by the final concentration of the tracer (Lukaski, 1987).

The two most common solutions used as tracers in determining total body water are tritium and deuterium. The major restriction for using tritium in studies is its radioactive makeup. Studies using tritium as the tracer which involve children and women of childbearing age may not be approved by human-subject review boards (Gregory et al., 1991; Lukaski, 1987; Lukaski & Johnson, 1985). Baumgartner et al. (1990) reviewed four previous studies (Delozier et al., 1988; Hoffer et al., 1969; Hoffer et al., 1970; Lukaski & Johnson, 1985) and found an error of measurement of 2 to 3 percent between total body water determined by electrical impedance versus deuterium and tritium dilution.

The literature shows a strong correlation between total body water measurements by bioelectrical-impedance readings and the radioisotope-dilution technique. The studies verifying the validity of bioelectrical impedance started with Hoffer et al. (1969) and have progressed through the early 1990s.

Lukaski et al. (1985) found that total body water is related to height squared/impedance. This group studied 37 healthy men aged 28.8 + 7.1 years, comparing bioelectrical-impedance measurements to radioisotope-dilution. The study involved two consecutive days of testing. The first day of testing was conducted after an overnight fast, and the second day the subjects were allowed to eat a light breakfast. They found a correlation of 0.95 when comparing total body water between the two methods of measurements.

Segal, Lutin, Presta, Wang, and Van Itallie (1985) measured total body water in 75 adults. This test population consisted of both men and women. As did other researchers, they found height squared/impedance was linked to total body water. The correlation in this study was 0.96 between the two test groups.

In 1986, Kushner and Schoeller found that bioelectrical impedance was a strong predictor of total body water. They studied 58 subjects, comparing total body water measurements by deuterium isotope dilution to bioelectrical impedance. The subjects were grouped by sex and weight (non-obese males, non-obese females, obese males, and obese females). After the subjects fasted overnight, the researchers found no significant differences using the bioelectrical-impedance or isotope-dilution techniques in any of the test groups. The correlation between the two tests equalled 0.99.

In 1987, 188 men and women ranging from the ages of 18 to 64 years were assessed by a bioelectrical-impedance analyzer and by deuterium dilution for total body water (Van Loan & Mayclin, 1987). A reliability test preceded the study using the bioelectrical-impedance analyzer. The reliability of this instrument was determined by taking total body water readings twice a day for 11 days on eight subjects. Once the reliability of the analyzer was determined, the correlation between the two methods of calculating total body water was found to be 0.83.

P. S. Davies et al. (1988) measured total body water in 26 children and adolescents (12 boys and 14 girls) with a variety of disorders. Their health problems consisted of inflammatory bowel disease, growth hormone deficiency, and diabetes mellitus. This atypical population, compared to previous validity studies dealing with total body water, still showed a correlation of 0.97 between bioelectrical impedance and a stable isotope dilution.

Delozier et al. (1988) measured total body water by bioelectrical-impedance and deuterium-dilution techniques with a correlation of 0.87. In this study, the researchers monitored 59 children with ages ranging from four to eight years.

Gray (1988) found the bioelectrical-impedance measurements showed a strong correlation ($r = 0.94$) in estimating acute total body water changes. This study compared impedance and isotope-dilution measurements after short-term fasting.

Bohm et al. (1990) found that assessing total body water by bioelectrical impedance yielded reliable results even during periods of rapid change in hydration levels. The researchers conducted measurements on 38 patients (19 males and 19 females) who had various types of renal disease. The subjects' total body water levels were monitored by the dialyzer and the bioelectrical-impedance analyzer. Readings were taken 10 minutes prior to dialysis and 10 minutes after dialysis, with a correlation of 0.99 between the two testing methods.

Kushner et al. (1990) determined that by measuring total body water through the use of bioelectrical-impedance analysis, fat loss can be accurately monitored. The subjects were enrolled in a nutrition and weight control clinic. The researchers tested the 12 obese women on a weekly basis throughout their weight-loss program. There was a 0.97 correlation between the body water measurements recorded by the bioelectrical impedance and deuterium dilution.

In 1990, Van Loan did a survey of six previous studies examining the relationship of body impedance to total body water. The correlation between bioelectrical-impedance readings and isotope-dilution measurements ranged from 0.86

to 0.99. Van Loan concluded that bioelectrical impedance is a useful tool in estimating total body water.

Gregory et al. (1991) stated that research shows bioelectrical impedance is a valid tool for assessing total body water in the adult population. Additionally, their study tested 34 children, comparing bioelectrical impedance to an isotopical dilution. Their results were very similar to the study by P. S. Davies et al. (1988). Both groups showed a strong correlation between bioelectrical impedance and radioisotope dilution in the pediatric population.

## Dehydration

Dehydration results when the output of body water exceeds fluid intake. This fluid deficit transpires through massive water loss or lack of water consumption. Examples of abnormal losses of body water are due to malfunction of the kidneys, excessive bleeding, vomiting, excessive sweating, or diarrhea (Whitney & Hamilton, 1981). The effects of dehydration can range from thirst to serious health problems (Wardlaw & Insel, 1990). The likelihood of dying as a result of dehydration is much greater than from dying of the absence of food (Krause & Mahan, 1979). An individual can survive weight losses of up to 40 percent of body weight through starvation. Starvation of this magnitude occurs over several weeks, depleting most of the body's fat and glycogen. However, the body has the ability to give up water at a much faster rate (Guthrie, 1989).

Water losses of only 20 percent can cause death much quicker than any degree of starvation (Krause & Mahan, 1979).

Water, next to oxygen, is the body's most important and abundant ingredient. From a structural and functional point of view, water is the body's chief element. Water makes up about two-thirds of the body's total weight (Krause & Mahan, 1979; Vander, Sherman, & Luciano, 1975). This figure may vary as much as 40 percent, depending on the amount of lean body tissue in the individual. A person with large amounts of body fat may have as little as 40 percent body water. Conversely, an individual who is thin with little body fat may have water levels approaching 80 percent of their body weight (Vander et al., 1975). This higher percentage is possible because muscle tissue contains about three times as much water as does adipose tissue (Guthrie, 1989).

All living organisms contain water. Water acts as a solvent, bringing the exact ingredients it needs to the cell for maintenance of life. At the same time, water takes away unwanted byproducts from the cells and their surroundings (Hamilton et al., 1991). The body relies on water for many additional functions. Water is essential for growth, lubrication of joints, and body temperature regulation and acts as a catalyst for various cell reactions (Guthrie, 1989).

Body water is classified by its location in relationship to the cell membrane. Intracellular fluid is located within the cell membrane, making up about 40 percent of total body weight. In comparison, the extracellular fluid is located outside of the cell membrane. Extracellular fluid is also called interstitial or intercellular fluid due to its location between the cells. However, this liquid can move freely across the cell membrane (Whitney & Hamilton, 1981). The fluid outside the cells makes up approximately 20 percent of the body's weight. Not all extracellular fluid is found surrounding the cells; some of this fluid moves through the body in the form of lymph, spinal fluid, or blood plasma (Katch & McArdle, 1983). Blood plasma is responsible for exchanging oxygen, nutrients, and waste products within the extracellular fluid (Vander et al., 1975).

Loss of body fluids through dehydration is an artificial way to lose weight (ACSM, 1987b). Van Itallie and Yang (1977) found in the early stages of weight loss (non-obese and obese subjects), about 56 percent of the reduction is water loss (Van Itallie & Yang, 1977). As fasting or weight reduction continues, fat stores to overall body weight increases. Weight loss showing no change in or an increase in percent body fat indicates the weight loss is directly due to dehydration (Webster et al., 1990). Since most of a wrestler's weight loss is over a relatively short period of time throughout the season, fat stores generally remain untouched (Brownell et al., 1987; Ribisl & Herbert, 1970). Body water and lean muscle tissue are affected the most by a wrestler's weight fluctuations (Brownell et al., 1987).

## The Effect of Dehydration on Muscle Strength

Research has not provided the needed objective data to discourage the rapid weight loss common in the sport of wrestling (Herbert & Ribisl, 1972). Studies presented to the wrestling community have left them with conflicting results regarding the effects of dehydration on muscle strength. There are a number of variables which may account for discrepancies in the studies dealing with total body water losses and muscle strength. The level of physical condition, how accustomed the subject is to weight cycling, the size of the muscle group tested, and the speed of the muscle contraction may all play roles in the disagreement of test results.

### Dehydration: No Change in Muscle Strength

Nine studies were found, and reference was made to three others in the literature to support the conclusion that dehydration has no effect on muscle strength. In the first study, conducted in 1943, Tuttle compared the hand-grip strength of wrestlers. Six subjects were tested before and after losing 3.6 to 4.9 percent of their body weight. The researcher concluded that dehydration of less than

5 percent of an individual's body weight does not affect muscle strength.

In separate studies, Taylor et al. (1957) and Ahlman and Karvonen (1961) found that acute water losses did not affect muscle strength. Ahlman and Karvonen believed strength preservation was true only for subjects who were accustomed to weight cycling. They actually showed one muscle group to improve in strength after acute weight loss.

In a study by Saltin (1964a), isometric muscle contractions were used in determining the effect of dehydration on strength. Upon completion of a pretest and post test of the quadriceps and biceps, the researcher found that acute water losses have no effect on muscle strength.

In a study conducted over five consecutive days, Singer and Weiss (1968) found that dehydration alone had no adverse effects on muscle strength. Ten members of a college wrestling team took part in the study. After losing up to 7 percent of their total body weight, a cable tensiometer was used to measure muscle strength of the biceps, triceps, hamstrings, and rectus femoris. In independent studies, Bryan and Nichols (cited in Singer & Weiss, 1968) studied the effect of decreased body weight on muscle strength. They found that weight loss of between 10 and 11.9 percent of body weight had no detrimental effect on the muscles' ability to perform a maximal contraction.

Through a review of literature, Ribisl (1974) speculated that water losses of 5 to 10 percent body weight will not significantly affect cellular dehydration. For a reduction in strength to occur in large muscles, the researcher hypothesized that water levels of the cells must be greatly reduced.

Serfass et al. (1984) compared the hand-grip strength of 11 men. These men were asked to lose 5 percent of their body weight over a period of three days. Hand-grip measurements were taken before and after the weight reduction. Comparing the hand-grip measurements of the pretest and post test, the conclusion of this study supported the finding that muscle strength is not affected by acute dehydration.

Dehydration: Decreased Muscle Strength

In a review of literature, five studies were found showing dehydration having a negative effect on muscle strength. The first two studies (Bosco et al., 1974; Bosco et al., 1968) measured muscle strength by the use of isometrics. Bosco et al. (1968) found that the nine subjects tested over three consecutive weeks demonstrated a reduction in muscle strength; however, only elbow flexion showed a significant difference in the muscle groups tested. Bosco et al. (1974) also found that maximal strength is reduced when the body is in a dehydrated state. This study compared strength testing of 21 subjects as their water stores were depleted over a three-day period.

The final three studies used isokinetic devices to measure muscle strength. Houston et al. (1981) compared dynamic knee strength by testing the quadriceps at speeds of 30, 180, and 300 degrees-per-second. All four subjects showed a decrease in strength after body weight was reduced by 8 percent over a four-day period. The 30-degrees-per-second setting resulted in the greatest reduction in muscle strength. This testing parameter was the only one of the three to have a significant difference.

In a study by Konin et al. (1990), isokinetic muscle testing at 60 degrees-per-second was used in determining the effect of 3 percent dehydration on muscle strength. A group of 14 college students (eight males and six females) were subjected to non-exercise weight loss by the use of a sauna. The results of the study showed a decrease in the strength of the knee extensors and the elbow flexors.

In a study conducted over a 36-hour period, Webster et al. (1990) found that dehydration significantly reduced the peak torque in the muscles in the shoulder. The muscle strength of the knees showed a decrease, but not to the same degree as that of the shoulder muscles. The seven wrestlers in this study were pretested and post tested using isokinetic equipment at speeds of 90 and 300 degrees-per-second. Upon completion of weight reduction, the wrestlers lost an average of 4.9 percent of their body weight. The authors concluded that weight loss through dehydration was detrimental to the muscles.

## The Effect of Dehydration on Muscle Endurance

Before the use of isokinetic dynamometers, designing studies to accurately measure muscle endurance had been difficult (Houston et al., 1981). This statement is supported by the relatively small number of studies found dealing with the effect of dehydration and muscle endurance.

### Dehydration: No Change in Muscle Endurance

In independent research, Bryan and Nichols (cited in Singer & Weiss, 1968) concluded that muscle endurance was not affected by reductions in body weight. Both of these studies were conducted with the wrestlers losing large amounts of weight. The 14 subjects Bryan (cited in Singer & Weiss, 1968) tested had an average body weight loss of 11.9 percent.

Serfass et al. (1984) tested 11 wrestlers using a hand-grip dynamometer. The athletes were instructed to squeeze and then relax for a period of six minutes. By averaging the amplitude of predetermined contractions, the investigator was able to place an objective number on the muscle endurance of the flexors of the hand. A comparison of the hand-grip measurements of the pretest to the post test after a 5 percent reduction in body weight showed no effect on the muscles' ability to sustain work over a period of six minutes.

Dehydration: Decreased Muscle Endurance

Bosco et al. (1974) used a timed sit-up test to measure the effect of dehydration on muscle endurance. Over a 15-day period, 21 men had a 9 percent decrease in the number of sit-ups. This reduction was attributed to the loss of water and electrolytes.

In 1979, Torranin et al. found that muscle endurance decreased significantly with a reduction of 4 percent of body weight. Twenty males volunteered to take part in isotonic and isometric muscle-endurance testing. A weight-loaded test was performed to measure isometric muscle endurance. The subjects were timed while holding a weight at a preset position for as long as possible (70 percent minimum). The pretest and post test times were compared, finding a decrease in the time in the post test. The researcher used a fatigue test to measure isotonic endurance of the muscles. The subjects were asked to perform hand grips, bicep curls, and bench presses until full range of motion by the muscle was unattainable. The post test results showed a decrease in muscle endurance due to the loss of body weight.

## Isokinetic Muscle Testing

The concept of isokinetics was first put into practice by Perrine in the late 1960s (G. J. Davies, 1984; Moffroid, Whipple, Hofkosh, Lowman, & Thistle, 1969). This type of exercise equipment did not rely on the previous principle of constant weight with variable speeds through the range of motion. The term accommodating variable resistance best describes the function of isokinetics (Roy & Irvin, 1983). The key factor of isokinetics is in the machine's design of totally accommodating the resistance at a fixed speed throughout the range of motion (G. J. Davies, 1984).

The mechanical design of an isokinetic machine includes the ability to control the speed of the muscle contraction. The speed of contraction is controlled by the time it takes hydraulic fluid to travel through the cylinders within the machine. The diameter of the opening of these cylinders changes, depending on the predetermined setting. The speed of the contraction is proportional to the size of the opening of the cylinder. A large diameter opening of the cylinder allows for a fast-speed muscle contraction. Conversely, a small opening of the cylinder will decrease the speed of the muscle contraction (Webster et al., 1990). By controlling the speed and increasing the workload of the muscle, there is an increase in energy absorption, causing an increase in the resistance of the muscles (Hislop & Perrine, 1967; Moffroid et al., 1969). In an isotonic exercise, as the muscular output increases, an acceleration by the working limb will occur with no increased resistance to the muscle.

Isokinetics allows the tester to preset the speed of the muscle contraction; however, the patient has complete control over the amount of resistance to the contracting muscle. By presetting the speed of the muscle contraction, the involved body part travels through a movement pattern at a constant, predetermined velocity (Moffroid et al., 1969). The preset speed of a muscle contraction using an isokinetic device can range from 1 degree-per-second to 300 degrees-per-second (G. J. Davies, 1984).

The resistance for isokinetic exercises is proportional to the amount of force exerted by the muscle. As the muscle contracts, an equal counterforce from the isokinetic device will increase or decrease the resistance supplied to the working muscle (Moffroid et al., 1969; Thorstensson et al., 1976). This concept of accommodating variable resistance allows maximal resistance to be placed on the contracting muscle through the entire range of motion.

Isokinetic-type equipment measures force output of a muscle in torque. By definition, torque is a force produced by a muscle which acts about a joint axis of rotation (Moffroid et al., 1969). The quantitative unit of measure associated with torque measurements using the Orthotron KT2 is pounds-per-square-inch. Peak torque is the maximum torque production within any given set of exercises. The measurement of peak torque is one of the most common and reliable torque parameters (Burdett & Van Swearingen, 1987).

Validity and Reliability of Isokinetic Testing Equipment

The use of isokinetics has become a popular tool in muscle testing for strength and endurance by clinicians and researchers (Burdett & Van Swearingen, 1987). G. J. Davies (1984) cited three advantages of using isokinetics in measuring the contraction capabilities of muscles. These include the validity of the equipment, the reliability of the equipment, and the reproducibility of the testing reliability. In a recent study pertaining to the reliability of isokinetics, Montgomery, Douglass, and Deuster (1989) found that a high correlation existed when the muscle contraction was performed at a slower velocity. In the same study by Montgomery (cited in Montgomery et al., 1989), knee extension proved to have a greater reliability than did knee flexion.

Montgomery et al. (1989) found that the use of isokinetic testing was ideal for measuring muscle strength and muscle endurance. The peak torque readings have shown extreme accuracy after any type of experimental intervention. Cybex (1991) listed numerous isokinetic studies which were published in referenced journals from 1966 to the present. The use of a computer readout for data collection in isokinetic research is the most common; however, in this bibliography by Cybex (1991), the use of visual readings for measurements of muscle strength and muscle endurance were used in studies cited 42 times in 21 separate journals.

# CHAPTER 3

## Methodology and Procedures

This study was conducted over a four-and-one-half-month period using a college wrestling team during the 1991-1992 wrestling season. The data collection began three weeks prior to the first official wrestling practice and continued until four weeks before the postseason championship. Within this time frame, each wrestler took part in a pretest and two post tests (post test A and post test B).

### Institutional Review Board for Human Subjects

The Institutional Review Board for Human Subjects in Research at James Madison University reviewed the proposal prior to the start of testing (see approval form in Appendix A). After permission was granted by the review board, orientation meetings were set up with the coaching staff and the wrestling team.

### Subjects

The initial subject group ($N$ = 36) was any college student who had contacted the coaches with a desire to be a member of the wrestling team. Seventeen of the pretest subjects eliminated themselves from the wrestling team before the study was completed.

Since this research was conducted in the wrestler's natural environment during the season, any injury to a wrestler affected his participation in the study. Injuries to a wrestler's knee or other body part which resulted in the end of his need to cut weight also prevented some student athletes' completion of the testing. These injuries affected either the quadricep muscle strength and endurance component or the hydration component of the study.

Orientation Session

The general orientation of the athletes and coaches involved in the study was held at the first preseason wrestling meeting. This meeting occurred several weeks prior to the first official wrestling practice. At that time, the purpose and methodology of the study were explained to the group.

The next orientation period was conducted individually over a period of two weeks prior to the first pretest. Participation in this individual orientation was required for a wrestler's further involvement in the study. This orientation session consisted of a general question-and-answer period and instructions about the Orthotron KT2. At this time, all wrestlers ($\underline{N}$ = 36) performed one set of 15 repetitions (both legs) under test conditions.

The final orientation period was conducted just prior to the pretest dates to answer any final questions and to post the testing schedule. Student athletic trainers were used to remind the wrestlers of their scheduled test times throughout the weeks of testing.

Once the season began, follow-up meetings took place as needed at the beginning of wrestling practice. The follow-up meetings were designed primarily for the scheduling of the post tests. The reasons for asking wrestlers to refrain from exercise for a minimum of one and one-half hours prior to any of the pretesting or post-testing sessions were explained and reinforced at each of the orientation and follow-up meetings.

## Facility

A climate-controlled laboratory with three separate rooms was assigned for the testing by the Department of Physical Education and Sport. All data were collected in the same environment over the four-and-one-half-month period due to the sensitivity of the bioelectrical-impedance analyzer. Temperature regulation was an essential factor for maintaining normal skin temperature during total body water measurements.

The first room was set up as a reception area. Information pertaining to height, weight, determination of dominant leg, signing the informed consent form, and filling out any needed questionnaires took place in this area. The second room was set up for the measurement of total body water using the bioelectrical-impedance analyzer. The third room had the muscle-testing equipment set up for measuring muscle strength and muscle endurance of the quadricep muscles. The Borg Scale of Perceived Exertion (see Appendix B) was also administered in the third room.

## Instruments

A standard cloth tape measure (manufactured by Mead Johnson, Bristol-Myers Company, Evansville, Indiana) secured to a wall was used to determine the height of each wrestler. The height of each individual was measured in inches to the nearest one-quarter of an inch (for example, 67.25 inches).

A standard physician's scale, manufactured by Detecto Scales, Inc., Brooklyn, New York (Detecto-Medic, serial number 3PY1003), was used for all body weight measurements. Calibration was done prior to each testing session by using a preweighed 10-pound weight. Body weight was measured in pounds to the nearest one-quarter of a pound.

The bio-resistance body-composition analyzer used to collect body water data for this experiment was a model 1990B, manufactured by Valhalla Scientific, Inc. in San Diego, California (serial number 46-794). This instrument uses a tetrapolar electrode arrangement that introduces a painless test current to the body of 500 amperes at a constant frequency of 50 kHz.

The bio-resistance body-composition analyzer is internally calibrated. The sequence of calibration by the model 1990B starts with the phase detector and progresses to voltage, current, and Ohm. The Ohm calibration is set by the National Bureau of Standards at 499 Ohms. All readings for total body water in the study had a calibration level of 0.0 for current, voltage, Ohm error, and fat error. Calibration could have been conducted at any time during the testing session. Standard calibration for this study took place at the beginning of each testing period.

Data on muscle strength and muscle endurance for the research were collected using an Orthotron KT2, serial number KT2-3020110 (manufactured by Cybex, a division of Lumex, Inc., Ronkonkoma, New York). The calibration of the Orthotron KT2 is preset at the factory. There are no additional means of calibration once the equipment is delivered without sending the equipment back to the company, nor is it assumed to be necessary.

The Borg Scale of Perceived Exertion (see Appendix B) was used as the method for rating perceived exertion in this research population. This scale runs from zero to a reading of 10-plus (Noble, 1982). On this scale, zero is considered as no exertion at all, while the 10-plus rating is when the athlete is unable to perform at the maximum workload.

## Pretest

It was essential that the pretest collection of muscle strength and endurance data and total body water measurements occurred before the wrestlers started reducing weight toward their competitive weight classes. Consequently, testing occurred on five days over a two-week period prior to the official start of the wrestling season.

Following an explanation of their responsibilities by the researcher, student athletic trainers coordinated the duties of the reception area. The informed consent form was read and explained to the athletes in a prior orientation meeting; however, the first stage of the pretest consisted of the athletes re-reading, asking questions about, and signing the letter (see Appendix C). After the informed consent form was witnessed, the athlete had the opportunity to keep an identical copy of the consent form.

A circuit with all needed stages of the pretest was set up in the reception area. The first area was designated for the collection of informational data. In this area, the pretest work sheet was coded and filled out (see Appendix D). The information requested was related to age, projected weight class, dominant body parts, and reasons for cutting weight. Each athlete was asked two questions to help determine their dominant leg:

1. What do you consider to be your dominant leg?

2. If given a football, what leg would you use to kick it?

The second area of the circuit consisted of the balance-step test. The administration of this test consisted of the athlete standing with eyes shut and feet spread shoulder-width apart. Without warning, the athlete was gently pushed from behind. The student athletic trainer in charge of this station was instructed to apply the force to the vertebral column between the scapulas. The foot which moved forward to regain the athlete's balance was noted as the dominant leg. This test was used to confirm the wrestler's answers pertaining to their dominant leg. If the answers to the two questions dealing with the dominant leg did not match the results of the balance-step test, the step test was repeated. For the purpose of this study, the results of the balance-step test was the final indicator of dominant leg.

The next station in the first room was set up for the measurement of body height. The testing protocol consisted of no shoes or socks, heels and head against the wall, chin parallel to the ground, and toes hyperextended. A standard eight-inch plastic architect's triangle (30 degrees/ 60 degrees) was used to mark the height measurement. By placing the side of the triangle opposite the 30-degree angle against the wall and lowering the adjacent side to touch the head, an accurate height measurement was taken.

The final station in the reception area was for the purpose of measuring the subject's body weight. The body weight test protocol consisted of the removal of shoes, socks, and heavy clothing and standing still with arms to the sides. The student athletic trainer assigned to this station was responsible for weighing and recording the athletes' weights.

Once all needed information was obtained in the reception area, the wrestlers then moved, one at a time, to the bioelectrical-impedance area in the second room. A second researcher, with a terminal degree in exercise physiology from Indiana University, was responsible for the test administration and collection of the data in this area.

Total body water was measured, employing the bio-resistance body-composition analyzer, model 1990B. A low-level electrical signal operating at a frequency of 50 kHz is produced by the model 1990B. This signal penetrates the body's deep tissues, providing a volume and density of the biological system. Measurements of bio-resistance are directly related to the total volume of water in the body. These measurements provided data on total body water in liters and percent of water to total body weight. This information provided an index for evaluating the state of hydration of the wrestlers.

The administration of the bio-resistance body-composition analyzer includes proper body positioning and electrode placement. The athlete needs to be in a supine position on the table with his left side nearest the impedance unit. The forearm needs to be in a pronated position with the palms flat on the table. The back of the heels need to be in contact with the table with shoes and socks off. The foot should be in a slightly plantar-flexed position, allowing for easier access for electrode placement. The correct body positioning just described was maintained throughout testing for every athlete in this study.

The proper preparation and placement of the surface electrodes are very important to obtaining accurate data. Preparation started by removing any excess hair on the wrist, hand, ankle, and foot. The removal was accomplished by using a standard disposable razor. Rubbing alcohol was then applied to eliminate any dirt or loose hair on or around the area. This hair removal assured a good connection between the patient's skin and the surface electrodes.

The first set of color-coded electrodes was positioned on the dorsal surface of the left hand. The first electrode was placed on the wrist halfway between the head of the ulna and the styloid process of the radius. The second electrode was then placed on the distal end of the third metacarpal just below the proximal phalange of the third finger.

The second pair of color-coded electrodes was placed on the dorsum of the left foot. The first electrode was placed in the area of the dorsal pedal pulse. This mark was located by drawing an imaginary line between the medial and lateral malleolus of the tibia and fibula. Once the imaginary line was drawn, the electrode was placed distal to the halfway-point of the divided line. The second electrode in this pair was placed on the distal end of the metatarsals between the second and third toe.

Upon completion of the total body water measurement, the results were coded and delivered to the second researcher. The athlete then moved into the final room of the laboratory for quadricep testing of the left and right legs. The muscle testing was done on an Orthotron KT2 manufactured by Cybex. The Orthotron KT2 is an isokinetic device which measures concentric reciprocal movements. In this study, the action of extension was the involved movement. A preset speed of 90 degrees-per-second was determined as the speed of the muscle contraction for the test.

The athlete was asked to sit down in the testing chair. The positioning of the athlete in this chair was loosely structured. The only requirement throughout the test was that the wrestler remain in contact with the back of the seat. This was made possible by the feature of the KT2 that allows the back of the seat to be moved forward or backward.

The placement of the foot pad for the testing was adjusted, allowing the athlete to actively dorsal flex his foot without any contact between the top of the foot and the bottom of the pad. The general rule used was to place one to two fingers between the top of the foot and the bottom of the pad.

The athlete was instructed to do one set of 15 repetitions at maximal contractions through a full range of motion starting with the non-dominant leg. The testing of the uninvolved leg first acted as a check to ensure the athlete understood the test protocol. The athlete was asked to count the number of repetitions throughout the exercise. However, on the eleventh repetition, they counted aloud. The non-dominant leg quadricep was the first muscle group tested, followed by the dominant leg.

The muscle strength and endurance of the quadriceps were recorded after visual reading of the Orthotron KT2. To increase the accuracy of the reading, the use of the "lazy hands" on the Orthotron gauge was used to register the peak torque. The peak torque on the orthotron is measured in pounds-per-square-inch; however, this figure was converted into a muscle-strength and endurance/body weight ratio. This ratio gave a relative number to work with for statistical calculations, along with factoring in individual weight loss. The recording of muscle strength was done after the third repetition. Muscle endurance was recorded upon the completion of the fifteenth contraction.

The final component of the study involved the wrestlers rating the intensity of their exercise workload. Upon completion of the muscle strength and endurance section, the athletes were asked to rate their perceived exertion using the Borg Scale of Perceived Exertion (see Appendix B). This scale is designed for estimating anaerobic stress due to high intensity work (Noble, 1982). By using Borg's scale, the researcher is able to place an objective number on perceived exertion. Since the athletes were expected to perform maximum contraction for each repetition, the subjects using this scale were asked whether they could maintain this intensity over a longer period of time. This was made clear to each athlete by explaining that a "10-plus" or "maximal" rating on Borg's scale meant that they could not perform the sixteenth repetition at a maximal contraction. After all paperwork was turned in at the reception area, the wrestlers were free to leave.

### Post Test A and Post Test B

The testing protocol for post tests A and B was identical to the procedures for the pretest. The test dates for post tests A and B were based on the competitive wrestling schedule. These tests were as close to the end of the wrestling season as possible. This allowed for the greatest amount of time to observe whether total body water decreased throughout the wrestling season. The next factor which was considered in choosing the post test dates was the amount of time between weigh-ins. The athletes needed a few days to rehydrate before scheduling post test A; however, post test B needed to be several days after post test A in order to give each wrestler time to cut weight for the next match. Post test B was conducted two to six hours prior to weigh-ins for the next match. Wrestlers who were not wrestling in the upcoming tournament were still required to make the weight that was assigned to them by the wrestling coach.

The one change in the facility for post test A from the pretest was in the reception area. This change consisted of filling out only parts of the work sheet (see Appendix E). These areas of the work sheet included the last weight class the wrestlers were required to make and their body weight.

The only change between the setup for the two post tests was in the collection of data in the reception area. These changes included filling out a separate work sheet (see Appendix E). In addition to answering questions about the wrestler's weight class for the upcoming match and body weight at the time, the athletes were also asked to fill out an information questionnaire (see Appendix F).

Upon completion of the set protocol for the bioelectrical-impedance and orthotron areas in rooms 2 and 3 (same as pretest), the wrestlers were free to go. At this time, they were reminded of their unrestricted access to the information collected.

## Statistical Analyses

Statistical Packages for the Social Sciences (SPSSx), second edition, was used for the analysis of the data. A repeated measures multivariate analysis of variance (MANOVA) was used to analyze the variables of muscular strength, muscular endurance, perceived exertion, and hydration. The Tukey post-hoc test followed when the overall MANOVA was found to be significant. Bruning and Kintz (1977) described this statistical procedure in The Computational Handbook of Statistics.

# CHAPTER 4

## Analyses of Data

The purpose of this study was to investigate whether total body water in wrestlers decreased from preseason to midseason. The second component of this research was to determine the effects changes in total body water have on muscle strength and muscle endurance of the dominant quadricep. Additional information pertaining to the rating of perceived exertion and physical characteristics of the wrestlers is also reported in this chapter.

Nineteen of the 36 wrestlers completed all three trials of the study throughout the season. A repeated measures multivariate analysis of variance (MANOVA) was performed for each dependent variable. For this study, an alpha level of .05 was selected as the critical level of statistical significance. The Tukey Test was performed for any results showing a significant difference.

### Total Body Water

Total body water measurements of each individual obtained by the bioelectrical-impedance analyzer are shown in Appendices G through I. Table 4.1 shows the means, standard deviations, and ranges of the total body water measurements of the wrestlers participating in the study.

Individual changes in body water between the trials are shown in Appendix J. The means and standard deviations for the changes in total body water are shown in Table 4.2. The mean changes in body water between the pretest and post test A showed a decrease of .05 liters, between the pretest and post test B showed a decrease of 3.62 liters,

Table 4.1

Means, Standard Deviations, and Ranges of Total Body Water

| Condition | Means (liters) | Standard deviations | Ranges (liters) |
|---|---|---|---|
| Pretest | 50.92 | 6.75 | 41.5 - 66.4 |
| Post test A | 50.87 | 6.04 | 40.1 - 65.4 |
| Post test B | 47.30 | 6.73 | 37.1 - 67.5 |

Table 4.2

Means and Standard Deviations of the Amount of Total Body Water Loss Between Trials

| | Means and standard deviations | | |
|---|---|---|---|
| Condition | Pretest | Post test A | Post test B |
| Pretest | - | -0.05*/2.94 | -3.62*/4.36 |
| Post test A | - | - | -3.57*/3.49 |
| Post test B | - | - | - |

*Liters.

and between post test A and post test B showed a decrease of 3.57 liters.

The multivariate analysis of variance (MANOVA) shown in Table 4.3 resulted in an F-ratio of 17.22 (probability = .000) between subjects and an F-ratio of 12.35 (probability = .000) between tests. This analysis indicates, using an alpha level of .05, a significant difference did exist between the subjects and between the tests. Even though the MANOVA showed a significant

Table 4.3

Liters of Total Body Water

| | Means and standard deviations | | |
|---|---|---|---|
| Condition | N | Mean | S.D. |
| Pretest | 19 | 50.92 | 6.75 |
| Post test A | 19 | 50.87 | 6.04 |
| Post test B | 19 | 47.30 | 6.73 |

| | Multivariate analysis of variance | | | | |
|---|---|---|---|---|---|
| Source | SS | DF | MS | F | Sig. |
| Subject | 2,055.01 | 18 | 114.17 | 17.22 | .000 |
| Test | 163.71 | 2 | 81.85 | 12.35 | .000 |
| Error | 238.64 | 36 | 6.63 | | |

difference between the pretest and the post tests, this analysis did not indicate whether the difference was due to chronic dehydration, acute dehydration, or both.

A post-hoc analysis known as Tukey's test was used to determine where the significant differences existed. A critical value of 2.03 was determined by Tukey's test to be the variance needed to show significant difference at the .05 level of confidence. By subtracting the total body water mean of the pretest (50.92 liters) from the mean of post test A (50.87 liters), a difference of 0.05 was found. Table 4.4 shows that a significant difference did not exist

Table 4.4

Means, Standard Deviations, and Post-Hoc Analysis of Total Body Water

| | | Size-Ordered-Means | | |
|---|---|---|---|---|
| Condition | Means (liters) | 50.92 | 50.87 | 47.30 |
| Pretest | 50.92 (6.75)* | - | 0.05 | 3.62** |
| Post test A | 50.87 (6.04)* | | - | 3.57** |
| Post test B | 47.30 (6.73)* | | | - |

*Standard deviation. **$p < .05$ with a critical value of 2.03.

between the pretest and post test A (chronic dehydration). However, a significant difference did exist between the pretest and post test B, as well as between post test A and post test B. The differences among these two tests (3.62 liters and 3.57 liters) are greater than the critical value of 2.03 to indicate significance.

A power analysis was used to determine whether the design of the study was sensitive enough to detect changes in body water. A .80 standard was set as the power needed to detect changes due to treatment. In Table 4.5, the power for detecting changes in total body water between subjects (1.000) and between tests (0.993) was found to be sufficient.

Table 4.5

Power Analysis

| | TBW** (power) | DQS*** (power) | DQE**** (power) | RPE***** (power) |
|---|---|---|---|---|
| Subject | 1.000* | 0.995* | 0.940* | 0.967* |
| Test | 0.993* | 0.055 | 0.377 | 0.317 |

*Observed power at the .05 level using .80 as sufficient test sensitivity. **Total body water. ***Dominant quadricep strength. ****Dominant quadricep endurance. ****Rate of perceived exertion.

## Muscle Strength/Muscle Endurance

The dominant quadricep muscle strength and endurance to body weight ratios by individuals obtained using the Orthotron KT2 are shown in Appendices G through I. Table 4.6 and Table 4.7 show the means, standard deviations, and

Table 4.6

Means, Standard Deviations, and Ranges of Quadricep Muscle Strength to Body Weight Ratio

| Condition | Means (ratio) | Standard deviations | Ranges (ratio) |
|---|---|---|---|
| Pretest | 1.67 | 0.25 | 1.29 - 2.09 |
| Post test A | 1.67 | 0.18 | 1.38 - 2.03 |
| Post test B | 1.68 | 0.30 | 0.88 - 2.29 |

Table 4.7

Means, Standard Deviations, and Ranges of Quadricep Muscle Endurance to Body Weight Ratio

| Condition | Means (ratio) | Standard deviations | Ranges (ratio) |
|---|---|---|---|
| Pretest | 1.33 | 0.22 | 0.78 - 1.63 |
| Post test A | 1.42 | 0.21 | 1.08 - 1.77 |
| Post test B | 1.45 | 0.27 | 0.76 - 1.89 |

ranges of these ratios of the athletes participating in the study.

Individual changes in muscle strength/endurance to body weight ratios between the trials are shown in Appendices K and L). The means and standard deviations for the changes in quadricep muscle strength and muscle endurance to body weight ratio are shown in Tables 4.8 and 4.9. The mean changes in the amount of dominant quadricep strength/ endurance to body weight ratio between the pretest and post test A demonstrated a slight increase of .0042/.0932, between the pretest and post test B demonstrated an increase of .0132/.1195, and between post test A and post test B demonstrated an increase of .0100/.0216.

Table 4.8

Means and Standard Deviations of the Amount of Quadricep Muscle Strength Change Between Trials

| | Means and standard deviations | | |
|---|---|---|---|
| Condition | Pretest | Post test A | Post test B |
| Pretest | - | .0042*/.2185 | .0132*/.3156 |
| Post test A | - | - | .0100*/.2454 |
| Post test B | - | - | - |

*Ratio muscle strength to body weight.

Table 4.9

Means and Standard Deviations of the Amount of Quadricep Muscle Endurance Change Between Trials

| | Means and standard deviations | | |
|---|---|---|---|
| Condition | Pretest | Post test A | Post test B |
| Pretest | - | .0932*/.2742 | .1195*/.3086 |
| Post test A | - | - | .0216*/.2442 |
| Post test B | - | - | - |

*Ratio muscle endurance to body weight.

The MANOVA shown in Table 4.10 resulted in an F-ratio of 3.40 (probability = .001) between subjects and an F-ratio of 0.03 (probability = .975) between tests. This analysis of changes in quadricep strength to body weight ratio indicates that at an alpha level of .05, a significant difference did exist between the subjects. However, these figures demonstrate that there was no significant difference between the pretest, post test A, and post test B.

The results in Table 4.11 using a MANOVA to detect changes in quadricep muscle endurance tc body weight ratio are similar to the results found in the muscle strength component of this study. The F-ratio between subjects was 2.25 (probability = .019), showing a significant difference.

Table 4.10

Quadricep Muscle Strength to Body Weight Ratio
of Dominant Leg

| Condition | Means and standard deviations | | |
|---|---|---|---|
| | N | Mean | S.D. |
| Pretest | 19 | 1.67 | 0.25 |
| Post test A | 19 | 1.67 | 0.18 |
| Post test B | 19 | 1.68 | 0.30 |

| Source | Multivariate analysis of variance | | | | |
|---|---|---|---|---|---|
| | SS | DF | MS | F | Sig. |
| Subject | 2.07 | 18 | .12 | 3.40 | .001 |
| Test | .00 | 2 | .00 | .03 | .975 |
| Error | 1.22 | 36 | .03 | | |

Table 4.11

Quadricep Muscle Endurance to Body Weight Ratio of Dominant Leg

| | Means and standard deviations | | | | |
|---|---|---|---|---|---|
| Condition | N | | Mean | | S.D. |
| Pretest | 19 | | 1.33 | | 0.22 |
| Post test A | 19 | | 1.42 | | 0.21 |
| Post test B | 19 | | 1.45 | | 0.27 |
| | Multivariate analysis of variance | | | | |
| Source | SS | DF | MS | F | Sig. |
| Subject | 1.56 | 18 | .09 | 2.25 | .019 |
| Test | .15 | 2 | .07 | 1.95 | .157 |
| Error | 1.38 | 36 | .04 | | |

No significant difference was found between the tests. The F-ratio between tests was 1.95 with a probability of .157.

The variation between subjects for muscle strength and endurance was expected due to differences in body size and preexisting muscle strength/endurance levels. No post-hoc analysis was performed between subjects due to the insignificant role these data played in the purpose of the study. Since no significant difference was found using the MANOVA for either muscle strength or muscle endurance, no post-hoc analysis was indicated.

## Rating of Perceived Exertion

The ratings for perceived exertion by individuals obtained using the Borg Scale of Perceived Exertion (see Appendix B) are shown in Appendices G through I. Table 4.12 shows the means, standard deviations, and ranges of the rating of perceived exertion of the wrestlers participating in the study.

Table 4.12

Means, Standard Deviations, and Ranges of Rating of Perceived Exertion

| Condition | Means | Standard deviations | Ranges |
|---|---|---|---|
| Pretest | 6.90 | 1.34 | 4.5 - 9.5 |
| Post test A | 7.29 | 1.32 | 5.0 - 9.0 |
| Post test B | 7.34 | 1.27 | 4.5 - 9.0 |

Individual changes in perceived exertion between trials are shown in Appendix M. The means and standard deviations for the changes in the rating of perceived exertion are shown in Table 4.13. The mean changes in the rating of perceived exertion between the pretest and post test A showed an increase of .395, between the pretest and post test B showed an increase of .447, and between post test A and post test B showed an increase of .053.

Table 4.13

Means and Standard Deviations of the Changes in Perceived Exertion Between Trials

| | Means and standard deviations | | |
|---|---|---|---|
| Condition | Pretest | Post test A | Post test B |
| Pretest | - | .395/1.505 | .447/1.855 |
| Post test A | - | - | .053/1.452 |
| Post test B | - | - | - |

The MANOVA shown in Table 4.14 yielded an F-ratio of 1.94 (probability = .044) between subjects and an F-ratio of .87 (probability = .427) between tests. This analysis indicated a significant difference did exist between the subjects. However, these data indicate that a significant

Table 4.14

Rating of Perceived Exertion

| | Means and standard deviations | | |
|---|---|---|---|
| Condition | N | Mean | S.D. |
| Pretest | 19 | 6.90 | 1.34 |
| Post test A | 19 | 7.29 | 1.32 |
| Post test B | 19 | 7.34 | 1.27 |

| | Multivariate analysis of variance | | | | |
|---|---|---|---|---|---|
| Source | SS | DF | MS | F | Sig. |
| Subject | 45.58 | 18 | 2.53 | 1.94 | .044 |
| Test | 2.27 | 2 | 1.14 | .87 | .427 |
| Error | 46.89 | 36 | 1.30 | | |

difference did not exist between the pretest, post test A, and post test B.

No post-hoc analysis was performed between subjects due to the insignificant role these data played in the purpose of the study. Since no significant differences were found using MANOVA for the rating of perceived exertion, no post-hoc analyses were needed between the tests.

## Physical Characteristics

The physical characteristics by individuals during the study are shown in Appendices N through P. Body weight, changes in body weight, and changes in percent body weight are the only physical characteristics reported in this chapter. Table 4.15 shows the means, standard deviations, and ranges of the body weights of the wrestlers during the pretest, post test A, and post test B.

Table 4.15

Means, Standard Deviations, and Ranges of Body Weight

| Condition | Means (pounds) | Standard deviations | Ranges |
|---|---|---|---|
| Pretest | 171.17 | 26.75 | 134.75 - 241.00 |
| Post test A | 168.30 | 25.75 | 130.25 - 239.25 |
| Post test B | 162.12 | 27.03 | 122.75 - 241.75 |

Individual changes in body weight between trials and changes in percent body weight are shown in Appendices Q and R. The mean changes in body weight between the pretest and post test A showed a decrease of 2.88 pounds, between the pretest and post test B showed a decrease of 9.05 pounds, between post test A and post test B showed a decrease of 6.17 pounds (see Table 4.16).

Table 4.16

Means and Standard Deviations of the Amount of Body Weight Loss Between Trials

| | Means and standard deviations | | |
|---|---|---|---|
| Condition | Pretest | Post test A | Post test B |
| Pretest | - | -2.88*/4.21 | -9.05*/8.31 |
| Post test A | - | - | -6.17*/5.91 |
| Post test B | - | - | - |

*Pounds.

The means and standard deviations for the changes in percent of body weight loss are shown in Table 4.17. The mean changes in percent body weight loss between the pretest and post test A showed a decrease of 1.6 percent, between the pretest and post test B showed a decreased of 5.3 percent, and between post test A and post test B showed a decrease of 3.8 percent.

The wrestling study survey (Appendix F) was used to help establish whether the subjects used for the collection of these data were typical of other wrestling populations. The results of this survey are shown in Appendix S (Raw Data--Wrestling Study Survey). Questions 1a, 1b, and 2 give the most insight into the number of times the wrestlers' weight fluctuated throughout the season. The average number

Table 4.17

**Means and Standard Deviations of the Percent of Body Weight Loss Between Trials**

| | Means and standard deviations | | |
|---|---|---|---|
| Condition | Pretest | Post test A | Post test B |
| Pretest | - | -1.60/2.41 | -5.30%/4.58 |
| Post test A | - | - | -3.80%/3.45 |
| Post test B | - | - | - |

of times the athletes made their post test B weight was 4.68 times. Weight cycling of 10 or more pounds occurred on an average of 4.05 times during the season by this population. An average of 68.4 percent felt they were wrestling at their ideal weight.

# CHAPTER 5

## Summary, Findings, and Conclusions

### Summary

The purposes of this study were: (1) to determine if body water levels of 19 wrestlers from James Madison University (Harrisonburg, Virginia) declined due to weight cycling over the course of the season and (2) to determine if muscle strength and endurance of the quadricep were affected by the changes in body water. The study was conducted during the 1991-1992 wrestling season.

Prior to the pretest, wrestlers were required to attend orientation meetings. They became familiar with the testing equipment and purposes of the study at this time. A pretest and two post tests followed the orientation period. During these tests, data were collected on the following: (1) measurements of physical characteristics, (2) muscle strength; (3) muscle endurance, (4) total body water, and (5) rating of perceived exertion.

The premise for this study was based on the belief of wrestlers that preseason muscle strength and muscle endurance levels are not affected by weight loss during the season (ACSM, 1987b; Tipton & Tcheng, 1970). The primary objective of this study was to generate information concerning the effect on wrestlers of losing large quantities of weight during the wrestling season.

## Findings

### Physical Characteristics

The wrestling population used in this study was atypical during the season in many areas pertaining to body weight and composition in comparison to other teams described in the literature. The American College of Sports Medicine (ACSM) stated in their position stand that wrestlers weighing less than 190 pounds have a preseason average percent body fat of 8 percent with a range of 1.6 to 15.1 percent (ACSM, 1987b). This study's population of wrestlers weighing less than 190 pounds had a higher percent body fat of 13 percent with a range of 7.4 to 18.3 percent. Other studies showed wrestlers losing between 3 percent and 20 percent of total body weight during the season (Thorland, Johnson, Cisar, & Housh, 1987; Tipton & Tcheng, 1970; Zambraski et al., 1976). However, the data collected in this study were based on wrestlers who lost no more than 13.7 percent of their body weight. Yarrows (1988) reported that wrestlers will weight cycle anywhere from 15 to 30 times during the season. This wrestling population reported that weight cycling occurred an average of only 4.68 times during the season (see Appendix S).

From the survey taken during post test B (see Appendix S), 68.4 percent of these athletes felt they were wrestling in the appropriate weight class. The small amount of weight loss and weight cycling during the period before post test A indicated that this group of wrestlers' competitive weights were relatively close to their preseason weights. This similarity contradicts the amount of weight the athletes planned to lose during the pretesting. At that time, the wrestlers projected an average weight loss of 17.42 pounds between their present weight and the weight classes they planned to wrestle in by the end of the season. However, by post test A, the athletes lost an average of only 2.88 pounds. These findings go against the basic assumption that the wrestlers used in this study were representative of all college wrestlers. This lack of weight loss and weight cycling affected the amount of manipulation available in showing changes in the dependent variables by chronic dehydration.

Total Body Water

The wrestlers in the study lost an average of 2.88 pounds from the pretest to post test A. With relatively little weight loss, the amount of water loss measured by the bioelectrical-impedance analyzer showed no significant difference between these two tests. Therefore, the first null hypothesis dealing with chronic dehydration and total body water losses was accepted. Additional research is needed to determine if weight cycling in wrestling does cause gradual water loss. No other studies were found that addressed chronic dehydration. Through the use of the bioelectrical-impedance analyzer, changes in a wrestler's total body water can be collected with relative ease.

Additional information collected in this study pertaining to changes in total body water dealt with acute dehydration. Using a multivariate analysis of variance (MANOVA) and Tukey's test, the water loss in the wrestlers between post test A and post test B demonstrated that a significant difference did exist. Accounting for all members of the wrestling team, this data showed these athletes were able to regain preseason water levels before post test A; however, through acute dehydration and rapid weight loss, the wrestlers were able to make weight at the time of weigh-ins (post test B).

Even though there was no significant difference between the pretest and post test A, the wrestlers were at high risk for heat illness due to the total amounts of weight loss. In this study, the wrestlers lost 5.3 percent of their preseason body weight by the time of post test B. The American Academy of Orthopaedic Surgeons (1991) states that weight loss of 4 to 5 percent of body weight can lead to heat exhaustion, heat stroke, and even death. Due to the reduction in body water through dehydration, the viscosity of the blood increases, causing an increase of the body's core temperature (Saltin, 1964a). This increase in core temperature and blood viscosity has the potential to impair the heat regulatory system located in the hypothalamus of the brain (Tipton, 1980).

The results of this study supported the statements from the ACSM (1987b) and Tipton (1980) that acute dehydration is the most widely used method by wrestlers to make their competitive weights. It is important to educate wrestlers about the need to try to rehydrate before competition if acute dehydration is their primary means of weight loss. Education alone may not be enough since in many cases wrestlers do not have the needed amount of time between weigh-in and competition to rehydrate. College wrestlers have a minimum of five hours, and high school athletes may have as little as one hour to rehydrate before a match (Allen, Smith, & Miller, 1977). Studies show that one to five hours is insufficient time for a wrestler to completely rehydrate (Herbert & Ribisl, 1972; Zambraski et al., 1976). This incomplete rehydration and additional water loss during competition makes it necessary for wrestlers to avoid losing large amounts of weight during the season.

<u>Muscle Strength/Muscle Endurance</u>

It is not possible to speculate about chronic dehydration and the effect it has on muscle strength and muscle endurance from this study. Since the first null hypothesis (the practice of intentional dehydration and weight loss over a four-and-one-half-month period will not cause a decrease in total body water) was accepted, there was not enough manipulation of the independent variable to affect the dependent variables. This did not allow the researcher to accept or reject the second null hypothesis (the practice of intentional dehydration and weight loss over a four-and-one-half month period will not cause a decrease in the strength of the quadricep muscles) or third null hypothesis (the practice of intentional dehydration and weight loss over a four-and-one-half month period will not cause a decrease in the endurance of the quadricep muscles).

On the basis of the data obtained from this study, information dealing with acute dehydration and its effects on muscle strength and endurance can be added to the existing body of knowledge. Between the pretest and post test B, the wrestlers lost an average of 3.62 liters of water and 5.3 percent of their body weight. The body water measurements and percent of weight loss between post test A and post test B were 3.57 liters and 3.45 percent, respectively. The results of the MANOVA indicated there was no significant difference in muscle strength or muscle endurance of the dominant quadricep muscle using acute dehydration as the independent variable. Craig and Cummings (1966) stated that "although a man deprived of water will eventually become exhausted, he can undergo a substantial dehydration without much loss of strength" (p. 1).

The finding that acute dehydration did not affect muscle strength is consistent with 62 percent of the studies examined in the review of literature. The results from this study that muscle endurance was not affected by body water loss is consistent with 60 percent of previous research reviewed by the investigator. Ribisl (1974) states that acute weight loss of 5 to 10 percent of body weight will not significantly affect the intracellular fluid. Without changing the fluid level inside the cells, the strength of large muscles apparently remains unaffected (Ribisl, 1974).

The studies by Ahlman and Karvonen (1961), Byram (1953), Nichols (1957), Saltin (1964a), Serfass et al. (1984), Singer and Weiss (1968), Taylor et al. (1957), and Tuttle (1943) were in agreement with the findings of this study that muscle strength is not affected by dehydration. Of the studies reviewed, an average of 6.7 percent (range 1.6 to 11.9) of body weight was lost. This figure compares to 3.8 and 5.3 percent (range -1.8 to 13.7) during the data collection of this research.

Studies by Byram (1953), Nichols (1957), and Serfass et al. (1984) looked at the effects of dehydration on muscle endurance. These studies were conducted with the subjects losing an average of 9 percent of their body weight. They concluded that muscle endurance in college wrestlers was not affected by rapid weight loss.

No comparisons can be made with body water loss. All previous studies found in the literature search looked at percent body weight lost to determine dehydration, not liters of water lost. Saltin's study (1964a) is the only one using the quadriceps that is in agreement that muscle strength or endurance is not affected by acute dehydration. The other studies in agreement used the smaller muscle groups of the hands, arms, or legs.

Five studies administered in controlled settings were found with conflicting results from this research. The studies by Bosco et al. (1968), Bosco et al. (1974), Houston et al. (1981), Konin et al. (1990), and Webster et al. (1990) concluded that rapid weight loss adversely affects muscle strength. An average weight loss of 5 percent was used as the independent variable in these studies. These studies were similar to present research in that four of five studies tested the quadriceps and three of five studies used isokinetic testing equipment as the means of measuring muscle strength. However, none of the previous studies collected data in the natural environment during the wrestling season as did this study.

A small amount of data were found supporting the premise that dehydration negatively affects the ability of a muscle to contract over a prolonged period of time. Research gathered by Bosco et al. (1974) and Torranin et al. (1979) disagreed with findings of the present study. They concluded that rapid weight loss of 4 to 5.75 percent decreases the muscle endurance of hand flexor, bicep, pectoralis major, deltoid, and quadricep muscles.

## Rating of Perceived Exertion

This subjective response by the wrestlers after working both quadriceps showed an interesting trend. As total body water decreased in wrestlers, their rating of perceived exertion increased. However, no significant difference between tests comparing perceived exertion and changes in body water was found. Further research in this area may show that even if wrestlers are not losing strength through dehydration, they may be mentally less ready to compete in the later minutes of the match due to the lower levels of body water. The higher a wrestler rates his perceived exertion after work tends to indicate how much pain he is experiencing or the length of time a specific level of intensity can last.

## Conclusion

Many articles and position papers state that dehydration significantly affects muscle strength and muscle endurance negatively (ACSM, 1987b; Guthrie, 1989; Wardlaw & Insel, 1990; Yarrows, 1988). However, research does not show a definitive pattern that supports the claims that dehydration affects the muscle's ability to perform. If clear proof existed that dehydration hurt wrestling performance, then the practice of weight cycling would probably stop immediately.

Rapid weight loss by wrestlers has brought about criticism by the public and the medical community (CMAS, 1967; Tipton, 1980; Yarrows, 1988). Conflicting results pertaining to objective measurements, such as muscle strength and endurance, have made it difficult for the medical community to decrease the practice of intentional weight loss. It is often difficult to change common practices among athletes by educating them about health risks alone.

Even though this study did not show objective information that chronic dehydration did exist or that acute dehydration affected muscle strength and muscle endurance in wrestlers, the researcher still believes the practice of extreme intentional dehydration should be stopped. Muscle strength and endurance make up only two of the five components of physical fitness. Winning and losing wrestling matches is a combination of all five components of physical fitness. The adverse health risks alone should discourage coaches from allowing and wrestlers from practicing extreme weight loss during the wrestling season.

Many unanswered questions about the effect of dehydration on muscle strength and endurance still exist in the sport of wrestling. The athletes wrestle for three periods at a time, using many of the body's muscles. To say that the dominant quadricep muscle is not affected after a match or even after several matches in a tournament cannot be addressed with objective measurements. The health of the athlete needs to be the primary concern in deciding what is the safe amount of weight loss possible, not how much weight a wrestler can lose and still win matches (CMAS, 1967).

## Recommendations

The following suggestions are recommended by the investigator:

1. Stress to coaches and athletic trainers the importance of rehydration between weigh-ins and competition.

2. Stress to all students through health and physical education classes the harmful side effects of improper weight reduction and weight cycling.

3. Have all students learn about proper weight loss and weight gain methods through health and physical education classes.

4. Instruct all students through health and physical education classes about the importance of rehydration before, during, and after exercise.

## Contributions of Study to the Research Community

The following contributions have been made to the research community by the investigator:

1. The utilization of a bioelectrical-impedance analyzer in conjunction with a college wrestling team,

2. A comprehensive review of related literature,

3. Research pertaining to long-term dehydration in wrestlers, and

4. Research using total body water as a means to determine dehydration versus percent of weight loss.

## Suggestions for Future Studies

The following suggestions for further research are recommended by the investigator:

1. Research the effect of dehydration on perceived exertion.

2. Repeat the same study using a Cybex instead of an Orthotron KT2.

3. Repeat the same study using smaller muscle groups (upper and lower body).

4. Look at water loss (true dehydration) versus weight loss (apparent dehydration).

**APPENDICES**

# APPENDIX A

## PROPOSAL APPROVAL FORM

# APPENDIX A

## PROPOSAL APPROVAL FORM

Serial#9192003

Proposal Approval Form
The Institutional Review Board (IRB)
on the Use of Human Subjects in Research
James Madison University

PRINCIPAL INVESTIGATOR: Herbert K. Amato

PROJECT TITLE: The Effects of Dehyrdation on Muscle Endurance in College Wrestlers

Certification of Review and Approval
Project Involving Human Subjects

In accordance with JMU Policy Number 1:01:06 and the Guidelines of the Department of Mental Health and Mental Retardation, it is hereby certified that the above stated project:

✓ being exempt from full review was reviewed by subcommittee and in its present form was

____ was reviewed by the IRB and, in its revised form, was

approved on 9/13/91
disapproved on ______

Comments. A Follow-Up Report for Research Proposal form is attached and should be returned on or before May 1.

Human subjects are adequately informed of any risks.

Signature. [signature]
Chair

Date 9/13/91

## APPENDIX B

## BORG SCALE OF PERCEIVED EXERTION

# APPENDIX B

## BORG SCALE OF PERCEIVED EXERTION

| Ratio of Perceived Exertion (RPE) | |
|---|---|
| 0 | nothing at all |
| 0.5 | very, very weak |
| 1 | very weak |
| 2 | weak |
| 3 | moderate |
| 4 | somewhat strong |
| 5 | strong |
| 6 | |
| 7 | very strong |
| 8 | |
| 9 | |
| 10 | very, very strong (almost maximal) |
| 10+ | maximal |

## APPENDIX C

## INFORMED CONSENT FORM

APPENDIX C

INFORMED CONSENT FORM

Yes, I_______________________________________________ am
(print name)

willing to participate in the study of the effects of dehydration on muscle endurance/strength. The proposed study will consist of a pretest and two post tests lasting until the middle of the wrestling season.

Note: In the event you find that any of the following information is not clear, please ask the investigator to explain immediately.

Weight loss through dehydration is a common practice in wrestling. The purpose of this study is to look at the effects of hydration levels in college wrestlers on muscle strength and the muscles' ability to maintain strength over a prolonged period.

In this study I understand that the following measurements will be conducted on three separate occasions: (1) recording of body weight (this will be measured using a standard laboratory weighing scale), (2) measurement of muscle strength and muscle endurance (these readings will be measured by an Orthotron manufactured by Cybex), (3) measurement of the hydration level of the body (this measurement will be taken with the use of bio-resistance body-composition analyzer/electrical impedance).

I understand the purpose of the study and that the benefits to me are primarily informational. However, the data collected may help me make an informed decision about losing weight through the use of dehydration. I have been informed that muscle strength and muscle endurance testing may cause a slight discomfort to the working muscles. However, there is no risk in having hydration levels measured by the use of electrical impedance. I also understand that my participation is voluntary and is not required by the James Madison University Athletic Department to remain a member of the wrestling team. I have been assured that the results of this study will remain strictly anonymous. Upon completion of this study, an individual conference will be made available to me to discuss the results of my participation.

Date Signature

Date Signature

APPENDIX D

PRETEST WORK SHEET

## APPENDIX D

## PRETEST WORK SHEET

Name_______________________

Code #_____________________

Age________________________

Dominant Limb: Leg__________

Body Weight_____________ Projected Weight Class__________

Body Height_____________ inches

Total Body Water________ liters

Total Body Fat__________ percent

---

| | Muscle Strength 1 X 3 | | Muscle Endurance 1 X 15 | |
|---|---|---|---|---|
| | R | L | R | L |
| Knee Extension (quadriceps) | | | | |
| #Body Weight/Ratio Strength/Wt | | | | |

---

Perceived Exertion (Borg Scale of Perceived Exertion)

Lower Extremity

Pretest ______________

APPENDIX E

POST TEST WORK SHEETS

# APPENDIX E

## POST TEST WORK SHEETS

### Post Test A Work Sheet

Code #__________________

Body Weight______________ (Weight Class___________)

Body Height______________ inches

Total Body Water_________ liters

| | Muscle Strength 1 X 3 | | Muscle Endurance 1 X 15 | |
|---|---|---|---|---|
| | R | L | R | L |
| Knee Extension (quadriceps) | ______________ | | ________________ | |
| #Body Weight/Ratio Strength/Wt | _____________ | | ________________ | |

Perceived Exertion (Borg Scale of Perceived Exertion)

Lower Extremity

Pretest _______________

## Post Test B Work Sheet

Code #__________________

Body Weight______________ (Weight Class___________)

Body Height______________ inches

Total Body Water_________ liters

| | Muscle Strength 1 X 3 R | Muscle Strength 1 X 3 L | Muscle Endurance 1 X 15 R | Muscle Endurance 1 X 15 L |
|---|---|---|---|---|
| Knee Extension (quadriceps) | | | | |
| #Body Weight/Ratio Strength/Wt | | | | |

Perceived Exertion (Borg Scale of Perceived Exertion)

Lower Extremity

Pretest _______________

# APPENDIX F

# WRESTLING STUDY SURVEY

## APPENDIX F

## WRESTLING STUDY SURVEY

1. a. How many times this season have you weighed this post test weight? ________________

   b. Do you feel this is your ideal wrestling weight?

   Yes_____ No_____

   (If No) Higher_____ Lower_____

2. How many times have you cut more than 10 pounds to make weight this season? ______________

3. a. How many times have you cut more than 10 pounds to make weight in your wrestling career? _____________

   b. How many years have you been wrestling competitively? ____________________

4. Do you feel it is harder to lose weight at the end of wrestling season compared to the beginning of the season? (For example, losing five pounds at the beginning of the season vs. losing five pounds at the end of the season)

   At the beginning__________ At the end __________

5. Do you feel it was harder to lose weight during this wrestling season compared to last season?

   During this season________ During last season________

APPENDIX G

RAW DATA

PRETEST

# APPENDIX G

## RAW DATA

## PRETEST

| Subject Number | TBW (liters) | DQS (ratio) | DQE (ratio) | RPE |
|---|---|---|---|---|
| 1 | 49.7 | 1.66 | 1.51 | 7.5 |
| 2 | 42.8 | 1.96 | 0.78 | 6.0 |
| 3 | 49.7 | 1.90 | 1.36 | 8.5 |
| 4 | 42.9 | 1.52 | 1.19 | 7.0 |
| 5 | 51.0 | 1.75 | 1.51 | 6.0 |
| 6 | 42.8 | 1.54 | 1.11 | 5.0 |
| 7 | 47.1 | 1.90 | 1.37 | 6.0 |
| 8 | 54.9 | 1.38 | 1.22 | 9.5 |
| 9 | 66.4 | 1.83 | 1.62 | 5.0 |
| 10 | 51.4 | 1.82 | 1.63 | 8.0 |
| 11 | 53.5 | 1.95 | 1.43 | 8.0 |
| 12 | 60.8 | 2.09 | 1.59 | 5.5 |
| 13 | 47.6 | 1.31 | 1.25 | 7.5 |
| 14 | 60.4 | 1.67 | 1.39 | 7.0 |
| 15 | 45.5 | 1.35 | 1.41 | 4.5 |
| 16 | 41.5 | 1.34 | 1.11 | 8.0 |
| 17 | 56.1 | 1.57 | 1.41 | 8.0 |
| 18 | 52.0 | 1.29 | 0.98 | 7.0 |
| 19 | 51.4 | 1.87 | 1.42 | 7.0 |
| **Means:** | 50.92 | 1.67 | 1.33 | 6.90 |
| **S.D.:** | 6.75 | 0.25 | 0.22 | 1.34 |

APPENDIX H

RAW DATA

POST TEST A

# APPENDIX H

## RAW DATA

## POST TEST A

| Subject Number | TBW (liters) | DQS (ratio) | DQE (ratio) | RPE |
|---|---|---|---|---|
| 1 | 49.2 | 1.68 | 1.55 | 9.0 |
| 2 | 44.5 | 1.82 | 1.58 | 5.0 |
| 3 | 50.9 | 1.51 | 1.42 | 7.0 |
| 4 | 46.2 | 1.79 | 1.53 | 8.0 |
| 5 | 46.4 | 1.76 | 1.23 | 6.0 |
| 6 | 43.4 | 1.50 | 1.16 | 7.0 |
| 7 | 45.6 | 2.03 | 1.77 | 7.0 |
| 8 | 52.4 | 1.66 | 1.43 | 7.0 |
| 9 | 65.4 | 1.71 | 1.57 | 5.0 |
| 10 | 52.8 | 1.68 | 1.49 | 8.5 |
| 11 | 50.3 | 1.94 | 1.59 | 9.0 |
| 12 | 58.1 | 1.66 | 1.61 | 7.0 |
| 13 | 52.3 | 1.44 | 1.08 | 8.0 |
| 14 | 54.2 | 1.38 | 1.15 | 7.0 |
| 15 | 47.7 | 1.61 | 1.16 | 7.5 |
| 16 | 40.1 | 1.61 | 1.55 | 9.0 |
| 17 | 58.1 | 1.55 | 1.39 | 5.0 |
| 18 | 53.5 | 1.52 | 1.15 | 8.0 |
| 19 | 55.4 | 1.93 | 1.65 | 8.5 |
| **Means:** | 50.87 | 1.67 | 1.42 | 7.29 |
| S.D.: | 6.04 | 0.18 | 0.21 | 1.32 |

APPENDIX I

RAW DATA

POST TEST B

# APPENDIX I

## RAW DATA

## POST TEST B

| Subject Number | TBW (liters) | DQS (ratio) | DQE (ratio) | RPE |
|---|---|---|---|---|
| 1 | 39.6 | 1.23 | 1.23 | 5.0 |
| 2 | 39.3 | 1.65 | 1.42 | 6.0 |
| 3 | 49.6 | 1.63 | 1.24 | 7.0 |
| 4 | 44.2 | 1.76 | 1.56 | 7.5 |
| 5 | 48.5 | 1.65 | 1.33 | 9.0 |
| 6 | 38.5 | 1.58 | 1.19 | 8.5 |
| 7 | 45.6 | 2.29 | 1.89 | 7.0 |
| 8 | 47.6 | 1.76 | 1.51 | 8.0 |
| 9 | 67.5 | 1.66 | 1.49 | 6.0 |
| 10 | 50.4 | 1.88 | 1.75 | 8.0 |
| 11 | 45.8 | 1.91 | 1.56 | 8.0 |
| 12 | 49.3 | 1.92 | 1.81 | 6.5 |
| 13 | 47.7 | 1.54 | 1.19 | 8.5 |
| 14 | 48.7 | 1.53 | 1.43 | 8.0 |
| 15 | 48.0 | 1.80 | 1.64 | 8.0 |
| 16 | 37.1 | 1.79 | 1.47 | 8.0 |
| 17 | 53.7 | 0.88 | 0.76 | 4.5 |
| 18 | 51.9 | 1.51 | 1.39 | 9.0 |
| 19 | 45.7 | 1.98 | 1.70 | 7.0 |
| **Means:** | 47.30 | 1.68 | 1.45 | 7.34 |
| **S.D.:** | 6.73 | 0.30 | 0.27 | 1.27 |

APPENDIX J

AMOUNT OF TOTAL BODY WATER (LITERS)

LOSS BETWEEN TRIALS

# APPENDIX J

## AMOUNT OF TOTAL BODY WATER (LITERS)

## LOSS BETWEEN TRIALS

| Subject Number | Pretest to Post Test A | Pretest to Post Test B | Post Test A to Post Test B |
|---|---|---|---|
| 1 | -0.50 | -10.10 | -9.60 |
| 2 | +1.70 | - 3.50 | -5.20 |
| 3 | +1.20 | - 0.10 | -1.30 |
| 4 | +3.30 | + 1.30 | -2.00 |
| 5 | -4.60 | - 2.50 | +2.10 |
| 6 | +0.60 | - 4.30 | -4.90 |
| 7 | -1.50 | - 1.50 | 0.00 |
| 8 | -2.50 | - 7.30 | -4.80 |
| 9 | -1.00 | + 1.10 | +2.10 |
| 10 | +1.40 | - 1.00 | -2.40 |
| 11 | -3.20 | - 7.70 | -4.50 |
| 12 | -2.70 | -11.50 | -8.80 |
| 13 | +4.70 | + 0.10 | -4.60 |
| 14 | -6.20 | -11.70 | -5.50 |
| 15 | +2.20 | + 2.50 | +0.30 |
| 16 | -1.40 | - 4.40 | -3.00 |
| 17 | +2.00 | - 2.40 | -4.40 |
| 18 | +1.50 | - 0.10 | -1.60 |
| 19 | +4.00 | - 5.70 | -9.70 |
| Means: | -0.05 | - 3.62 | -3.57 |
| S.D.: | 2.94 | 4.36 | 3.49 |

APPENDIX K

AMOUNT OF QUADRICEP MUSCLE STRENGTH (RATIO)

LOSS BETWEEN TRIALS

# APPENDIX K

## AMOUNT OF QUADRICEP MUSCLE STRENGTH (RATIO)

## LOSS BETWEEN TRIALS

| Subject Number | Pretest to Post Test A | Pretest to Post Test B | Post Test A to Post Test B |
|---|---|---|---|
| 1 | +0.02 | -0.43 | -0.45 |
| 2 | -0.14 | -0.31 | -0.17 |
| 3 | -0.39 | -0.27 | +0.12 |
| 4 | +0.27 | +0.24 | -0.03 |
| 5 | +0.01 | -0.10 | -0.11 |
| 6 | -0.04 | +0.04 | +0.08 |
| 7 | +0.13 | +0.39 | +0.26 |
| 8 | +0.28 | +0.38 | +0.10 |
| 9 | -0.12 | -0.17 | -0.05 |
| 10 | -0.14 | +0.06 | +0.20 |
| 11 | -0.01 | -0.04 | -0.30 |
| 12 | -0.43 | -0.17 | +0.26 |
| 13 | +0.13 | +0.23 | +0.01 |
| 14 | -0.29 | -0.14 | +0.15 |
| 15 | +0.26 | +0.45 | +0.19 |
| 16 | +0.27 | +0.45 | +0.18 |
| 17 | -0.02 | -0.69 | -0.67 |
| 18 | +0.23 | +0.22 | -0.01 |
| 19 | +0.06 | +0.11 | +0.05 |
| Means: | .0042 | .0132 | .0100 |
| S.D.: | .2185 | .3156 | .2454 |

APPENDIX L

AMOUNT OF QUADRICEP MUSCLE ENDURANCE (RATIO)

LOSS BETWEEN TRIALS

# APPENDIX L

## AMOUNT OF QUADRICEP MUSCLE ENDURANCE (RATIO)

## LOSS BETWEEN TRIALS

| Subject Number | Pretest to Post Test A | Pretest to Post Test B | Post Test A to Post Test B |
|---|---|---|---|
| 1 | +0.04 | -0.28 | -0.32 |
| 2 | +0.80 | +0.64 | -0.16 |
| 3 | +0.06 | -0.12 | -0.18 |
| 4 | +0.34 | +0.37 | +0.03 |
| 5 | -0.28 | -0.18 | +0.01 |
| 6 | +0.05 | +0.08 | +0.03 |
| 7 | +0.40 | +0.52 | +0.12 |
| 8 | +0.21 | +0.29 | +0.08 |
| 9 | -0.05 | -0.13 | -0.08 |
| 10 | -0.14 | +0.12 | +0.26 |
| 11 | +0.16 | +0.13 | -0.03 |
| 12 | +0.02 | +0.22 | +0.20 |
| 13 | -0.17 | -0.06 | +0.11 |
| 14 | -0.24 | +0.04 | +0.28 |
| 15 | -0.25 | +0.23 | +0.48 |
| 16 | +0.44 | +0.36 | -0.08 |
| 17 | -0.02 | -0.65 | -0.63 |
| 18 | +0.17 | +0.41 | +0.24 |
| 19 | +0.23 | +0.28 | +0.05 |
| **Means:** | .0932 | .1195 | .0216 |
| **S.D.:** | .2742 | .3086 | .2442 |

## APPENDIX M

## CHANGES IN PERCEIVED EXERTION BETWEEN TRIALS

# APPENDIX M

## CHANGES IN PERCEIVED EXERTION BETWEEN TRIALS

| Subject Number | Pretest to Post Test A | Pretest to Post Test B | Post Test A to Post Test B |
|---|---|---|---|
| 1 | +1.5 | -2.5 | -4.0 |
| 2 | -1.0 | 0.0 | +1.0 |
| 3 | -1.5 | -1.5 | 0.0 |
| 4 | +1.0 | +0.5 | -0.5 |
| 5 | 0.0 | +3.0 | +3.0 |
| 6 | +2.0 | +3.5 | +1.5 |
| 7 | +1.0 | +1.0 | 0.0 |
| 8 | -2.5 | -1.5 | +1.0 |
| 9 | 0.0 | +1.0 | +1.0 |
| 10 | +0.5 | 0.0 | -0.5 |
| 11 | +1.0 | 0.0 | -1.0 |
| 12 | +1.5 | +1.0 | -0.5 |
| 13 | +0.5 | +1.0 | +0.5 |
| 14 | 0.0 | +1.0 | +1.0 |
| 15 | +3.0 | +3.5 | +0.5 |
| 16 | +1.0 | 0.0 | -1.0 |
| 17 | -3.0 | -3.5 | -0.5 |
| 18 | +1.0 | +2.0 | +1.0 |
| 19 | +1.5 | 0.0 | -1.5 |
| **Means:** | .395 | .447 | .053 |
| **S.D.:** | 1.505 | 1.855 | 1.452 |

# APPENDIX N

## PHYSICAL CHARACTERISTICS OF SUBJECTS

## PRETEST

# APPENDIX N

## PHYSICAL CHARACTERISTICS OF SUBJECTS

## PRETEST

| Subject Number | Age (years) | Height (inches) | Weight (pounds) | % Body Fat | Dominant Limb |
|---|---|---|---|---|---|
| 1 | 18 | 69.50 | 166.00 | 14.0 | Right |
| 2 | 18 | 66.50 | 148.25 | 17.0 | Right |
| 3 | 18 | 65.75 | 157.75 | 8.7 | Right |
| 4 | 19 | 66.75 | 151.00 | 18.3 | Right |
| 5 | 18 | 66.00 | 169.00 | 13.3 | Right |
| 6 | 19 | 65.00 | 140.00 | 11.7 | Right |
| 7 | 18 | 67.00 | 153.00 | 11.1 | Right |
| 8 | 20 | 68.50 | 181.00 | 13.1 | Right |
| 9 | 19 | 73.50 | 241.00 | 27.2 | Right |
| 10 | 22 | 72.00 | 165.25 | 10.1 | Right |
| 11 | 18 | 70.50 | 174.50 | 11.5 | Left |
| 12 | 18 | 70.50 | 200.75 | 13.5 | Right |
| 13 | 19 | 69.75 | 160.00 | 14.5 | Right |
| 14 | 18 | 61.00 | 216.00 | 24.0 | Right |
| 15 | 19 | 67.75 | 156.00 | 16.3 | Right |
| 16 | 18 | 67.50 | 134.75 | 10.9 | Right |
| 17 | 22 | 70.50 | 198.75 | 13.0 | Right |
| 18 | 18 | 66.75 | 163.00 | 7.4 | Right |
| 19 | 20 | 69.75 | 176.25 | 17.0 | Left |

Means: Age (years) = 18.89, Height (inches) = 68.13, Weight (pounds) = 171.17, % Body Fat = 14.35.

S.D.: Age (years) = 1.29, Height (inches) = 2.86, Weight (pounds) = 26.75, % Body Fat = 4.90.

APPENDIX O

PHYSICAL CHARACTERISTICS OF SUBJECTS

POST TEST A

# APPENDIX O

## PHYSICAL CHARACTERISTICS OF SUBJECTS

## POST TEST A

| Subject Number | Age (years) | Height (inches) | Weight (pounds) | Dominant Limb |
|---|---|---|---|---|
| 1 | 18 | 69.50 | 161.00 | Right |
| 2 | 18 | 66.50 | 145.25 | Right |
| 3 | 18 | 65.75 | 159.00 | Right |
| 4 | 19 | 66.75 | 150.75 | Right |
| 5 | 18 | 66.00 | 167.25 | Right |
| 6 | 19 | 65.00 | 133.25 | Right |
| 7 | 18 | 67.00 | 152.50 | Right |
| 8 | 20 | 68.50 | 175.00 | Right |
| 9 | 19 | 73.50 | 239.25 | Right |
| 10 | 22 | 72.00 | 161.00 | Right |
| 11 | 18 | 70.50 | 170.00 | Left |
| 12 | 18 | 70.50 | 192.50 | Right |
| 13 | 19 | 69.75 | 167.25 | Right |
| 14 | 18 | 61.00 | 209.50 | Right |
| 15 | 19 | 67.75 | 155.00 | Right |
| 16 | 18 | 67.50 | 130.25 | Right |
| 17 | 22 | 70.50 | 187.50 | Right |
| 18 | 18 | 66.75 | 165.00 | Right |
| 19 | 20 | 69.75 | 176.25 | Left |

Means: Age (years) = 18.89, Height (inches) = 68.13, Weight (pounds) = 168.30.

S.D.: Age (years) = 1.29, Height (inches) = 2.86, Weight (pounds) = 25.75.

APPENDIX P

PHYSICAL CHARACTERISTICS OF SUBJECTS

POST TEST B

# APPENDIX P

## PHYSICAL CHARACTERISTICS OF SUBJECTS

## POST TEST B

| Subject Number | Age (years) | Height (inches) | Weight (pounds) | Dominant Limb |
|---|---|---|---|---|
| 1 | 18 | 69.50 | 146.00 | Right |
| 2 | 18 | 66.50 | 133.75 | Right |
| 3 | 18 | 65.75 | 153.00 | Right |
| 4 | 19 | 66.75 | 147.50 | Right |
| 5 | 18 | 66.00 | 158.00 | Right |
| 6 | 19 | 65.00 | 126.50 | Right |
| 7 | 18 | 67.00 | 148.50 | Right |
| 8 | 20 | 68.50 | 165.25 | Right |
| 9 | 19 | 73.50 | 241.75 | Right |
| 10 | 22 | 72.00 | 154.50 | Right |
| 11 | 18 | 70.50 | 173.00 | Left |
| 12 | 18 | 70.50 | 188.00 | Right |
| 13 | 19 | 69.75 | 155.50 | Right |
| 14 | 18 | 61.00 | 196.25 | Right |
| 15 | 19 | 67.75 | 156.00 | Right |
| 16 | 18 | 67.50 | 122.75 | Right |
| 17 | 22 | 70.50 | 171.50 | Right |
| 18 | 18 | 66.75 | 165.00 | Right |
| 19 | 20 | 69.75 | 177.00 | Left |

Means: Age (years) = 18.89, Height (inches) = 68.13, Weight (pounds) = 162.12.

S.D.: Age (years) = 1.29, Height (inches) = 2.86, Weight (pounds) = 27.03.

# APPENDIX Q

## AMOUNT OF WEIGHT LOSS BETWEEN TRIALS

# APPENDIX Q

## AMOUNT OF WEIGHT LOSS BETWEEN TRIALS

| Subject Number | Pretest to Post Test A | Pretest to Post Test B | Post Test A to Post Test B |
|---|---|---|---|
| 1 | - 5.00 | -20.00 | -15.00 |
| 2 | - 3.00 | -14.50 | -11.50 |
| 3 | + 1.25 | - 4.75 | - 6.00 |
| 4 | - 0.25 | - 3.50 | - 3.25 |
| 5 | - 1.75 | -11.00 | - 9.25 |
| 6 | - 6.75 | -13.50 | - 6.75 |
| 7 | - 0.50 | - 4.50 | - 4.00 |
| 8 | - 6.00 | -15.75 | - 9.75 |
| 9 | - 1.75 | + 0.75 | + 2.50 |
| 10 | - 4.25 | -10.75 | - 6.50 |
| 11 | - 4.50 | - 1.50 | + 3.00 |
| 12 | - 8.25 | -12.75 | - 4.50 |
| 13 | + 7.25 | - 4.50 | -11.75 |
| 14 | - 6.50 | -19.75 | -13.25 |
| 15 | - 1.00 | 0.00 | + 1.00 |
| 16 | - 4.50 | -12.00 | - 7.50 |
| 17 | -11.25 | -27.25 | -16.00 |
| 18 | + 2.00 | + 2.50 | + 0.50 |
| 19 | 0.00 | + 0.75 | + 0.75 |
| Means: | - 2.88 | - 9.05 | - 6.17 |
| S.D.: | 4.21 | 8.31 | 5.91 |

APPENDIX R

PERCENT OF BODY WEIGHT LOSS

BETWEEN TRIALS

# APPENDIX R

## PERCENT OF BODY WEIGHT LOSS BETWEEN TRIALS

| Subject Number | Pretest to Post Test A | Pretest to Post Test B | Post Test A to Post Test B |
|---|---|---|---|
| 1 | 3.0 | 12.0 | 9.3 |
| 2 | 2.0 | 9.8 | 7.9 |
| 3 | -0.8 | 3.0 | 3.8 |
| 4 | 0.2 | 2.3 | 2.2 |
| 5 | 1.0 | 6.5 | 5.5 |
| 6 | 4.8 | 9.6 | 5.1 |
| 7 | 0.3 | 2.9 | 2.6 |
| 8 | 3.3 | 8.7 | 5.6 |
| 9 | 0.7 | -0.3 | -1.1 |
| 10 | 2.6 | 6.5 | 4.0 |
| 11 | 2.6 | 0.9 | -1.8 |
| 12 | 4.1 | 6.4 | 2.3 |
| 13 | -4.5 | 2.8 | 7.0 |
| 14 | 3.0 | 9.1 | 6.3 |
| 15 | 0.6 | 0.0 | -0.7 |
| 16 | 3.3 | 8.9 | 5.8 |
| 17 | 5.7 | 13.7 | 8.5 |
| 18 | -1.2 | - 1.5 | -0.3 |
| 19 | 0.0 | - 0.4 | -0.4 |
| Means: | 1.6% | 5.3% | 3.8% |
| S.D.: | 2.41 | 4.58 | 3.45 |

APPENDIX S

RAW DATA

WRESTLING STUDY SURVEY

# APPENDIX S

## RAW DATA

## WRESTLING STUDY SURVEY

| Subject Number | Q1 | Q1B | Q2 | Q3 | Q3B | Q4 | Q5 |
|---|---|---|---|---|---|---|---|
| # | 5 | Higher | 5 | 39 | 11 | Yes | Yes |
| # | 5 | Higher | 5 | 19 | 5 | Yes | Yes |
| # | 1 | Ideal | 7 | 50 | 7.5 | No | Yes |
| # | 7 | Ideal | 0 | 0 | 15 | No | No |
| # | 1 | Ideal | 0 | 10 | 8 | Yes | No |
| # | 3 | Higher | 3 | 49 | 6 | No | Yes |
| # | 5 | Ideal | 0 | 0 | 5 | Yes | No |
| # | 4 | Ideal | 4 | 51 | 4 | No | No |
| # | 9 | Ideal | 9 | 101 | 8 | No | Yes |
| # | 4 | Ideal | 3 | Many | 7 | No | Yes |
| # | 5 | Ideal | 0 | Many | 8 | Yes | No |
| # | 1 | Ideal | 6 | 31 | 5 | No | Yes |
| # | 3 | Higher | 4 | 51 | 7 | Yes | Yes |
| # | 4 | Ideal | 4 | 4 | 9 | No | Yes |
| # | 6 | Ideal | 5 | 7 | 5 | No | Yes |
| # | 7 | Higher | 7 | 75 | 6 | Yes | Yes |
| # | 6 | Ideal | 6 | 12 | 15 | Yes | No |
| # | 12 | Ideal | 0 | 0 | 3 | No | No |
| # | 1 | Higher | 9 | 51 | 14 | No | No |
| Means: | 4.68 | NA | 4.05 | 32.35 | 7.82 | NA | NA |
| S.D.: | 2.87 | NA | 2.99 | 29.46 | 3.58 | NA | NA |

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