THE COMPARISON OF THE MAX JONES QUADRATHLON WITH THE VERTICAL JUMP AND WINGATE CYCLE TESTS AS A METHOD TO ASSESS ANAEROBIC POWER IN FEMALE DIVISION I COLLEGE BASKETBALL PLAYERS

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The purpose of this study was to determine whether a significant relation existed between the Max Jones Quad test and two established anaerobic power tests in female Division I basketball players. A secondary purpose was to develop models to predict:

1. Anaerobic power (as measured by the Wingate cycle and vertical jump tests) using anthropometric measures and components of the Max Jones Quadrathlon
2. Basketball performance from anaerobic power (as determined by the Vertical Jump, Wingate cycle, and Max Jones Quadrathlon tests).

Thirteen members of the University of Pittsburgh Women's Division I basketball team were recruited for this investigation and had the support and approval of the University of Pittsburgh Department of Athletics, head women's Basketball Coach, and strength and conditioning coach. The women's basketball team met for testing on three separate days. On the first day, anthropometric measurements and the vertical jump test were performed. Peak and mean anaerobic power were determined using equations based on each subject's individual vertical jump height in centimeters (cm), body mass in kilograms (kg), and height in centimeters (cm). On the second day, the Max Jones Quadrathalon Test was performed, which consists of four stations: 1) standing broad jump, 2) 3 consecutive broad jumps, 3) overhead shot put toss, and 4) 30 meter sprint. The standing broad jump, 3 consecutive broad jumps, and overhead shot put toss were measured in meters (m) and centimeters (cm), while the 30 meter sprint was timed in seconds. On the third and final day, the subjects performed the 30-second Wingate cycle ergometer test. Peak and mean anaerobic power, as well as the fatigue index (percent change) over the 30-seconds, were calculated by a computer program during the test. Relationships between the Max Jones Quadrathlon total score and anaerobic power determined by the Vertical Jump and Wingate cycle tests were not significant. A significant relationship was found between anaerobic power on the Wingate cycle test and the 30 meter sprint ($p<0.05$), but with no other components of the Max Jones Quadrathlon for either anaerobic power test. Additionally, correlations between vertical jump height and Max Jones Quadrathlon components were found to be significant ($p<0.05$ and $p<0.01$). Models to predict anaerobic power from anthropometric measures and Max Jones Quadrathlon components and models to predict basketball performance from anaerobic power were created. Several equations for each case were deemed significant ($p=0.000$) for predicting either anaerobic power or basketball performance in female players. This was the first study comparing the Max Jones Quadrathlon to established tests to measure anaerobic power. The preliminary results of the present study did not establish a relationship between the Wingate Cycle and Vertical Jump Tests and the Max Jones Quadrathlon. There exists a need to explore updated and sport specific measurement techniques.

PREFACE

The author would like to acknowledge the committee members: Dr's Elizabeth Nagle-Stilley, Fredric Goss, Robert Robertson, and James Irrgang for their continued support throughout this investigation. I would like to extend a special thanks to Dr. Nagle who has advised me and worked with me from the start. Through the ups and downs of the dissertation process, she was always there as my number one supporter and as a superb mentor. I would like to thank Dr. Thomas Loughran for his help in the statistical analysis component of this investigation. I would also like to thank Tim Beltz for his help in the development of this investigation and subject recruitment and Jeffrey Murphy for his help in data collection. Finally, I would like to thank my family and friends for continuously supporting me during this educational undertaking. I would especially like to thank my parents, Samuel and Eileen, for always being there to support me in every endeavor I decided to tackle. You have always given me direction in my life and continue to be my inspiration.

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CHAPTER 1

INTRODUCTION

Rationale

Identifying critical components of athletic performance and the ability to track and monitor improvements is a goal and priority for those involved with sports and athletics, both on the amateur and professional levels. Such components can be considered both physiological and psychological in nature. A physiological measure that incorporates cardiovascular, neuromuscular, and metabolic components is required to determine anaerobic power, an integral contributor to athletic performance (Brooks et al, 2000). Anaerobic power involves the exertion of force through a given distance in as short a time as possible (Beckenholdt and Mayhew, 1983). The ability of the body's musculature to generate significant amounts of power is considered to be a strong predictor of athletic success (Bompa, 1993). Currently anaerobic power tests are implemented in both clinical and field settings and assess an athlete's capability to produce both power and speed in a short period of time or over a relatively short distance.

Determining an individual's maximal oxygen uptake (VO_2 max) has long been acknowledged as a valid and reliable test for determining aerobic power and capacity (Powers and Howley, 1996; Foss and Keteyian, 1998; Brooks et al., 2000). Recently, as a clinical measure, the Wingate anaerobic power test on a cycle ergometer has been considered the most valid and reliable test in assessing peak power and anaerobic capacity (Adams, 1998; Inbar et al., 1996; Powers, 1996). The most common field tests used to evaluate anaerobic power and performance in athletes are the vertical jump test and the 40-yard dash. During the vertical jump, total jump height and peak power can be measured (Adams, 1998; Brooks, 2000). In the 40 yard dash, an inverse relationship suggests that lower (faster) time is usually associated with higher power output and anaerobic capacity (Adams, 1998). However, an anaerobic test to assess power needs and output for athletes participating in particular sports has neither been established nor validated by researchers in an athletic performance setting.

In order to assess the anaerobic characteristics that an athlete possesses, sport specific activities must be integrated. Specificity of training is defined as "principle underlying construction of a training program for a specific activity or skill and the primary energy system(s) involved during performance" (Foss and Keteyian, 1998). The most valid measures of performance use sport specific skill components that are closely related to the sport itself (Brooks et al., 2000). Functional movements that are utilized and are considered an integral part of a given sport should be addressed when deciding on an appropriate test. Sport specific functional movements that may require short bursts of speed and change of direction should be incorporated into methods that measure anaerobic power.

Basketball is a prime example of a sport that predominantly utilizes anaerobic metabolism (Foss and Keteyian, 1998; Hoffman et al., 2000; Hoffman et al., 1999) that would benefit from anaerobic testing procedures which incorporate sport specific movements. Although considered a team sport, individual play in basketball requires jumping, sprinting speed, agility, muscular strength and endurance, hand-eye coordination, as well as both anaerobic and aerobic metabolism (Hoffman et al., 2000). Functional movements, such as jumping and sprinting, are significantly related to playing time and performance in basketball (Hoffman et al., 1996). Therefore, it seems logical that testing procedures that incorporate anaerobic power and sport specific movements would provide a valuable tool to assess and monitor components of basketball performance.

To date, numerous tests have been used in an attempt to successfully measure anaerobic power and output in basketball players, however no particular test has gained acceptance as a standard measure of anaerobic power in basketball players. The following tests have been used to evaluate anaerobic capacities of both male and female elite and collegiate basketball players:

1. Wingate anaerobic cycle test
2. Vertical jump test
3. 30 yard sprint test and a 40 yard sprint test
4. Standing broad jump
5. Anaerobic line drill test
6. Seated shot put test

(Hoffman et al., 1999; Koziris et al., 1996; Ashley and Weiss, 1994; Bale, 1991; Hoffman et al., 1996; Hoffman et al., 2000; Johnson and Bahamonde, 1996; Mayhew et al., 1994)

The Max Jones Quadrathalon, or Quad test, was developed in 1982 by Max Jones, a national Olympic throws coach for England's Track and Field team. The Quadrathalon was devised to test explosive power improvement of the Great Britain National Throws Squad (Dunn and McGill, 2003). Considered relatively easy to administer, the Quadrathalon had been used primarily to test Division I track and field and football athletes. When first developed, it was intended that the test be used to gauge an athlete's improvements in power throughout the off-season. The Quadrathalon consists of a series of drills that are used to assess an athlete's level of speed, strength, explosiveness, and power. The test drills include: 1) Standing long (broad) jump for distance, 2) Three consecutive standing long (broad) jumps for distance, 3) Thirty meter sprint for time, and 4) Sixteen pound overhead shot-put throw for distance. The athlete's time to completion or distance covered for each given section can be converted into a numerical score found in the standardized testing tables.

Previously, the Quad test has been used primarily as a testing device to evaluate power outputs of male athletes only (Dunn and McGill, 2003). This is also the case with previously validated Wingate cycle ergometer (Vandewalle et al., 1985; Murphy et al., 1986; Maud and Shultz, 1986; Koziris et al., 1996) and Vertical jump tests (Maud and Shultz, 1986; Bale, 1991; LaMonte et al., 1999). Due to the lack of research performed on female athletes, the quantity of the data available is lagging (Inbar et al., 1996) and particularly evident in the sport of basketball.

Statement of the Problem

The purpose of this investigation will be to determine whether a significant relationship existed between the Max Jones Quad test and its components and the: 1) Wingate cycle ergometer test; and 2) Vertical jump test in female basketball players.

Subproblem

It was a subproblem to establish models to predict the following:

3. Anaerobic power (as measured by the Wingate cycle and vertical jump tests) using anthropometric measures and components of the Max Jones Quadrathlon

4. Basketball performance from anaerobic power (as determined by the Vertical Jump, Wingate cycle, and Max Jones Quadrathlon tests).

Significance of Study

To date, the Max Jones Test has not been compared to established anaerobic power tests, and therefore cannot be used as a valid evaluation of anaerobic power. The Max Jones Quadrathalon has only been used previously to assess power performance in male track and field athletes and football players in non-research settings. The Quadrathalon has not been used to evaluate the power performance of female athletes, and in particular basketball players. It is anticipated that the Quadrathalon will be a more effective testing tool in assessing anaerobic power in basketball athletes since it presents components that are more sport specific. The Quadrathalon test scores can provide a coach as well as the sports performance team with vital information that may help evaluate anaerobic fitness improvements, performance characteristics by position, as well as assist with the modification and improvement of existing training protocols. Additionally, the need for anaerobic power testing in the field of women's athletics is a growing area of interest. There is an increasing need to identify performance characteristic in female athletes and to examine how they differ from their male counterparts. The findings of the present investigation will be considered an initial step towards identifying the accuracy of the Max Jones Quad test for future research investigations.

CHAPTER II

LITERATURE REVIEW

Background

The primary purpose of this investigation was to examine the relationship of the Max Jones Quadrathalon as an anaerobic test in female basketball players to the Wingate anaerobic cycle ergometer and the vertical jump tests. It was a subproblem to establish models to predict the following:

5. Anaerobic power (as measured by the Wingate cycle and vertical jump tests) using anthropometric measures and components of the Max Jones Quadrathlon
6. Basketball performance from anaerobic power (as determined by the Vertical Jump, Wingate cycle, and Max Jones Quadrathlon tests).

Anaerobic Power

The term anaerobic means "in the absence oxygen" and the term power can be considered "the rate of performing work." Power is defined as "the weight or mass of an object being moved times the vertical distance the object is moved divided by the time it takes to move the given object" (Fleck and Kraemer, 1997). By definition, anaerobic power, or anaerobic fitness, represents a local characteristic of a muscle that exists independent of blood and oxygen supply to that muscle (Foss and Keteyian, 1998). Brooks et al. (2000) chooses to refer to anaerobic power as "high-intensity exercise," instead of the most common nomenclature. This term avoids linking this type of exercise with strictly anaerobic metabolic pathways. Collectively, the anaerobic power produced during a muscular contraction (concentric) depends on both force and velocity factors.

Measurement of Maximal Power

The relationship between force and velocity is hyperbolic (Hill, 1938) or exponential (Fenn and Marsh, 1935). The maximal power that a muscle is able to generate is obtained at optimal values of force and velocity (Vandewalle et al., 1987). Three ranges, or zones, can be distinguished on the force-velocity-power continuum dealing with the relationship of the three components. Maximal power is obtained in a narrow range of forces (zone 2) where force and velocity are at their optimal levels. Zone 1 corresponds to high velocity exercises with low power output. In zone 3, force is too heavy and velocity is too low, which does not enable maximal power to be generated.

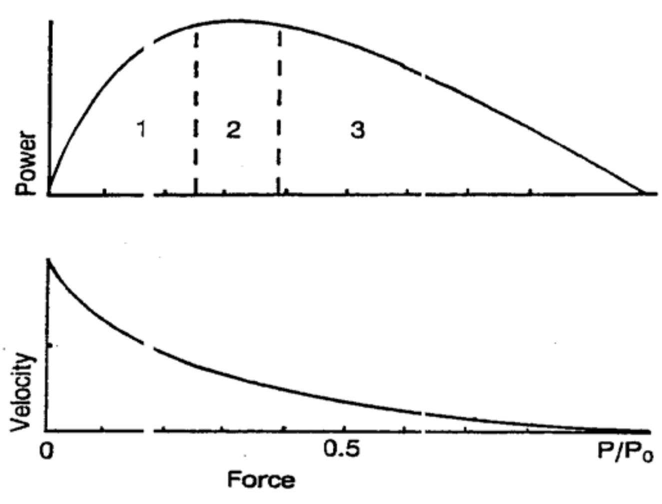

Figure 1. Force-velocity and force power relationship during *in vitro* muscle shortening. (Vandewalle et al., 1987).

Upon the determination of the mechanisms responsible for development of power, short-term, anaerobic power tests were originated to assess maximal power development by active muscle.

History of Anaerobic Tests

A prevailing lack of interest in anaerobic performance as a component of health and fitness has led to the development of anaerobic tests used today. This was due, in part, to a lack of a valid and easily administered laboratory test. Currently, anaerobic performance tests similar in comparison to the treadmill tests used for prediction of maximal oxygen uptake (VO_2) do not exist (Inbar et al., 1996).

The oldest documentation of short-term muscle force activity was the Sargent Vertical Jump Test (Sargent 1921). Mechanical work performed to accomplish the jump could be determined by using the distance that was measured. However, power could not be calculated since the time that force acted on the body was unknown. It was determined that the calculation of power utilized during a vertical jump could only be measured through the use of a force plate (Davies and Rennie, 1968).

Margaria et al. (1966) established a running-step test which allowed peak mechanical power to be determined over a period lasting less than one second. This test examined muscle energetics during supramaximal, short-term exercise. The Wingate Anaerobic Test (WAnT) was developed in 1974 at the Wingate Institute for Physical Education and Sports in Israel (Bar-Or, 1987). The Wingate Test is performed on a cycle ergometer and lasts thirty seconds in duration. The test was developed to assess muscular power, endurance, and fatigability (Inbar, 1996).

Despite the introduction of the previously mentioned anaerobic power tests, research in the area of anaerobic performance is still lacking. Even today, health professionals and fitness appraisers exclusively associate physical fitness and work capacity with only aerobic fitness. Reasons associated with a lack of interest in measuring anaerobic power to assess fitness levels include: the lack of motivation of subjects, use of suboptimal resistance when calculating power output, measuring mean power rather than peak power, and the limitation of exercise equipment (Brooks et al., 2000). Yet it should be emphasized that there are specific characteristics of physical performance that can only be addressed by using short duration, anaerobic power tests because they require fast-acting metabolic pathways.

Characteristics of Anaerobic Power Tests

Anaerobic performance tests involve the measurement of high-intensity exercise ranging from a fraction of a second to several minutes (Skinner and Morgan, 1985). Very brief anaerobic tests are those lasting one to ten seconds in duration. These include step tests, jumping tests, and short running or cycling sprints. Brief anaerobic tests are those lasting twenty to sixty seconds in duration. Tests falling in this category primarily use either an arm/leg cycle ergometer or a treadmill as the assessment tool. Most anaerobic tests are considered reliable if the subjects participating in the investigation are a properly motivated homogeneous sample.

There appears to be conflicting opinions between tests concerning what exactly each assessment measures. First, it is thought that there is no true “gold standard” with which to compare test results. Unlike submaximal and maximal VO_2 aerobic tests, there are no accepted criteria for what should be measured and how it should be measured when dealing with anaerobic tests (Inbar et al., 1996). Second, the diversity among anaerobic tests and laboratory protocols demand differing measurement devices to be used. The apparent differences in measurement accuracy and terminology make it difficult to not only compare results of different assessments, but also to compare the same anaerobic tests performed in separate laboratories. Lastly, anaerobic tests must assess components of anaerobic fitness that deal with the population of the subjects used in the assessment. The present investigation proposes to show that sport specific anaerobic tests incorporating running, jumping, and agility movements would be more beneficial in assessing power outputs in female basketball players. However, current tests that most closely address power output assessments in both basketball and non-basketball players must first be examined.

The Wingate Anaerobic Test

The Wingate Anaerobic Test (WAnT) was developed at the Wingate Institute for Physical Education and Sport, Isreal, during the early 1970's. Since its inception in 1974 (Ayalon et al., 1974), the Wingate anaerobic test has been used in laboratory settings both as an assessment of anaerobic performance and as a means to analyze physiological responses to supramaximal exercise (Bar-Or, 1987). At that time, there was a growing need for the development of an anaerobic test that allowed researchers to accurately assess the anaerobic performance of both the general public and athletes, alike. Bar- Or (1987) stated that the test was designed to be simple to administer; inexpensive; used with easily accessible equipment; non-invasive; intended to measure muscle performance; feasible for administration to a wide variety of population. The Wingate test was not designed to replace biochemical analysis of anaerobic metabolism or to investigate the basic properties dealing with muscle contractility.

Measurement Indices

The Wingate Anaerobic Test requires a subject to pedal for thirty seconds at a maximal speed against a constant force on an arm or leg cycle ergometer. The force used is predetermined based on the individual's gender and fitness level. It is intended to yield a supramaximal mechanical power and to induce a substantial amount of fatigue in the exercising musculature (a subsequent drop in mechanical power) within the first few seconds (Inbar, 1996). Bar-Or (1987) describes three performance indices that are measured by the Wingate test:

1) Peak power (PP) is the highest mechanical power elicited during the test which typically occurs in the first few seconds; this index is usually taken as the average power displayed over any three too five second period (Measured in watts (W).
2) Mean Power (MP) is the average power that is sustained throughout the thirty second period (Measured in watts (W).
3) Rate of Fatigue (Fatigue Index or FI) is the degree of power drop-off during the thirty second test (Measured as a percentage).

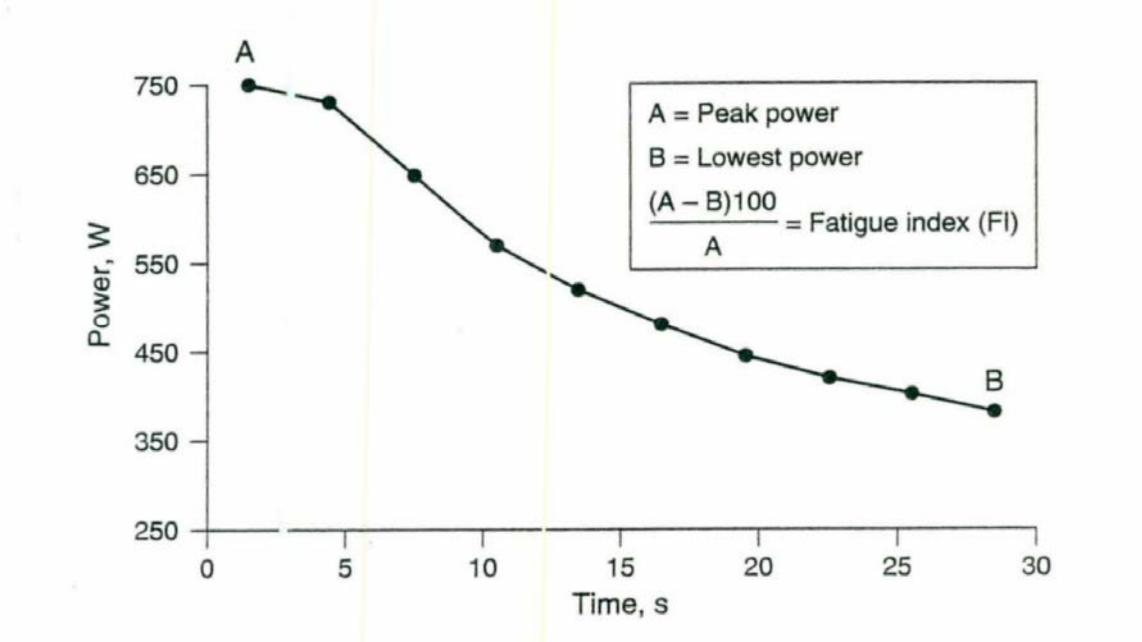

Figure 2. A typical Curve for the Wingate Anaerobic Test (Inbar et al., 1996.)

It is safe to assume that peak power is a reflection of the ability of either the arms or the legs to produce high amounts of mechanical power in a short time (seconds). Mean power reflects the endurance of the muscle groups involved in the test, either upper or lower body musculature, and their ability to sustain extremely high power output over thirty seconds.

Wingate Protocol

The simplest way to administer the Wingate anaerobic test is through the use of a mechanical ergometer and a stopwatch. Pedal revolutions can be visually counted and recorded for each five-second stage of the test. More sophisticated techniques currently used incorporate the use of electromagnets interfaced to computers (Bar-Or, 1987). Preceding the start of the test, a five to ten minute intermittent warm-up is a sufficient amount of time to allow for increased blood flow, muscular warming, and motor adaptations. A shorter warm-up has also been used consisting of two to four minutes of pedaling interspersed with two to three maximal sprints each lasting four to 8 seconds. A three to five minute rest period typically follows the warm-up to eliminate fatigue before the start of the actual test

The subjects are given a “start” command at the onset of the test, at which time they begin to pedal at a maximum speed. A minimal resistance caused by the inertial and frictional resistance of the flywheel must be overcome to allow for top speed to be reached, usually occurring after the first three to five seconds. Once the subject reaches the maximal speed needed to overcome the initial resistance, the predetermined load can be applied and the test can begin. As soon as the resistance is applied, the revolutions are counted by an observer or by a computer for each five second interval and for the entire thirty seconds. Verbal encouragement should be given throughout the duration of the test and especially during the final ten to fifteen seconds (Inbar et al., 1996). At the conclusion of the test, a three to five minute cool down will allow the lactic acid accumulated during the high-intensity test in the active muscles to be shuttled into the circulatory system (Inbar, 1996). The cool down will reduce the muscle soreness that follows high intensity exercises and will decrease the accumulation of metabolic waste.

Load Optimization

For the Wingate test, a force setting should be chosen that will elicit the highest possible peak and mean power for each subject. Assuming the test was performed on a Monark ergometer, Ayalon et al. (1974) suggested that a force setting of 0.075 kp per kg body mass (0.075 $kp \cdot kg^{-1}$) be used. This force is equivalent to a mechanical work measurement of 4.41 Joules per pedal revolution per kg body mass (4.41 $J \cdot rev^{-1} \cdot kg^{-1}$). While this load resistance was chosen based on a study conducted on a small group of young untrained individuals, it was apparent that this initial work setting was too low to obtain maximal power outputs in adult subjects. Subsequent studies revealed that the optimal force setting should be higher than originally suggested by Ayalon et al. (1974).

In a study performed by Evans and Quinney (1981), twelve male physical education and varsity athletes performed cycle tests at various resistances on a modified Monark ergometer. It was shown that the resistance (group average) that yielded the highest mean power (MP) was 0.098 $kp \cdot kg^{-1}$, which is equivalent to 5.76 $J \cdot rev^{-1} \cdot kg^{-1}$. Mean power outputs at this particular power setting significantly exceeded (*$p < .05$) the Wingate power outputs (661.6 W vs. 588.4 W), with peak power (PP) measuring 838.6 W for the given study. Dotan and Bar-Or (1983) used a Fleisch ergometer to test 18 female and 17 male physical education students. Five sessions were completed by each subject with resistances ranging from 2.43 to 5.39 $J \cdot rev^{-1} \cdot kg^{-1}$. A parabola-fitting technique was employed to define optimal loads from the mean power output data. As a result, the optimal resistance was 0.0872 $kp \cdot kg^{-1}$ (5.13 $J \cdot rev^{-1} \cdot kg^{-1}$) and 0.0857 $kp \cdot kg^{-1}$ (5.04 $J \cdot rev^{-1} \cdot kg^{-1}$) for men and women, respectively.

A third study conducted by Patton et al. (1985) used 19 male physically active military and civilian laborers that completed multiple Wingate tests on a modified Monark ergometer. Multiple sessions were completed by the subjects using resistances ranging from 3.23 to 6.76 $J.rev^{-1} \cdot kg^{-1}$. The resistances that elicited the highest peak power (PP) and mean power (MP) outputs were 5.65 and 5.53 $J.rev^{-1} \cdot kg^{-1}$ (0.0961 and 0.0941 $kp \cdot kg^{-1}$), respectively (Average of 5.59 $J.rev^{-1} \cdot kg^{-1}$). Both peak power (888W vs. 770 W) and mean power (627W vs. 555W) were significantly higher ($p<0.001$) using a resistance load of 5.59 compared to the Wingate setting of

4.41 $J.rev^{-1}\cdot kg^{-1}$. Adams (1998) recommended resistance settings of 0.086 and 0.09 $kp\cdot kg^{-1}$ for nonsedentary adult women and men, respectively, while resistance settings between 0.09 and 0.10 $kp\cdot kg^{-1}$ were recommended for anaerobically fit female and male athletes. For practical purposes, the use of body weight as a criterion in determination of optimal load resistance during the Wingate cycle test is applicable. However, it is important that resistances used should consistently account for subject's age, gender, and fitness level to ensure the production of maximal peak and mean power outputs during the Wingate anaerobic cycle test.

The Vertical Jump Test

Biomechanists state the vertical jump test is a more true power test than a straight ahead sprint or a cycle ergometer test. The jump test combines hip and knee extension in addition to plantar flexion which occurs at the ankle joint (Glencross, 1966). These muscle actions, working maximally together, create instantaneous power to propel an individual's center of gravity vertically. The Sargent Vertical Jump Test (Sargent 1921) was the first jump test introduced intended to assess short-term muscle activity. The mechanical work performed to accomplish the jump could be determined by using the distance that was measured. The equation P=w/t (P=Power, w=work, and t=time) is used to calculate power in the vertical jump test. The force component can be taken from the weight, in either kilograms(kg) or Newtons(N) of the jumper and the time component can be measure electronically as the time in the air from an electronic contact mat attached to a special timer (Adams,1998).

In the past, the vertical jump test has been considered an explosive strength test (Glencross, 1966), partly because the single explosive jump itself is performed in less than one second. However, this may be an inaccurate assumption since maximal force is not elicited during muscle contraction. The ability to perform well on the vertical jump test can be related to three main physiological aspects. First, the percentage of fast twitch muscle fibers, or type IIb fibers, in the musculature involved in jumping plays an important role (Bosco et al., 1983; Harman et al., 1991; Johnson and Bahamonde, 1996). Characteristics of Type IIb muscle fibers such as large motor unit size, fast conduction velocity, large phosphocreatine stores, high anaerobic enzyme activity, fast contraction time, high force production, and elasticity help to contribute to power development during a jump test. Second, the noncontractile element of the muscle, such as the parallel and series elastic components, are responsible for the storage and release of elastic energy in the musculotendinous tissue (Brooks et al., 2000). The series elastic component is mainly responsible for the storage of elastic energy when a muscle is stretched and then the translation of the stored energy into force. Last, since jumping is a learned process, an individual's skill level contributes greatly to success during a jump test (Adams, 1998). Neurological aspects and proprioceptive feedback from the periphery contribute to one's skill level and allow for enhanced performance on the jump test.

Vertical Jump Test Protocol

The vertical jump test is primarily used on athletes to measure both vertical jumping distance and power output. There are numerous techniques in which the vertical jump test is administered and most are derived from the original Sargent jump test (Sargent, 1921). The basic jump test requires the athlete to stand with his or her dominant hand side against a plane wall or one that has measurements drawn on in order to record reach and jump height. The athlete raises their arm overhead and reaches to the highest point on the wall while standing flat-footed on the floor. This highest point of reach is marked on the wall with chalk or recorded by a measuring device. The athlete is then advised to jump as high as possible, and another mark is made at the peak of their jump. The vertical jump score is the difference between the two marks, usually measured in inches (Klavora, 2000). A common variation of the original jump and reach test is performed on an apparatus known as a The Vertec. This device includes colored plastic swivel vanes arranged in half-inch increments. These vanes are attached to a metal pole that can be adjusted to the athlete's standing reach height (Klavora, 2000). The athlete's maximum vertical jump is determined when he or she cannot displace the same horizontal swivel vane on two consecutive jumps.

Recently, a device has been utilized that obtains measurements of vertical jump heights through calculations involving air time (Bosco et al., 1983). The athlete stands on a mat that is attached to a hand held computer. Microswitches that are embedded in the mat allow time between toe off and first foot contact to be determined. The computer displays both air time, within 0.01 seconds, and jump height to the nearest half inch (Klavora, 2000). The switch mat technique provides advantages over traditional tests such as increased precision, accommodation of larger subject numbers in shorter amounts of time, and eliminates the need to measure an athlete's reach height. Even though this technique offers greater practicality, the original jump and reach test and the The Vertec are the most commonly used jump tests administered to measure vertical jump height in athletes.

Power Measurement

The determination of power during a vertical jump test can be assessed by using a force plate, or by entering jump height and body mass into a given equation. A force-plate can either be portable and resemble a set of scales, or fixed into the floor. Sensors are built into the platform of the force plate which constantly measures the take-off force. The height and power of the jump are automatically calculated from the take-off force. The most pertinent information derived from the force plate is the amount of force an athlete can impart in a certain amount of time (Johnson and Bahamonde, 1996). Power output of the jumper is calculated as the product of force and velocity. Force exerted by the jumper's muscles results in vertical ground reaction forces at the feet. These ground reaction forces act on the body's center of mass and accelerate the body upward (Harman et al., 1991). The product of these two variables is mechanical power. The use of a force platform provides the researcher with the most accurate assessment of power output during a vertical jump. However, force plates are relatively expensive and unavailable, and require the use of a computer to perform calculations of power and to show biomechanical actions of the body.

A more practical, but less accurate way to assess power outputs during jump tests is through the use of power equations. Fox and Mathews (1974) published the first equation used to assess power output during a vertical jump. The equation is known as the Lewis formula:

$$P\ (\text{kg} \cdot \text{m} \cdot \text{sec.}^{-1}) = \sqrt{4.9} \cdot \text{body mass (kg)} \cdot \sqrt{\text{jump-reach score (m)}}$$

The Lewis formula was developed to obtain a true measure of power output, where body weight and jump speed were taken into account. However, Harman et al. (1991) revealed that the Lewis formula has several limitations. First, the Lewis formula does not use the standard units recognized for measuring power known as Watts (W) or newton meters per second. Kilograms are a unit of mass and not weight or force. The multiplier 9.8 (the acceleration of gravity in m · $sec.^{2-1}$) was added to the original formula in order to convert kilograms to newtons, allowing Watts to be the unit measuring power. This also took into consideration the effect that gravity has on the body as it falls back to the ground.

$$P\ (W) = \sqrt{4.9} \cdot 9.8 \cdot BM\ (kg) \cdot \sqrt{\text{jump-reach score (m)}}$$

A second problem with the original Lewis formula is that it does not specify whether the equation estimates peak or average power. Harman et al. (1991) found that the Lewis formula only predicts the average power of the jumper as the individual falls back to the ground. Through the use of a force plate, Harman et al. (1991) established equations for both peak and average power through multiple regression procedures. The two equations are listed below:

$$\text{Peak power (W)} = 61.9 \cdot \text{jump height (cm)} + 36.0 \cdot \text{body mass (kg)} + 1{,}822$$

$$\text{Average power (W)} = 21.2 \cdot \text{jump height (cm)} + 23.0 \cdot \text{body mass (kg)} - 1{,}393$$

The correlation between the peak and average power outputs on the force platform and the equation-predicted method were 0.88 and 0.73, respectively. These values were greater than those seen when the peak and average powers derived from the force plate were compared to those estimated by the Lewis formula (correlated 0.83 and 0.72 with force-platform determined peak and average power).

Johnson and Bahamonde (1996) also devised simple equations to predict both peak and average power using a countermovement jump and a force plate. Sixty-nine male college athletes (13 baseball, 23 football, 12 tennis, 8 track & field, and 13 volleyball players) and forty-nine college female athletes (10 basketball, 13 softball, 7 tennis, 12 track & field, and 7 volleyball players) were used to establish the multiple regression equations. Certain physical characteristics such as vertical jump height, body mass, and body height, were the significant variables selected by the stepwise multiple regression equations to predict peak and average mechanical power. These three variables accounted for 91% of variance in peak power output and 82% of variance in average power output. The prediction equations developed by Johnson and Bahamonde (1996) are:

$$\text{Power}_{peak}\ (\text{W}) = 78.6 \cdot \text{VJ (cm)} + 60.3 \cdot \text{mass (kg)} - 15.3 \cdot \text{height (cm)} - 1{,}308$$

$$\text{Power}_{avg}\ (\text{W}) = 43.8 \cdot \text{VJ (cm)} + 32.7 \cdot \text{mass (kg)} - 16.8 \cdot \text{height (cm)} + 431$$

The correlation between the peak and average power outputs on the force platform and vertical jump height were 0.88 and 0.82, respectively. This strong correlation between jump height and peak and average power displays the importance of generating maximal ground reaction forces and takeoff velocity during the vertical jump test.

Energy System Contributions

Energy, in the form of adenosine triphosphate (ATP), used by the body during physical activity is provided by three main metabolic systems. The adenosine triphosphate-phosphocreatine (ATP-PC) system, anaerobic glycolysis, and aerobic metabolic system all provide energy to the functioning body during varying bouts and intensities of physical activity. The ATP-PC system provides energy to the body during high intensity activities lasting less than 10-seconds. Anaerobic glycolysis uses glucose or glycogen, and lactic acid, which is the metabolic byproduct of anaerobic exercise, for activities lasting from 30-seconds up to 2 to 3 minutes. The aerobic metabolic system provides the majority of the ATP production during bouts of exercise lasting from 3 to 5 minutes up to physical activity completion (Powers and Howley, 1996). All three of these energy systems can be evaluated by using certain laboratory and field measurement tests.

There exists conflicting opinions on the nature of contributions of various energy systems used in certain anaerobic power tests. One theory states that anaerobic power tests should be chosen that most closely mimic the movement patterns and energy systems utilized in a given activity. This is termed a "sport specific movement or activity"(Mayhew et al., 1994). When sport specific movements are used to assess anaerobic power, the athlete is already familiar with the movement patterns and does not require a learning period (Glaister et al., 2003). In addition, these movement patterns will potentially utilize the same energy pathways as those performed in a given sport or activity. It is essential that the predominant energy systems called upon during an anaerobic power test closely resemble those energy systems utilized for optimal performance during physical activity. For example, basketball requires change of direction (agility), linear and vertical explosion (sprinting and jumping), and considerable amounts of anaerobic metabolism. Therefore, an anaerobic test should be chosen that addresses these physical characteristics.

During a vertical jump test, power output required to attain maximal jump height and complete a single test is reached between one and two seconds (Harman et al., 1991; Johnson and Bahamonde, 1996). This suggests that only the ATP-PC energy system is utilized since the test duration is so short. Also, since three to five trials will be required for each vertical test and recovery time will be minimal, ATP-PC stores should not be substantially depleted. However, the Wingate anaerobic cycle test requires contributions from all of the three main energy systems.

In order for the Wingate test to be identified as "anaerobic," the anaerobic a distinction must be determined among energy systems. The amount of energy contributed during a Wingate test by aerobic means is measured by the net VO_2 and related to the overall energy requirement for the test. The total energy required for the test can be calculated from the mechanical work produced, assuming a certain mechanical efficiency (Inbar et al., 1996). Mechanical efficiency deals with energy and forces and their effects on the body during manual operations, such as biking (Inbar et al., 1976). To date, there is no data regarding the mechanical efficiency of a supramaximal activity of the Wingate test. It is likely the mechanical efficiency of a Wingate test is lower than an aerobic submaximal test, which can be taken as 20-25%, and is probably closer to 16-20% (Inbar et al., 1996). Inbar et al. (1976) used two mechanical efficiencies, 22% and 18%, to determine aerobic and anaerobic energy contributions during a Wingate cycle test. The 22% estimate resembled a mechanical efficiency used during a submaximal aerobic test, where the 18% estimate was related more to the mechanical efficiency during a supramaximal bike test.

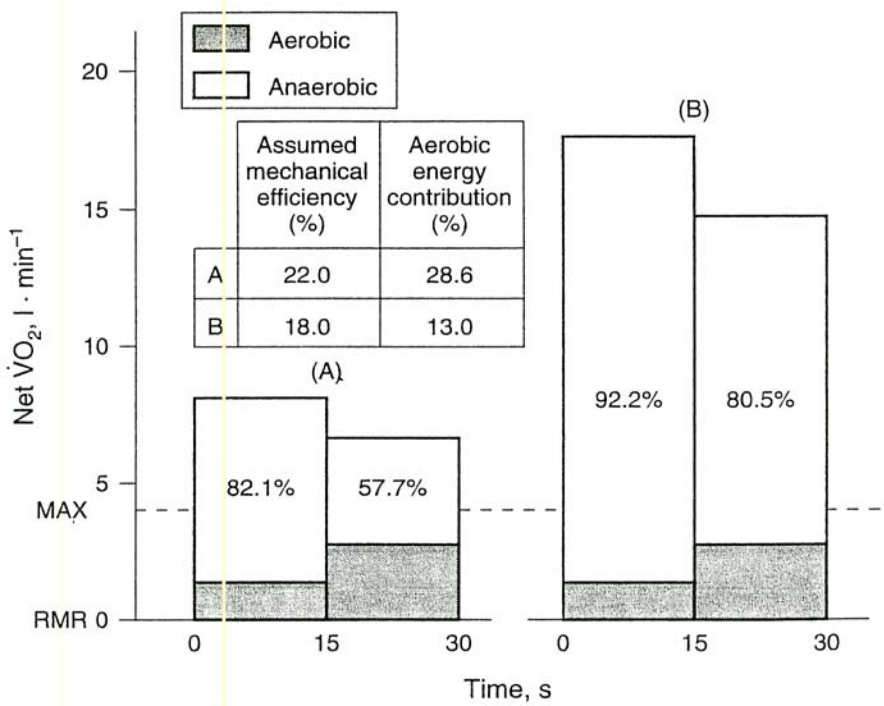

Figure 3. Energy Contributions during the Wingate Cycle Test, assuming a mechanical efficiency of (a) 22% and (b) 18%. (Inbar et al., 1996)

When the mechanical efficiency was estimated to be 22%, the aerobic and anaerobic contributions were 28.6% and 71.4 %, respectively. When the mechanical efficiency was 18%, the contribution of aerobic and anaerobic energy changed to 13.0% and 87.0%. As the mechanical efficiency decreases, the contribution of anaerobic metabolism during a given activity increases and vice versa. Since the Wingate cycle test is a supramaximal activity in which mechanical efficiency is assumed to be low, the predominant energy source will come from anaerobic metabolism.

Smith and Hill (1991) estimated the contributions of ATP-PC, anaerobic glycolytic and aerobic energy systems to measure work in a Wingate cycle test. This was done by assuming ATP-PC utilization contributed 100% of the energy during the exercise bout until peak power was reached. Since peak power is observed within the first 5-seconds, the ATP-PC system contributes for only a brief period during the test. Aerobic contribution was calculated from breath by breath VO_2 measures. The glycolytic contribution was determined by subtraction of the ATP-PC and aerobic contributions from the total work performed. Over the entire 30 second duration of the test, energy contribution was 16%, 56%, and 28% for aerobic, anaerobic glycolytic, and ATP-PC systems, respectively. Anaerobic contribution was estimated to be 84% of the energy system utilization during the Wingate test. In another study, Beneke et al. (2002) looked at the contributions of aerobic, anaerobic alactic acid (ATP-PC), and lactic acid (anaerobic glycolysis) metabolism during a Wingate cycle test. Energy derived from aerobic, ATP-PC, and lactic acid metabolism was 18.6%, 31.3%, and 50.3%, respectively. The results of the previously mentioned studies suggest that the Wingate cycle test requires the use of predominantly anaerobic energy, primarily from glycolytic pathways. The studies also indicate that the mechanical efficiency during the Wingate test was lower than those identified in aerobic exercise tests.

It has been estimated that the energy system contributions for the sport of basketball are approximately 60% ATP-PC/Anaerobic Glycolysis, 20% Anaerobic Glycolysis/Aerobic, and 20% Aerobic (Foss and Keteyian, 1998). These percentages closely reflect the energy system contributions experienced during the Wingate anaerobic power test as mentioned in the previous studies. While the energy system contributions between the Wingate test and the sport of basketball may be similar, the Wingate test does not provide sport specific test modality. An anaerobic power test for basketball ideally should utilize movements that incorporate jumping, sprinting speed, and agility to allow for an accurate assessment of anaerobic performance.

Gender Differences in Anaerobic Power Tests

Physical characteristics such as power development, muscular strength, endurance, and speed have been studied using mainly male samples. Athletic performances of males have been examined and it has been suggested that males are more adept at performing anaerobic activities compared to their female counterparts. A rationale that three differential characteristics of females contribute to a decrease in performance may explain differences in anaerobic performance compared to males. This is due to how the skeletal and muscular systems of females differ from males in respect to hip size, antagonist muscle strength ratios, and ligamentous restraints at and surrounding joints (Powers and Howley, 1996). These discrepancies between the genders can cause a decrease in mechanical efficiencies in such activities as landing from a jump, pedaling at a maximal rate on a bike, or sprinting over a relatively short distance. On average, females also have a higher percentage of adipose tissue and correspondingly, a lower percentage of fat-free mass resulting in lower overall power and strength outputs. Lastly, females have lower lactic acid levels in the blood and muscle following all-out physical effort (Inbar et al., 1996). This is caused by lower power outputs in a given anaerobic activity as a result of decreased utilization of anaerobic energy.

Males traditionally display higher absolute power output measurements during anaerobic test. However, when anaerobic power outputs are expressed in term relative to anthropometric measurements such as body weight and lean body mass, the gap between the genders is markedly reduced. In a study conducted by Murphy et al. (1986), 19 male and 18 female physically active individuals were assessed using the Wingate cycle test. Absolute anaerobic power of men was 35% and 40% higher ($p<0.001$) than women for peak and mean power, respectively. These differences decreased to 17% and 23% for peak and mean power when expressed relative to kilograms of body weight, and 10% and 17% for peak and mean power when expressed relative to kilograms of lean body mass. Similar findings were noted by Maud and Shultz (1986) who conducted Wingate cycle tests on 52 male and 50 female college age students. A 50.9% and 48.0% difference existed between males and females for peak and mean power output when expressed in absolute terms. This difference decreased to 17.3% and 15.2% and then to 5.0% and 2.5% when expressed relative to body weight and lean body mass for peak and mean power output.

In contrast, Koziris et al. (1996) used 41 female and 34 male recreationally trained individuals to assess power using the Wingate cycle test. A 15% and 16.2% difference existed between males and females for peak and mean power outputs respectively when expressed in absolute terms. When power outputs were expressed relative to body mass, there was a 4.3% and 3.3% difference in peak and mean power in favor of the female sample. This difference increased to 15.3% and 14.2% for peak and mean power outputs when expressed relative to fat-free mass. The males in this study tended to have less lean body mass and higher body weights than previous studies mentioned. Overall, when expressed in absolute terms, peak and mean power values in females tend to be anywhere from 35% less than males in untrained individuals and 50% less than males in athletic populations (Inbar et al., 1996).

Power output differences between males and females also exist in other anaerobic tests. Mayhew and Salm (1990) found that there was a 34.8% difference when power output was expressed in absolute terms during a vertical jump test in 82 untrained men and 99 females. This difference was reduced to 17.6% and 5.5% when expressed relative to body mass and lean body mass. Maud and Shultz (1986) found a 45.6% difference in vertical jump height between males and females when expressed in absolute terms. This difference was reduced to 12.9% and 0.0% when expressed relative to body mass and lean body mass. Mayhew and Salm (1990) also had subjects perform a 40 yard dash to determine sprint power. A difference of 46.2% was express in absolute terms between men and women. When body mass and lean body mass were taken in to account, the differences were reduced to 32.4% and 22.6%, respectively. In general, the power outputs in most anaerobic power test are higher for males then for females. This situation holds true for both a recreationally active and athletic population as well.

Characteristics of Basketball Players

Physical fitness and performance characteristics differ between male and female basketball players and also between the three main positions, guards, forwards, and centers. Data describing the physical nature of today’s male and female basketball players, at any level, is limited. Previous studies conducted on basketball players mainly involved physical variables, such as height and weight, and body composition measurements. Vertical jump tests and lower body anaerobic power tests, such as the

Wingate cycle test, are less commonly used. Recently, positional profiles have been documented in order to differentiate physical characteristics amongst players.

In a study by Latin et al. (1994), strength and conditioning coaches and athletic trainers of the 297 Division I NCAA universities participating in men's basketball received surveys involving physical and performance characteristics. A total of 45 schools responded with 437 athletes represented where only the top 10 players on the team were included. Physical characteristics reported were: height (428), weight (427), and body fat and fat-free weight (255 each). Vertical jump was the most commonly used assessment tool (349), with the forty-yard dash (77) and thirty-yard dash (40) used minimally. By position, the guards were shorter and weighed less, had lower body fat percentages, had higher vertical jump heights, and had faster times in the 30 and 40-yard dash when compared with the forwards and centers. The centers had the greatest power outputs, total body weights, and higher body fat percentages compared to the other positions.

LaMonte et al. (1999) described the physical and performance characteristics, by position, of 46 Division I female basketball players in the Western Athletic Conference. Much like their male counterparts, guards had lower body weights, were shorter, and had lower body fat percentages when compared to the forwards and centers. The forwards had slightly higher vertical jump heights than the guards and had the highest absolute peak and mean power outputs. When peak power was expressed relative to total body mass and fat-free mass, the guards displayed the highest power outputs. Both Latin et al. (1994) and LaMonte et al. (1999) expressed a need for additional research to determine physical chacteristics and performance profiles of male and female basketball players by position.

Performance Tests on Basketball Players

The predominant performance tests used on both male and female basketball players are vertical jump tests, line drills (also known as suicide drills), and the Wingate anaerobic cycle test. A player's straight-ahead speed is tested by using the 30 or 40-yard dash and aerobic fitness is commonly tested by using a distance run, such as the mile (Latin et al., 1994; Hoffman et al., 1996).

Hoffman et al. (2000) used nine members of the Israeli National Youth male basketball program (17 years old) to compare the Wingate test to the vertical jump and a line drill. Subjects with the fastest sprint times in the line drill also had the highest mean power outputs and highest vertical jump heights. However, the resistance setting for the Wingate test was 0.052 kg · kg body mass^{-1} (5.13 J · pedal revolution^{-1} · kg body mass^{-1}) which is lower than the 0.075 kg · kg body mass^{-1} suggested by Ayalon et al. (1974) in their original Wingate study. A possible limitation may have been that the optimal resistance to elicit maximal power output was too low affecting the reliability of the results. Hoffman et al. (1999) used twenty members of the Israeli National Youth and Collegiate male basketball teams (19-21 years old). The Wingate cycle test was used to assess anaerobic power and was compared to the line drill in addition to a treadmill test to determine aerobic capacity. Again, the resistance used for the Wingate test was 0.052 kg · kg body mass^{-1} (5.13 J · pedal revolution^{-1} · kg body mass^{-1}). No significant relationship between the Wingate test and the line drill was observed.

The most commonly used sport performance and anaerobic power test in basketball is the vertical jump test. Much like other tests used to assess anaerobic function, the vertical jump test is used primarily in studies where the subjects involved are males. A four year study conducted on the University of Connecticut Men's basketball from 1988 to 1992 investigated how performance test results reflected playing time (Hoffman et al., 1996). The two anaerobic tests used were the vertical jump and a 27 meter (30 yard) sprint to assess performance. The strongest and most consistent correlations were obtained between vertical jump height and playing time ($r = 0.68$), with a moderate to moderately high negative correlation between the 27 meter sprint times and playing time ($r = -0.62$). These correlations were strongest between the years 1988 and 1990.

In 1996, Johnson and Bahamonde used 69 male and 49 female athletes competing in sports such as baseball, softball, football, men's and women's track and field, men's and women's volleyball, men's and women's tennis, and women's basketball. Of the 118 athletes that participated, 10 were on the women's basketball team. The women's basketball team had higher vertical jump heights and peak and average power compared to the other female athletes that participated. Also, there were significant differences for both peak and average mechanical power between men and women. However, when vertical jump, body mass, and height were held constant, the effect of gender on peak and average mechanical power was not significant. Since subjects involved were both male and female college athletes, the prediction equations for peak and average mechanical power developed were population-specific. In contrast to the original Lewis equation

(Fox and Mathew, 1974), Johnson and Bahamonde found that the established prediction equations under estimated power outputs during a vertical jump test.

Performance Tests on Female Basketball Players

As previously stated, research in the field of women's athletics, including basketball, is lacking considerably. Most performance conducted on female athletes is involves individual sports (e.g. track and field, swimming, biking). Since basketball is a team sport, researchers possibly view the significance of assessing its athletes as less important than other sports that rely heavily on individual motivation and performance. Only two studies conducted in the early 1990's explored the significance of performance and anaerobic testing on female basketball players.

In 1991, Bale conducted a descriptive study using eighteen members of an under seventeen England basketball team to observe anthropometric measurements and their relationship to vertical jump and anaerobic power in guards, forwards, and centers. The mean characteristics were as followed: Body Mass = 63.6 kg (SD±7.8), body fat percentage = 18% (SD=1.8), fat-free weight = 52.1 kg (SD=6.0, vertical jump = 47.4 cm (SD=5.2) and anaerobic power = 97.2 $kg \cdot m \cdot sec^{-1}$ (SD±13.2). When compared by position, guards and forwards had lower percent body fat percentages than centers (17.9 vs. 18.3), and the centers had great body weights compared to forwards and guards (71.2kg vs. 63.9kg vs.57.9kg). Guards, forwards, and centers had similar vertical jump heights (47.6 vs. 47.2 vs. 47.6), and centers had the greatest anaerobic power followed by forwards and guards (108.5 vs. 97.5 vs. 88.9 $kg \cdot m \cdot sec^{-1}$). The findings of this study were very similar to those observed by LaMonte et al. (1999) in female basketball players.

In a second study, Mayhew et al. (1994) examined the interrelationships among selected tests of anaerobic power among college female athletes. Sixty-four college female athletes, who were members of varsity volleyball (7), basketball (21), soccer (18), tennis (6), and softball (12) teams, had anaerobic power measured through the use of a vertical jump test, standing long jump, 40-yard dash, and seated shot put. The highest significant correlation seen between standing long jump and vertical jump was r = 0.57. It was suggested that in sports dominated by speed of movement (e.g. basketball), anaerobic power should be evaluated using the standing long jump, vertical jump, and 40 yard sprint. This supports the theory that tests of anaerobic power should be more sport specific to allow for more valid assessments of anaerobic performance in basketball.

Max Jones Quadrathalon

The Max Jones Quadrathalon, or Quad test, was developed in 1982 by Max Jones, a national throws coach for England's track and field team. The Quadrathalon was devised to test explosive power improvement of the Great Britain National Throws Squad (Dunn and McGill, 2003). The Quadrathalon is relatively easy to administer and had been used primarily to test Division I track and field and football athletes. When first developed, Max Jones hoped that his test would be used to measure and monitor progress during the off-season. The Quadrathalon consists of a series of drills that are used to assess an athlete's level of speed, strength, explosiveness, and power. The athlete gets three attempts at each event with the greatest distance or fastest time recorded for each trial used in the scoring procedure. The four components of the Max Jones Quad Test are as followed:

1. Standing Long Jump- Athlete starts with feet at the edge of a long jump pit or at a set mark on a flat surface. The athlete crouches, leans forward, swings his/her arms backward, then jumps horizontally as far as possibly, jumping from both feet and landing with both feet in a sand pit or level surface. Jump is measured in meters to the nearest point of contact. The measurement should be taken from the starting position to the closest disturbance of the sand where the athlete lands.

2. Three Standing Long Jumps- Athlete starts with feet at the edge of a long jump pit or at a set mark on a flat surface. The athlete takes three continuous two-footed bounds into the sand pit or level surface. Jump is measured in meters to the nearest point of contact upon completion of the third jump. Measurement is taken from the starting position to the closest disturbance of the sand where the athlete lands.

3. 30 Meter Sprint- On the starters command, moves to the set position (Either upright, staggered stance or sprinters stance). Athlete has option to use starting blocks. On the starter's signal, the athlete sprints as fast a possible to the finish line. The timer starts the watch when the athlete's back foot makes contact with the ground on the first step, and stops when the athlete breaks the finish line. If using motion timers, time will start upon first movement by the athlete and ceases when they cross the finish line.

4. Overhead Shot/Med-Ball Throw- Use a 16lbs. (male) or 12 lbs. (female) shot put or medicine ball. Standing on top of a shot put stopboard (the athlete's back to the landing area), dip down (much like the preparatory crouch for a vertical jump), swing the shot or med-ball between the legs, and then extend and throw the shot or med-ball overhead backwards. It is not necessary to remain on the stopboard. Measurement is taken from the lip of the stopboard to the first point of impact in meters.

*See Appendix ___for the Quadrathlon scoring tables. Athlete's scores can be converted into the numerical scores provided, and total for your MJQ rating.

Components of the Max Jones Quadrathalon

In the past, the Quad test has been used primarily as a testing device to evaluate power outputs of male athletes, and has never been used to assess basketball players. There is no available research using total standized Max Jones test scores since validation studies do not exist on the Max Jones test as a whole. Therefore, examining the validity of separate components of the Quad test is necessary.

The standing broad jump has been used in numerous studies to assess leg power and jumping ability, and is typically combined with other anaerobic performance tests. The first study to address the use of the standing broad jump as a test to assess physical characteristics when compared to another jump test was conducted by Glencross (1966). A sample of 85 Teacher Training College students (Age mean = 19.3) completed a vertical jump and a standing broad jump to determine muscle power. Since the Lewis formula (Fox and Mathews, 1974) did not exist, the study used an apparatus called the power lever to predict lower body anaerobic power. This was a simple pulley device that permitted the measurement of the average horsepower developed in a variety of single, explosive movements. The differences between the correlations of the power lever tests with the vertical jump and standing broad jump were non-significant. This suggested that variables measured by the power lever test (e.g. lower body power and jumping ability) be considered components of common variance to both jump tests. These results demonstrated the similar physical characteristics needed to perform the vertical jump and the standing broad jump.

Numerous studies have included several components of the Max Jones test to assess anaerobic power in athletes. Seiler et al. (1990) used a standing long jump, standing five-jump tests, and 40-yard dash to investigate the interrelationships of these tests in forty-one Division I football players. Significant correlations (*p<0.01) were found between the five jump test and the standing broad jump (r=0.90), the standing broad jump and the 40-yard sprint (r=0.89), and the five jump test and the 40-yard sprint (0.87). Significant correlations (*p<0.01) were also found between power in the vertical jump test and Wingate test and all measurements in the three previously mentioned tests. In contrast, fifty male athletes participating in football (14), soccer (12), baseball (10), basketball (8), and wrestling (6) completed a standing broad jump, vertical jump for distance and power, and a 40-yard dash (Beckenholdt and Mayhew, 1983). Results showed the 40-yard dash had a significant negative correlation (*p<0.01) with both the standing broad jump (r = -0.70) and the vertical jump (r = -0.76). In a final study performed on thirty-one college age males, Manning et al. (1988) had their subjects execute a 40-yard dash and standing broad jump, along with a vertical jump and Wingate cycle test. Again, significant negative correlations (*p<0.01) were found with the 40-yard dash and standing broad jump (r = -0.62).

Studies involving female athletes and the use of components of the Max Jones test to assess anaerobic power are sparse. In a study conducted by Mayhew and Salm (1990) 82 men and 99 females were assessed using a standing broad jump, 40 yard dash, and vertical jump for height and power. Males were significantly different (*p<0.001) from the females on all power and distance/time measurements. These differences decreased considerably when the measurements were expressed relative to body mass and lean body mass. Mayhew et al. (1994) conducted a study on 64 college female athletes using vertical jump height and power, standing long jump, 40-yard dash, and seated shot put to determine specificity among different anaerobic tests. The highest correlations were seen between the standing long jump and vertical jump (r = 0.57) and vertical jump and seated shot put (r = 0.46). The authors determined that no single power test can identify an individual's diverse anaerobic abilities.

The component of the Max Jones Quad test that is most lacking in documented research is the overhead shot put/medicine ball toss. Beside the aforementioned study involving the seated shot put used to assess female athletes, a single study involving horizontal/vertical displacement of a weighted object was observed from a seated position incorporating a push-pass technique. Mayhew et al. used the seat shot put to assess upper body power in male college weight training students (1991), adolescent wrestlers (1992), and college football player (1993). In all three studies, the performance in the seated shot put had a moderate to strong correlation to bench press power (r = 0.66 to r = 0.75). The existing research in the area of anaerobic power tests similar to components of the Max Jones Quad test is considered limited, suggesting further exploration in a female athletic population needs to be addressed.

Conclusion

The Wingate cycle and vertical jump tests have been used to assess anaerobic power in athletes for the purpose of providing vital information to coaches and medical staff personal regarding anaerobic performance of athletes in a given sport. Less familiar anaerobic performance tests such as the standing broad jump, 30 or 40-yard dash, or the shot put throw for distance are occasionally used in selective sports. These tests provide a level of specificity in certain sports that the Wingate test especially does not reflect. In addition to the need for more sport specific anaerobic power and performance testing, there also is a demand for performance testing involving female athletes. No previous investigations have used the Max Jones Quadrathalon as a means to assess anaerobic performance. Collectively, the lack of research in the field of women's basketball and the need for more sport specific tests to assess anaerobic performance has lead to the development of the present proposed investigation.

CHAPTER III

METHODS

Subjects

Sixteen members of the University of Pittsburgh Women's Division I basketball team currently participating in basketball and conditioning activities were recruited for this investigation. All participation was voluntary and had the support and approval of the University Of Pittsburgh Department Of Athletics, head women's Basketball Coach, and strength and conditioning coach. The potential risk and benefits, as well as the underlying rationale for the investigation, were explained to all subjects where-upon their written consent to participate will be obtained (Appendix D). All test trials took place between 7:00 and 8:00am, did not interfere with practices, and complied with NCAA regulations. At the time of testing, all athletes had undergone six weeks of pre-season training. All procedures were approved by the University of Pittsburgh Institutional Review Board committee prior to data collection.

Orientation and Performance Testing

Day 1	Testing Day 2	Testing Day 3
Overview of Study Informed Consent Anthropometric Data Vertical Jump Test	Orientation and Practice of Max Jones Quad Test Max Jones Quad Test	Wingate Cycle Test

Subjects reported for testing on three consecutive days. On the first day, subjects were provided an overview of the study where IRB consent was obtained. Athletes then had the opportunity to ask questions about the tests they would be performing. Anthropometric data was taken and the Vertical Jump test was also performed on the first day of testing. On the second day, the Max Jones Quad Test was explained in detail and demonstrated to the group. The subjects then performed the Quad test which consisted of four stations: 1) standing broad jump, 2) 3 consecutive broad jumps, 3) overhead shot put toss, and 4) 30 meter sprint. The standing broad jump, 3 consecutive broad jumps, and overhead shot put toss were measured in meters (m) and centimeters (cm). On the third and final day, the subjects performed the 30-second Wingate cycle ergometer test. Peak and mean anaerobic power, as well as the fatigue index (percent change) over the 30-seconds, were calculated by a computer program during the Wingate cycle test.

Day 1 Orientation and Overview of Study

Subjects reported to the University of Pittsburgh Men's and Women's basketball training facility in the Petersen Events Center. Informed consent forms approved by the University of Pittsburgh Institutional Review Board committee were distributed at this time. All aspects of the research investigation was addressed including the purpose of the study, tests to be conducted, and the risk and benefits of the investigation. Any questions regarding the procedures within the study were answered at this time.

Anthropometric Measurements

Anthropometric measurements were conducted at the University of Pittsburgh Men's and Women's basketball training facility in the Petersen Events Center and included height, body mass, lean body mass, and fat mass. Height in centimeters (cm) and body mass in kilograms (kg) were measured using a physician's scale calibrated prior to testing (Detecto, Webb City, MO). Body composition was assessed at the orientation session using a Tanita (Arlington Height, IL) bioelectrical impedance analyzer (BIA) scale. The BIA is a non-evasive pain-free procedure for assessing body composition in which a low-grade electrical impulse is transmitted through the body. The resistance to current flow through tissues reflects the relative amount of fat present. After height and weight had been entered and shoes and socks were removed, the Tanita scale was set to Athletic Mode and the subject stood on the scale for approximately 10 seconds to obtain body composition assessment. Two trials were performed for each subject to assure similar results and to determine accurate body compositions.

Vertical Jump

The subjects performed the vertical jump tests at the University of Pittsburgh Men's and Women's basketball training facility in the Petersen Events Center**.** Prior to the vertical jump test, the subjects were lead through an 8-10 minute dynamic warm-up. The dynamic warm-up consisted of squats, lunges, burpees, good mornings, walking leg kicks, knee grabs, quad stretches, shuffle-slides, back-peddle jogs, and 20, 30, and 40 yard progressive jogging exercises. This warm-up was lead by the strength and conditioning coach. The vertical jump was performed as described in the laboratory protocol of Adams (1998). The apparatus used in this investigation to measure vertical jump height was the Vertec (Power Systems, Knoxville, TN). This standing scale resembles a volleyball standard with red, white, and blue vanes, or markers spaced 0.5 inches apart. The red vanes are spaced every 6.0 inches apart, the blue vanes every 1.0 inches apart, and the white vanes every 0.5 inches, with the exception of where there is already a red or blue vane. The subject stood with their dominant arm closest to the standard and extended upward as far as possible. The standard was adjusted so that the tip of the tallest finger during the reach was at the bottom surface of the lowest vane on the Vertec. The highest reach was observed and then recorded.

After the standing reach was measured, the jumper moved the feet to a jumping position, approximately shoulder width apart. At this time, the subjects were allowed to practice proper form and body positioning. The feet were not permitted to deviate from this original position prior to the jump (e.g. hop or step prior to jump). The subject was allowed one quick dip, or countermovement, of the knees and one arm swing. The subject made the jump while touching or swatting the measuring vanes at the peak of the jump. The jumper's hand caused several of the measuring vanes to be displaced near the peak of the jump. The highest vane that was moved represented the height of the jump. Investigators calculated the number of inches, to the nearest 0.5 inches, to the highest vane moved. Since the Vertec was zeroed prior to the beginning of the test based on the subjects reach, the highest touched vane represented the jump height that is recorded. Due to the rapid recovery of the relatively small volume of anaerobic energy used for performing one vertical jump, the several seconds taken to observe and record the height of the jump was sufficient recovery between trials. Jump trials were continued until the subject did not exhibit an increase in jump height, usually within three to five jumps. The primary investigator of the study administered the test and recorded the results as well as the number of trials on prepared data recording sheets.

Anaerobic Power Calculations

Two measures of power output were determined by the vertical jump test using equations developed and validated by Johnson and Bahamonde (1996). Peak power (P_{pk}) reflected the highest power output during a single moment of the push off phase during the vertical jump. Average power (P_{ave}) represented the average power output over the entire duration of the push off phase.

$$Power_{peak}\ (W) = [78.6 \cdot VJ\ (cm)] + [60.3 \cdot BM\ (kg)] - [15.3 \cdot ht\ (cm)] - 1{,}308$$

$$Power_{avg}\ (W) = [43.8 \cdot VJ\ (cm)] + [32.7 \cdot BM\ (kg)] - [16.8 \cdot ht\ (cm)] + 431$$

Where:

VJ = Vertical Jump   BM = Body Mass (Weight)   ht = Height

The highest jump (cm) for each subject was used in the two equations, along with body mass and subject height, to determine peak and mean power. The equations were calculated on a computer and produced peak and mean power in watts.

Day 2 Testing

Max Jones Quad Test

On day 2, the subjects reported to the Charles L. Cost Sports Center on the University of Pittsburgh campus to perform the Max Jones Quad Test. The Max Jones Quadrathalon consisted of four test stations; 1) broad jump, 2) 3 consecutive broad jumps, 3) Overhead shot put toss, and 4) 30 meter sprint. The broad jump, 3 consecutive broad jumps, and the overhead shot put throw were measured in meters and centimeters, while the 30-meter sprint was timed in seconds. All tests were conducted on the Astroturf surface in the Charles L. Cost Sports Center's indoor regulation sized football field. Prior to the Quad test**,** the subjects were lead through an 8-10 minute dynamic warm-up. The dynamic warm-up consisted of squats, lunges, burpees, good mornings, walking leg kicks, knee grabs, quad stretches, shuffle-slides, back-peddle jogs, and 20, 30, and 40 yard progressive jogging exercises. This warm-up was lead by the strength and conditioning coach.

Immediately following the dynamic stretching period, the Max Jones Quad Test was explained in detail and demonstrated to the group. The strength and conditioning coach and primary investigator supervised each station and provided feedback on execution and technique of the skills. When the primary investigator, strength and conditioning coach, and the subjects felt comfortable and familiar with the movements, the Quad test was administered. Rest periods consisted of a greater than a 1:4 work to rest ratio prescribed for this type of short-term, maximal intensity activity (Foss and Keteyian, 1998). This work to rest ratio ensured total recovery of the ATP-PC energy system after each trial. An active recovery also took place when the subjects rotated between each station. In order to minimize fatigue, the broad jump, 3 consecutive broad jumps, and overhead shot put were done before the 30-meter sprint.

The broad jump station and the 3 consecutive broad jump station consisted of a taped line on the Astroturf surface marking the take off point and a Komelon Measuring Tape (Komelon USA, Gulfport, MS). The measuring tape extended to 8 meters (26 feet) out from the take off line and was secured to the Astroturf by athletic tape at both stations. Each subject was required to start with both feet behind the take off line and were permitted a deep knee bend and arm swing prior to the jumping phase. Three jump trials were performed at each station with the distance from the take off line to the heel of the foot closest to the take off line was measured and recorded on the data sheet. An exercise physiology graduate student measured and recorded the broad jump and the primary investigator measured and recorded the 3 consecutive broad jumps. The greatest distance recorded from the three trials was used in the scoring.

The overhead shot put station consisted of a Komelon Measuring Tape (Komelon USA, Gulfport, MS), a 12 pound indoor soft shell shot put (Gill Athletics, Champaign, IL), and a shot put stop board with throwing circle supplied by the University of Pittsburgh Track and Field team. The measuring tape extended 16 meters (52 feet) out from the stop board and was placed off to the side of the throwing area. The subject stood on the stop board facing away from the landing area with the feet a comfortable distance apart. The shot put was cupped in both hands while being lowered between the subject's legs and then the subject drove upward to throw the shot put back over their head. There was no penalty for not remaining on the stop board, as momentum carried the subject off the stop board into the landing area. Two overhead throw trials were performed with the greatest distance being recorded for the data collection. Measurements to the nearest centimeter were taken from the inside edge of the stop board to where the shot put first made contact with the ground in the landing area and were recorded on the data sheet by the strength and conditioning coach.

Subjects then combined into one group for the final station that consisted of the 30-meter sprint. The 30 meters required for the sprint was measured using a Komelon Measuring Tape (Komelon USA, Gulfport, MS). Tape was placed on the Astroturf surface to mark both the starting and finishing lines. The Speed Trap II timing system (Power Systems, Knoxville, TN) was used to record the time of the run. The timing system was be calibrated prior to the initial 30-meter sprint. A touch start pad was placed on the starting line and two infrared electric eyes with built in transmitters were mount on two separate tripods at the finish line. The athlete assumed a starting position with their foot or hand on the touch start pad. The timer started immediately upon the athlete's acceleration. The timer stopped when the athlete crossed the infrared beam between the two tripods stationed at the finish line. The investigator used a handheld display, which recorded the time of the test within 1/100th of a second. The subject was permitted two trials, with the lowest time recorded for the investigation.

Each component of the Max Jones Quad Test was individually scored based on the distance or time recorded. These scores were obtained by matching the test distance or time with its appropriate individual standardized score (Appendix G). The four (4) individual event scores were then totaled to obtain an overall score for the Max Jones Quad Test. Example:

Standing Broad Jump Distance = 1.95m = 36 points

Standing 3 Broad Jumps Distance = 6.07m = 39 points

Overhead Shot-Put Throw Distance = 10.86m = 41 points

30m Sprint Time = 4.89 seconds = 33

Total Score = 149

These scores can be compared within the subject group being tested, or with other groups who may display similar characteristics.

Day 3 Testing

Wingate Anaerobic Cycle Test

Ergometer Description

On the third day, the subjects reported to the Center for Exercise and Health-Fitness Research at the University of Pittsburgh to perform the Wingate anaerobic cycle test. Maximal anaerobic power of the lower body was evaluated by the Wingate anaerobic cycle test on a Monark 828 E cycle ergometer (Monark Exercise AB, Sweden). The ergometer utilized a constant force concept where the resistance did not change during the course of the test (Adams, 1998). The Monark bike incorporated a mechanical braking system where the speed of pedaling determined the power output in the ergometer. When resistance was applied to the ergometer, the subject's pedaling was braked by the brake belt which surrounded the brake surface of the flywheel. The brake power was changed by either the pedaling speed of the subject or by increasing or decreasing the tension of the brake belt by means of the load tension knob.

Ergometer Set-up

Prior to the start of the Wingate test, all ergometer settings were adjusted to fit the subject being tested. The height of the seat was adjusted so that the knee was only slightly flexed (5^o-10^o) when sitting comfortably with the middle of the foot resting on the pedal and with the pedal in the lowest position. Pedals were equipped with toe stirrups to allow for a pushing and pulling force to be exerted on the pedal throughout the full revolution (Bar-Or, 1987). The handlebar position was adjusted to the specificity of the subject to allow for maximal comfort throughout the test.

Power Output, Revolutions Counter and Timing Device

Values of anaerobic power were determined by the SMI Optosensor (Sports Medicine Industries, Inc., St. Cloud, MN). The SMI Power software calculated power output for each second of the test as a function of the resistance load applied to the flywheel and the velocity of the flywheel. Revolutions of the flywheel were measured with an optical sensor attached to the Monark frame. The sensor was interfaced with an IBM Personal Systems 2 computer to determine anaerobic power indices. The power indices that were calculated and used in this investigation are peak power (PP), mean power (MP), and fatigue index (FI). The timer on the computer that records the duration of the test was the official timepiece for the 30-second test. The primary investigator indicated to the individual recording test information on the data sheet when to record the total revolutions per 5-second interval according to the test timer on the computer.

Force Setting

The Wingate anaerobic cycle test consisted of a supramaximal, all out 30-second sprint against a predetermined resistance. Body weight in kilograms (kg) was required to prescribe the force (kg; N) setting on the cycle ergometer. The force selection for this investigation was 0.090 kg $\cdot$ kg of body mass^{-1} (0.90 N) based on recommendations by Adams (1998) for anaerobically fit female persons (athletes). The force selection used in this investigation was multiplied with each subject's body mass in order to determine resistance setting for each respective subject.

Wingate Test Protocol

A modified version of the original Wingate anaerobic cycle ergometer test (Inbar et al., 1996) was used in this investigation. Prior to the Wingate anaerobic cycle test, the subjects were lead through an 8-10 minute dynamic warm-up. The dynamic warm-up consisted of squats, lunges, burpees, good mornings, walking leg kicks, knee grabs, quad stretches, shuffle-slides, back-peddle jogs, and 20, 30, and 40 yard progressive jogging exercises. This warm-up was lead by the strength and conditioning coach. The recommended 5-minute warm-up on the bike was used prior to the start of the test. The subsequent 2-5 minute recovery interval was used at the completion of the test. An acceleration period consisting of 2 brief phases preceded the beginning of the Wingate test. The first phase had the subject pedal at about 20 to 50 revolutions per minute (rpm) for 5 to 10 seconds at a resistance one-third of that prescribed for the test. In the second phase, the subject increased the rpm to a near-maximal rate while the investigator loaded the prescribed force within 3 to 5 seconds.

Once the prescribed force was reached, the force-setter yelled “go” and the timer officially started the clock to begin the test. The subject began pedaling as fast as possible for a 30-second period while remaining seated on the bike for the duration of the test. At the end of the 30-seconds, the investigator yelled, “stop.” The force-setter reduced the resistance to a cool-down recovery setting (between 1 and 2 kg) while the subject continued to pedal at about 50 rpm for 2 to 3 minutes. Verbal encouragement was given throughout the duration of the test and particularly during the final ten to fifteen second (Inbar et al., 1996). At this stage of the test, the subjects felt extreme discomfort in their extremities and were experiencing intense mental fatigue. The cool down period alleviated these symptoms, and the subject stopped pedaling when she felt that the discomfort in her legs had been sufficiently decreased. Each subject was allowed one Wingate anaerobic power test trial.

Statistical Analysis

Data analysis was performed using the SPSS 11.0 for Windows statistical software. Using a power of 0.80 and an α level of 0.05, a sample size of 16 subjects was needed for a significant correlation ($r = 0.60$). Descriptive data for subject characteristics and experimental variables was calculated as mean ± SD. Results from the anaerobic power tests were analyzed as a team as well as by player position: Guards, Forwards, and Centers. A Pearson product-moment correlation was calculated between the Max Jones test and Wingate cycle ergometer as well as the Vertical jump tests. Analysis of separate Max Jones Quad Test components, in addition to anthropometric measures were also correlated with both the Wingate cycle ergometer and Vertical Jump test. Due to the nature of the small homogeneous sample used, stepwise regression equations using only a two component model to predict Wingate cycle and Vertical jump test power performance were created using: (1) anthropometric measurements and (2) Max Jones Quad tests components. Analysis of anaerobic power test results were also correlated with performance statistics, such as points, rebounds, assists per game and minutes played. Models were developed to predict basketball performance form anaerobic power outputs determined by the Vertical Jump and Wingate cycle tests.

CHAPTER IV

RESULTS

The purpose of this investigation was to determine whether a significant relationship existed between the Max Jones Quad Test and the: 1) Wingate cycle ergometer test; and 2) Vertical jump test in female basketball players. A secondary purpose of this investigation was to examine the relationship between all three anaerobic power tests and specific individual basketball performance statistics.

Statistical Results

Thirteen members of the University of Pittsburgh Women's Division I basketball team participated in this investigation and were assigned to one of three groups based on the position they play: 1) Guards, 2) Forwards, and 3) Centers. The guard group consisted of 6 subjects, the forward group consisted of 4 subjects, and the center group consisted of 3 subjects. Subject descriptive data are presented in Table 1.

Table 1. Subject Descriptive Data

	Group Total	Group		
Variable		Guards	Forwards	Centers
Age (yr)	19.7 ± 1.1	19.8 ± 1.2	19.5 ± 0.6	19.7 ± 1.5
Height (cm)	177.8 ± 7.9	171.1 ± 3.5	180.9 ± 6.4	187.1 ± 0.9
Weight (kg)	79.3 ± 18.2	66.6 ± 8.1	80.5 ± 12.8	103.1 ± 15.5
Body Fat (%)	21.9 ± 5.3	20.7 ± 2.8	19.4 ± 7.2	27.4 ± 2.5
Fat Mass (kg)	17.9 ± 8.1	13.7 ± 0.9	16.3 ± 9.0	28.5 ± 6.4
Fat Free Mass (kg)	61.4 ± 11.4	52.9 ± 8.0	64.2 ± 4.8	74.6 ± 9.3

Values are means ± SD; N = 6 (Guards), 4 (Forwards), 3 (Centers)

Fat mass (kg) was calculated by multiplying the subject's weight (kg) with the body fat (%) expressed as a decimal. The calculated fat mass was then subtracted from the subject's weight to determine the fat free mass (kg).

Each subject completed the Vertical Jump, Max Jones Quadrathalon, and Wingate Anaerobic Cycle Test on three consecutive days. The subjects were separated into groups based on basketball position. Vertical Jump and Wingate peak power were examined as absolute and relative to subject body weight and fat free mass values. Subject test results are presented in Table 2.

Table 2. Anaerobic Power Results

Variable	Group Total	Group		
		Guards	Forwards	Centers
VJ Height(cm)	42.7 ± 5.9	43.8 ± 6.01	45.4 ± 5.22	36.9 ± 2.2
VJ PP (W)	4106.2 ± 993.1	3528.4 ± 780.5	4346.5 ± 810.5	4941.5 ± 1115.9
VJ PP (W/kg)	52.2 ± 6.7	53.2 ± 8.1	54.0 ± 6.1	47. 6 ± 3.4
VJ PP (W/FFM)	66.6 ± 8.1	66.4 ± 8.8	67.6 ± 10.1	65.7 ± 6.6
Wingate PP (W)	570. 7 ± 348.7	391.8 ± 101.2	557.5 ± 204.1	946.0 ±577.9
Wingate PP (W/kg)	6.8 ± 2.3	5.8 ± 0.9	6.7 ± 1.5	8.7 ± 4.0
Wingate PP (W/FFM)	8.8 ± 3.4	7.3 ± 1.2	8.6 ± 2.5	12.2 ± 5.8
Fatigue Index (%)	30.5 ± 11.1	25.9 ± 9.1	37.9 ± 14.6	29.9 ± 6.1
Max Jones Total Score	138.9 ± 21.3	142.1 ± 15.1	154.0 ± 14.9	112.0 ± 15.4

Values are means ± SD; N = 6 (Guards), 4 (Forwards), 3 (Centers)
VJ, Vertical Jump; PP, Peak Power; Fat Free Mass, FFM (kg)

The Max Jones Quadrathalon consisted of four test stations; 1) broad jump, 2) 3 consecutive broad jumps, 3) Overhead shot put toss; and 4) 30 meter sprint. Each component of the Max Jones Quad Test was individually scored based on the distance or time recorded. The average test component distance/time and point totals are presented in Table 3.

Table 3. Max Jones Quad Test Results

	Group Total	Group		
Variable		Guards	Forwards	Centers
Broad Jump (m)	2.00 ± 0.17	2.01 ± 0.15	2.13 ± 0.14	1.82 ± 0.09
Broad Jump (pts)	37.9 ± 6.5	38.17 ± 5.9	42.8 ± 4.9	31.0 ± 3.6
Three Broad Jump(m)	6.3 ± 0.5	6.3 ± 0.5	6.8 ± 0.2	5.9 ± 0.4
Three Broad Jump (pts)	42.4 ± 6.1	41.5 ± 5.9	47.8 ± 3.1	37.3 ± 4.5
Overhead Throw (m)	9.1 ± 1.1	8.6 ± 1.2	9.7 ± 1.1	9.3 ± 0.8
Overhead Throw (pts)	30.9 ± 6.5	28.0 ± 6.8	34.3 ± 6.7	32.0 ± 4.6
30-Meter Sprint (sec)	5.04 ± 0.3	4.8 ± 0.13	5.01 ± 0.08	5.5 ± 0.15
30-Meter Sprint (pts)	27.6 ± 10.2	34.5 ± 4.6	29.3 ± 2.9	11.7 ± 5.1
Max Jones Total Score	138.9 ± 21.3	142.1 ± 15.1	154.0 ± 14.9	112.0 ± 15.4

Values are means ± SD; N = 6 (Guards), 4 (Forwards), 3 (Centers)
(m) meters, (pts) points

Vertical Jump Height and Max Jones Quadrathalon Components

A Pearson product moment correlation was used to analyze the relationship between subject vertical jump height and the separate components and total score of the Max Jones Quadrathalon. A significant correlation was found between vertical jump height and broad jump score (r = 0.637), three broad jump score (r = 0.556), 30-meter sprint score (r = 0.687), and total score (r = 0.696). Table 4 represents the correlation between vertical jump height and individual scores on the Max Jones Quadrathalon. Table 5 represents the correlation between vertical jump height and absolute measures, in meters and seconds, for each Max Jones Quadrathalon component.

Table 4. Pearson Product-Moment Correlation Between Vertical Jump Height and Max Jones Quadrathlon Component Scores

	Broad Jump	3 Broad Jump	Overhead Throw	30m Sprint	Total Score
Vertical Jump Height(m)	0.64*	0.56*	0.05	0.69**	0.70**

m, meter
* significant $p < 0.05$ (2-tailed); **significant $p < 0.01$ (2-tailed)

Table 5. Pearson Product-Moment Correlation Between Vertical Jump Height and Max Jones Quadrathlon Component Absolute Measures

	Broad Jump(m)	3 Broad Jump(m)	Overhead Throw(m)	30m Sprint(sec)
Vertical Jump Height(m)	0.65*	0.58*	0.05	-0.69**

m, meter; sec, seconds
* significant $p < 0.05$ (2-tailed); **significant $p < 0.01$ (2-tailed)

Max Jones Quadrathalon vs. Anaerobic Power Tests

A Pearson product moment correlation was used to analyze the relationship between anaerobic power determined by the Vertical Jump and Wingate cycle tests. A significant correlation (r = 0.85) was found between the Vertical Jump and Wingate anaerobic power tests. Pearson product moment correlations were also used to analyze the relationship between the measured power outputs determined by the Vertical Jump and Wingate Cycle Ergometer Tests and the total Max Jones Quadrathalon score. A non-significant negative correlation (r = -0.31) was found between anaerobic power output during the Wingate cycle test and total Max Jones Quadrathalon score, while no correlation was found between anaerobic power measured with the vertical jump test and total Max Jones Quadrathalon score. However, a significant negative correlation (r = -0.57) was found between the Wingate Cycle Test and the 30-meter sprint component. Table 6 represents the correlation between anaerobic power determined by vertical jump and the Wingate test and individual scores and total score for each component of the Max Jones Quadrathalon. Table 7 represents the correlation between anaerobic power determined by vertical jump and the Wingate test and absolute measures, in meters and seconds, for each component of the Max Jones Quadrathalon.

Table 6. Pearson Product-Moment Correlation Between Max Jones Quadrathlon Component Scores and Anaerobic Power Tests

	Broad Jump	3 Broad Jump	Overhead Throw	30m Sprint	Total Score
Vertical Jump PP (W)	-0.03	0.17	0.41	-0.38	-0.02
Wingate PP (W)	-0.33	-0.04	0.23	-0.57*	-0.31

* significant p < 0.05 (2-tailed); PP, Peak Power
(BJ) Broad Jump,(3BJ) 3 Broad Jump, (OHDT) Overhead Throw, (30m) 30 meter sprint, (TS) Total Score

Table 7. Pearson Product-Moment Correlation Between Max Jones Quadrathlon Component Absolute Measures and Anaerobic Power Tests

	Broad Jump(m)	3 Broad Jump(m)	Overhead Throw(m)	30m Sprint(sec)
Vertical Jump PP (W)	-0.02	0.18	0.43	0.38
Wingate PP (W)	-0.32	-0.05	0.25	0.56*

* significant p < 0.05 (2-tailed); PP, Peak Power
(BJ) Broad Jump,(3BJ) 3 Broad Jump, (OHDT) Overhead Throw, (30m) 30 meter sprint, (TS) Total Score

Anthropometric Measurements vs. Anaerobic Power Tests

A Pearson product moment correlation was used to analyze the relationship between the anthropometric measurements of the subjects and the three anaerobic power tests. Significant correlations (*p < 0.05 & *p < 0.01) were found between all anthropometric measurements and the Wingate cycle test, and between three out of the four anthropometric measurements and the Vertical Jump power test. Percent body fat was the only anthropometric measurement that was found to have a significant relationship (*p < 0.05) with the Max Jones Quad Test total score. The correlation coefficients are presented in Table 8.

Table 8. Pearson Product-Moment Correlations Between Anthropometric Measurements and Anaerobic Power Tests

	Height(cm)	Weight(kg)	% Body Fat	Fat Free Mass(kg)
Vertical Jump PP (W)	0.58*	0.88**	0.39	0.89**
Wingate PP (W)	0.60*	0.91**	0.56*	0.85**
Max Jones (TS)	-0.33	-0.34	-0.65*	-0.17

* significant p < 0.05 (2-tailed); ** significant p < 0.01 (2-tailed)
TS, Total Score; W, Watts; cm, centimeter; kg, kilogram

Multiple Regression Models to Predict Vertical Jump and Wingate Anaerobic Power

All variables from the anthropometric measures and the separate Max Jones components were submitted to stepwise multiple regression analysis.

<u>Vertical Jump Power</u>

The use of lean body mass (kg) as an anthropometric measure provided the best single variable model (r^2 = 0.785, *p = 0.000) to predict vertical jump anaerobic power.

The resulting equation was:

VJ Peak (W) = 77.5 x Lean Body Mass (kg) – 650.6

The combination of weight in kilograms (*p=0.000) with 30-meter sprint time in seconds (*p=0.006) provided the best model (r^2 = 0.898) to predict vertical jump anaerobic power using one anthropometric measure and one Max Jones Quadrathalon Test measure (*p= 0.000). The resulting equation was:

VJ Peak (W) = 67.8 x Weight (kg) – 1764.5 x 30 meter sprint (sec) + 7631.7

The combination of weight with standing broad jump (r^2 = 0.848, *p=0.000), 3 standing broad jumps (r^2 = 0.842, *p=0.000), and overhead shot put (r^2 = 0.776, *p=0.001) were determined to be significant in predicting vertical jump anaerobic power. Lean body mass and standing broad jump (r^2 =0.805, *p=0.000), 3 standing broad jumps (r^2 =0.804), *p=0.000), overhead shot put (r^2 =0.803, *p=0.000), and 30 meter sprint time (r^2 = 0.848, *p=0.000) also provided strong models to predict vertical jump anaerobic power. Stepwise Multiple Regression Models for predicting vertical jump anaerobic power are presented in Table 9.

Table 9. Stepwise Multiple Regression Models Using All Possible Combinations of Anthropometric and Max Jones Test Results to Predict Vertical Jump Power

Predictors	Beta Value	r^2	P Value
Weight	48.00	0.772	0.000
Height	72.60	0.334	0.039
Lean Body Mass	77.48	0.785	0.000
Height, Standing Broad Jump	77.1, 794.6	0.352	0.114
Height, 3 Standing Broad Jumps	75.9, 494.6	0.392	0.083
Height, Overhead Shot Put	60.7, 183.8	0.367	0.102
Height, 30 meter Sprint	87.1, -526.1	0.344	0.122
Weight, Standing Broad Jump	53.1, 1663.4	0.848	0.000
Weight, 3 Standing Broad Jumps	49.4, 542.5	0.842	0.000
Weight, Overhead Shot Put	46.3, 66.8	0.776	0.001
Weight, 30 meter Sprint	67.8, -1764.5	0.898	0.000
LBM, Standing Broad Jump	79.7, 820.5	0.805	0.000
LBM, 3 Standing Broad Jumps	76.9, 282.3	0.804	0.000
LBM, Overhead Shot Put	86.5, -153.6	0.803	0.000
LBM, 30 meter Sprint	95.9, -1137.7	0.848	0.000

Wingate Cycle Ergometer Anaerobic Power

The use of weight (kg) as an anthropometric measure provided the best single variable model (r^2 = 0.821, *p=0.000) to predict Wingate cycle ergometer anaerobic power.

The resulting equation was:

$$\text{Wingate Peak (W)} = 17.4 \times \text{Weight (kg)} - 807.9$$

The combination of weight in kilograms (*p=0.000) with overhead shot put throw distance in meters (p=0.280) provided the best model (r^2 = 0.842) to predict Wingate cycle ergometer anaerobic power using one anthropometric measure and one Max Jones Quadrathalon Test measure (*p= 0.000). The resulting equation was:

$$\text{Peak (W)} = 18.7 \times \text{Weight (kg)} - 49.9 \times \text{Overhead Throw (m)} - 453.1$$

The combination of weight with standing broad jump (r^2 = 0.822, *p=0.000), 3 standing broad jumps (r^2 = 0.823, *p=0.000), overhead shot put (r^2 = 0.842, *p=0.000), and 30 meter sprint (r^2 = 0.835, *p=0.000) were determined to be significant in predicting Wingate cycle ergometer anaerobic power. Lean body mass and standing broad jump (r^2 =0.753, *p=0.001), 3 standing broad jumps (r^2 =0.731), *p=0.001), and 30 meter sprint time (r^2 = 0.724, *p=0.002) also provided strong models to predict vertical jump anaerobic power. Stepwise Multiple Regression Models for predicting vertical jump anaerobic power are presented in Table 10.

Table 10. Stepwise Multiple Regression Models Using All Possible Combinations of Anthropometric and Max Jones Test Results to Predict Wingate Cycle Power

Predictors	Beta Value	r^2	P Value
Weight	17.39	0.821	0.000
Height	26.25	0.354	0.032
Lean Body Mass	26.13	0.724	0.000
Height, Standing Broad Jump	24.2, -357.5	0.384	0.089
Height, 3 Standing Broad Jumps	26.3, 12.5	0.354	0.112
Height, Overhead Shot Put	26.9, -11.1	0.355	0.111
Height, 30 meter Sprint	17.4, 319.3	0.383	0.090
Weight, Standing Broad Jump	17.2, -67.9	0.822	0.000
Weight, 3 Standing Broad Jumps	17.5, 30.3	0.823	0.000
Weight, Overhead Shot Put	18.7, -49.9	0.842	0.000
Weight, 30 meter Sprint	19.7, -207.1	0.835	0.000
LBM, Standing Broad Jump	25.2, -347.7	0.753	0.001
LBM, 3 Standing Broad Jumps	26.2, -60.7	0.731	0.001
LBM, Overhead Shot Put	33.9, -133.2	0.837	0.000
LBM, 30 meter Sprint	25.6, 33.9	0.724	0.002

Basketball Performance

Basketball Performance Statistics vs. Anaerobic Power Tests

The relationship between individual basketball performance statistics for the entire season and the three anaerobic power tests was calculated. Significant correlations (*$p < 0.05$) were found between rebounds and blocks with both the Vertical Jump ($r = 0.61$ and $r = 0.67$, respectively) and Wingate cycles tests ($r = 0.66$ and $r = 0.60$, respectively) when position played was not taken into consideration. Points were also correlated with the Wingate Cycle test (r = 0.63). No significant correlations were observed between the Max Jones Quadrathalon total score and any of the performance measures. The correlation coefficients are presented in Table 11.

Table 11. Pearson Product-Moment Correlation Between Basketball Performance Statistics and Anaerobic Power Tests

	Minutes	Rebounds	Assists	Blocks	Points
Vertical Jump PP	0.21	0.61*	-0.27	0.67*	0.52
Wingate PP	0.25	0.66*	-0.24	0.60*	0.63*
Max Jones (TS)	0.25	0.22	0.07	0.22	0.10

* significant $p < 0.05$ (2-tailed)

Regression Models to Predict Performance Variables from Vertical Jump and Wingate Anaerobic Power

Vertical Jump and Wingate cycle ergometer anaerobic power were used to determine models to predict individual performance variables for basketball. Points, rebounds and blocks were chosen as criterion variables to build the models. The resulting equations using Vertical Jump anaerobic power were:

Rebounds = 0.05 x Vertical Jump Peak (W) - 117.82

Blocks = 0.01 x Vertical Jump Peak (W) – 17.04

and the resulting equations using Wingate cycle ergometer anaerobic power were:

Points = 0.20 x Wingate Peak (W) + 23.5

Rebounds = 0.15 x Wingate Peak (W) – 4.49

Blocks = 0.02 x Wingate Peak (W) – 1.6

Regression Models for predicting points, rebounds, and blocks are presented in Tables 12 and 13.

Table 12. Stepwise Multiple Regression Models Using Vertical Jump Power to Predict Rebounds and Blocks

Predictors	Beta	r^2	P Value
Vertical Jump (Rbs)	0.05	0.368	0.028
Vertical Jump (Blks)	0.01	0.451	0.012

(Rbs) Rebounds, (Blks) Blocks

Table 13. Stepwise Multiple Regression Models Using Wingate Cycle Ergometer Anaerobic Power to Predict Points, Rebounds, and Blocks

Predictors	Beta	r^2	P Value
Wingate (Pts)	0.20	0.396	0.021
Wingate (Rbs)	0.15	0.435	0.014
Wingate (Blks)	0.02	0.360	0.030

(Pts) Points, (Rbs) Rebounds, (Blks) Blocks

CHAPTER V

DISCUSSION

It was the purpose of the present study to determine if a relationship existed between the Max Jones Quadrathlon and two established anaerobic power tests in female Division I basketball players. It was a subproblem to establish models to predict the following:

7. Anaerobic power (as measured by the Wingate cycle and vertical jump tests) using anthropometric measures and components of the Max Jones Quadrathlon
8. Basketball performance from anaerobic power (as determined by the Vertical Jump, Wingate cycle, and Max Jones Quadrathlon tests).

Descriptive Characteristics

Anthropometric Variables

The present study provided descriptive data on female basketball players. The average height (177.8 ± 7.9 cm) of the players reported in the present study is comparable to previously reported values of women participating on Division I basketball teams (LaMonte, et al., 1999). Subjects in the present study were 7 cm taller, on average, than a group of highly skilled female basketball players who were 4 years younger in age (Bale, 1991). However, players profiled in the present study averaged 9 cm taller compared to female college volleyball, soccer, tennis, and softball players (Mayhew, et al., 1994) as well as 8 cm taller compared to female college track & field, softball, tennis, and volleyball players (Johnson and Bahamonde, 1996). When compared to recreationally trained college females of the same age, basketball players in the current study were on average, 14 cm (Murphy, et al., 1986), 10 cm (Maud, et al, 1986), and 11 cm (Koziris, et al., 1996) taller. As expected, stature differences between Division I female basketball players and college females of similar age did exist based on the given physiological requirements for competing at high levels of female basketball.

As a group, the current subjects averaged 9 kg greater in body weight compared to female college basketball players of similar age (LaMonte, et al., 1999) and 16 kg greater compared to 15 year-old elite female basketball players (Bale, 1991). The current subjects also averaged 16 kg greater in body weight compared to female college volleyball, soccer, tennis, and softball players (Mayhew, et al., 1994) and female college track & field, softball, tennis, and volleyball players (Johnson and Bahamonde, 1996) of similar age. Compared to recreationally trained college females of the same age, basketball players in the present study were, on average, 20 kg (Murphy, et al., 1986), 20 kg (Maud, et al, 1986), and 18 kg greater in body weight. The differences observed between the body weights of the subjects in the present study and previous studies performed using recreationally trained college females may once again be attributed to variations in body composition expected in competitive female basketball players.

Percent fat values of the present study were, on average, 5% greater than female college basketball teams (LaMonte, et al., 1999) and 4% greater than young female elite level basketball players (Bale, 1991). The body fat percentage of the current subjects averaged 1% greater than female college volleyball, soccer, tennis, and softball players (Mayhew, et al., 1994) and 2% greater than a group of recreationally trained college females of similar age (Koziris, et al., 1996). In contrast, subjects were 1.5% (Murphy, et al., 1986) and 3% (Maud, et al, 1986) lower than a second and third group of recreationally trained college females of similar age. It is suggested that the variation in percent body fat with the present subjects in addition to previous studies may be expected due to possible variations in heights, weights, and different training levels of female basketball players.

Lean body mass for the current group averaged 4 kg greater than the female team values reported (LaMonte, et al., 1999), 9 kg greater than young female elite level basketball players (Bale, 1991), and 11 kg greater than female college volleyball, soccer, tennis, and softball players (Mayhew, et al., 1994). The female basketball players in the present study averaged 34 kg (Murphy, et al., 1986), 32 kg (Maud, et al, 1986), and 34 kg (Koziris, et al., 1996) greater in lean body mass when compared to recreationally trained college females of similar age. The higher lean body mass observed with the current group may be attributed to higher body weights of the individuals as a result of sport-specific training performed on a regular basis.

Anaerobic Power Performance

It has been estimated that the energy system contributions for the sport of basketball are approximately 60% ATP-PC/Anaerobic Glycolysis, 20% Anaerobic Glycolysis/Aerobic, and 20% Aerobic (Foss and Keteyian, 1998). Considering the majority of energy in basketball performance is primarily from anaerobic contributions, the implementation of tests to assess the anaerobic attributes of basketball players would be of great value. In the current investigation, a significant correlation ($r = 0.85$) was found between the Vertical Jump and Wingate anaerobic power tests. Both tests rely heavily on ATP/PC energy system contributions to produce/sustain maximal anaerobic power. Also, weight had a considerable impact on performance on these two tests. The heavier subjects in the current investigation had higher anaerobic power outputs on both the Vertical Jump and Wingate tests. Positive correlations such as these between the Vertical Jump and Wingate anaerobic power tests have been seen in previous literature. Previously, the vertical jump and Wingate power tests have been administered to athletes and recreationally active individuals to assess anaerobic contributions, and are considered relatively valid and reliable as suggested previously in the literature. However, to date there has been no single test created recognized as both a general indicator of anaerobic power as well as sport-specific in nature.

Vertical Jump Performance

In the present study, mean overall vertical jump height for the participants was 42.7 ± 5.9 cm, which was 6 cm less than height reported by LaMonte, et al. (1999) and 5 cm less than height reported by Bale (1991). Results from the vertical jump test also indicate that mean jump heights varied between positions. Forwards demonstrated the highest vertical jump heights (45.4 cm), while centers exhibited the lowest jump heights (36.9 cm) in the present study. However, when compared to subjects from the aforementioned studies (LaMonte, et al., 1999 and Bale, 1991), the basketball players in the current study demonstrated lower vertical jump heights than all of their counterparts by position. The current group of individuals, on average, jumped 3 cm higher than female college volleyball, soccer, tennis, and softball players (Mayhew, et al., 1994), but

1 cm lower than female college track & field, softball, tennis, and volleyball players (Johnson and Bahamonde, 1996) of similar age. When compared to recreationally active college females of similar age, the current subjects averaged 6 cm higher in vertical jump height.

The present study used equations developed by Johnson and Bahamonde (1996) to predict vertical jump power in watts (W) from height, mass, and vertical jump height. These equations were chosen to determine the power output of the current group since it was developed by using female college athletes, which included 10 basketball players.

The equations are:

$$Power_{peak}\,(W) = [78.6 \cdot VJ\,(cm)] + [60.3 \cdot BM\,(kg)] - [15.3 \cdot ht\,(cm)] - 1{,}308 \quad (^{*}r^2 = 0.916)$$

$$Power_{avg}\,(W) = [43.8 \cdot VJ\,(cm)] + [32.7 \cdot BM\,(kg)] - [16.8 \cdot ht\,(cm)] + 431 \quad (^{*}r^2 = 0.831)$$

Peak power (P_{pk}) reflects the highest power output during a single moment of the push off phase during the vertical jump. Average power (P_{ave}) represents the average power output over the entire duration of the push off phase. Based on the previously mentioned equations, the current subjects averaged 821.2 W (peak power) and 87.2 W (average power) higher than the female college age athletes used by Johnson and Bahamonde (1996). Two viable explanations for these differences may be that samples were not all basketball players, and that the athletes in the current study were, on average, heavier and recorded greater heights on the vertical jump test.

It is also important to look at the discrepancies between correlation involving the Max Jones Quadrathlon and Vertical Jump tests. Significant correlations ($p < 0.05$ and $p < 0.01$) were observed between Max Jones Quadrathalon components (broad jump, three broad jump, and 30 meter sprint) and vertical jump height. However, Max Jones Quadrathlon components were not correlated with vertical jump anaerobic power determined by the prediction equations. This inconsistency may be explained by the looking at the nature of the measurements. Vertical jump height and the Max Jones Quadrathlon are absolute measures of performance in female basketball players, where as anaerobic power was determined through the use of prediction equations. The equations were developed using both male and female Division I athletes participating in baseball, football, track and field, volleyball, basketball, softball, and tennis. These prediction equations might not have produced "true" anaerobic power outputs for the female basketball players in this current investigation.

Wingate Cycle Performance

The Wingate cycle test has not been widely used to assess anaerobic performance in basketball players, yet its utility has been demonstrated in a wide range of athletes and recreationally trained individuals. Established as both a valid and reliable measure (Ayalon et al., 1974; Bar-Or, 1987), the Wingate cycle test assessed anaerobic performance in the current study. Anaerobic power output on the Wingate cycle test averaged 92.7 W lower than Wingate performance expressed in the LaMonte, et al. (1999) study. By position, guards averaged 237.5 W lower, forwards averaged 135.6 W lower, but centers averaged 277.6 W higher when compared to their counterparts from the LaMonte, et al. (1999) study. A subject in the current study had an anaerobic peak power output of 1,600 W, which skewed the average power of the centers. It may be that the current subjects displayed limited anaerobic power when compared to other Division I female basketball players.

Peak power outputs displayed by the current group from the Wingate cycle test were also compared to recreationally trained female college students of similar age. Their power performance (570.7 W) was comparable to results by Murphy, et al. (1986) (503 W) and Koziris, et al. (1996) (572.2 W), but averaged 190 W higher power outputs than those found by Maud, et al (1986). These results also expressed the considerable lack of anaerobic power production expected of Division I female basketball players. The failure of the current group to exhibit anaerobic power outputs considerably greater than recreationally trained females of similar age is a cause of concern. Athletes of their skill and supposed fitness level did not perform to the standards expected at the onset of the study.

Max Jones Quadrathlon

The Max Jones Quadrathlon was developed in 1982 by Max Jones to measure and monitor progress during the off-season training phase in an athletic population. The Quadrathlon was devised to test explosive power improvement of the Great Britain National Throws Squad (Dunn and McGill, 2003) and has been primarily used in this country to assess anaerobic power in male track athletes and football players. Unlike the vertical jump test and Wingate cycle test in which only certain components of anaerobic power are tested, the Quad Test is used to assess an individual's level of speed, strength, explosiveness, and power. The Max Jones Quad test consists of four drills: a standing long jump, three consecutive standing long jumps, an overhead shot put throw, and a thirty-meter sprint.

Standing Long Jump The mean broad jump distance for the group in the present study was 2.00 meters, which was, on average, 0.16 m greater than female college volleyball, soccer, tennis, and softball players reported by Mayhew, et al. (1994). The mean standing broad jump distance of 1.84 m (Mayhew, et al., 1994) was closest to the mean standing broad jump distances (1.82 m) exhibited by the centers in the current study. In a study by Koch, et al. (2003), 3 female college aged track & field athletes had a mean standing broad jump distance 0.28 m greater than subjects in the current study, while 13 untrained females of similar age had a mean standing broad jump distance 0.39 m less than the present group. A mean standing broad jump distance of 1.59 m was reported by Mayhew and Salm (1990) on 99 untrained women of college age. On average, this distance was 0.41 m less than the basketball players in the present investigation. Therefore, it is likely that certain athletes (track & field) have the ability to jump greater distances than the female basketball players in the present study. However, athletes participating in other sports, such as women's volleyball, soccer, tennis, and softball and untrained college aged females appear to exhibit shorter jump distances than those reported in the current group.

Three Standing Broad Jumps Previous literature using multiple standing broad jump test protocols to assess jumping ability is sparse. Subjects in the present study had a mean three standing broad jump distance of 6.3 m. Forwards demonstrated the greatest three jump distance (6.8 m), while guards had the second greatest distance (6.3 m) and centers exhibited the shortest jump distance (5.9 cm) in the present study. While in certain athletic populations, such as basketball, the standing three jump test may be a useful test to assess foot-ground contact time and overall jumping ability, an established validated testing protocol is necessary.

Overhead Shot Put Throw As was the case with the three standing broad jump component, existing literature using the overhead shot put throw does not exist. Previous research using a weighted object to assess upper body strength and power is limited to the seated shot put test (Mayhew, et al., 1991; Mayhew, et al., 1992; Mayhew, et al., 1993; Mayhew, et al., 1994). Subjects in the present studied had a mean overhead shot put throw distance of 9.1 m. Forwards demonstrated the greatest overhead shot put throw distance (9.7 m), while centers had the second greatest distance (9.3 m) and guards exhibited the shortest distance (8.6 cm) in the present study. In basketball populations the overhead shot put throw may be a functional tool to assess linear power (jumping ability), as well as upper body strength and power.

Thirty Meter Sprint The mean thirty-meter (30 m) sprint time for the group in the present study was 5.04 seconds, which was 0.14 seconds on average slower than female college volleyball, soccer, tennis, and softball players reported by Mayhew, et al. (1994). The mean 30 m sprint time of 4.90 seconds (Mayhew, et al., 1994) was closest to the mean 30 m sprint time of 4.80 seconds exhibited by the guards and 5.01 seconds by the forwards in the current study. In a study by Mayhew and Salm (1990), 99 untrained women of college age had a mean 30 m sprint time of 5.38 seconds. This was 0.34 seconds slower than the mean time of the overall group, but was 0.12 seconds faster than centers in the present study. Previous research shows that athletes participating in other sports, such as women's volleyball, soccer, tennis, and softball, exhibit faster sprint times than female basketball players in the present study. However, the present group had a faster mean sprint time than untrained females of similar age. Additional research into the validity of the 30 m sprint test as a tool to assess both speed and short-term power in female basketball players is needed.

Performance Differences by Position

The current group displayed positional differences in descriptive characteristics and anaerobic power performance. On average, the centers were the tallest, heaviest, and had the greatest percent body fat when compared to forwards and guards in the study. The guards were shorter in stature and weighed the least, while the forwards had the lowest percent body fat out of the three positions. By position, the current group was comparable in height to female college basketball players used by LaMonte, et al. (1999), but weighed more and had a higher percent body fat for each position. The greatest difference was seen between the weight of the centers in the present study (103.1 kg) and the weight of centers in the LaMonte, et al. (1999) study (79.9 kg). The anthropometric differences by position in basketball may potentially have a negative effect on particular performance outcomes and in ability to perform given skills.

In the present the study, differences were also observed between the positions when anaerobic power tests were examined. Forwards had the highest vertical jump heights, vertical jump power outputs, and total Max Jones Quad Test scores, while the centers had the highest peak anaerobic power on the Wingate cycle test. Centers had the lowest vertical jump height and Max Jones Quad Test scores, while the guards had the lowest power outputs on the vertical jump test and the Wingate anaerobic cycle test. LaMonte, et al. (1999) displayed higher vertical jump heights for all positions when compared to the present study. In the present study, guards averaged 5.6 cm, forwards averaged 4.03, and centers average 6.6 lower jump heights than their counterparts in the LaMonte, et al. (1999) study.

In regards to performance on the Wingate cycle test, guards (391.8 W) and forwards (557.5 W) in the present study averaged lower power outputs compared to guards (629.3 W) and forwards (693.1 W) in the aforementioned study. Centers (946.0 W) in the present study averaged higher power outputs on the Wingate cycle test compared to centers (668.5 W) in the LaMonte, et al. (1999) study. If the center in the current study (that demonstrated an anaerobic peak power output of 1,600 W) is removed from the analysis, results are comparable to the centers in the other study. Subjects in the present study performed poorer on anaerobic power tests for all positions when compared to other female Division I basketball players. The inability to produce adequate anaerobic power in female basketball players could contribute to decreased agility, speed, jumping ability, and overall sport performance. Therefore, this lack of anaerobic power may contribute to decreased performance variables and/or ability and skill levels in the sport of women’s basketball.

Comparison of Max Jones Quadrathlon and Anaerobic Power Tests

Max Jones Quadrathlon vs. Vertical Jump Height

As expected, significant relationships were observed between component and total scores (points) and absolute measures of the Max Jones Quadrathlon when compared with vertical jump height. Correlation coefficients (r) ranged from r = 0.556 to r = 0.687 on individual scores and from r = 0.578 to r = -0.691 on absolute measures for Max Jones test components. These correlations were significant at the $p < 0.05$ level (standing broad jump and three broad jump) and the $p < 0.01$ level (30-meter sprint). Previous research shows significant correlations between vertical jump height and standing long jump distance in female (Mayhew and Salm, 1990; Mayhew, et al., 1994) and male (Glencross, 1966; Beckenholdt and Mathew, 1983; Manning, et al., 1988; Seiler, et al., 1990) college age students. Previous research has also shown significant relationships between vertical jump height and short sprint distances in female (Mayhew, et al., 1994) and male (Beckenholdt and Mathew, 1983; Manning, et al., 1988; Seiler, et al., 1990) college age students.

Physiologically, the mechanics of the standing broad jump and a vertical jump are similar, with the only difference being that force is exerted to move the body horizontally, rather than vertically. Conventional thinking expresses that individuals who perform better on short sprints and jumping activities possess greater amounts of fast twitch muscle fibers. This may help to explain why a significant relationship was seen between vertical jump height and 30 meter sprint time.

Max Jones Quadrathlon vs. Vertical Jump and Wingate Cycle Power Output

Correlations of Max Jones components with peak power outputs on the vertical jump and Wingate cycle tests were extremely weak and not anticipated

(r = -0.02 to r = 0.43). The only significant relationship occurred between the Wingate cycle test and the 30-meter sprint (r = 0.56). The poor relationship between the Max Jones test and peak power on the Vertical Jump and Wingate cycle tests may be explained by a discrepancy in physiological requirements. When performing the vertical jump and Wingate cycle tests, the subjects in the present study with greater heights and/or weights exhibited the ability to generate greater power outputs. The prediction equation used to determine anaerobic power based on vertical jump height also used height and weight as variables. This suggests that individuals taller and/or heavier would be predicted to a have higher anaerobic power output. On the contrary, these same physical characteristics were found detrimental to an individual's performance on the Max Jones Quadrathlon.

Multivariate Models to Predict Anaerobic Power and Basketball Performance

Vertical Jump Power Predictions

Prediction models to predict Vertical Jump anaerobic power included anthropometric variables and Max Jones Quadrathlon Test components. Models to predict vertical jump anaerobic performance based on anthropometric data have been developed in the past (Bosco, et al., 1983; Harman, et al., 1991; Johnson and Bahamonde, 1996), however, female basketball samples have not been used. Considering the Max

Jones Quadrathlon has not been used to assess anaerobic performance in previous research, prediction models to predict anaerobic power by using components of the test are not available. All anthropometric and Max Jones Quadrathlon Test variables were submitted to stepwise multiple regression analysis. The strongest prediction of Vertical Jump power from a single anthropometric variable was lean body mass (LBM) and accounted for 78.5% of the variance. Multiple regression model for women's basketball anaerobic performance demonstrated that weight (r^2 = 0.772) and 30-meter sprint (r^2 = 0.143) contributed to the best prediction of Vertical Jump power and accounted for 91.5% of the variance.

It is understandable that these variables contributed to a high degree when explaining the variance of the prediction model. An individual's performance on a vertical jump test is greatly influenced by body mass (weight) and ability to generate power (speed). A person who has less weight to move vertically will be able to overcome gravity easier, but this does not necessarily mean that they possess a greater ability to generate anaerobic power. Also, the ability to perform a counter movement rapidly will store greater potential energy in the elastic components of the active muscles, and will enable an individual to generate more explosive power. Jumping ability and short distance sprint speed have been attributed to both the efficiency of the stretch-shortening cycle to store potential energy and the function of the stretch reflex in active muscles (Bosco and Komi, 1979; Bosco, et al., 1983).

Wingate Power Predictions

Models to predict Wingate cycle anaerobic power included anthropometric variables and Max Jones Quadrathlon Test components. Models to predict Wingate cycle anaerobic performance based on anthropometric data have not been developed considering that power output performance on the test can be directly determined by using specific computer software. All anthropometric and Max Jones Quadrathlon Test variables were submitted to stepwise multiple regression analysis to predict anaerobic power on the Wingate test. The strongest prediction of Wingate cycle power from a single anthropometric variable was lean body weight and accounted for 82.1% of the variance. Multiple regression models for women's basketball anaerobic performance demonstrated that weight (r^2 = 0.821) and overhead shot put distance (r^2 = 0.061) contributed to the best prediction of Wingate cycle anaerobic power and accounted for 84.2% of the variance, respectively.

An individual's performance on the Wingate is greatly influenced by that person's weight. Correspondingly, the resistance that is applied to the flywheel of the cycle ergometer for the duration of the test is determined by multiplying a predetermined "optimal load" with the subject's weight. In theory, a person weighing more will have to pedal against a greater resistance, and will ultimately be able to generate a greater power output on the test. This ability to generate greater power may have been reflected in the overhead shot put component in the present study, where the tendency was for individuals with higher body weights to throw the shot put greater distances. Since adequate performance on the overhead shot put component typically requires a greater deal of upper body strength, this may be potentially associated with those individuals who possess a greater body weight as well.

Overall, Max Jones Quadrathlon component scores alone demonstrated low concurrent validity in predict anaerobic power. Only when paired with anthropometric characteristics did the ability to account for a greater variance in predicting anaerobic power in the Vertical Jump and Wingate cycle tests occur. It is speculated that this was due to the increased dependency of anthropometric variables (especially body weight) in the determination of anaerobic power in the Vertical Jump and Wingate cycle tests. Greater body weight contributed to higher predicted anaerobic power from the Vertical Jump and Wingate cycle tests, while weight had an inverse relationship with performance on the Max Jones Quad test components. Overhead shot put throw was the only Max Jones Quad test component that had a positive relationship with weight, however the correlation was not significant. Body fat percentage, lean body mass, and height also had inverse relationships with Max Jones Quad test components in the present study.

Basketball Performance Predictions

Models created to predict basketball performance variables from anaerobic power determined by Vertical Jump and Wingate tests were extremely weak and lacked demonstration of construct validity. The strongest prediction of Vertical Jump power from a performance variable was blocks and only accounted for 45.1% of the variance. The strongest prediction of Wingate cycle power from a performance variable was rebounds and only accounted for 43.5% of the variance. Based on these models, it has been established that basketball performance predicted from anaerobic power tests does not demonstrate construct validity. The limited ability to predict basketball performance from tests of anaerobic power is an indication that other variables are responsible for success on the basketball court. Basketball performance may be better predicted if the anaerobic tests mimic sport-specific movements and skills. Tests that incorporate jumping, sprinting speed, agility, muscular strength and endurance, and hand-eye coordination would provide a valuable tool to assess and monitor basketball performance.

Limitations

The present study contained certain limitations that may have contributed to the results observed:

1. Sample size was restricted since the basketball team included only thirteen members on its roster. The small sample size decreased the statistical significance and overall power of the study.
2. Practice time for the Max Jones Quadrathlon was allotted on the second day of testing. Even though all subjects demonstrated sufficient knowledge of how to perform each component, a possibility exists that not every subject had ample practice time to execute each component to the best of their ability.
3. Verbal encouragement was administered by all people monitoring the testing procedures. Although it was observed that most of the subjects seemed to be competing against each other in order to score higher on the test, there were still those participants that were giving less than their full effort.

4. The time of testing on each day matched the usually time in which the subjects regularly trained during their off-season. However, fatigue could have been a limiting factor since the tests were performed early in the morning.
5. Three consecutive days of testing could have been limited to two days. The Vertical Jump test and Max Jones Quadrathlon could have been performed on the same day with ample time allowed complete recovery between the two tests. Unlike the Wingate cycle test, these two tests would not be extremely taxing on the anaerobic energy system.
6. The resistance selection for the Wingate cycle test administered in the current investigation was 0.090 kg · kg of body mass^{-1} (0.90 N). This resistance is recommended for anaerobically fit female athletes (Adams, 1998). However, it was observed that several of the basketball players in the present study struggled with this resistance setting which might have contributed to lower absolute power outputs.
7. Performance on certain tests may have been influenced by a lack of sport specificity. An all out sprint on a cycle ergometer or throwing a weighted implement backwards over one's head are not requirements of female basketball players during competition. Sport specific movements that mimic common functional activities needed to compete in women's basketball may have been of greater use.
8. The methods for recording power output for the anaerobic power tests differed for all three tests. Use of force plates to determine the actual anaerobic power produced during the Vertical Jump test, instead of prediction equations, would

have allowed for more accurate results. Force plates could have also been used to determine anaerobic power in Watts for the four components of the Max Jones Quadrathlon. This would have assured measurements for all three tests to be recorded in Watts, and could have possibly lead to increased significance.

Conclusion

It was the purpose of the present study to determine if a relationship existed between the Max Jones Quadrathlon and the Vertical Jump and Wingate cycle anaerobic power tests in female Division I basketball players. A significant relationship was not determined between the Max Jones Quadrathlon total score and the Vertical Jump or Wingate cycle test. However, significant relationships were observed between the two anaerobic tests and certain individual components of the Max Jones Quadrathlon.

It was also the intent of this study to develop equations to predict anaerobic power from Max Jones Quadrathlon components and to predict basketball performance from anaerobic power determined by the Vertical Jump and Wingate cycle tests. Several equations for each case were deemed significant for predicting either anaerobic power or basketball performance in female players.

The equations predicting anaerobic power from the Max Jones Quadrathlon can be used by the coaching and training staff to evaluate female basketball players as they compare to other members of their team. Next, these equations may be used as tools to gauge and monitor progress throughout a season. Finally, equations predicting basketball performance from the Vertical Jump and Wingate cycle can allow a coaching and training staff to determine which female players may be key contributors to a team's success throughout a given season.

It is felt that the Max Jones Quadrathlon is an important performance test of power athletes. The preliminary results of the present study did not establish a relationship between the Wingate Cycle and Vertical Jump Tests and the Max Jones Quadrathlon. There exists a need to explore updated and sport specific measurement techniques. Tests that mimic functional movements required to perform sport specific skills need to be addressed when dealing with an athletic population. Therefore, it is recommended that the Max Jones Quadrathlon, and other sport specific assessments, be considered when performing tests to assess anaerobic power on an athletic population.

Recommendations for Future Research

Based upon the findings of this investigation, future research involving the Max Jones Quadrathlon, Vertical Jump Power, and Wingate Anaerobic Cycle Tests should consider the following:

1. Recreate the current investigation using a larger sample size (Recruit subjects from other Division I schools in the Pittsburgh area). This will provide the study with a higher degree of statistical power and would presumably result in more reliable correlations and regression models.
2. The present investigation employed female Division I basketball players. It would be of interest to compare the test results of these athletes to those participating on the Division II and Division III female collegiate basketball level.

3. Investigate both male and female athletic populations. Traditionally, the Max Jones Quadrathlon has been an anaerobic power test reserved for track and field athletes and football players. It would be of interest to compare the test results of these athletes to those participating in other athletic endeavors.
4. Examine gender differences in Anaerobic Power tests and the Max Jones Quadrathlon. It would be other interest to see how different genders perform on the Max Jones Quadrathlon.
5. Comparison of anaerobic power test results of an athletic subject population with a physically active non-athletic population of similar age, gender, and anthropometric measurements.
6. The current investigation used the Max Jones Quadrathlon scoring system based on the subject's performance in each of the 4 test components. It would be of interest to use force plates to record actual power outputs, in watts, of the four components of the Max Jones Quadrathlon. These power outputs could then be compared to the power outputs displayed in the Vertical Jump and Wingate Cycle Tests.
7. The current investigation created models to predict anaerobic power in the Vertical Jump and Wingate cycle tests. It would be of interest to use a cross-sample (cross validation) of a separate sample and their predicted versus actual anaerobic power outputs in the Vertical Jump and Wingate cycle tests.
8. It would be of interest to possibly eliminate/add tests from the Max Jones Quadrathlon to make it more sport specific for basketball players. The overhead shot put throw could be replaced with a seated shot put throw to assess upper

body strength and power. A line drill or plyometric jumping component could also be added to address sport specific functional movements such as agility, reaction time, and repeated jumping ability.

APPENDIX A

Departmental Scientific Review Approval

MEMO

TO: University of Pittsburgh
Institutional Review Board

FROM: John M. Jakicic, Ph.D.
Chair, Department of Health, Physical, and Recreation Education

DATE: September 28, 2004

RE: Scientific Merit Review

The protocol titled "The Use of the Max Jones Quadrathalon to Assess Anaerobic Power in Female Division I College Basketball Players: Comparison to the Wingate Cycle and Vertical Jump Test" has been reviewed by faculty in the Department of Health, Physical, and Recreation Education. This protocol has received a favorable scientific merit review by the faculty who reviewed this protocol. This conforms to the departmental policies for scientific merit review prior to submission to the IRB.

Please let me know if the department can be of further assistance in this matter.

APPENDIX B

Outside Departmental Scientific Review Approval

University of Pittsburgh

School of Health and Rehabilitation Sciences
Department of Physical Therapy

6035 Forbes Tower
Pittsburgh, Pennsylvania 15260
Phone: (412) 647-1237
Fax: (412) 647-1454

September 16, 2004

To Whom It May Concern:

Please be advised that I have reviewed the proposal entitled “The Use of the Max Jones Quadrathalon to Assess Anaerobic Power in Female Division I College Basketball Players: Comparison to Wingate Cycle and Vertical Jump Tests" and I find the scientific merit and the risk to benefit ratio to be acceptable. The protocol requires minor house keeping changes.

Sincerely

James J. Irrgang PhD PT ATC

APPENDIX C

Physical Activity Readiness Questionnaire (PAR-Q and YOU)

PAR – Q & YOU

Physical Activity Readiness
Questionnaire - PAR-Q(revised 1994)

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.
If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.
Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
☐	☐	2. Do you feel pain in your chest when you do physical activity?
☐	☐	3. In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition? condition?
☐	☐	7. Do you know of any other reason why you should not do physical activity?

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-O and which questions you answered YES.

- You may be able to do any activity you want - as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active - begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal - this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively.

DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of temporary illness such as a cold or a fever – wait until you feel better; or
- If you are or may be pregnant – talk to your doctor before you start becoming more active

Please note: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional.
Ask whether you should change your physical activity plan.

<u>Informed Use of the PAR-Q</u>: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

NAME: ______________________________

SIGNATURE: ______________________________ **DATE:** ______________________
SIGNATURE OF PARENT: ______________________ **WITNESS:** ______________________
or GUARDIAN (for participants under the age of majority)

Note: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

APPENDIX D

Informed Consent Form

University of Pittsburgh
Institutional Review Board
Approval Date: December 8, 2004
Renewal Date: December 7, 2005
IRB Number: 0410048

CONSENT TO ACT AS A SUBJECT IN A RESEARCH STUDY

TITLE: The Use of the Max Jones Quadrathalon to Assess Anaerobic Power in Female Division I College Basketball Players: Comparison to Wingate Cycle and Vertical Jump Tests

PRINCIPLE INVESTIGATOR: Kory Stauffer, MS, ATC/L
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412-648-8320

SOURCE OF SUPPORT: None

Participant's Initials: _____

Why is this research being done?

The University of Pittsburgh is conducting a research study to determine the relationship between the Max Jones Quadrathalon and two established anaerobic power (the performance of work in the absence of oxygen) tests: 1) Wingate anaerobic cycle ergometer test, and 2) Vertical jump test. It is anticipated that the results of this investigation will provide women's basketball coaches and strength and conditioning coaches a more sport specific test to evaluate the anaerobic power of their athletes.

Who is being asked to take part in this research study?

You are being invited to participate in this research study because you meet the following criteria: 1) are a member of the University of Pittsburgh Women's Basketball team; 2) are not suffering from any pre-existing injuries or illnesses; and 3) are willing to participate in all testing sessions. This study will be performed on a total of 16 subjects and will take place at the University of Pittsburgh Men's and Women's Basketball Team training facility and the University of Pittsburgh's Center for Exercise and Health-Fitness Research. You are being asked to participate in the following:

- One session of anthropometric data collection
- One Vertical Jump testing session
- One Max Jones Quadrathalon testing session
- One Wingate anaerobic cycle ergometer testing session

What procedures will be performed for research purposes?

Experimental Procedures

If you qualify to take part in this research study, you will undergo the orientation and experimental procedures listed below. These procedures will take place in the University of Pittsburgh Men's and Women's basketball training facility, the Charles L. Cost Center, and the University of Pittsburgh's Center for Exercise and Health-Fitness Research. On the first testing day, you will be given a brief overview of the study. At this time, any questions that you have concerning the testing procedures should be addressed. You will be oriented with all equipment that will be used during the investigation and proper technique required to complete each test will be demonstrated. Your height, weight, and body composition will also be determined at this time. In order to measure your jump height and in turn calculate your anaerobic power we will conduct a vertical jump test. This test will be performed on a basketball floor and will use a devise call a Vertec to measure your jump height. Prior to the vertical jump test, you will be lead through a series of static stretches by the primary investigator (quad, hamstring, calf, gluteus, and hip flexor stretches). You will be asked to perform maximal jumps until you

Participant's Initials: _____

do not exhibit an increase in jump height, usually within three to five jumps. Your standing reach will be measured with your feet flat on the floor and your dominant arm reached directly overhead. During the test, you will be allowed no more than 5 seconds in between each successive jump.

On the second day of testing, you will be lead through a 12-15 minute dynamic warm-up consisting of squats, lunges, burpees, good mornings, and walking hamstring and quadriceps stretches that target the quad, hamstring, calf, gluteal, and hip flexor muscles. This warm-up will be lead by the primary investigator. Immediately following the dynamic stretching period, the Max Jones Quad Test will be explained in detail and demonstrated to the group. You will be split into three groups, consisting of five subjects per group, and will be assigned to a specific station to practice the Max Jones Quad test. The Max Jones Quadrathalon consists of four test stations; 1) broad jump, 2) 3 consecutive broad jumps, 3) overhead shot put toss, and 4) 30 meter sprint. Three (3) trials will be permitted at each station except the 30 meter sprint station, which will involve 2 trials. A one minute active rest period, consisting of walking or jogging to the next station, will be allowed between each component of the Max Jones Quad test as your group rotates from station to station.

On the last day of testing, you will be lead through a 12-15 minute dynamic warm-up consisting of squats, lunges, burpees, good mornings, and walking hamstring and quadriceps stretches that target the quad, hamstring, calf, gluteal, and hip flexor muscles. This warm-up will be lead by the primary investigator. Testing on this day will consist of the Wingate anaerobic cycle ergometer test. Prior to the start of the Wingate test, all ergometer settings will be adjusted to fit your height and body type. The height of the seat will be adjusted so that your knee is only slightly flexed (5^{o}-10^{o}) when sitting comfortably with the middle of the foot resting on the pedal and with the pedal in the lowest position. The handlebar position will be adjusted to your specific requirements to allow for maximal comfort throughout the test. The Wingate anaerobic cycle test consists of a supramaximal, all out 30-second sprint against a predetermined resistance. A 5-minute warm-up will be used prior to the start of the test and the subsequent 2-5 minute recovery interval will be used at the completion of the test. An acceleration period consisting of 2 brief phases will precede the beginning of the Wingate test. The first phase will have you pedal at about 20 to 50 revolutions per minute (rpm) for 5 to 10 seconds at a resistance one-third of that prescribed for the test. In the second phase, the subject will increase the rpm to a near-maximal rate while the investigator loads the prescribed force within 3 to 5 seconds. Once the prescribed force is reached, the force-setter will yell "go" and the timer will officially start the clock to begin the test. You will begin pedaling as fast as possible for a 30-second period while remaining seated on the bike for the duration of the test. At the end of the 30-seconds, the investigator will yell, "stop."

Participant's Initials: _____

The force-setter will reduce the resistance to a cool-down recovery setting (between 1 and 2 kg) while you continue to pedal at about 50 rpm for 2 to 3 minutes. Verbal encouragement will be given throughout the duration of the test and particularly during the final ten to fifteen seconds.

The projected timeline for the three testing days are:

- Testing Day 1 Overview of study, informed consent, anthropometric measurements, and Vertical jump test (will last 60-90 minutes)
- Testing Day 2 Explanation and demonstration of Max Jones Quadrathalon followed by performance of Max Jones Quadrathalon (will last 45 minutes)
- Testing Day 3 Wingate cycle ergometer anaerobic power test (will last 10-15 minutes)

What are the possible risks, side effects, and discomforts of this research study?

Abnormal responses, such as shortness of breath, chest pain, and heart rhythm irregularity, are rare during anaerobic exercise performed by young healthy females and males.

- The risk of death during or immediately following anaerobic exercise tests is less than 0.01% (1 out of 1,000 people).
- Approximately 0.75 and 0.13 per 100,000 young male and female athletes die during vigorous exertion and testing per year.

In order to minimize these risks associated with maximal exercise testing, you will be asked to complete the PAR-Q and YOU cardiovascular screening questionnaire (recall the pre-participation screening process). It is very important that
you answered the PAR-Q and YOU accurately and honestly, because it provides the investigators critical information on your ability to exercise without risks to your overall health. To minimize anxious feelings during any of the 3 testing days you will have the opportunity to become familiar with all the equipment during the orientation period and before each specific anaerobic test. An explanation of the termination procedures for each test will be given in detail by the primary investigator prior to the start of each test.

Participant's Initials: _____

The exercise intensity during the vertical jump test and the Max Jones Quadrathalon will be similar to what you will experience (feel) during your drills at basketball practice. The Wingate cycle test will require a supramaximal effort and will be similar to running a fast break for 30 consecutive seconds at the end of a game. Again, if an abnormal response occurs during the tests (i.e. you experience any chest pain/discomfort) the test will be immediately discontinued and you will be given proper medical attention.

When participating in the anaerobic power tests, you may experience some general delayed muscle soreness. The effects may begin 8-24 hours after testing and peak 24-72 hours post-testing, however this is only temporary. The likelihood of this occurring is greatest following the Wingate cycle test, since you are not accustom to performing this type of movement.

All testing sessions will be supervised by at least 2 individuals certified by the American Red Cross in CPR for the Professional Rescuer, AED, and Community First Aid and Safety. During all testing, an Automated External Defibrillator (AED) will be on site for a cardiac emergency, as well as, bag valve masks, oral airway and oxygen administration cylinders for breathing emergencies. This equipment would be used during an emergency to reestablish your heart rate, assist with the administration of CPR and oxygen. In the event of an emergency, the emergency action plan (EAP) will go into effect. The emergency action plan states that one person remains with you to assess airway, breathing, and circulation while another person dials 811 (campus police) and advise the guard of arriving emergency medical personnel.

What are the possible benefits from taking part in this study?

The possible benefits to you for your participation in this research study include information concerning your level of anaerobic fitness (compared to the team's average), vertical jump height, and percentage of body fat. You will also be provided with information on physical components essential to basketball that you need to address in order to maximize your potential.

If I agree to take part in this research study, will I be told of any new risks that may be found during the course of the study?

You will promptly notified if, during the conduct of this research study, any new information develops which may cause you to change your mind about continuing to participate in this study.

Participant's Initials: _____

Will my insurance provider or I be charged for the costs of any procedures performed as part of this research study?

Neither you nor your insurance provider will be charged for the costs of any of the procedures performed for the purpose of this research study (i.e., the Screening and Experimental Procedures described above).

Will I be paid if I take part in this study?

There will be no charge to you, nor will you be paid to participate in this investigation. It is a NCAA violation to pay athletes for participation in any type of research study and could ultimately lead to ineligibility of the athlete, as well as probation for the institution.

Who will pay if I am injured as a result of taking part in this study?

University of Pittsburgh investigators and their associates who provide services at the University of Pittsburgh Medical Center (UPMC) recognize the importance of your voluntary participation to their research studies. These individuals and their staffs will make reasonable efforts to minimize, control, and treat any injuries that may arise as a result of this research.

If you believe that you are injured as the result of the research procedures being performed, please contact immediately the Principal Investigator listed on the cover sheet of this form. Emergency medical treatment for injuries solely and directly relating to your participation in this research will be provided to you by hospitals of the UPMC.

It is possible that the UPMC may bill your insurance provider for the costs of this emergency treatment, but none of these costs will be charged directly to you. If your research-related injury requires medical care beyond this emergency treatment, you will be responsible for the costs of this follow-up care unless otherwise specifically stated below. You will not receive monetary payment for, or associated with, any injury that you suffer in relation to this research.

Who will know about my participation in this research study?

Any information about the subject obtained from the research will be kept as confidential (private) as possible. All records related to your involvement in this research study will be stored in a locked file cabinet located in the office of the primary investigator. The identity of the subject will be indicated by a case number rather than by

Participant's Initials: _____

name, and the information linking these numbers with a specific subject's identity will be kept separate from the research records. This will ensure that individual data will not be identifiable by anyone other than the investigators and co-investigator. The information will only be accessible to the investigators and their research study co-investigators listed on the first page of this document. Subject confidentiality will be ensured by the investigators by not releasing information regarding the results of any performance test used in this study to the coaching staff without written consent from each subject. Also, no member of the coaching staff will be present during any performance test session. University of Pittsburgh policy requires that research records be kept for a period of not less than five years. You will not be identified by name in any publication of research results unless you sign a separate form giving your permission (release). Results will be made available to the coaching staff only with the permission of the athlete.

Will this research study involve the use of disclosure of my identifiable medical information?

This research study will not involve the use or disclosure of your identifiable medical information.

Who will have access to identifiable information related to my participation in this research study?

In addition to the investigators listed on the first page of this authorization (consent) form and their research staff, the following individuals will or may have access to identifiable information related to your participation in this research study:

The University of Pittsburgh Research Conduct and Compliance Office may review your identifiable research information for the purpose of monitoring the appropriate conduct of this research study.

In unusual circumstances, you understand that your identifiable information related to your participation in this research study may be inspected by appropriate government agencies or may be released in response to an order from a court of law. If investigators learn that you or someone with whom you are involved is in serious danger or potential harm, they will need to inform, as required by Pennsylvania law, the appropriate agencies.

Participant's Initials: _____

For how long will the investigators be permitted to use and disclose identifiable information related to my participation in this research?

The investigators may continue to use and disclose, for the purposes described above, identifiable information related to your participation in this research study for a period of 5 years as required by University policy.

Is my participation in this research study voluntary?

Your participation in this research study is completely voluntary. You do not have to take part in this research study and, should you change your mind, you can withdraw from the study at any time. If you choose to withdraw from the study you will only be given results obtained up until that point. Your decision to participate or not in this study will in no way affect your status as a basketball player at the University of Pittsburgh.

May I withdraw, at a future date, my consent for participation in this research study?

You may withdraw, at any time, your consent for participation in this research study, to include the use and disclosure of your identifiable information for the purposes described above. (Note, however, that if you withdraw your consent for the use and disclosure of your identifiable information for the purposes described above, you will also be withdrawn, in general, from further participation in this research study). Any identifiable research information recorded for, or resulting from your participation in this research study prior to the date that you formally withdrew your consent may continue to be used and disclosed by the investigators for the purposes described above.

To formally withdraw your consent for participation in this research study you should provide a written and dated notice of this decision to the principal investigator of this research study at the address listed on the first page of this form. Your decision to withdraw your consent for participation in this research study will have no effect on your current or future relationship with the University of Pittsburgh. Your decision to withdraw your consent will have no effect on your current or future medical care at a UPMC hospital of affiliated health care provider or your current or future relationship with a health care insurance provider.

If I agree to take part in this research study, can I be removed from the study without my consent?

It is possible that you may be removed from the research study by the researchers if, for example, you do not follow the study protocol which had been established.

Participant's Initials: _____

University of Pittsburgh
Institutional Review Board
Approval Date: December 8, 2004
Renewal Date: December 7, 2005
IRB Number: 0410048

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VOLUNTARY CONSENT

All of the above has been explained to me and all of my questions have been answered. I understand that I am encouraged to ask questions about any aspect of this research study during the course of this study, and that such future questions will be answered by the researchers listed on the first page of this form. Any questions that I have about my rights as a research participant will be answered by the Human Subject Protection Advocate of the IRB office, University of Pittsburgh (1-866-212-2668). By signing this form, I agree to participate in this research study.

____
Participant's Name (Print)

______________________ ________________
Participant's Signature Date

CERTIFICATION OF INFORMED CONSENT

I certify that I have explained the nature and purpose of this research study to the above-named individual, and I have discussed the potential benefits, and possible risks associated with participation. Any questions the individual has about this study have been answered, and we will always be available to address future questions as they arise.

_______________________ __________________________
Printed Name of Person Obtaining Consent Role in Research Study

_______________________ __________________________
Signature of Person Obtaining Consent Date

APPENDIX E

Emergency Action Plan (EAP)

Emergency Response System

**The Emergency Action Plan for Trees Hall, Cost Center, and Petersen Events Center is:

UNIVERSITY OF PITTSBURGH FACULTY AND & STAFF

In the event of an emergency, you should do the following:

1. Begin Emergency Care
   Establish level of consciousness
   Check for Airway, Breathing, Circulation, Bleeding, etc
2. Send 2ndary party to Campus Police in the lobby of Trees Hall, Cost Center, or to the Guard Station in the Petersen Events Center or Call Campus Police 811 or 4-2121
3. Instruct them to mention the following:
   "I am calling from Trees Hall/Cost Center/Petersen Events Center [location] and my name is [your name]. We've had an accident where [briefly describe your victim-include degree of consciousness] and will need an ambulance **IMMEDIATELY.**
4. Send 2ndary assistance to doors to meet ambulance
5. Get as much information on the victim for accident report before victim leaves the facility
6. Fill out release form if the situation calls for one
7. Report incident/accident report and hand in to your supervisor A.S.A.P.

**Ambulance response is approximately 5 minutes with nearby hospitals approximately 2 minutes away from each facility.

**Trees Hall has an Automated External Defibrillator (AED) located in the First Aid room; the Cost Center has an Automated External Defibrillator (AED) located in the campus police station in the lobby; and the Petersen Events Center has an Automated External Defibrillator (AED) located in the guard station and in the sports medicine training room. All facilities have trained personnel in the building at all times in the event of a cardiac emergency.

**Staff are certified in American Red Cross CPR for the Professional Rescuer including AED certification and training.

APPENDIX F

Medical History

MEDICAL HISTORY

Name________________________

Date_____________

Please answer all of the following questions to the best of your knowledge. Use the back if necessary.

How would you categorize your general physical condition?
( ) Excellent ( ) Very Good ( ) Adequate ( ) Poor

Are you currently taking any medications? If so, what are they and for what condition(s)?
____
____
____
____

Dosage(s) ____

Frequency____

DO YOU NOW, OR HAVE YOU HAD ANY OF THE FOLLOWING CONDITIONS?

	YES	NO
1. History of heart problems, chest pain or stroke?	____	____
2. Increased blood pressure?	____	____
3. Any chronic illness or condition?	____	____
4. Difficulty with physical exercise?	____	____
5. Advice from a physician not to exercise?	____	____
6. Recent surgery? (Last 12 months)	____	____
7. Pregnancy? (Now or within the last 3 months)	____	____
8. History of breathing of lung problems?	____	____
9. Muscle, joint, back disorder, or any previous injury still affecting you?	____	____
10. Diabetes or thyroid condition	____	____
11. Cigarette smoking habit?	____	____
12. Increased blood cholesterol?	____	____
13. History of heart problems in your immediate family	____	____
14. Any condition that may be aggravated by lifting weights?	____	____
15. Do you have any condition limiting your movement?	____	____
16. Are you aware of being allergic to any drugs or insect bites?	____	____
17. Do you have asthma?	____	____
18. Do you have epilepsy, convulsions, or seizures of any kind?	____	____
19. Do you follow any specific diet?	____	____

Please explain in detail any "YES" answers:

Family History

Has any member of your immediate family had any of the above? If so, please specify.

Have you ever stopped participating in physical activity due to an illness or injury for an extended period of time? _____Yes _____No If yes, please explain.

I certify that all answers to the above questions are honest and accurate to the best of my knowledge. I understand that by not answering honestly and accurately to any of the above questions, I could put myself at risk during my testing sessions.

______________________	______________________
NAME (PRINTED)	SIGNATURE
______________________	______________________
WITNESS	DATE

APPENDIX G

Max Jones Quadrathlon Scoring Table

TEST QUADRATHLON TABLES (1992)

Points	3 Jumps	S.L.J.	30m	O.H. Shot	Points	3 Jumps	S.L.J.	30m	O.H. Shot
1	3.00	1.00	5.80	4.00	51	7.04	2.36	4.38	12.58
2	3.08	1.02	5.77	4.17	52	7.12	2.39	4.35	12.75
3	3.16	1.05	5.74	4.34	53	7.20	2.41	4.33	12.92
4	3.24	1.08	5.71	4.51	54	7.28	2.44	4.30	13.10
5	3.32	1.10	5.68	4.68	55	7.36	2.47	4.27	13.27
6	3.40	1.13	5.66	4.85	56	7.44	2.50	4.24	13.44
7	3.48	1.16	5.63	5.03	57	7.52	2.52	4.21	13.61
8	3.56	1.19	5.60	5.20	58	7.60	2.55	4.18	13.78
9	3.64	1.21	5.57	5.37	59	7.63	2.58	4.16	13.95
10	3.72	1.24	5.54	5.54	60	7.76	2.60	4.13	14.13
11	3.80	1.27	5.51	5.71	61	7.84	2.63	4.10	14.30
12	3.88	1.30	5.49	5.83	62	7.92	2.66	4.07	14.47
13	3.96	1.32	5.46	6.06	63	8.01	2.69	4.04	14.64
14	4.05	1.35	5.43	6.23	64	8.09	2.71	4.02	14.81
15	4.13	1.38	5.40	6.40	65	8.17	2.74	3.99	14.98
16	4.21	1.40	5.37	6.57	66	8.25	2.77	3.96	15.16
17	4.29	1.43	5.34	6.74	67	8.33	2.80	3.93	15.33
18	4.37	1.46	5.32	6.91	68	8.41	2.82	3.90	15.50
19	4.45	1.49	5.29	7.09	69	8.49	2.85	3.87	15.67
20	4.53	1.51	5.26	7.26	70	8.57	2.88	3.85	15.84
21	4.61	1.54	5.23	7.43	71	8.65	2.90	3.82	16.02
22	4.69	1.57	5.20	7.60	72	8.73	2.93	3.79	16.19
23	4.77	1.60	5.17	7.77	73	8.81	2.96	3.76	16.36
24	4.85	1.62	5.15	7.94	74	8.89	2.99	3.73	16.53
25	4.93	1.65	5.12	8.12	75	8.97	3.01	3.70	16.70
26	5.02	1.68	5.09	8.29	76	9.06	3.04	3.68	16.87
27	5.10	1.70	5.06	8.46	77	9.14	3.07	3.65	17.05
28	5.18	1.73	5.03	8.63	78	9.22	3.10	3.62	17.22
29	5.26	1.76	5.01	8.80	79	9.30	3.12	3.59	17.39
30	5.34	1.79	4.98	8.97	80	9.38	3.15	3.56	17.56
31	5.42	1.81	4.95	9.15	81	9.46	3.18	3.53	17.73
32	5.50	1.84	4.92	9.32	82	9.54	3.20	3.51	17.90
33	5.58	1.87	4.89	9.49	83	9.62	3.23	3.48	18.03
34	5.66	1.90	4.86	9.66	84	9.70	3.26	3.45	18.25
35	5.74	1.92	4.84	9.83	85	9.78	3.29	3.42	18.42
36	5.82	1.95	4.81	10.01	86	9.86	3.31	3.39	18.59
37	5.90	1.98	4.78	10.13	87	9.94	3.34	3.36	18.76
38	5.98	2.00	4.75	10.35	88	10.03	3.37	3.34	18.93
39	6.07	2.03	4.72	10.52	89	10.11	3.40	3.31	19.11
40	6.15	2.06	4.69	10.69	90	10.19	3.42	3.28	19.28
41	6.23	2.09	4.67	10.86	91	10.27	3.45	3.25	19.45
42	6.31	2.11	4.64	11.04	92	10.35	3.48	3.22	19.62
43	6.39	2.14	4.61	11.21	93	10.43	3.50	3.20	19.79
44	6.47	2.17	4.58	11.38	94	10.51	3.53	3.18	19.96
45	6.55	2.20	4.55	11.55	95	10.59	3.56	3.15	20.14
46	6.63	2.22	4.52	11.72	96	10.67	3.59	3.12	20.31
47	6.71	2.25	4.50	11.89	97	10.75	3.61	3.09	20.48
48	6.79	2.28	447	12.07	98	10.83	3.64	3.06	20.65
49	6.87	2.30	4.44	12.24	99	10.91	3.67	3.03	20.82
50	6.95	2.33	4.41	12.41	100	11.00	3.70	3.01	21.00

Additional Points

3 Jumps: 1 Point extra for each 8 cms above 11.00

S.L.J.: 1 point for each 3 cm above 3.70

30m: 1 point for each 0.03 below 3.01

O.H. Shot: 1 point for each 7 cm above 21.00

BIBLIOGRAPHY

BIBLIOGRAPHY

Adams, G.M. Exercise Physiology Laboratory Manual, 3rd ed. Boston, MA: McGraw-Hill, 1998.

Ashley, C.D., and Weiss, W. (1994). Vertical Jump Performance and Selected Physiological Characteristics of Women. Journal of Strength and Conditioning Research, 8(1),5-11.

Ayalon, A., Inbar, O., and Bar-Or, O. Relationships Among Measurements of Explosive Strength and Anaerobic Power. In Nelson and Morehouse (Eds) International Series on Sports Sciences, Vol I, Biomechanics IV, 527-532. Baltimore, Maryland: University Park Press, 1974.

Bale, P. (1991). Anthropometric, Body Composition, and Performance Variables of Young Elite Female Basketball Players. Journal of Sports Medicine and Physical Fitness, 31, 173-177.

Ballard, T.O., Fafara, L., and Vukovich, M.D. (2004). Comparison of Bod Pod and DXA in Female
Collegiate Athletes. Medicine and Science in Sport and Exercise, 36(4), 731-735.

Bar-Or, O. (1987). The Wingate Anaerobic Test: An Update on Methodology, Reliability, and Validity. Sports Medicine, 4, 381-394.

Beckenholdt, S.E., and Mayhew, J.L. (1983). Specificity Among Anaerobic Power Tests in Male Athletes. Journal of Sports Medicine,23, 326-332.

Beneke, R., Pollmann, C., Bleif, I., Leithauser, R.M., and Hutler, M. (2002). How Anaerobic is the Wingate Anaerobic Test for Humans? European Journal of Applied Physiology, 87, 388-392.

Bompa, T.O. Periodization of Strength. Toronto, Ontario: Veritas Publishing Inc, 1993.

Bosco, C., Luhtanen, P., and Komi, P.V. (1983). A Simple Method for Measurement of Mechanical Power in Jumping. European Journal of Applied Physiology, 50, 273-282.

Bosco, C., and Komi, P.V. (1979). Mechanical Characteristics and Fiber Composition of Human Leg Extensor Muscles. European Journal of Applied Physiology, 41, 275-284.

Bosco, C., and Komi, P.V. (1980). Influence of Aging on the Mechanical Behavior of Leg Extensor Muscles. European Journal of Applied Physiology, 45, 209-219.

Brooks, G.A., Fahey, T.D., White, T.P., and Baldwin, K.M. Exercise Physiology:Human Bioenergetics and its Applications, 3rd ed. Mountain View, CA: Mayfield Publishing Company, 2000.

Calbet, J.A.L., Chavarren, J., and Dorado, C. (1997). Fractional Use of Anaerobic Capacity During a 30- and a 45-s Wingate Test. European Journal of Applied Physiology, 76, 308-313.

Davies, C.T.M., and Rennie, R. (1968). Human Power Output. Nature, 217,770.

Dotan, R., and Bar-Or, O. (1983). Load Optimization for the Wingate Anaerobic Test. European Journal of Applied Physiology, 51, 409-417.

Driss, T., Vandewalle, H., and Monod, H. (1998). Maximal Power and Force-Velocity Relationships During Cycling and Cranking Exercises in Volleyball Players: Correlation with the Vertical Jump Test. Journal of Sports Medicine and Physical Fitness, 38, 286-93.

Dunn, G.D., and McGill, K. The Throws Manual, 3rd ed. Mountain View, CA: Tafnews Press, 2003.

Evans, J.A., and Quinney, H.A. (1981). Determination of Resistance Settings for Anaerobic Power Testing. Canadian Journal of Applied Sports Science, 6(2), 53-56.

Fenn, W.O., and Marsh, B.S. (1935). Muscular Force at Different Speeds of Shortening. European Journal of Applied Physiology, 85, 277-297.

Fields, D.A., Hunter, G.R., and Goran, M.I. (2000). Validation of the Bod Pod with HydrostaticWeighing: Influence of Body Clothing. International Journal of Obesity and Related Metabolic Disorder: Journal of the International Association for the Study of Obesity, 24(2), 200-205.

Fleck, S.J., and Kraemer, W.J. Designing Resistence Training Programs, 2nd ed. Champaign,IL: Human Kinetics, 1997.

Foss, M.L., and Keteyian, S.J. Physiological Basis for Exercise and Sport, 6th ed. Boston, MA; McGraw-Hill, 1998.

Glaister, M., Stone, M.H., Stewart, A.M., Hughes, M., and Moir, G.L. (2003). Reliability of Power Output During Short-Duration Maximal-Intensity Intermittent Cycling. Journal of Strength and Conditioning Research, 17(4), 781-784.

Glencross, D.J. (1966). The Nature of the Vertical Jump Test and the Standing Broad Jump. Research Quarterly, 37(3), 353-359.

Harman, E.A. (1991). The Importance of Testing Power Output. National Strength and Conditioning Journal, 13(5), 72-73.

Harman, E.A., Rosenstein, M.T., Frykman, P.N., Rosenstein, R.M., and Kraemer, W.J. (1991). Estimation of Human Power Output From Vertical Jump. Journal of Applied Sport Science Research, 5(3), 116-120.

Hill, A.V. (1938). The Heat of Shortening and the Dynamic Consent of Muscle. Proceedings of the Royal Society of London, 126, 136-195.

Hoffman, J.R., Epstein, S., Einbinder, M., and Weinstein, Y. (2000). A Comparison Between the Wingate Anaerobic Power Test to Both Vertical Jump and Line Drill Tests in Basketball Players. Journal of Strength and Conditioning Research, 14(3), 261-264.

Hoffman, J.R., Epstein, S., Einbinder, M., and Weinstein, Y. (1999). The Influence of Aerobic Capacity on Anaerobic Performance and Recovery Indices in Basketball Players. Journal of Strength and Conditioning Research, 13(4), 407-411.

Hoffman, J.R., Tenenbaum, G., Maresh, C.M., and Kraemer, W.J. (1996). Relationship Between Athletic Performance Tests and Playing Time in Elite College Basketball Players. Journal of Strength and Conditioning Research, 10(2), 67-71.

Inbar, O., Bar-Or, O., and Skinner, J.S. The Wingate Anaerobic Test. Champaign, IL: Human Kinetics, 1996.

Inbar, O., Dotan, R., and Bar-Or, O. (1976). Aerobic and Anaerobic Components of a Thirty-Second Supramaximal Cycling Task. Medicine and Science in Sport and Exercise, 8, S51.

Johnson, D.L., and Bahamonde, R. (1996). Power Output Estimate in University Athletes. Journal of strength and Conditioning Research, 10(3), 161-166.

Klavora, P. (2000). Vertical Jump Tests: A Critical Review. National Strength and Conditioning Journal, 22(5), 70-75.

Koch, A.J., O'Bryant, H.S., Stone, M.E., Sanborn, K., Proulx, C., Hruby, J., Shannonhouse, E., Boros, R., and Stone, M.H. (2003). Effect of Warm-Up on the Standing Broad Jump in Trained and Untrained Men and Women. Journal of Strength and Conditioning Research, 17(4), 710-714.

Koziris, L.P., Kraemer, W.J., Patton, J.F., Triplett, N.T., Fry, A.C., Gordon, S.E., and Knuttgen, H.G. (1996). Relationship of Aerobic Power to Anaerobic Performance Indices. Journal of Strength and Conditioning Research, 10(1), 35-39.

LaMonte, M.J, McKinney, J.T., Quinn, S.M., Bainbridge, C.N., and Eisenman, P.A. (1999). Comparison of Physical and Physiological Variables for Female College Basketball Players. Journal of Strength and Conditioning Research, 13(3), 264-270.

Latin, R.W., Berg, K., and Baechle, T. (1994). Physical and Performance Characteristics of NCAA Division I Male Basketball Players. Journal of Strength and Conditioning Research, 8(4), 214-218.

Maddalozzo, G.F., Cardinal, B.J., and Snow, C.A. (2002). Concurrent Validity of the Bod Pod and Dual Energy X-ray Absorptiometry Techniques for Assessing Body Composition in Young Women. Journal of American Diet Association, 102(11), 1677-1679.

Manning, J.M., Manning, C.D., and Perrin, D.H. (1988). Factor Analysis of Various Anaerobic Power Tests. Journal of Sports Medicine and Physical Fitness, 28, 138-144.

Margaria, R., Aghemo, P., and Rovelli, E. (1966). Measurement of Muscular Power (Anaerobic) in Man. Journal of Applied Physiology, 21, 1662-1664.

Maud, P.J., and Shultz, B.B. (1986). Gender Comparisons in Anaerobic Power and Anaerobic Capacity Tests. British Journal of Sports Medicine, 20(2), 51-54.

Mayhew, J.L., and Salm, P.C. (1990). Gender Differences in Anaerobic Power Tests. European Journal of Applied Physiology, 60, 133-138.

Mayhew, J.L., Bemben, M.G., Rohrs, D.M., and Bemben, D.A. (1994). Specificity Among Anaerobic Power Tests in College Female Athletes. Journal of Strength and Conditioning Research, 8(1), 43-47.

Mayhew, J.L., Bemben, M.G., Piper, F.C., Ware, J.S. Rohrs, D.M., and Bemben, D.A. (1993). Assessing Bench Press Power in College Football Players:The Seated Shot Put. Journal of Strength and Conditioning Research, 7(2), 95-100.

Mayhew, J.L., Bemben, M.G., Rohrs, D.M., Ware, J.S., and Bemben, D.A. (1991). Seated Shot Put as a Measure of Upper Body Power in College Males. Journal of Human Movement Studies, 21,137-148.

Mayhew, J.L., Bemben, M.G., Rohrs, D.M. (1992). Seated Shot Put as a Measure of Upper Body Power in Adolescent Wrestlers. Pediatric Exercise Science, 4, 78-84.

Mayhew, J.L., Piper, F.C., Schwegler, T.M., and Ball, T.E. (1989). Contributions of Speed, Agility, and Body Composition to Anaerobic Power Measurement in College Football Players. Journal of Applied Sports Science Research, 3(4), 101-106.

Murphy, M.M., Patton, J.F., and Frederick, B.S. (1986). Comparative Anaerobic Power of Men and Women. Aviation, Space, and Environmental Medicine, 57, 636-641.

Patton, J.F., Murphy, M.M., and Frederick, B.S. (1985). Maximal Power Outputs During the Wingate Anaerobic Test. International Journal of Sports Medicine, 6(2), 82-85.

Patton, J.F., and Duggan, A. (1987). An Evaluation of Tests of Anaerobic Power. Aviation, Space, and Environmental Medicine, 58, 237-242.

Powers, S.K., and Howley, E.T. Exercise Physiology:Theory and Application to Fitness and Performance, 3 ed. Boston, MA: McGraw-Hill, 1996.

Sargent, D.A. (1921). The Physical Test of a Man. American Physical Education Review, 26,188-194.

Seiler, S., Taylor, M., Diana, R., Layes, J., Newton, P., and Brown, B. (1990). Assessing Anaerobic Power in Collegiate Football Players. Journal of Applied Sports Science Research, 4(1), 9-15.

Semenick, D. (1984). Testing and Practical Applications. National Strength and Conditioning Association Journal, October-November.

Skinner, J.S., and Morgan, D. . Aspects of Anaerobic Performance. In *Limits of Human Performance*,ed. D. Clarke and H Eckert, 31-44. Champaign, IL:Human Kinetics,1985.

Smith, J.C., and Hill, D.W. (1991). Contribution of Energy Systems During a Wingate Power Test. British Journal of Sports Medicine,25(4), 196-199.

Vandewalle, H., Peres, G., and Monod, H. (1987). Standard Anaerobic Exercise Tests. Sports Medicine, 4, 268-289.

Vandewalle, H., Peres, G., Heller, J., Panel, J., and Monod, H. (1987). Force-Velocity Relationship and Maximal Power on a Cycle Ergometer. European Journal of Applied Physiology, 56, 650-656.

Vandewalle, H., Peres, G., Heller, J., and Monod, H. (1985). All Out Anaerobic Capacity Tests on Cycle Ergometers: A Comparative Study on Men and Women. European Journal of Applied Physiology, 54, 222-229.

Zajac, A., Jarzabek, R., and Waskiewicz, Z. (1999). The Diagnostic Value of the 10- and 30-Second Wingate Test for Competitive Athletes. Journal of Strength and Conditioning Research, 13(1), 16-19.