

ABSTRACT

LENCKI, T. P. The relationship between aerobic and anaerobic capacities in wrestlers. M.S. in Exercise and Sport Science-Human Performance, August 1997, 62pp. (N.K. Butts).

The purpose of this study was to determine the relationships among physical characteristics and aerobic and anaerobic capacities in wrestlers. A group of 15 male athletes between the ages of 18 - 27 years of age from the University of Wisconsin-La Crosse wrestling team volunteered for this study. A $VO_{2\text{ max}}$ test on the cycle ergometer was used to assess aerobic capacity, and the Wingate anaerobic power test assessed anaerobic capacity. The average $VO_{2\text{ max}}$ for this group was $45.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, while the average peak and mean anaerobic powers were 793.3 and 621.3 Watts, respectively. The $VO_{2\text{ max}}$ values fell short of the average when compared to wrestlers in other studies; however, peak and mean anaerobic power values were well above the reported average. A significant ($p < .05$) relationship was found when aerobic capacity was expressed in absolute terms ($\text{L}\cdot\text{min}^{-1}$) to body weight and lean body mass. No significant ($p > .05$) correlations were found when these variables were compared to relative aerobic power. Significant ($p < .05$) relationships were found between mean and peak power and the physical characteristics of height, percent body fat, body weight, and lean body mass. When expressed in absolute terms ($\text{L}\cdot\text{min}^{-1}$) $VO_{2\text{ max}}$ was significantly ($p < .05$) related to mean and peak anaerobic power. These results reveal that an increase in physical size (i.e., height, weight, and lean body mass) contributes to a greater absolute aerobic capacity and anaerobic capacity. The finding that there were no significant ($p > .05$) correlations between relative aerobic and anaerobic capacities of wrestlers in the present study suggests that each energy system acts as its own entity.

THE RELATIONSHIP BETWEEN AEROBIC AND
ANAEROBIC CAPACITIES IN WRESTLERS

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CHAPTER I

INTRODUCTION

Background

Many physical activities involve the interplay of both aerobic and anaerobic energy systems (Butts, 1990). These primary energy systems replenish muscle cells with ATP which allows an individual to continue exercising. The aerobic energy system for producing ATP is dominant when adequate oxygen is delivered into the cell to meet energy production needs, such as when the muscle is at rest or during steady state exercise. Organelles called mitochondria are the sites for aerobic energy (ATP) production (Kosich, 1991). A $VO_{2\max}$ test is the most frequently used method to assess an individual's maximal aerobic capacity (Boulay et al., 1985). This test frequently applies a progressive workload that pushes the individual to exhaustion while directly measuring oxygen uptake (Horswill, 1992).

In contrast, the anaerobic energy system refers to the resynthesis of ATP through chemical reactions that do not require the presence of oxygen (Willoughby, 1993). Without sufficient oxygen, as when a muscle cell needs to generate much force very quickly, such as lifting a heavy weight, the muscle cell shifts to this anaerobic phase. The anaerobic production of ATP occurs inside the cell, but outside the mitochondria.

(Kosich, 1991). A number of testing protocols have been developed for testing anaerobic capacity. Some of these tests include the Wingate anaerobic power test, Margaria-Kalamen power test, vertical jump test, and the 40-yard dash. Despite the numerous protocols there is no single best power test that can be used to measure anaerobic power as compared to the VO_2 max test that is used to obtain aerobic power.

The aerobic and anaerobic energy systems play a crucial role in many sports and physical activities (Butts, 1990). Athletes such as powerlifters, weightlifters, and sprinters predominately use the anaerobic energy system. On the other hand, athletes participating in sports that involve running, cross country skiing, cycling, and swimming for long distances rely primarily on the aerobic energy system. In addition to the different energy systems used, these athletes very often have different physiques.

Training for power (anaerobic capacity) tends to decrease the percentage of body fat by increasing the amount of lean muscle tissue without necessarily changing the absolute amount of fat thereby resulting in an increase in body weight (Horswill, 1992). For example, anaerobic athletes tend to be larger and stronger than aerobic athletes. In 1991, Docherty and Gaul found that body mass (i.e., height and weight) is the strongest predictor of anaerobic performance. In contrast, aerobic training requires considerable expenditure of energy which reduces body fat without necessarily changing the amount of muscle, resulting in a decrease in body weight (Horswill, 1992). Furthermore, Avlonitou (1994) studied a group of swimmers and

found that the mean body weight for long distance swimmers was lower than all other types of swimmers. It can be seen that the energy system an athlete uses most often can have an impact on body mass.

Wrestling is a physically demanding sport that requires both aerobic and anaerobic energy production. Power in wrestlers is associated with quick, explosive maneuvers that lead to control of the opponent. The energy necessary for these maneuvers is derived from phosphagens (ATP-PC) and anaerobic glycolysis. Compared with other athletes, wrestlers' anaerobic performances are more similar to power athletes than endurance athletes (Horswill, 1992). The two most commonly used tests to evaluate the maximum ability of wrestlers to generate power and use the anaerobic energy system are the Margaria-Kalamen stair climb and the Wingate anaerobic power test.

The ability to sustain activity over the course of a match also requires the use of the aerobic energy system. In comparison to other athletes, elite wrestlers have $VO_{2\max}$ values that are average to above average when compared with untrained individuals but are below average compared to endurance athletes (Horswill, 1992). The testing protocol for most studies (Horswill, Scott, & Galea, 1989; Seals & Mullin, 1982; Stine, Ratliff, Shierman & Grana, 1979) consists of running on a treadmill to determine $VO_{2\max}$. It has been suggested by Horswill (1992), however, that a more valuable tool is the evaluation of peak oxygen uptake of segments of the body (i.e., peak oxygen uptake during arm and leg cycling).

Wrestling competition is organized by weight divisions, which provide a wide range in body mass. This range in body mass may result in a difference in aerobic and anaerobic capacities among wrestlers. Although the extent to which athletes use each of these energy systems has been studied, there is limited research regarding the relationship between aerobic and anaerobic capacities. Therefore, this study sought to examine the relationship between aerobic and anaerobic capacities in wrestlers.

Purpose of the Study

The purpose of this study was to determine the relationships among physical characteristics, aerobic capacities measured on a cycle ergometer, and anaerobic capacities as measured by a Wingate anaerobic power test in college wrestlers.

Hypothesis

The hypothesis of this study was: there will be no relationship between aerobic and anaerobic capacities in college wrestlers.

Basic Assumptions

The basic assumptions of this study were:

1. All subjects reached their true $VO_{2\max}$ and performed to the best of their ability during the Wingate anaerobic power test.
2. The Wingate anaerobic power test gives a true measure of anaerobic power.
3. All subjects were healthy at the time of testing.

Delimitations

This study was delimited to:

1. All subjects were members of the University of Wisconsin-La Crosse (UW-L) wrestling team between the ages of 18 - 27 years.
2. The subjects were volunteers and not randomly chosen.

Limitations

The following are limitations to this study:

1. This study consisted of a sample of wrestlers from the UW-L wrestling team.
2. Testing was conducted following the wrestling season.

Definition of Terms

The following terms were used in this study:

Anaerobic Capacity - mean power determined over a 30-second time period during the Wingate anaerobic power test.

College Wrestler - a current (1997) member of the UW-L wrestling team.

Fatigue Index - the rate, expressed as a percentage, at which power output declines during the course of the Wingate anaerobic power test.

Maximal Oxygen Uptake (VO_{2 max}) - the ability of an athlete to generate aerobic power using a progressive workload on a cycle ergometer to exhaustion.

Power - the amount of force, measured in Watts, an athlete can generate in a given period of time.

Wingate Anaerobic Power Test - a test to evaluate the maximum ability of an athlete

to generate anaerobic power during an "all-out" 30-second burst on the cycle ergometer.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

The purpose of this study was to determine the relationships among physical characteristics and aerobic and anaerobic capacities in wrestlers. This chapter provides a review of the aerobic and anaerobic energy systems, their relationship, and the protocols used to measure them. In addition, a physiological profile of wrestlers including aerobic and anaerobic characteristics, as well as body composition, are discussed.

Aerobic Energy System

The aerobic energy system for producing ATP is dominant when adequate oxygen is delivered to the cell to meet energy production needs, such as when the muscle is at rest or during steady state exercise. Organelles called mitochondria are the sites for aerobic energy (ATP) production (Kosich, 1991). This aerobic or oxidative system is a low-power, high capacity system mainly associated with the prolonged exercise of an endurance athlete (Boulay et al., 1985). A number of tests are available to assess the aerobic capacity of an individual. Assessment of aerobic capacity frequently applies a progressive workload test that pushes the athlete to exhaustion while measuring maximum oxygen uptake (Horswill, 1992). A $VO_{2\max}$

test is the most commonly used method to assess an individual's aerobic capacity (Boulay et al., 1985).

Aerobic Testing Protocols

Treadmill ergometry is probably the most popular method for determining the aerobic capacity of an individual and represents an efficient, valid, and reproducible tool for $VO_2 \text{ max}$ testing (McConnell, 1988). McConnell also stated that treadmill running elicits the highest values for $VO_2 \text{ max}$ in most subjects.

McArdle, Katch, and Pechar (1973) evaluated $VO_2 \text{ max}$ during six of the more commonly used continuous and discontinuous treadmill and cycle ergometer tests. Fifteen male undergraduate students from Queens College volunteered as subjects. The following $VO_2 \text{ max}$ tests were used. The first test was a continuous cycle ergometer test that required the subject to pedal at a rate of 60 rpm. The workload was increased $180 \text{ kgm}\cdot\text{min}^{-1}$ every 2 minutes until the subject was unable to continue or the pedal rate dropped below 47 – 50 rpm. The second test was a discontinuous cycle ergometer test that initially required the subject to pedal at 60 rpm at 2 kg for 5 minutes. After a 10-minute rest interval the resistance was increased to 3 kg. It was increased $180 \text{ kgm}\cdot\text{min}^{-1}$ thereafter during each 5 minute run until the subject was unable to continue. The third test used a treadmill ergometer with the Balke protocol. The test began with a treadmill speed of 3.4 mph while the subject walked a zero percent grade for the first 2 minutes. The grade was then raised 2% and increased at a rate of 1% every minute until the subject was unable to continue. The fourth test used

a treadmill ergometer with a slightly different continuous protocol which required the subject to run for 2 minutes at 6 mph at 0% grade. The treadmill elevation was increased by 2.5% for each successive two-minute interval until the subject could no longer continue. The fifth test used a treadmill ergometer with a discontinuous protocol that initially required the subject to walk for 10 minutes at 3 mph at a 10% grade which was followed by a 10-minute rest interval. The subject then ran at 6 mph at a grade of 2.5% for 2 minutes. After another 10-minute rest interval, the treadmill was elevated 2.5% for the next 2 minute, 30-second run. This same procedure of 2-minute, 30-second runs at higher grades with 10-minute rest periods continued until the subject was exhausted. The final treadmill test was also a discontinuous protocol requiring the subject to run at 6 mph for 5 minutes at a 2.5% grade. This was followed by a 10-minute rest period. The grade was then increased by 2.5% for each successive 5-minute run. If the subject completed a 5 minute run he was required to attempt a run at the next higher treadmill elevation. Expired air was collected during each of the last 2 minutes of each 5 minute run at lower elevations and each minute between minutes two through five at higher workloads. The results indicated that all mean values for $VO_2 \text{ max}$ on the cycle ergometer tests were significantly lower than treadmill values. These differences ranged from 10.2 – 11.2% below values on the treadmill running tests and 6.4% below the average $VO_2 \text{ max}$ on the Balke walking test. There was a small difference between the continuous and discontinuous cycle ergometer tests, however, this difference was not significant. In addition, no

significant differences were observed in the comparisons of $\text{VO}_2 \text{ max}$ values between continuous and discontinuous treadmill running tests. However, the mean values for $\text{VO}_2 \text{ max}$ were significantly lower on the Balke walking test in comparison to the three running tests.

In an earlier study, McArdle and Magel (1970) compared $\text{VO}_2 \text{ max}$ during treadmill and cycle ergometry using 23 male students from Queens College. The treadmill protocol began at a speed of 3.4 mph with the subject walking at a 0% grade for the first 2 minutes. The grade was then raised by 2%, with a 1% increase per minute until the subject was unable to continue. In instances where the subject continued walking at the maximum elevation of the treadmill (22%), the speed was increased $0.1 \text{ mph} \cdot \text{min}^{-1}$ until the subject was unable to continue. A $\text{VO}_2 \text{ max}$ was also determined by use of a continuous test on the cycle ergometer. The subjects pedaled at a rate of 60 rpm, with the workload increased by $180 \text{ kgm} \cdot \text{min}^{-1}$ every 2 minutes until the subject was unable to continue. The results show that $\text{VO}_2 \text{ max}$ measured on the cycle ergometer was an average of $.324 \text{ L} \cdot \text{min}^{-1}$ ($4.23 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) lower than treadmill values, with these differences being highly significant. Differences ranged from .5 – 20% below treadmill values in 21 subjects, and 2% and 10% higher in the remaining two subjects. The two subjects having a higher $\text{VO}_2 \text{ max}$ on the cycle ergometer reported to be involved in cycling as a form of outdoor recreation. This suggests that performance on the cycling protocol may reflect a specific muscular development that would favor those individuals training in this form of exercise.

A study by Hermansen and Saltin (1969) using 55 subjects showed that $\text{VO}_2 \text{ max}$ while running on a treadmill uphill was $.28 \text{ L}\cdot\text{min}^{-1}$ higher than on the cycle ergometer (50 rpm). However, the individual variation was large and the difference in $\text{VO}_2 \text{ max}$ between the treadmill and cycle protocols varied from -3.9 to 18.7% . The authors concluded that physical fitness level or type of physical training could have influenced the results.

Predicted $\text{VO}_2 \text{ max}$ Tests

Storer, Davis, and Caiozzo (1990) developed an equation to predict $\text{VO}_2 \text{ max}$ using a standard cycle ergometer graded exercise test. Subjects cycled for 4 minutes at 0 Watts, thereafter, the cycle ergometer work rate increased in $15 \text{ Watt}\cdot\text{min}^{-1}$ increments until the subject reached exhaustion. A formula was developed using maximum Watts generated, body mass (kilograms), and age (years) for each gender.

Similarly, an equation was developed using a 1 mile track walk to determine $\text{VO}_2 \text{ max}$ by Kline et al. (1987). Each subject performed two, 1 mile walks on a measured track. Subjects were asked to walk as fast as possible, with elapsed time and heart rate used for analysis. An equation was developed using time, heart rate, weight, age, and gender. The results indicate that this 1 mile walk test protocol provides a valid submaximum assessment for $\text{VO}_2 \text{ max}$ estimation.

Grant, Corbett, Amjad, Wilson, and Alchison (1995) using 22 male subjects compared the methods of predicting $\text{VO}_2 \text{ max}$. Four aerobic tests including a submaximal cycle ergometer test, maximal treadmill test (criterion measure),

multistage progressive shuttle run test, and a Cooper 12-minute walk/run test were compared. The findings from this study indicate that the Cooper walk/run test is the best predictor of $\text{VO}_2 \text{ max}$ when using the treadmill as the criterion measure.

Anaerobic Energy System

The ATP-CP and lactic acid systems are the primary sources of ATP when there is not an adequate supply of oxygen to meet the needs of the muscle cell; collectively these systems make up the anaerobic energy system. When a muscle cell needs to generate a lot of force very quickly in order to lift a heavy weight or sprint a short distance, the muscle cell shifts to an anaerobic phase to produce ATP (Kosich, 1991). The ATP-CP system is a high power-low capacity system that can replenish ATP stores for a few seconds while the lactic acid system is primarily involved in regeneration of ATP with exercise lasting up to 2 minutes (Boulay et al., 1985). Unlike the determination of aerobic power, anaerobic power has not been so clearly defined or tested. There is no single, widely accepted test to measure this phenomenon (Beckenholdt & Mayhew, 1983).

Anaerobic Testing Protocols

The Wingate anaerobic power test has been accepted in laboratories around the world to assess muscle power, muscle endurance, and fatigability (anaerobic power). The test as described by Inbar, Bar-Or, and Skinner (1996) requires pedaling or arm cranking for 30 seconds at maximal speed against a constant force. This force is predetermined to yield a supramaximal mechanical power and to induce a noticeable

development of fatigue (i.e., drop in mechanical power) within the first few seconds. The test is administered on a cycle ergometer (e.g., Fleisch, Monark, or Bodyguard) with data evaluated and recorded through the use of a microcomputer. The warm-up usually consists of 2 to 4 minutes of pedaling interspersed with two or three "all-out sprints" each lasting 4 to 8 seconds. Subjects begin the test by pedaling as fast as possible, when maximal speed is reached, the tester applies the full load of resistance to begin the 30 second test. The subject is instructed to pedal as fast as possible throughout the 30 seconds. Upon completion of the test a 2 to 3 minute cool-down of pedaling against a light resistance is prescribed.

Choosing a force setting that elicits the highest possible peak and mean power is important. Using a Monark cycle ergometer the Wingate group originally suggested $.075 \text{ kp}\cdot\text{kg}^{-1}$ body mass (Inbar et al., 1996). Evans and Quinney (1981) studied male physical education students and varsity athletes using a modified Monark ergometer. The resistance that yielded the highest mean power was $.098 \text{ kp}\cdot\text{kg}^{-1}$ body mass which is equivalent to $5.76 \text{ J}\cdot\text{Rev}^{-1}\cdot\text{kg BW}$. Murphy, Patton, and Frederick (1985) tested 19 physically active military men to determine the resistance that would elicit maximal values of power output. The mean resistance eliciting the highest peak and mean power outputs were 5.65 and $5.53 \text{ J}\cdot\text{Rev}^{-1}\cdot\text{kg BW}$, respectively.

Esbjornsson, Sylven, Holm, and Jansson (1993) compared males and females with similar training backgrounds with regard to the relationship between anaerobic performance and muscle characteristics using the Wingate anaerobic power test.

Eighteen male and 16 physically active females from a college for sports and physical education volunteered to participate in the study. Subjects performed three 30-second all-out sprints on a cycle ergometer separated by 20-minute rest intervals. The average peak and mean powers for the three tests were taken. Needle muscle biopsies of the quadriceps femoris and vastus lateralis were taken at rest one or two days before the performance test. The results showed peak and mean power values for males to be 927 and 677 Watts, respectively, while female values for peak and mean power were 655 and 459 Watts, respectively. When these data were related to body weight, the differences between genders were smaller. There was no difference between the male and female subjects in either the relative number of the different muscle fiber types or relative fiber type areas, although total cross-sectional fiber areas were larger in males. The authors concluded that anaerobic performance of both males and females is directly related to fast contractile (Type II) metabolic properties of skeletal muscle.

Prior to the Wingate anaerobic power test, Margaria, Aghemo, and Rovelli (1966) developed a test for maximum anaerobic power. The test required subjects to run at top speed up ordinary stairs, two steps at a time. The time it took to cover an even number of stairs was measured using a clock driven by a photoelectric cell that emitted a light beam across the stairs. The running subject interrupted this light beam. The vertical component was calculated by knowing the vertical and horizontal dimensions of the stairs. For measurement of power, the time it took from the fourth

to sixth step was recorded. The results of anaerobic power are generally measured in mechanical work output ($\text{kgm}\cdot\text{kg}\cdot\text{sec}^{-1}$ or Watts). The test does not require a particular skill either from the operator or from the subject, the time required is very short, and the data obtained are very reproducible.

Beckenholdt and Mayhew (1983) compared different tests used to assess anaerobic power. Fifty male athletes representing six sports were used to compare the Margaria-Kalamen (MK) test, vertical jump (VJ), standing broad jump (SBJ), and the 40 yard dash. The MK test was very similar to the one described by Margaria et al. (1966). Electronic switch mats were placed on the third and ninth steps of a staircase with time recorded in 1/100 of a second. The subject approached the steps from 6 meters away and negotiated them three at a time. Time and vertical distance were measured. The VJ was administered through the use of a special platform that held a cloth tape and resistance roller device. The subject had a belt around his waist with a loop that ran between his legs and attached to the cloth tape that was threaded through the roller device. After the tape was drawn tight and measurement recorded, the subject jumped vertically with maximum effort, and the jump distance was recorded. The SBJ began with the subject assuming a position behind a line drawn on a Tartan surface. Simultaneously, the subject jumped off both feet in a horizontal direction as far as possible and jump distance was recorded. The 40-yard dash was run on an indoor track using photoelectric cells at the start and finish to record time. The authors concluded that anaerobic power is not a factor that is easily measured like

VO_2 max. Furthermore, the authors suggested that if the major concern is to move body mass with power, then the VJ and MK tests should be used. On the other hand, if the major concern is power developed through quick movements, short sprints and jumps should be employed.

In a similar study by Mayhew, Bemben, Rohrs, and Bemben (1994), the degree of specificity among selected anaerobic tests in college females was determined. The tests were very similar to those described by Beckenholdt and Mayhew (1983). In addition, the authors described two new tests for measuring anaerobic power for the upper body: the bench press power (BPP) and the seated shot put (SSP). The BPP was a measurement of the time it took to move the lever arm of a Nautilus plate-loaded bench press machine through a .19 meter distance. The weight used was 40% of the subject's one-repetition maximum bench press. The following equation was used to calculate power: $\text{power (W)} = \text{mass (kg)} \times 9.8 \text{ N}\cdot\text{kg}^{-1} \times \text{distance (m)}/\text{time (s)}$. The SSP test required the subject to sit with his/her back against a support with knees flexed at 90 degrees. A 4.5-kilogram shot was used and thrown as far as possible. The average distance thrown was used for analysis. In conclusion, the authors stated that the pattern for the relationships among the various anaerobic power tests using female athletes was similar to that noted by Beckenholdt and Mayhew (1983) for male athletes. Finally, the authors stated that selection of the proper power test depends on the specificity of the test to the sport performance.

Manning, Dooly-Manning, and Perrin (1988) attempted to determine the single

best predictor of anaerobic power. It was found that there is no single anaerobic power test that can be used to measure anaerobic power as compared to $VO_{2\max}$ for obtaining aerobic power. Factor analysis, when applied to numerous field and laboratory anaerobic power tests, showed that unrelated aspects exist among these tests and that they are not measuring similar qualities.

Physiological Profile of Wrestlers

Wrestling is a physically demanding sport that requires an athlete to possess superior strength and endurance (Stine et al., 1979). Both aerobic and anaerobic energy production play an important role in the sport of wrestling. Power in wrestlers is associated with quick, explosive maneuvers that lead to control of the opponent. The energy necessary for these maneuvers is derived from the phosphagens (ATP-CP) and anaerobic glycolysis. The ability to sustain activity over the course of a match also requires the use of the aerobic energy system, therefore, the activity of wrestling is thought to contribute to the development of both anaerobic and aerobic fitness, in addition to technical skill development (Horswill, 1992).

Aerobic Characteristics

In general, wrestlers have $VO_{2\max}$ values between 50-60 $ml \cdot kg^{-1} \cdot min^{-1}$ when measured with a treadmill running protocol (Horswill, 1992). In comparison to other athletes, elite wrestlers have $VO_{2\max}$ values that are average to above average when compared with untrained individuals but are below average compared to endurance athletes (Horswill, 1992). Saltin and Astrand (1967) looked at $VO_{2\max}$ values in

other athletes. It was reported that cross-country skiers had $VO_{2 \max}$ values in excess of $80 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ with distance runners having values between $70\text{-}80 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Swimmers' $VO_{2 \max}$ values average more than $60 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Weightlifters and sprinters have $VO_{2 \max}$ values between $45\text{-}55 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ with the lowest values coming from untrained subjects who averaged just over $40 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Despite the use of the aerobic energy system, it appears that oxygen uptake is not a major determinant of success between successful and unsuccessful wrestlers (Horswill, 1992). Stine et al. (1979) and Horswill et al. (1989) showed that at three levels, Olympic, collegiate, and scholastic, the $VO_{2 \max}$ is not significantly different between successful and less successful competitors.

The protocol for most studies (Horswill et al., 1989; Seals & Mullin, 1982; Stine et al., 1979) consists of running on a treadmill to determine $VO_{2 \max}$. The relevance of such a test to the sport of wrestling should be questioned. According to Horswill (1992) a more valuable tool is the evaluation of $VO_{2 \max}$ using segments of the body (i.e., $VO_{2 \max}$ during arm cranking and leg cycling). It was suggested by Seals and Mullin (1982) that $VO_{2 \max}$ determined on the treadmill is average but the aerobic capacity of the isolated upper body of trained athletes, such as wrestlers, might be well above average. Seals and Mullin looked at the $VO_{2 \max}$ values attained in different types of exercise (i.e., arm cranking, leg cycling, arm and leg cranking, and treadmill ergometry) across groups of non-upper body trained individuals and well-trained upper body individuals. Among the well-trained upper body individuals were

wrestlers. It was found that the $VO_{2\text{ max}}$ ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) values in wrestlers for arm cranking, leg cycling, arm and leg cranking, and treadmill ergometry were 40.6, 45.4, 56.8, and 62.4, respectively. The authors concluded that upper-body trained athletes appear to attain a higher $VO_{2\text{ max}}$ than non-upper body trained individuals whenever the mode of exercise involves substantial use of the upper body musculature. It should be noted that arm and leg cranking combined and treadmill running elicited the highest $VO_{2\text{ max}}$ values across all individuals.

Horswill et al. (1989) examined the physiologic work capacities of elite and nonelite junior wrestlers. The $VO_{2\text{ max}}$ was determined with an incremental treadmill running protocol and was found to be the same, statistically, for both groups. The elite group averaged $52.6\text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ for $VO_{2\text{ max}}$ compared to $51.5\text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ for the nonelite group. These findings are in agreement with Stine et al. (1979) who reported nonsignificant differences between NCAA place winners ($61\text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and qualifiers who did not place in the NCAA tournament (approximately $57\text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$).

A study by Fahey, Akka, and Rolph (1975) measured $VO_{2\text{ max}}$ values and body composition of 30 exceptional athletes, including wrestlers, who trained extensively with weights. A $VO_{2\text{ max}}$ was determined on a cycle ergometer while subjects performed incremental work to exhaustion with the highest $VO_{2\text{ max}}$ values attained by wrestlers ($5.07\text{ L}\cdot\text{min}^{-1}$) and the lowest by bodybuilders ($3.49\text{ L}\cdot\text{min}^{-1}$). The highest $VO_{2\text{ max}}$ value was found in a 165 pound wrestling champion who usually jogs

5–10 miles daily in addition to heavy weight training. The difference in $\text{VO}_2 \text{max}$ between the groups seems to reflect the amount of aerobic activity in their training programs.

Saltin and Astrand (1967) conducted a study that looked at $\text{VO}_2 \text{max}$ in athletes, among which were 10 wrestlers. Subjects who were primarily runners performed their maximal exercise on the treadmill. The rest of the subjects who were bicyclists or supposed to have very strong legs (e.g., weight lifters, wrestlers, cross-country skiers, and sprinters) performed maximal work on the cycle ergometer. The results showed that the wrestlers had a range in $\text{VO}_2 \text{max}$ from 52–64 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Results of other athletes studied found that cross-country skiers had $\text{VO}_2 \text{max}$ values in excess of 80 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, distance runners had values between 70–80 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$, while weightlifters and sprinters had $\text{VO}_2 \text{max}$ values between 45–55 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$.

In 1974, Gale and Flynn examined the $\text{VO}_2 \text{max}$ of high ability wrestlers who tried out for the U.S. Olympic team. The 19 wrestlers varied in height and weight and had a mean $\text{VO}_2 \text{max}$ of 53 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. There were no differences in the means of the aerobic capacities of the 48–100 kg weight classes of those who made the Olympic team and those who did not. These values were found to be lower than those of endurance athletes, but similar to values reported for other wrestlers.

Anaerobic Characteristics

According to Horswill (1992) wrestlers' anaerobic performances are more similar to power athletes than endurance athletes. Most wrestlers, at any level, exceed the

65th percentile of anaerobic capacity and anaerobic power of the legs. On the basis of equivalent bodyweights ($\text{W}\cdot\text{kg}^{-1}$), Bar-Or (1987) reported that distance runners and ultra marathoners have leg power values of 8.9 and 9.3 $\text{W}\cdot\text{kg}^{-1}$, respectively. In contrast, college wrestlers have values of 9.4 $\text{W}\cdot\text{kg}^{-1}$. The two most commonly used tests to evaluate the maximum ability of wrestlers to generate power and use the anaerobic energy system are the Margaria-Kalamen stair climb and the Wingate anaerobic power test.

In 1989, Horswill et al. studied elite and nonelite junior wrestlers to identify physiologic differences that may contribute to success. The Wingate anaerobic test was used to measure anaerobic power. The mean power, peak power, percent fatigue, and mean power relative to bodyweight were calculated. The mean anaerobic power of the legs was 467 and 540 Watts for the nonelite and elite wrestlers, respectively. The average peak power for the elite wrestlers was 672 watts while the non-elite wrestlers averaged 569 Watts. When power was expressed relative to bodyweight the elite wrestlers had an average of 8.6 $\text{W}\cdot\text{kg}^{-1}$ with the nonelite wrestlers at 7.4 $\text{W}\cdot\text{kg}^{-1}$. It was concluded that body composition (i.e., lean body mass and fat weight) and specificity of training of the wrestlers contributed to the differences in anaerobic power. The authors assumed that the elite group had a greater percentage of lean body mass and, therefore, more muscle contributing to force production.

A recent study conducted by Terbizan and Seljevold (1996) investigated the physiological characteristics of 328 wrestlers grouped by age. Some of the

physiological characteristics included: body composition, muscular endurance, flexibility, and aerobic and anaerobic capacities. Anaerobic capacity was tested using the 30-second Wingate anaerobic power test. Workloads were set at approximately $0.05 \text{ kp}\cdot\text{kg}^{-1}$ body mass for the arms and $0.075 \text{ kp}\cdot\text{kg}^{-1}$ body mass for the legs. Mean anaerobic power for the arms was found to be between 363.9 and 432.2 Watts, while leg powers averaged between 475.2 and 542.2 Watts. It must be noted that the older age group (>17 years) achieved the highest mean anaerobic power with the youngest group (<15 years) receiving the lowest mean anaerobic power. In conclusion, the authors stated that this difference in power between age groups was a result of more muscle mass in the older group.

An interesting study by McMurray, Proctor, and Wilson (1991) manipulated the diets of 12 collegiate wrestlers to determine the effect of short term dieting on aerobic and anaerobic exercise performance. The wrestlers were divided into two groups, one receiving a normal dietary composition (NC) and the other receiving a high carbohydrate diet (HC). The Wingate anaerobic power test was used to determine peak and mean anaerobic power as well as fatigue rate with the resistance set at $0.098 \text{ kp}\cdot\text{kg}^{-1}$ body mass. Both groups were pretested and 7 days later posttested. The average pretest scores for the HC group were 790 Watts (peak power) and 638 Watts (mean power), while posttest scores were 802 Watts (peak power) and 640 Watts (mean power). The pretest scores for the NC group were 928 Watts (peak power) and 712 Watts (mean power), while posttest scores were 898 Watts (peak power) and 667

Watts (mean power). Dieting did not significantly alter rate of fatigue of either group. The authors concluded that 7 days of caloric restriction significantly reduced total and mean power output and also a trend in reduction of peak power of the NC group while the HC diet maintained all power measures.

Body Composition

Optimal body composition is a concern of the wrestler because competitors are matched by bodyweight. The majority of wrestlers attempt to maximize the amount of lean body mass, minimize the amount of body fat, and minimize the total bodyweight (Horswill, 1992). This increase in lean body mass, as discussed by Terbizan and Seljevold (1996) and Horswill et al. (1989), can lead to an increased anaerobic power and, therefore, greater success. Body composition of wrestlers has been assessed by using the criterion method of underwater weighing, skinfold thickness, skeletal width measurements, and bioelectrical impedance.

Whether measured in-season or off-season, most wrestlers are very lean possibly due to the year round training and/or their genetic makeup. Off-season values for percent body fat measured by means of hydrostatic weighing and skinfold calipers range from 8-16%, with well-trained subjects typically 3-13% fat (Horswill, 1992). Similarly, Stine et al. (1979) found the competitors at the NCAA Championships to be between 3.7 and 9.2% fat via skinfold calipers. Sinning (1974) examined 35 collegiate wrestlers and found the range to be 4.0 - 20.5% fat with an average of 8.8% fat via hydrostatic weighing. Finally, McMurray et al. (1991) found body fat in

collegiate wrestlers to range from 8.9 - 10.5% fat using the criterion measure of hydrostatic weighing.

Relationship Between Aerobic and Anaerobic Capacities

Relationships can be shown among many fitness variables, including aerobic and anaerobic performance, simply based on body mass. The contribution of the aerobic energy system increases with the increasing duration of anaerobic capacity (Koziris et al., 1996). Oxidative metabolism has been shown to contribute only 3% of the energy produced in a 10-second test, and 9 - 28% in a 30-second test. For a 90-second test, the contribution of the oxidative (aerobic) pathway was shown to be 46% (Serresse, Lortie, Bouchard, & Boulay, 1988).

Recently, Koziris et al. (1996) examined the relationship of aerobic power to anaerobic performance indices using 41 women and 34 recreationally trained men. Aerobic power was assessed via a continuous treadmill protocol while anaerobic power was determined by a Wingate anaerobic power test. To examine aerobic power relationships with anaerobic power at various phases of the test, mean power output was determined for a full 30 seconds: each of the six, 5 second segments, each of the three, 10 second segments, and both 15-second segments. Fatigue was also calculated from the Wingate anaerobic power test. Results indicated that there was a trend of stronger positive relationships with increasing duration of Wingate test segments (i.e., from the first 5 seconds to the first 10 seconds to the first 15 seconds to 30 seconds). Also, the groups showed a trend of stronger positive relationships for subsequent

segments of similar duration (i.e., from the first 5 seconds to the second 5 seconds to the third 5 seconds, etc.). In regards to fatigue a stronger relationship occurred when the fatigue variable involved a segment from the latter part of the Wingate test. This study supports the concept that there is a decreasing role of aerobic power with decreasing duration of an anaerobic power test.

To estimate the contribution of the various energy systems during maximal work of short duration, Serresse et al. (1988), submitted 25 male subjects to a $VO_{2 \max}$ test and 10-, 30-, and 90-second maximal test on a Monark cycle ergometer. Results of the 30-second test indicated that the relative contributions of the energy systems were 23, 49, and 28% for phosphagenic, glycolytic, and oxidative pathways, respectively. For the 90-second test, these estimates were 12, 42, and 46% for the three metabolic systems. During the 90-second test, $VO_{2 \max}$ was reached after approximately 60 seconds. It was concluded that the 30-second and 90-second tests are not strictly anaerobic although they all have large anaerobic components. This meaning that short bursts of intense exercise utilize primarily the anaerobic system, however, it is not used exclusively.

Butts (1990) examined the relationship between aerobic and anaerobic power/capacity in untrained males and females. The $VO_{2 \max}$ was obtained on a cycle ergometer and expressed in absolute terms $L \cdot \min^{-1}$, $ml \cdot kg^{-1} \cdot \min^{-1}$, and $ml \cdot kg^{-1} LBW \cdot \min^{-1}$. Anaerobic capacity was obtained by a "all-out" 30-second burst on a cycle ergometer with a resistance setting of $1.0 N \cdot kg^{-1}$ and $0.9 N \cdot kg^{-1}$ for males

and females, respectively. The following variables were measured for each trial: average absolute power obtained in the 30 seconds, average power output expressed relative to body weight, average power output expressed relative to lean body weight, peak absolute power obtained during the first 5 seconds, peak power output expressed relative to body weight, and peak power expressed relative to lean body weight. It was found that when $VO_{2 \max}$ was expressed relative to body weight and lean body weight, all men's power values were significantly higher than females', with the exception of peak power when expressed relative to lean body weight. Body weight influenced the power outputs differently between the genders. Body weight accounted for 62% of the variance in peak and average power in the females but less than 5% in the males. When peak and average power outputs were expressed relative to body weight there was a significant inverse relationship in the males but no relationship was found in the females. This inverse relationship was also present when male anaerobic power was expressed relative to lean body weight. A positive correlation was found between absolute $VO_{2 \max}$ ($L \cdot \min^{-1}$) and peak power output, however, there was a gender difference. The absolute $VO_{2 \max}$ ($L \cdot \min^{-1}$) values were significantly related to absolute peak and average power in women but not men. In contrast, the men's $VO_{2 \max}$ ($ml \cdot kg^{-1} \cdot \min^{-1}$) values were significantly related to relative peak and average power when expressed relative to body weight. This was not demonstrated in females. The author concluded that there may be a gender difference in the relationship between aerobic and anaerobic energy that is dependent

upon the method of expression.

Katch and Weltman (1979) examined the relationship between anaerobic power output, anaerobic capacity, and aerobic power ($\text{VO}_{2 \text{ max}}$). The $\text{VO}_{2 \text{ max}}$ was determined by using a continuous treadmill ergometer protocol. An all-out cycle ergometer ride for 120 seconds with a frictional resistance of $34 \text{ kp}\cdot\text{rev}^{-1}$ was used to determine anaerobic capacity. The initial 6 seconds of the anaerobic capacity test was used to calculate anaerobic power. Correlations between the three estimates, holding body weight constant, were $r = -0.57$ between $\text{VO}_{2 \text{ max}}$ and anaerobic power output; $r = 0.27$ between $\text{VO}_{2 \text{ max}}$ and anaerobic capacity, and $r = 0.42$ between anaerobic capacity and anaerobic power output. The authors concluded that these data are supportive of a specificity hypothesis regarding the three energy systems. That is, individual differences in the three energy systems are essentially unrelated to each other.

Summary

ATP must be produced in order for muscle to continue working. Muscle cells replenish ATP via the aerobic and anaerobic energy systems (Kosich, 1991). The aerobic energy system works in the presence of oxygen and primarily during activities that are continuous and long in duration. Treadmill and cycle ergometry as well as different types of submaximal exercise tests are the means by which aerobic capacity is measured (Grant et al., 1995; Hermansen & Saltin, 1969; Kline et al., 1987; McArdle & Magel, 1970; McArdle et al., 1973; Storer et al., 1990). The anaerobic

energy system operates in the absence of oxygen and is primarily involved in short sprint and power performances. Common testing protocols for anaerobic capacity include: Wingate anaerobic power test, Margaria-Kalamen stair test, vertical jump, standing broad jump and the 40 yard dash to name a few (Beckenholdt & Mayhew, 1983; Inbar et al., 1996; Margaria et al., 1966; Mayhew et al., 1994).

Wrestling is a physically demanding sport that requires an athlete to possess superior strength and endurance (Stine et al., 1979). Both aerobic and anaerobic energy production play an important role in the sport of wrestling. In general, wrestlers have $VO_{2\max}$ values between 50-60 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ using a treadmill running protocol. These values are average to above average when compared to untrained individuals, but are below average when compared to endurance athletes. Compared with other athletes, wrestlers' anaerobic performances are more similar to power athletes than to endurance athletes. Most wrestlers, at any level, exceed the 65th percentile of anaerobic capacity and anaerobic power of the legs (Horswill, 1992). Body composition of wrestlers has been assessed by using the criterion method of underwater weighing, skinfold thickness, skeletal width measurements, and bioelectrical impedance. Off-season values for percent body fat range from 8-16%, with well-trained subjects typically 3-13% fat via hydrostatic weighing and skinfold calipers (Horswill, 1992; McMurray et al., 1991; Sinning, 1974; Stine et al., 1979). Relationships can be shown among many fitness variables, including aerobic and anaerobic components, simply based on body mass. The contribution of the aerobic

energy system increases with increasing duration of anaerobic power and anaerobic capacity tests (Koziris et al., 1996). When the relationship between aerobic and anaerobic capacity was studied among males and females it was found that there may be a gender difference in the relationship between aerobic and anaerobic energy that is dependent upon the method of expression (Butts, 1990). Finally, Katch and Weltman (1979) are supportive of a specificity hypothesis regarding the three energy systems. That is, individual differences in the three energy systems are essentially unrelated to each other.

In summary, this chapter has attempted to review the literature regarding the aerobic and anaerobic energy systems, the protocols used to measure them, and their relationship with each other. In addition, a physiological profile of wrestlers including aerobic and anaerobic characteristics as well as body composition was discussed.

CHAPTER III

METHODS AND PROCEDURES

Introduction

The purpose of this study was to determine the relationships among physical characteristics and aerobic and anaerobic capacities in wrestlers. This chapter will describe the methods used in: a) body composition determination; b) $VO_2 \text{ max}$ testing; and, c) the determination of anaerobic power using the Wingate anaerobic power test.

Pilot Study

A pilot study was undertaken to verify that all instruments and procedures functioned properly and that the tests were correctly administered. The pilot study included two students from the University of Wisconsin-LaCrosse (UW-L). The subjects signed an informed consent after a written and verbal explanation of the procedures and potential risks had been explained (see Appendix A). The subjects completed a $VO_2 \text{ max}$ test on the cycle ergometer. One week later the subjects were asked to return to complete a Wingate anaerobic power test. Data obtained from the $VO_2 \text{ max}$ test and Wingate anaerobic power test were consistent with that found in the literature. Moreover, the protocol used for each test seemed to challenge the

subject in the appropriate time frame, therefore, no further testing was necessary.

Testing Procedures

Subject Selection

Fifteen members of the UW-L wrestling team between the ages of 18 -27 volunteered for this study. All subjects signed an informed consent prior to participation (see Appendix A) in accordance with University policy.

Testing Schedule

Upon approval by the Institutional Review Board, the subjects were informed of this study at their weekly wrestling meeting. Following a brief explanation of the study, the wrestlers were asked to sign-up for one of the two testing sessions. An informational sheet explaining the testing procedures was handed out to all who agreed to participate (see Appendix B). The subjects were then told that the date and time for the second session would be determined after completion of the first session. The testing sessions lasted approximately 15-30 minutes depending on the test to be taken. The VO_2 _{max} testing session lasted 30 minutes while the Wingate anaerobic power test and the body fat testing session lasted 15 minutes. The sessions were carried out over a period of one month after the wrestling season.

Testing Sessions

The testing was conducted over two sessions. One session included a VO_2 _{max} test on the cycle ergometer. The second session included a Wingate anaerobic power test and measurement of body composition using Harpenden skinfold

calipers. The sessions were conducted as follows:

Session #1 - Upon arrival in the Human Performance Laboratory at UW-L, the subjects were asked to sign a consent form (see Appendix A) and any questions regarding the testing procedures were answered at this time. Following these questions the height and weight of each subject were recorded (see Appendix C). The data for height and weight were entered into the Quinton metabolic cart (Quinton Instrument Co., Bothell, WA) to determine the relative and absolute $\text{VO}_2 \text{ max}$, respiratory exchange ratio (RER), and ventilation (V_E).

$\text{VO}_2 \text{ max}$ Test

The test was performed on a Monarch cycle ergometer according to the following protocol. During the test, all subjects wore a tightly fitted nose clip to prevent the leakage of air from the nose. Expired gas was directed via a rubber mouthpiece and plastic tubing towards a Quinton Metabolic cart (Quinton Instrument Co., Bothell, WA). The gas analyzers were calibrated prior to each test using gases of known percentages, previously determined by the Scholander technique. The calibration of the flow meter was done using a 3,000-liter syringe pump at various flow rates. All subjects received a 5 minute warm-up at a pedaling rate of 60 rpm and a workload of 1 kg ($360 \text{ kgm}\cdot\text{min}^{-1}$) prior to the actual test. Following the warm-up, the subjects performed the maximal test pedaling at a rate of 60 rpm. Initially, the resistance remained at 1 kg and then was increased .75 kg every 2 minutes at 60 rpm until volitional exhaustion. Subjects were verbally

encouraged throughout the test. The test was terminated when two of the following three criteria were met: 1) a plateau or leveling off ($<150 \text{ ml}\cdot\text{min}^{-1}$) of $\text{VO}_2 \text{ max}$ with increasing workload; 2) RER greater than 1.0; or 3) a RPE of 19 and volitional exhaustion. Heart rate was recorded using a Polar Vantage XL heart rate monitor (Polar CIC Inc., Port Washington, NY) and rating of perceived exertion using the Borg scale was recorded at the end of each stage until exhaustion.

Session #2 - Upon arrival to the Human Performance Laboratory, body composition was measured. Body composition was calculated using an equation applicable to the college wrestling population (Sinning, 1974): $D=1.1030 - 0.000815 (\sum 3 \text{ skinfolds}) + 0.0000084 (\sum 3 \text{ skinfolds})$. The triceps, subscapular, and abdomen skinfolds were used for the calculation. Skinfolds were measured three consecutive times and an average taken. The triceps skinfold was measured on a vertical fold on the posterior midline of the upper arm (over the triceps muscle), halfway between the acromion and olecranon processes. The subscapular skinfold was taken on a diagonal line coming from the vertebral border to 1 to 2 centimeters from the inferior angle of the scapula. The abdominal skinfold was measured on a vertical fold taken at a lateral distance of approximately 2 centimeters from the umbilicus on the right side. After the skinfold measurements were taken any questions regarding the Wingate testing procedure were answered at this time.

Wingate Anaerobic Power Test

The test was performed on a Monark cycle ergometer. A desktop computer and software package (Sports Medicine Industries Inc., St. Cloud, MN) were used for timing, control, and data acquisition by reading the output of the counter at the end of each second of the test. The actual test was preceded by a 3 minute warm-up at $300 \text{ kgm}\cdot\text{min}^{-1}$. The warm-up was interspersed by two all out bursts of 4 to 8 seconds resulting in a heart rate of approximately 150-160 bpm. After this warm-up the subject rested for 2 minutes. The test began with the subject pedaling as fast as possible, resistance was added, and the subject continued for 30 seconds. A force setting that would elicit the highest possible peak power and mean power for an athlete was determined. This setting was determined by the following formula: weight of the subject multiplied by .098 (Evans & Quinney, 1981). After 30 seconds the resistance was removed and the subject was instructed to cool-down for an additional 2 to 3 minutes. The following performance variables were calculated: peak power (i.e., the highest 5-second power output) and mean power (the average power during the 30-second test) expressed in Watts. Fatigue index was also calculated as the decrease in power between peak power and the last 5-second power output expressed as a percentage.

Statistical Analyses

Descriptive statistics were used to characterize the subjects. A Pearson product moment correlation coefficient was used to determine the relationship between

aerobic and anaerobic capacities. Statistical analyses were done by computer using the Statistical Package for the Social Sciences (SPSS). The level of significance was set at $p < .05$.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The purpose of this study was to determine the relationships among physical characteristics and aerobic and anaerobic capacities in wrestlers. This chapter includes a presentation and discussion of the data collected.

Physical Characteristics

A group of 15 male subjects between the ages of 18 – 27 years of age from the UW-L wrestling team volunteered to participate in this study. Means, standard deviations, and ranges of their physical characteristics are presented in Table 1. Although percent body fat of subjects in this study was determined using skinfold predictions, findings were very similar to published reports of wrestling populations. Horswill (1992) reported off-season values of percent body fat ranged from 8 – 16%, while well-trained wrestlers range from 3 – 13% body fat via hydrostatic weighing and skinfold calipers. In another study, Sinning (1974) using the criterion measure of hydrostatic weighing examined collegiate wrestlers and found the body fat to range from 4.0 – 20.5%. Finally, McMurray et al. (1991) found a range of 8.9 – 10.5% body fat among collegiate wrestlers via hydrostatic weighing. The differences among these studies may partially be due to the means of measurement. Although hydrostatic weighing was found to be highly correlated with skinfold calipers,

Table 1. Physical Characteristics of Subjects ($N = 15$)

Variable	Mean	Standard Deviation	Range
Age (yrs)	19.6	2.29	18 – 27
Height (in)	68.8	2.70	63 – 73
Weight (kg)	80.5	11.50	65 – 105.91
% Body Fat	12.2	4.18	6.56 – 19.20

variations will occur in percent body fat with the use of these different means of measurement (Verrill et al., 1994).

It must be noted that body fat was measured approximately 3 to 4 weeks after the completion of the wrestling season and the values were still similar to those presented by previous studies. Kelly, Gorney, and Kalm (1978) reported that body fat did not change for college wrestlers during the wrestling season when compared to the off-season. The authors attribute the lack of change to the year round conditioning of the wrestlers. The percent body fat of the wrestlers in this study is comparable to those of other sports where Glada et al. (1996) reported soccer players and bodybuilders to be 11.8 and 12.8 % body fat, respectively. Kohrt, Malley, Dalsky, and Holloszy (1992) and Glada et al. (1996) found the average sedentary male between the ages of 16 and 31 to be 17.3% body fat, which is greater than the values found for wrestlers in this study. This difference is most likely due to the conditioning programs that the wrestlers follow.

Aerobic Characteristics

The means, standard deviations, and ranges for the $VO_{2\max}$ test data are presented in Table 2. The average $VO_{2\max}$ for this group was $45.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ which is quite similar to the values Seals and Mullin (1982) reported for their wrestlers ($45.4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) when using a cycle ergometer protocol; however, these values fall short of the average when other studies are compared. For example, Saltin and Astrand (1967) tested the $VO_{2\max}$ of wrestlers using a cycle ergometer protocol and found $VO_{2\max}$ values to range from $52 - 64 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Similarly, Gale and Flynn (1974) found the average $VO_{2\max}$ of high ability wrestlers to be $53 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. Other results reviewed include $5.07 \text{ L}\cdot\text{min}^{-1}$ (Fahey et al., 1975), $51.5 - 52.6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (Stine et al., 1979), and $57 - 61 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ (Horswill, 1992). It must be noted, however, that the results of the last three studies used a treadmill ergometer as the protocol. It is generally accepted that the $VO_{2\max}$ obtained on a treadmill test averages approximately 10% higher than that during a cycle test (McArdle et al., 1973). In some cases it has been reported to be as much as 21% higher (Hermansen & Saltin, 1969; McArdle & Magel, 1970). When the $VO_{2\max}$ values of wrestlers in this study are compared to those of average individuals and other athletes, the results are mixed. Zutl and Corbin (1977) found the average college freshman to have a $VO_{2\max}$ of $40.2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ using a cycle ergometer. This value is much lower than the $45.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ found for wrestlers in this study. Wrestlers were found to have

Table 2. Means, Standard Deviations, and Ranges of the $VO_{2\max}$ Test

Variable	Mean	Standard Deviation	Range
VO_2 ($L \cdot \text{min}^{-1}$)	3.590	.55	2.72 – 4.46
VO_2 ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$)	45.5	5.44	31.4 – 53.9
VO_2 ($\text{ml} \cdot \text{kg LBM}^{-1} \cdot \text{min}^{-1}$)	51.8	5.81	38.9 – 60.1

similar $VO_{2\max}$ values when compared to bodybuilders ($44.2 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) and sedentary individuals ($42.6 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$); however, when compared to soccer players ($52.4 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), distance runners ($72.7 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), and sprinters ($53.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$), the values are much lower (Glada et al., 1996; Perez, 1981). The lower $VO_{2\max}$ values found in wrestlers when compared to the other types of athletes may be a result of the wrestlers devoting less time to aerobic training. Furthermore, the wrestlers used in this study compete in Division III where skill level may not be as high, which may lead to the lower $VO_{2\max}$ values when compared to other studies.

Anaerobic Characteristics

The means, standard deviations, and ranges of the Wingate anaerobic power test data are presented in Table 3. The average peak power on the Wingate anaerobic power test was 793.3 Watts and average mean power was 621.5 Watts. These values are well above those reported by other studies (Horswill et al., 1989; Terbizan &

Table 3. Means, Standard Deviations, and Ranges of Wingate Anaerobic Power Test

Variable	Mean	Standard Deviation	Range
Peak Power (Watts)	793.3	123.3	594 – 1033
Mean Power (Watts)	621.5	92.8	469 – 773
Peak Power ($W \cdot kg^{-1} BW$)	9.86	.83	8.66 – 11.53
Peak Power ($W \cdot kg^{-1} LBW$)	11.25	1.01	9.85 – 13.13
Mean Power ($W \cdot kg^{-1} BW$)	7.74	.72	6.14 – 8.73
Mean Power ($W \cdot kg^{-1} LBW$)	8.82	.88	7.60 – 10.15
Fatigue (%)	36.08	8.72	19.20 – 47.20

Seljevold, 1996). Horswill et al. (1989) examined elite and nonelite wrestlers ages 14 – 18 and found mean anaerobic power to be 540 and 467 Watts, respectively. The average peak power for elite and nonelite wrestlers was 672 and 569 Watts, respectively. Age must be taken into consideration when comparing these variables. The average age for subjects in the present study was 19.6 years, while ages ranged from 14 – 18 in the study by Horswill et al. (1989). This increase in age may result in a greater percentage and total amount of lean body mass for the subjects in this study. An increase in lean body mass allows for more muscle to contribute to force production. Similarly, Arbizan and Seljevold (1996) looked at anaerobic capacities of wrestlers and found mean anaerobic power to range from 475.2 and 542.2 Watts,

with the highest power occurring in the older age group (i.e., >17 years of age). The authors concluded that the difference in power between age groups is a result of more muscle mass in the older group. The results of a study by McMurray et al. (1991) were more comparable to the results found in this study. McMurray et al. found that collegiate wrestlers on a high carbohydrate diet had an average peak anaerobic power of 802 Watts and a mean anaerobic power of 640 Watts.

It must be noted that the type of training each wrestler uses may have an impact on the amount of anaerobic power produced by each athlete. For example, one particular program might emphasize more weight training rather than cardiovascular training leading to an increased ability to generate anaerobic power.

The force setting used during the Wingate anaerobic power test must also be taken into consideration when comparing results of other studies. A variety of force settings are described in the literature (Evans & Quinney, 1981; Horswill et al., 1989; Inbar et al., 1996; Patton, Murphy, & Frederick, 1985; Terbizan & Seljevoid, 1996). These settings range from $.075 \text{ kp}\cdot\text{kg}^{-1}$ body weight to $.098 \text{ kp}\cdot\text{kg}^{-1}$ body weight. This study used a force setting of $.098 \text{ kp}\cdot\text{kg}^{-1}$ body weight because of its application toward an athletic population. Similarly, McMurray et al. (1991) used a force setting of $.098 \text{ kp}\cdot\text{kg}^{-1}$ body weight giving results similar to those of this study. Selecting the optimal force according to total body mass may not be the best approach, and perhaps fat-free mass or muscle mass may be a better alternative. For practical purposes, however, the use of body mass as a criterion seems reasonable (Inbar et al., 1996).

Correlations Among Physical Characteristics and Aerobic and Anaerobic Capacities

Correlation coefficients among physiological characteristics and results of the aerobic and anaerobic capacity tests are reported in this section. In addition, the correlation coefficients between aerobic and anaerobic capacities are presented and discussed.

Physical Characteristics and Aerobic Capacity

The correlation coefficients between physical characteristics (i.e., body fat, height, and weight) and aerobic capacity are listed in Table 4. As expected significant relationships ($p < .05$) were found between aerobic capacity expressed in absolute terms ($L \cdot \text{min}^{-1}$), body weight, and lean body mass. Thomas, Cox, LeGal, Verde, and Smith (1989) found similar correlations in a study conducted on the Canadian National Judo Team. Judo is a sport very similar to wrestling and involves the use of both aerobic and anaerobic energy systems. It was found that absolute $\text{VO}_{2 \text{ max}}$ ($L \cdot \text{min}^{-1}$) increased significantly ($p < .0001$) with increasing physical size ($r = .81$). These results suggest that an increase in physical size, due to both body weight and lean body mass, contribute to a greater absolute $\text{VO}_{2 \text{ max}}$.

In contrast, no significant ($p > .05$) correlations were found between relative aerobic capacity (expressed in $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and $\text{ml} \cdot \text{kg LBM}^{-1} \cdot \text{min}^{-1}$) and the physical characteristics of body fat, height, weight, and lean body mass. Conversely, Thomas et al. (1989) found a significant ($p < .0005$) inverse relationship between these

Table 4. Correlation Matrix for Physical Characteristics and Aerobic Variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Body weight	--	.69*	.72*	.95*	.55*	-.39	-.14
(2) Height			.36	.73*	.39	-.30	-.19
(3) % Body Fat				.48	.30	-.39	-.01
(4) Lean Body Mass					.60*	-.29	-.13
(5) VO_2 ($\text{L}\cdot\text{min}^{-1}$)						.52*	.69*
(6) VO_2 ($\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$)							.92*
(7) VO_2 ($\text{ml}\cdot\text{kg LBM}^{-1}\cdot\text{min}$)							--

* $p < .05$

variables. The authors speculated that their finding of relative aerobic power being inversely related to physical size was likely a function of a greater proportion of body fat in the larger athletes.

Physical Characteristics and Anaerobic Capacity

The correlation coefficients between physical characteristics and anaerobic capacity are listed in Table 5. Significant relationships ($p < .05$) were found between mean anaerobic power and the physical characteristics of height, percent body fat, body weight, and lean body mass. Significant ($p < .05$) relationships also existed between peak anaerobic power and the same physical characteristics (height, percent body fat, body weight, and lean body mass). These significant relationships between measures of physical size and absolute anaerobic capacity are a good example of how an increase in physical size contributes to a greater anaerobic capacity.

Table 5. Correlation Matrix for Physical Characteristics and Anaerobic Variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) Body weight	--	.69*	.72*	.95*	.75*	-.22	.12	.82*	-.11	.26
(2) Height			.36	.73*	.55*	-.07	.08	.59*	-.01	.17
(3) % Body Fat				.48	.56*	-.14	.33	.55*	-.15	.37
(4) Lean Body Mass					.73*	-.19	.03	.81*	-.06	.19
(5) Mean Power (W)						.46	.70*	.87*	.34	.61*
(6) Mean Power (W·kg ⁻¹ BW)							.88*	.18	.66*	.55*
(7) Mean Power (W·kg ⁻¹ LBM)								.43	.55*	.70*
(8) Peak Power (W)									.46	.72*
(9) Peak Power (W·kg ⁻¹ BW)										.85*
(10) Peak Power (W·kg ⁻¹ LBM)										--

* $p < .05$

Other investigators have also concluded that an increase in muscle mass and/or physical size leads to greater force production (Horswill et al., 1989; Terbizan & Seljevoid, 1996). In contrast, Butts (1990) found no correlations between body weight and peak power ($r = .04$) and absolute power ($r = .04$). The subjects in that study, however, were untrained males while the current study utilized collegiate wrestlers.

In contrast, no significant ($p > .05$) correlations were found when mean ($r = -.22$) and peak powers ($r = -.11$) were expressed relative to body weight. The finding of no correlation between absolute body weight and mean and peak power expressed relative to body weight may be due to the resistance used during the anaerobic power test. Patton et al. (1985) found that large individual variability among subjects exists

when choosing the resistance that produces maximal power output and that load could not be reliably predicted using body weight.

Aerobic Capacity and Anaerobic Capacity

The correlation coefficients between aerobic power ($L \cdot \text{min}^{-1}$, $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$, and $\text{ml} \cdot \text{kg LBM}^{-1} \cdot \text{min}^{-1}$) to absolute and relative peak and mean anaerobic power variables are shown in Table 6. When expressed in absolute terms ($L \cdot \text{min}^{-1}$), $\text{VO}_{2 \text{ max}}$ was significantly ($p < .05$) related to mean ($r = .67$) and peak ($r = .57$) anaerobic power. These were the only significant relationships found among aerobic and anaerobic capacities.

From these results it can be seen that an increase in $\text{VO}_{2 \text{ max}}$ ($L \cdot \text{min}^{-1}$) is related to an increase in anaerobic power. This is evident from the significant correlation between absolute $\text{VO}_{2 \text{ max}}$ ($L \cdot \text{min}^{-1}$) and mean and peak anaerobic powers.

Furthermore, in the present study it was found that as physical size increases so do anaerobic power and absolute $\text{VO}_{2 \text{ max}}$ ($L \cdot \text{min}^{-1}$). This explains the significant relationship between absolute $\text{VO}_{2 \text{ max}}$ and absolute mean and peak powers.

When aerobic and anaerobic variables were expressed relative to body weight, no significant relationships were found. In contrast, Katch and Weltman (1979), using endurance trained subjects, found an inverse relationship between these variables, while Boulay et al. (1985) and Butts (1990) found a positive relationship using

Table 6. Correlation Matrix for Aerobic and Anaerobic Variables

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) VO ₂ (L·min ⁻¹)	--	.52*	.69*	.67*	.20	.35	.57*	.08	.25	-.11
(2) VO ₂ (ml·kg ⁻¹ ·min ⁻¹)			.92*	-.05	.40	.21	-.25	.12	-.07	-.33
(3) VO ₂ (ml·kg LBM ⁻¹ ·min ⁻¹)				.18	.40	.39	-.04	.09	.09	-.36
(4) Mean Power (W)					.46	.70*	.87*	.34	.61*	-.13
(5) Mean Power (W·kg ⁻¹ BW)						.88*	.18	.66*	.55*	-.42
(6) Mean Power (W·kg ⁻¹ LBM)							.43	.55*	.70*	-.40
(7) Peak Power (W)								.46	.72*	.31
(8) Peak Power (W·kg ⁻¹ BW)									.85*	.33
(9) Peak Power (W·kg ⁻¹ LBM)										.30
(10) Fatigue Index										--

*p < .05

untrained individuals. This discrepancy may be due to the enhanced oxidative system and decreased glycolytic muscle metabolism of the endurance trained subjects (Boulay et al., 1985). Based on literature, it was surprising that no significant relationships were found in the present study, as relative aerobic and anaerobic values for wrestlers in the present study were similar to those in the studies by Boulay et al. and Butts.

The finding that there were no significant ($p > .05$) correlations between relative aerobic and anaerobic capacities of wrestlers in the present study suggests that each energy system acts as its own entity. This is in agreement with Boulay et al. (1985), where it was stated that the low common variance between aerobic and anaerobic power suggests that there is considerable specificity between these two properties.

Furthermore, Katch and Weltman (1979) are supportive of a specificity hypothesis regarding the ATP supply systems, which may be due to the nature of the muscle fibers necessary for completion of aerobic and anaerobic type work.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to determine the relationships among physical characteristics and aerobic and anaerobic capacities in wrestlers. A group of 15 male athletes between the ages of 18 - 27 years of age from the University of Wisconsin-La Crosse wrestling team volunteered for this study. The testing was conducted over two sessions. One session included a $VO_{2 \max}$ test on the cycle ergometer to assess maximum aerobic capacity, while the second session included a determination of body composition and the Wingate anaerobic power test to assess maximum anaerobic capacity. Data were analyzed using descriptive statistics and Pearson product moment correlations.

Aerobic Characteristics

The average $VO_{2 \max}$ for this group was $45.5 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ with a range from $31.4 - 53.9 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. According to Seals and Mullin (1982) the average $VO_{2 \max}$ for wrestlers when using a cycle ergometer protocol was $45.4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ which is almost identical to the mean values found in this study. However, these values fall short of the average when results from wrestlers in other studies are compared (Fahey

et al., 1975; Gale & Flynn, 1974; Horswill, 1992; Saltin & Astand, 1967; Stine et al., 1979).

Anaerobic Characteristics

The average peak power on the Wingate anaerobic power test was 793.3 Watts with a range from 594 – 1033 Watts. The average mean power was 621.3 Watts with a range from 469 – 773 Watts. These values are well above those reported for wrestlers by other studies (Horswill et al., 1989; Terbizan & Seljevoid, 1996), but similar to McMurray et al. (1991). The increased power values from wrestlers in this study may be due to a greater amount of lean body mass. This increase lean body mass allows for more muscle to contribute to force production. In addition, the choice of force setting may have had an impact on the power output that was generated.

Physical Characteristics and Aerobic Capacity

Significant ($p < .05$) relationships were found between aerobic capacity expressed in absolute terms ($L \cdot \text{min}^{-1}$) with body weight and lean body mass. These results suggest that an increase in physical size, due to both bodyweight and lean body mass, contribute to a greater absolute $\text{VO}_{2 \text{max}}$. In contrast, no correlations were found between relative aerobic capacity (expressed in $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ and $\text{ml} \cdot \text{kg LBM}^{-1} \cdot \text{min}^{-1}$) and the physical characteristics of body fat, height, weight, and lean body mass.

Physical Characteristics and Anaerobic Capacity

Significant relationships ($p < .05$) were found between mean anaerobic power and

the physical characteristics of height, percent body fat, body weight, and lean body mass. Significant ($p < .05$) relationships also existed between peak anaerobic power and the same physical characteristics (height, percent body fat, body weight, and lean body mass). These significant relationships between measures of physical size and absolute anaerobic capacity are a good example of how an increase in physical size contributes to a greater anaerobic capacity. In contrast, no correlations were found when mean and peak powers were expressed relative to body weight. The finding of no correlation between absolute body weight and mean and peak power expressed relative to body weight may be due to the force setting used during the anaerobic power test since it was directly related to body weight (i.e., $.098 \text{ kp}\cdot\text{kg}^{-1}$ body weight).

Aerobic Capacity and Anaerobic Capacity

The only significant ($p < .05$) relationships found between aerobic and anaerobic capacities occurred when absolute $\text{VO}_2 \text{ max}$ ($\text{L}\cdot\text{min}^{-1}$) was correlated with mean and peak anaerobic power. From these results it can be seen that an increase in $\text{VO}_2 \text{ max}$ ($\text{L}\cdot\text{min}^{-1}$) contributes to an increase in anaerobic power. The relationships between aerobic indices and mean anaerobic power, when expressed relative to body weight and lean body mass, were not significant ($p > .05$). Furthermore, the correlations between aerobic indices and peak anaerobic power were not significant ($p > .05$). The finding that there was no significant ($p > .05$) correlation between relative aerobic and anaerobic capacities in the present study suggest that each energy system acts as its own entity. This is in agreement with Boulay et al. (1985), where it was stated that

the low common variance between aerobic and anaerobic power suggests that there is considerable specificity between these two properties.

Conclusions

The results of this study indicate that the mean values for aerobic capacity were lower than the averages found for wrestlers in most other studies. However, anaerobic capacities were found to be higher when compared to other wrestlers. These differences could be explained by the diversity of subjects (i.e., age and skill level of wrestlers) that were examined in other studies, as this study dealt with only a Division III collegiate population. Also, testing was conducted in the off-season when the subjects may not have been as physically fit. Furthermore, the variety of force settings used during the Wingate anaerobic power test may have an impact on the maximal power output obtained by wrestlers.

The only significant correlation between aerobic and anaerobic capacity was found when both were expressed in absolute terms. These results reveal that an increase in physical size (i.e., height, weight, and lean body mass) contributes to a greater absolute aerobic and anaerobic capacity. This increase is likely due to the increased amount of lean body mass to consume oxygen as well as a greater ability to produce force. When aerobic and anaerobic capacity are expressed in relative terms, no significant correlations were found. This finding suggests that each energy system acts as its own entity; however, no energy system is responsible for 100% of the work.

Practical Implications

It can be seen that there is some overlap between the use of each of the three energy systems during activity. However, to properly train a specific energy system, one must employ a training strategy based on the energy system used most frequently. Wrestling is a unique sport in that it uses both the aerobic and anaerobic energy systems. It is important for a wrestler to train each of these systems separately in order to be successful.

Recommendations for Future Studies

Based on the results of this study, the following recommendations for further research are made:

1. Conduct this study during the wrestling season to get a better estimation of aerobic and anaerobic capacities.
2. Expand the testing procedures to include the use of an upper body power and/or aerobic test. The use of these additional tests may provide different results due to the extensive use of the upper body in the sport of wrestling.
3. Use a treadmill ergometer protocol to assess aerobic capacity. This would allow for a better comparison with other studies, as many use the treadmill protocol.
4. Body fat should be determined using the gold standard of hydrostatic weighing.

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APPENDIX A
INFORMED CONSENT

INFORMED CONSENT

The Relationship Between Aerobic and Anaerobic Capacities in Wrestlers.
Principle Investigator: Tim Lencki

I _____, have volunteered in this study to determine the relationship between aerobic and anaerobic capacities in wrestlers. I am aware that involvement in this study will require me to participate in one VO_2 max test on a cycle ergometer as well as one Wingate anaerobic power test.

The VO_2 max test will consist of a five minute warm-up at a workload of 1 kg ($360 \text{ kgm}\cdot\text{min}^{-1}$) and a pedaling rate of 60 rpm. Following the warm-up, the test will begin at the same rate and workload, however the workload will increase .75 kg every two minutes until I reach volitional exhaustion. During this test my heart rate will be monitored using a Polar Vantage XL heart monitor. Additionally, I will be required to inhale and exhale air out of a mouthpiece. The Wingate anaerobic power test will involve a short, no longer than 30 second, all-out effort on a cycle ergometer after an adequate warm-up period. The resistance will be based on my individual body weight.

Associated with any exercise are risks such as dizziness, shortness of breath, nausea, and fainting. The Wingate anaerobic power test may make my legs sore as would any high intensity, short duration activity. I understand that I will feel a considerable amount of fatigue following these tests, however, I can terminate the test at any time without penalty. All data obtained from this test will be held confidential, but may be used for publication purposes in anonymous form using only group data.

Time will be allowed for me to thoroughly stretch to help minimize the risk of injury. As mentioned earlier, a five minute warm-up will be given prior to the VO_2 max test and the Wingate anaerobic power test. During the stretching and warm-up period I will be able to ask the experimenter any questions I might have. The questions will be answered to the best of the experimenter's ability.

I acknowledge that I have read and fully understand all the statements above. I also acknowledge that all my questions to this point have been answered, therefore, I give my full consent to participate in this study.

Signed: _____ Date: _____

Witness: _____ Date: _____

APPENDIX B

TESTING INFORMATION SHEET

TESTING INFORMATION

CONTACT PERSON - TIM LENCKI 788-1287

- THE TESTING WILL BE COMPLETED OVER TWO DIFFERENT SESSIONS. (TOTAL TIME OF APPROXIMATELY 45 MINUTES)
- ONE SESSION WILL BE A VO_2 MAX TEST AND THE OTHER SESSION WILL CONSIST OF A WINGATE ANEROBIC POWER TEST AS WELL AS THE DETERMINATION OF BODY COMPOSITION USING SKINFOLD CALIPERS.
 1. THE VO_2 MAX TEST WILL BEGIN WITH A FIVE MINUTE WARM-UP FOLLOWED BY THE ACTUAL TEST ON A CYCLE ERGOMETER PEDALING TO EXHAUSTION. THE RESISTANCE WILL BE INCREASED EVERY TWO MINUTES. THIS SESSION SHOULD LAST 30 MINUTES.
 2. THE WINGATE ANAEROBIC TEST WILL BEGIN WITH A THREE MINUTE WARM-UP ON A CYCLE ERGOMETER FOLLOWED BY A TWO MINUTE REST PERIOD. THE ACTUAL TEST WILL BE AN ALL-OUT 30 SECOND BOUT ON THE CYCLE ERGOMETER. THE RESISTANCE WILL BE SET ACCORDING TO YOUR WEIGHT. THIS SESSION WILL LAST 15 MINUTES.
- I WOULD SUGGEST THAT YOU WEAR SHORTS AND A T-SHIRT ALONG WITH A PAIR OF RUNNING SHOES. IF YOU WANT TO TAKE A SHOWER THEN BRING A TOWEL.
- REMEMBER THAT THE BEST AEROBIC AND THE BEST ANAEROBIC SCORE WILL RECEIVE A \$ 10.00 GIFT CERTIFICATE FROM PIZZA HUT.
- THANK YOU FOR YOUR HELP. IT IS VERY MUCH APPRECIATED.
- THE DAY AND TIME OF THE SECOND SESSION WILL BE DETERMINED AT THE END OF THE FIRST SESSION.

THE DAY AND TIME OF YOUR FIRST SESSION IS:

APPENDIX C

VO₂ MAX, WINGATE, AND BODY COMPOSITION DATA SHEET

VO₂ MAX, WINGATE, AND BODY COMPOSITION DATA SHEET

Name _____

Height _____ Weight _____

Age _____ Max Heart Rate _____

<u>Stage</u>	<u>Resistance</u>	<u>RPE</u>	<u>HR</u>
Warm-up	_____	_____	_____
1	_____	_____	_____
2	_____	_____	_____
3	_____	_____	_____
4	_____	_____	_____
5	_____	_____	_____

Actual VO₂ MAX _____

WINGATE ANAEROBIC POWER TEST

Weight _____ Workload _____

Peak Power _____ Mean Power _____ Fatigue Index _____

BODY COMPOSITION

Tricep skinfold _____

Sum of 3 skinfolds _____

Subscapular skinfold _____

Percent body fat _____

Abdomen skinfold _____

Equation used: $D = 1.1030 - 0.000815 (\Sigma 3 \text{ skinfolds}) + 0.00000084 (\Sigma 3 \text{ skinfolds})$