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Title: An Examination of the Relationship Among Three Tests of Anaerobic Capacity.

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The purpose of this study was to determine the relationship among the scores of three tests of anaerobic capacity for Division II collegiate track and field athletes. Participants (N=38) completed each of the following tests: the Wingate Anaerobic Cycle Test (WAnT), the Cunningham and Faulkner anaerobic treadmill test, and the Running-based Anaerobic Sprint Test (RAST). The tests were conducted over a three-week period during the indoor track and field season. A Pearson-Product correlation was used to determine the strength of the relationship among the anaerobic capacity measurements of the tests. The correlation among all tests was significant at the $\underline{p} \leq 0.01$ level. A sub-area of this study was to develop a preliminary set of percentile-based norms for the Cunningham and Faulkner anaerobic treadmill test based on the results of collegiate level athletes. However, due to the small and selective sample, the norms presented in this study are to be used with caution and are for comparison purposes only.

AN EXAMINATION OF THE RELATIONSHIP

AMONG THREE TESTS

OF ANAEROBIC CAPACITY

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CHAPTER 1

INTRODUCTION

Measuring and evaluating training methods are essential components of training for athletes concerned with reaching their ultimate potential. A training program that does not prepare the proper energy system or muscle group for the athlete's specific sport or activity is an ineffective training program. Programs need to be developed in accordance with the individual needs of each athlete in order for the athlete to reach full potential.

A difficulty many athletes and coaches have with developing a proper training periodization is finding a way to measure progress and compare performance levels. Many athletes and coaches believe in the value of comparing their training progress and performances to personal past performances of themselves or performances of other athletes. Competitive situations are perhaps the simplest and most valid indicators of an individual's performance capabilities. However, for most athletes, performing at a peak competitive level year round is not a realistic option. As a result, other methods and testing procedures that can analyze an athlete's physical abilities and compare his/her training progress and performance with other athletes need to be identified and utilized.

A considerable number of athletic events require similar components. These components include agility, strength, flexibility, kinesthetic sense, anaerobic power/capacity, and or cardiovascular endurance (Stanbrough, 1999). Anaerobic activity is one component that is among the most common in athletic events. Anaerobic activities are those in which the muscles derive their energy from glycogen stored in the muscles. The glycogen is the primary source of Adenosine Triphosphate (ATP). During intense anaerobic activity, the ATP is reproduced in the absence of sufficient amounts of oxygen (Wilmore & Costill, 1999). These types of activities generally involve immediate power or short bursts of speed, with duration times lasting from less than one second to several seconds. Sports and athletic competitions, ranging from individual events in track and field, dual sports such as tennis, and a large number of popular teams sports such as soccer, basketball, and softball, require a high anaerobic ability as a basis for peak performance (Powers & Howley, 1997).

An athlete's anaerobic power is derived from the body's initial form of energy production: the Adenosine Triphosphate Phosphocreatine (ATP-PCr) system. The ATP-PCr system allows muscles to quickly produce power without relying on the use of oxygen. Power is generally defined as the maximal amount of energy that can be transformed (work) during a given length of time. The formula used to express power is written as Power = [(Distance x Force)/Time] (Fox, Bowers, & Foss, 1993).

Activities such as jumping, throwing, lifting weights and running short sprints all rely on anaerobic power. Anaerobic power is usually tested by using "very brief tests," which last less than 10 seconds in length. Examples of such tests are the Vertical Jump Test, One-Repetition Max weightlifting test, and the Margaria Step Test (running up stairs), and the Wingate Anaerobic cycle test (WAnT) (Adams, 1998).

The anaerobic glycolytic system is the second form of energy production. This process allows the muscles to continue to produce high amounts of energy, with very limited amounts of oxygen, after the ATP-PCr system has been exhausted (Wilmore & Costill, 1999). The total amount of energy that an individual has available in this energy system is referred to as anaerobic capacity (MacDougall, Wenger, & Green, 1982).

Individuals who are able to sustain this high energy/low oxygen process for relatively long periods of time, are said to have a high anaerobic capacity. Individuals who have a lesser ability to maintain this production are said to have a low anaerobic capacity. Anaerobic capacity is often directly or indirectly measured by the buildup of lactic acid, which is the waste product of anaerobic glycolysis (Robergs & Roberts, 2000).

When high amounts of lactic acid are rapidly built up in the body, the cell converts the lactic acid into lactate and a build up of hydrogen ions occurs. The build-up of hydrogen ions (H+) causes the blood pH to drop. When the blood pH drops below normal levels, the body loses its ability to break down glycogen and reproduce ATP. The body does have a buffering system (bicarbonate) to minimize these effects. However, during intense anaerobic exercise the buffering system will be depleted and the build-up of H+ will begin to inhibit muscular contraction, which ultimately leads to muscular fatigue (Wilmore & Costill, 1999).

Direct measurements of blood lactate have been used in testing of anaerobic capacity. Blood is drawn from either the forearm or fingertip after the completion of an exhaustive test and the lactate levels are analyzed. This method has been shown to be reliable. However, the personnel and the laboratory equipment needed to perform these types of tests have made them infeasible for most athletes and coaches (Wilmore & Costill, 1999).

Indirect (noninvasive) measurements of lactic acid buildup are often done by exercising the muscles at an intense level (110 – 150% of Max VO2) (McArdle, Katch & Katch, 1986) until the athlete is forced to cease activity due to severe muscular exhaustion. A person with a more efficient lactic acid buffering system will have a higher tolerance to lactic acid buildup and will be able to perform the intense exercise for longer periods of time than a person who has a less efficient system. Individuals who can perform these intense exercises or activities for relatively long periods of time have a high anaerobic capacity. Therefore, this type of indirect measurement of lactic acid can also be used as a measurement of anaerobic capacity (Adams, 1998).

In addition to tests to muscular fatigue, tests lasting a short specified time can also measure anaerobic capacity when they are performed against a predetermined resistance. The resistance causes a rapid buildup of lactic acid in the body, which inhibits muscular contraction as the activity progresses. The higher the anaerobic capacity possessed by an athlete, the better the athlete's performance will be during the time allotted (Powers & Howley, 1997).

Both of these types of tests, muscular fatigue and specified time, fall into the category of "brief tests," generally lasting between 10 to 60 seconds in length, although trained individuals may go for longer periods of time. The most common brief tests are performed either on a cycle ergometer or motorized treadmill. The Wingate is the most commonly used cycle ergometer test. This test is one which uses a specified time and resistance, rather than working to muscular fatigue (Inbar et al., 1996). The newly developed Running-based Anaerobic Sprint Test (RAST) uses a predetermined distance to assess a person's anaerobic abilities (Draper & Whyte, 1997).

Testing of anaerobic power or capacity can be beneficial to athletes and their coaches. Performing tests such as time trials and one-rep maximal efforts, can give a good indication of an athlete's current individual performance level, training progress, and how he/she compares to teammates. In addition, athletes who are able to utilize anaerobic tests that have had norms developed are able to compare their own progress and level with others who are approximately at the same level of athleticism. The knowledge gained by coaches and athletes from standardized anaerobic testing methods could help in the improvement of an athlete's training and performance.

Statement of the Problem

Testing of anaerobic power or capacity is generally done in any sport in which anaerobic ability is a necessity. With some activities, such as short sprints and jumps, the emphasis is on maximal anaerobic power. Several tests have been developed which are rather specific to these events (the one-repetition max, or vertical jump) and can easily be used to track progress and make comparisons to other athletes.

Athletes in activities that require a high level of anaerobic capacity, such as 400-meter sprints and 100-meter swimming, do not have as many options available to assess anaerobic capabilities. The Wingate Anaerobic Test (WAnT) has become the most widely used and accepted test of anaerobic capacity. Tests conducted over the past 20 years have shown the results of the Wingate test to be reliable and valid (Inbar et al., 1996). However, the Wingate test is done on a cycle ergometer. The cycling motion is specific to the sport of cycling, and this lack of specificity to running, has been a concern for some researchers (Draper & Whyte, 1997; Haub, M., personal communication, October 3, 2000).

There are numerous sporting activities that utilize a running motion as the primary mode of movement. There is a belief that individuals who participate in these types of sports may receive a better indication of their anaerobic capacity by using an anaerobic test that also utilizes a running motion. A treadmill test may be the most feasible laboratory running test. However, many colleges and institutions may not have the necessary equipment available to conduct a anaerobic treadmill test.

Draper and Whyte (1997) developed a test that provides an alternative to the Wingate test, as well as being an economical alternative to a laboratory treadmill test. The Running-based Anaerobic Sprint Test (RAST) is a field test that utilizes nonconsecutive 35-meter sprints. Preliminary research has shown this test to able to assess anaerobic capacity in much the same way as the WAnT (Draper & Whyte, 1997). Currently, there has been little research in comparing any of the anaerobic treadmill tests with the Wingate cycle test. In addition, the RAST is still undergoing initial studies of reliability and validity (Whyte, personal communication, November 2, 2000).

The Wingate anaerobic test is a one-effort test that lasts for a specific length of time against a set resistance. To make an equable comparison as possible, it would be desirable to use a anaerobic treadmill test that adheres closely to the Wingate protocol methods.

Most of the anaerobic treadmill tests use repeated test efforts, ranging from 2 trials (Marrin, Sharratt, & Taylor, 1978) to multiple 20-seconds efforts (with 100-second recovery in between), which continue until muscular failure is reached (Rusko, Nummela, & Mero, 1993). However, the test developed by Cunningham and Faulkner utilizes a one-time test effort. Since this test has been used as an indicator of anaerobic capacity and like the WAnT, uses a one-time test effort, it meets the needs of this study.

In addition to the WAnT and the Cunningham and Faulkner treadmill test, participants in this study also completed the RAST. The RAST is currently undergoing reliability and validity procedures at the University of Wolverhampton with the WAnT being used as the basis of comparison. Use of the RAST in this study will add to the body of knowledge.

Statement of Purpose

The purpose of this study is to determine the relationship among the scores of three tests of anaerobic capacity for collegiate Division II track and field athletes. A sub-area of this study is to develop a preliminary set of norms for the Cunningham and Faulkner anaerobic treadmill test based on the results of Division II collegiate track and field athletes.

Hypothesis

There is a relationship among the scores of the Wingate anaerobic cycle test, the Cunningham and Faulkner anaerobic treadmill test, and the Running-based Anaerobic Sprint Test for Division II collegiate track athletes.

Statement of Significance

Athletes who compete in sports that require high amounts of energy to be produced in a short amount of time require conditioning and training that is specific to the anaerobic energy system. There are several tests available to test training progress and levels of anaerobic power. However, there seem to be limited options of testing an athlete's anaerobic capacity, short of competition or expensive laboratory tests.

The ability to identify the anaerobic capacity of an athlete who is involved in a sport that relies heavily on the anaerobic energy system is important to both the athlete and the coach. The Wingate cycle test is the most widely used form of standardized anaerobic testing (Inbar et al., 1996). However, the cycling motion of the Wingate test may not be conducive to best-effort results for those athletes whose main mode of movement is a running motion. Few, if any studies, have attempted to compare the anaerobic capacity results of the Wingate with a laboratory test that utilizes a running motion, including the very limited testing with the Cunningham and Faulkner anaerobic treadmill test. In addition, no studies have compared the Wingate with a practical running field test other than competition-style runs.

Due to the expense of cycle ergometers and motorized treadmills, there appears to be a need for an inexpensive, practical field test that can test as many aspects of anaerobic performance as the Wingate test and also be as running specific as a treadmill test. The Running-based Anaerobic Sprint Test was developed with this purpose in mind.

Definitions

The following terms occur in the study and are defined here to provide the reader with a basic understanding of their meaning.

Adenosine Diphosphate (ADP) – a complex chemical compound which when combined with phosphate, forms ATP.

Adenosine Triphosphate (ATP) – A complex chemical compound which when broken down, provides energy to cells.

Adenosine Triphosphate Phosphocreatine (ATP-PCr) – A simple anaerobic energy system that functions to maintain ATP levels.

Aerobic – In the presence of oxygen.

Anaerobic – In the absence of sufficient oxygen.

Anaerobic Capacity – Ability to maintain a relatively high power output over a period of time using little or no oxygen. Often used interchangeably with Mean Anaerobic Power.

Anaerobic Power – Ability to produce a high amount of power in a short amount of time using little or no oxygen.

Blood Lactate – Produced continuously from the anaerobic metabolism of glucose.

Energy – The capability to produce force, perform work, or generate heat.

Ergometer – An exercise devise that allows the amount and rate of a person's physical work to be controlled (standardized) and measured.

Glucose – The principle nutrient derived from carbohydrates. The preferred fuel of most cells; a sugar.

Glycogen – The stored form of glucose. Usually stored in the liver and muscle fibers.

Glycogenolysis – The conversion of glycogen to glucose.

Glycolysis - The incomplete breakdown of glycogen. In anaerobic glycolysis the end product is lactic acid.

Lactate – A salt formed from lactic acid. Causes muscular fatigue.

Lactic Acid – A by-product of the glycolysis energy system.

Mean Anaerobic Power - Ability to maintain a relatively high power output over a period of time. Often used interchangeably with Anaerobic Capacity.

Newton – A unit of Work.

Noninvasive – A method of collecting data that does not require blood samples to be drawn.

Phosphocreatine (PCr) – An energy-rich compound that plays a critical role in providing energy for muscle action by maintaining ATP concentration.

Phosphogen – A group of compounds; collectively refers to ATP and PCr.

Power – The product of Force and Velocity.

Specificity – An exercise or motion that has a distinctive influence or has a high relationship with another exercise or motion.

Watt – A unit of Power.

Work – The use of movement to produce energy.

Review of Literature

The purpose of this study is to determine the relationship among the scores of three tests of anaerobic capacity for Division II collegiate track and field athletes. A sub-area of this study is to develop a preliminary set of norms for the Cunningham and Faulkner anaerobic treadmill test based on the results of Division II collegiate level track and field athletes.

The Wingate Anaerobic Test (WAnT) is the most commonly used test of anaerobic capacity (Inbar et al., 1996). However, the Wingate test is sport specific to cycling and may not be the best test for athletes competing in sports or activities that require running as the primary mode of motion. The Cunningham and Faulkner anaerobic treadmill test is a laboratory test used to determine anaerobic capacity (Green & Houston, 1975), and the Running-based Anaerobic Sprint Test (RAST) is a practical field test in which early tests have indicated it to be a measure of anaerobic capacity (Draper & Whyte, 1997).

The review of literature will discuss the components of the human energy system, specifically the anaerobic system. In addition, it will include sections on the three anaerobic capacity tests, the Wingate anaerobic test, the anaerobic treadmill test, the RAST, and how each has been designed in relation to assessing anaerobic capacity.

The Energy System

The body derives energy from the metabolic breakdown of foods, primarily carbohydrates and fats, with proteins providing a lesser-used third source. Carbohydrates are broken down through the process of glycolysis and through the Krebs cycle. The Krebs cycle, which is aerobic in nature, is also responsible for the breakdown of fats into energy (Fox, Bowers, & Foss, 1993).

Energy derived from the breakdown of foods is used to create a chemical compound known as adenosine triphosphate (ATP). ATP is stored in the cells of the muscles and is broken down to provide the energy needed for the cells to be capable of function. Energy production is a continuous process that generally requires both the anaerobic and aerobic pathways (Fox et al., 1993).

The energy system is divided into three stages. Despite their separation by terms of definition, they are not mutually exclusive. The body shifts from one system to the next in a graduated process, not an abrupt change from one system to another. The third system used by the body is largely aerobic, which implies the use of oxygen as a means of energy production.

The Anaerobic System

The word anaerobic means without air. This is the process of breaking down and reproducing ATP without the use of oxygen. The anaerobic system is divided into two sub-systems: the Adenosine Triphosphate Phosphocreatine (ATP-PCr) System and the Glycolytic System.

The ATP-PCr is the simplest of the body's energy systems and is sometimes referred to as the phosphogen system (Robergs & Roberts, 2000). PCr is a phosphocreatine (or creatine phosphate, CrP) molecule used by the body to rapidly resynthesize ATP. When ATP is broken down, it releases a phosphate molecule. The ATP then becomes a ADP (adenosine diphosphate) molecule. It is this molecular release that produces the energy. The PCr is also active during this process. The phosphate molecule is released from the creatine and is bound to an ADP molecule to form another molecule of ATP. At this point, the process is repeated. During intense activity, the PCr levels diminish rapidly, usually in less than 10 seconds (Fox et al., 1993).

This process is quick and is done without the presence of oxygen (Fox et al., 1993). This maximal amount of energy produced by this system, per units of time, is often referred to as anaerobic power (MacDougall, Wenger, & Green, 1982).

Some common types of tests for anaerobic power are the Wingate cycle test (Wilmore & Costill, 1999), vertical jump, Margaria power test, and 40-yard dash (Adams, 1998). These tests have been in use for several years and norms have been developed for several different types of athletes and populations.

As the body's phosphogen stores (from the PCr) are lowered, the body begins it's shift to the Glycolytic energy system (Whitmore & Costill, 1999), sometimes referred to as the Lactic Acid system (Fox et al., 1993). This system, like the ATP-PCr system, is able to produce energy anaerobically, although it utilizes glycogen stores rather than phosphocreatine (Wilmore & Costill, 1999).

In the body, all carbohydrates are converted into glucose and immediately used or converted and stored as glycogen for use at a later time. Through the process of glycogenolysis, glycogen is broken down and is used to re-synthesize ATP molecules. The glycolytic energy system is a much more complex process than the ATP-PCr system and does not yield as much energy. Despite this drawback, it does allow the muscles to perform high intensity exercise and produce force for durations lasting as long as two minutes with very limited amounts of oxygen. However, a major limiting factor of this system is the buildup of lactic acid, which is the waste or byproduct of anaerobic glycogenolysis (Wilmore & Costill, 1999).

During intense exercise, lactic acid buildup can only be tolerated to certain levels (depending on the physical conditioning of the athlete) before the athlete is ultimately forced to stop due to muscular fatigue (Fox et al., 1993). This is due to build up of hydrogen ions (H+) that occur when the lactic acid can no longer be buffered and is converted to lactate. The H+ is believed to interfere with the anaerobic metabolism as well as the contractile abilities of the actin and myosin protein filaments, which make up the muscle fibers. When the actin and myosin are no longer able to function properly, the muscles rapidly lose their ability to contract forcefully and the intense exercise must come to an end (Wilmore & Costill, 1999).

Some common noninvasive tests of anaerobic capacity are the Wingate cycle test (Stanbrough, 1999), exhaustive treadmill running, 200-600m running sprints, and 100-200m swimming sprints (Adams, 1998). These tests can be very demanding of the participant. It is important for participants to have high motivation in order to get accurate results from these types of tests.

Tests of Anaerobic Capacity

Under conditions of intense exercise and physical work, the body's ATP-PCr stores are quickly depleted and the glycolytic system is rapidly phased in as the primary source of energy production. The ability of the body to anaerobically use glycogen for energy while buffering the effects of lactic acid buildup is sometimes referred to as its anaerobic capacity (Robergs & Roberts, 2000).

There has been controversy concerning actual ability to test anaerobic capacity, chiefly because of the nature of the body to gradually shift energy production sources. While energy production during maximal efforts lasting 60-seconds or more primarily comes from the anaerobic pathway, studies have shown that as much as 30% of the energy may come from aerobic energy sources, which are beginning to be phased in at this point (Powers & Howley, 1994).

The most common indicator of the use of anaerobic energy are blood lactate levels (McArdle et al., 1986). When exercise places demands on the body beyond the ability to provide adequate supplies of oxygen (intense exercise), it utilizes the anaerobic system. When the glycogenic pathway is used, it produces lactic acid as a waste product. When lactic acid level can no longer be buffered by the system it is converted to lactate. A build up of hydrogen ions (H+) accompanies this rise in lactate. It is believed that the H+ are responsible for the rapid muscle fatigue, bringing an end to an athlete's efforts (Wilmore & Costill, 1999). By measuring the amount of lactate in the blood (blood lactate), it is possible to get an accurate account of an athlete's anaerobic capacity (Adams, 1998). However, measuring blood lactate is generally not a feasible option for most athletes and coaches. It requires special laboratory equipment and can be fairly expensive (Wilmore & Costill, 1999).

The tests discussed in this paper are noninvasive, predictive tests. They indirectly measure anaerobic capacity by either measuring mean anaerobic power over a specified distance, duration of time, or by total work completed during intense exercise to exhaustion. Some of these tests do require specific laboratory equipment such as a cycle ergometer or a motorized treadmill. However, these types of instruments are generally more common than the equipment necessary for blood lactate measurements (Wilmore & Costill, 1999), and the RAST, requires equipment no more sophisticated than two stopwatches and a calculator.

The wingate anaerobic cycle test (WAnT). Tests for anaerobic ability have been in use since the late 1960's. Research done in the area of muscle biopsies helped advance the understanding of the anaerobic energy system and it's effect on muscular work and performance (MacDougall, Wenger, & Green, 1982).

In the early 1970's, physiologists were using treadmills and cycle ergometers in studies of anaerobic ability. Inspired by a paper presented in 1972, researchers at the Wingate Institute in Israel decided to develop and standardize an anaerobic test (Inbar et al., 1996). Some of the objectives they aimed to meet were to create a test that:

1. Provided information on peak power, muscle endurance, and muscle fatigability.
2. Was simple, i.e., it would require equipment that was commonly available and could be administered by personnel who did not require special skills or training.
3. Was feasible, such that it could be performed by able-bodied and disabled people, by a wide spectrum of ages and fitness levels, and by either sex.
4. Was a safe, noninvasive procedure that would be socially acceptable to various age and ethnic groups.

5. Was highly reliable and repeatable, i.e., the score would reflect the subject's actual performance, rather than a random occurrence that might change from one measurement to another.
6. Was valid, i.e., the score would reflect the subject's supramaximal anaerobic performance capacity.
7. Was specific to anaerobic muscle performance rather than to fitness in general (Inbar et al., 1996).

The result was the Wingate Anaerobic Test (WAnT) (Inbar et al., 1996). This test uses either a cycle (leg) or crank (arm) ergometer to test anaerobic capacity. The cycle ergometer test has become the most popular anaerobic cycle test (Adams, 1998). This popularity is possibly due to the fact that the WAnT is capable of providing a thorough anaerobic test (power, capacity, muscular fatigue rate) in a relatively convenient manner (Inbar et al., 1996). Since it's inception, various modifications have been suggested for the WAnT by a number of researchers (Powers & Howley, 1994). However, the test, as it was originated, has largely remained unchanged in its general use to evaluate anaerobic power and capacity (Inbar et al., 1996).

Anaerobic capacity, as discussed by Inbar, the principle designer of the WAnT, is determined through the test by calculating the average power output or total work (Tharp, Newhouse, Uffelman, Thorland, & Johnson, 1985) during the 30-second trial (Inbar et al,, 1996; Adams, 1998). Although several researchers still prefer to utilize the term anaerobic capacity when discussing the WAnT test (Calbet, Chavarren, & Dorado, 1997; Drabbs & Maud, 1997; McArdle et al., 1986; Nicklin, O'Bryant, Zehnbauer, &

Collins, 1990; Parry-Billings, Reilly, & MacLaren, 1986; and Tharp et al., 1985), Inbar prefers the term Mean Anaerobic Power (Inbar et al., 1996).

The Wingate protocol for assessing anaerobic capacity (mean anaerobic power) calls for a 30-second maximal effort on a cycle ergometer against a predetermined resistance. The resistance (workforce in Newtons, N) is calculated by a ratio formula (Appendix A) based on the participant's weight and is applied to the ergometer flywheel (Adams, 1998). The work performed by the participant is derived using a formula (Appendix A) that utilizes the force (N) and the total number of pedal revolutions completed during the 30-second trial (Inbar et al., 1996).

Several studies have examined the relationship between the Wingate and other tests of anaerobic capacity. These tests include a 25-meter swim time (r= -.90); a 300-meter run time (r= -.88); a 500-meter ice skate speed (r= .76) and the Sergeant Anaerobic Skating test (r= .79) (Inbar et al., 1996). Reliability in test-retest comparisons has been shown to be high. These scores range from a low of r=.89 to as high as r=.98 (Adams, 1998).

While the Wingate test has been shown to be both a valid and reliable test of anaerobic performance, it does have a drawback. The WAnT may be too sport specific (Draper & Whyte, 1997). Although the designers utilized a cycle ergometer to provide an economical and convenient test to users (Inbar et al., 1996), the cycling motion utilized by the test may not allow those who take part in sports or activities that utilize a running motion, to achieve optimal results. Falk, Weinstein, Dolan, Abramson, and Mann-Segal (1998) stated "the WAnT my be an excellent cycling-specific test but may not possess strong validity as a predictor of running performance (p. 259)."

Anaerobic treadmill tests. Before the advent of the Wingate test and earlier cyclic tests, exercise and sports physiologist utilized treadmills to calculate anaerobic capacity in the laboratory. Since the late 1960's, there have been a variety of different approaches to using a treadmill to test anaerobic power and capacity. Cunningham and Faulkner (1969) utilized a single-effort treadmill test in their study on the effects of training on the anaerobic system. The protocol for the anaerobic treadmill test calls for the speed of the treadmill to be set at 8mph and the incline gradient at 20%. The participant runs until the muscles are fatigued.

Although the test's original intent was not specific to estimating anaerobic capacity, it has been used for this purpose by various researchers (Adams, 1998). Green and Houston (1977) utilized this test to measure anaerobic capacity in their test of training effects for two elite junior hockey teams. The capacity is derived from the formula W = Force x Distance (vertical) (Appendix B) which utilized the run time, participant's weight, speed of the treadmill, and the incline gradient (Adams, 1998).

Marrin, Sharratt, and Taylor (1980) modified the Cunningham and Faulkner test by having athletes (wrestlers) perform a second effort of the test after a 4 minute rest after the first trial. The results were compiled as the sum of the two running times and blood lactate was taken at both 5 and 10 minutes after the second test (MacDougall, Wenger, & Green, 1982).

Rusko, Nummela, and Mero (1993) developed the Maximal Anaerobic Running Power (MARP) test, later known as the Maximal Anaerobic Running Test (MART) (Nummela, Alberts, Rijntjes, Luhtanen, & Rusko, 1996). This was a further expansion on the anaerobic treadmill test. It was capable of testing a individual's anaerobic power, capacity, and fatigue index. The test consisted of *n* 20-second runs with 100-seconds rest between. The initial speed of the treadmill was 3.97 m/s (8mph) with an incline gradient of 5%. On each subsequent run the speed was increase by .35 m/s. The participant continued trial runs until physically unable to maintain speed. Blood lactate was tested after each run. The results of the lactate test showed that the majority of the energy used during the runs was released from the ATP-PCr and glycogen system (Rusko et al., 1993). The research has found a significant negative correlation between these levels and those obtained after completing a 400m run. It was concluded that the MART is a capable of a rough estimate of anaerobic capacity (Nummela et al., 1996). This test has also been used in Europe as part of a battery of tests to measure the different components of anaerobic performance (Falk et al., 1996).

Studies have shown that treadmill tests can be used to estimate anaerobic capacity (Adams, 1998) and possibly be a better predictor for athletes of running specific sports (Nummela et al. 1996). However, treadmill tests are not as commonly used as the Wingate test (McArdle et al., 1986).

There are some legitimate reasons for the under-use of treadmill tests. One reason is a motorized treadmill capable of meeting the needs of most anaerobic test is very expensive (Adams, 1998). Although cycle ergometers can be expensive, the Wingate test is capable of testing several factors of anaerobic performance that most treadmill tests cannot. Therefore, a cycle ergometer may be more cost effective for many colleges and institutions.

Another reason for the under-use of anaerobic treadmill tests is the apprehension these tests cause some participants, even those individuals who have experience with treadmill running (Adams, 1998). The fast moving belt may cause enough anxiety in a participant that he/she may not give a true maximal performance. As Inbar (1996) commented about the treadmill test, the "endpoint was often determined by the subject's level of fear, rather than by physiological causes (p. 2)."

A true set of norms has never been established with an anaerobic treadmill test, possibly due to the factors listed above. Adams (1998) states that more studies of the tests are needed to better establish reliability and validity. He also goes on to state that norms for these tests are needed, especially those expressed in total work units.

Anaerobic running test. The Running-based Anaerobic Sprint Test (RAST) is a practical field test developed to provide athletes and coaches measurements that are comparable to those of the Wingate anaerobic cycle test. The RAST provides measurements of peak power, mean power (capacity), and minimum power as well as a fatigue index. The RAST uses a formula (Appendix C) based on weight, time, and distance to determine mean anaerobic power. This test is still undergoing studies for validity and reliability at Wolverhampton University in the United Kingdom (Draper & Whyte, 1997).

Whyte believes that accurate testing of aerobic and anaerobic abilities in athletes is specific to each athlete's sport, "cyclist perform better on cycle-based aerobic tests and runners perform better on running tests" (1997, p 1). However, testing of complete anaerobic abilities has largely been restricted to the Wingate test (Draper & Whyte, 1997). Although the Cunningham and Faulkner anaerobic treadmill test is capable of measuring anaerobic capacity, measurements of anaerobic power and fatigue indexes are not feasible (Inbar et al., 1996). Draper & Whyte (1997) feel that the development of the

RAST will provide a practical running-based test capable of a more complete anaerobic analysis.

Summary

Noninvasive methods of testing anaerobic capabilities, especially anaerobic capacity, have largely been limited to the Wingate cycle test. The WAnT has become the most popular test due to it's ability to assess several characteristics of anaerobic performance. However, some researchers believe the test is too sport specific to cycling, thus not allowing for optimal results for other athletes, particularly those athletes who participate in running-based sports.

Some researchers have utilized treadmill tests for anaerobic capacity. But limitations, such as treadmill cost and the psychological fear-factor, have presented some difficulty in acquiring enough information to develop at true set of norms for the test.

The Running-based Anaerobic Sprint test seems to combine the multi-purpose function of the WAnT with the true running mechanics of the treadmill tests. Due to it's relatively new development, the RAST has not had enough data collected to establish reliability and validity.

The purpose of this study was to determine the relationship among the scores of three tests of anaerobic capacity for collegiate athletes. The WAnT is an established test with proven reliability and validity and is used as the benchmark for comparison of the treadmill test and the RAST. By establishing relationships among the tests, this study was able to prepare a much needed set of norms for the treadmill test, and also added to the current studies of reliability and validity of the RAST. The information obtained from this research provides to coaches and athletes of running-based sports the opportunity to conduct anaerobic tests in a manner that will provide optimum results.

CHAPTER 2

METHOD

The purpose of this study was to determine the relationship among the scores of three tests of anaerobic capacity for Division II collegiate track and field athletes. A sub-area of this study was to develop a preliminary set of norms for the Cunningham and Faulkner anaerobic treadmill test based on the results of Division II collegiate track and field athletes.

Participants

Target Population

The participants of this study were members of the intercollegiate track and field teams at a medium sized university (5,700 students) located in the Midwest. The athletic program competes in the Mid-America Intercollegiate Athletic Association (MIAA) conference and is a member of the National Collegiate Athletic Association Division II (NCAA II).

The total number of participants in this study was thirty-eight (N=38). Twenty-four of the participants were male (N=24). Fourteen of the participants were female (N=14). The participants in this study competed in a variety of track and field events including mid-distance (600m – 800m), long sprints (200m – 400m), short sprints (55m – 100m), jumps (long jump, triple jump, high jump, and pole vault), and multi-events (heptathlon and decathlon). The athletes ranged in skill from conference non-placers to athletes of national caliber. Therefore, the results obtained by using intercollegiate athletes at this university can be projected to intercollegiate athletes of varying athletic skill levels, particularly athletes who compete in track and field at the NCAA II level in the United States.

Sampling Procedures

This was a purposive sample. These athletes were chosen due to their familiarity with anaerobic training. All track and field athletes who competed in events involving distances of 800 meters or less were considered possible participants unless they were injured or sick.

Procedures

The Institutional Review Board for Treatment of Human Subjects at Emporia State University Permission granted permission to conduct this study (Appendix D). Permission to use the athletes was also obtained from the head coach of the Track and Field program. The tests were incorporated into the normal practice schedule and used as part of the planned workout. All participants were asked to sign the Informed Consent Form (Appendix E) prior to the start of testing.

Each test was completed on a separate day, with no less than six days and no more than thirteen days separating individual test efforts. Testing on separate days allowed the participants enough recovery time from the tests and the normal workouts for the body to be able to perform at a maximal level. This time period also limited the effects an increase or decrease in a participant's fitness level may have had on the tests.

The sprinters, jumpers and multi-eventers, completed the tests in the following order: the Running-based Anaerobic Sprint Test (RAST), the Cunningham and Faulkner anaerobic treadmill test, and the Wingate Anaerobic Test (WAnT). All tests were completed one week apart.

The middle distance runners completed the test in the following order: the Cunningham and Faulkner anaerobic treadmill test, the WAnT, and the RAST. The Cunningham and Faulkner and the WAnT were completed with seven days separating the two tests. A time period of thirteen days after the Wingate was needed to perform the RAST due to inclement winter weather conditions.

The Wingate Anaerobic Cycle Test (WAnT)

Three technicians were used for this test. One technician acted as the starter and timer. A second acted as the pedal revolution counter. The third technician recorded data onto a data collection sheet.

Prior to the start of the procedure, each participant was weighed in light attire. The weight was recorded onto the data sheet and used to determine the amount of resistance to be applied to the ergometer for each participant (Adams, 1998).

The seat of the cycle ergometer was then adjusted by one of the technicians. The seat was set so the participant's leg had a slight bend at the knee when the leg was extended at the lowest point of the pedal's revolution (Inbar, Bar-Or, and Skinner, 1996).

The procedure for this test consisted of three phases: the warm-up/familiarization phase, the test, and the cool down. Each phase was done in succession with the entire process lasting from twenty to thirty minutes (Adams, 1998). The warm-up consisted of a five-minute cycling period that was interspersed with 4-5 sprints of 4-6 seconds; with each sprint the resistance applied was increased (Adams, 1998). The warm-up allowed the participant to become familiar with the resistance and also allowed the body to adjust to the physiological and motor adaptations of the cycle ergometer (Inbar et al., 1996). A two to three minute rest was given to allow the body to recover from the warm-up and allow the participant to stretch (Adams, 1998). After two to three minutes, the participant returned to the cycle. The seat was double checked for the proper height and a technician secured the participant's feet to the pedals by adjusting the toe-clips.

The test phase was broken into two separate periods: the acceleration period, and the test period. The acceleration period lasted for 15 seconds. The participant began cycling between 20 to 50 rpm at approximately one-third of his/her force (N) setting. This activity lasted for 10 seconds. The participant then accelerated towards near maximal speed for the next five seconds while the technician began to increase the force towards the appropriate setting. When the correct force setting was reached, the technician yelled, "GO!" and the second period of the test phase began (Adams, 1998).

On "GO!" the technician started the watch and the participant began cycling as fast as possible while remaining seated. This test phase lasted for thirty seconds and was broken into six separate five-second intervals. The timer announced each of these intervals, while the second technician (the counter) stated the number of pedal revolutions made by the participant during the previous five seconds (rounded up to the nearest whole revolution). The third technician recorded the number of pedal revolutions on the a data collection sheet. At the end of the thirty seconds, the cool down phase began (Adams, 1998).

At the beginning of the cool down phase, the first technician reduced the force to a low setting and the participant continued to pedal at a moderate pace for two to three minutes. The participant then walked for two to three more minutes and then performed some light stretches.

The Anaerobic Treadmill Test

Two technicians were used for this test. One technician controlled the treadmill and the timer. The second technician stood behind the treadmill acting as the spotter.

Prior to beginning the procedure, each participant was weighed in his or her running attire. The weight was recorded onto a data collection sheet and was used in the final formula to calculate the participant's anaerobic capacity.

The procedure for the treadmill test consisted of four phases: the warm-up, the familiarization phase, the test, and the cool-down phased (Adams, 1998). Each phase was done in succession, with the entire process lasting from twenty to thirty minutes.

The warm-up phase consisted of a slow jog lasting approximately five minutes. Each participant was asked to stretch as needed to be able to perform a maximal running effort. The participant then proceeded to the treadmill to begin the familiarization phase (Adams, 1998).

During the familiarization phase each participant was shown in detail how to utilize the handrails to get on and off the moving treadmill belt. After the demonstration, each participant practiced the procedure with the treadmill moving at a slow pace. Each participant was allowed to practice getting on and off the moving treadmill belt as many times as they felt necessary to be comfortable with the method prior to the actual test. Short runs on a level gradient and brief bouts at test speeds and 20% gradient were used to familiarize the participant with the treadmill. When the participant felt he/she was ready, the test phase began (Adams, 1998).

At the beginning of the test phase, the technician set the treadmill at a 20% slope and at a speed of 8mph (3.58m/s). A spotter stood at the rear of the treadmill ready to support the runner if necessary (Adams, 1998). The participant, with hands on the handrails, stood alongside the treadmill. While still holding onto the handrails, the runner stepped onto the moving belt and began running. When the participant was comfortable with the pace, he/she released the handrails. As the participant released the handrails, the technician started the stopwatch. The runner then ran for as long a time as his/her muscles could continue the pace. When the participant could no longer maintain the pace, he/she took himself or herself off of the treadmill by using the handrails. The technician stopped the timer as soon as the handrails were touched (Adams, 1998). The treadmill was stopped and the technician recorded the time onto the data sheet. The participant then began the cool down phase.

The cool down phase consisted of slow walking for approximately five minutes. The participant then did some light stretching followed by a slow jog lasting five minutes.

The Running-based Anaerobic Sprint Test (RAST)

Three technicians were required for this test. One technician started the test and timed the sprints. A second technician timed the 10-second turn-arounds. A third technician recorded the data onto a data collection sheet (Draper & Whyte, 1997).

Prior to beginning of the procedure, each participant was weighed in his or her running attire. The weight was recorded onto the data collection sheet and was utilized in the final formula to calculate the participant's anaerobic capacity (Draper & Whyte, 1997).

The RAST consisted of four phases: the warm-up, the familiarization, the test, and the cool down (Draper & Whyte, 1997). Each phase was done in succession, with the entire process lasting twenty to thirty minutes.

The warm-up phase consisted of a slow jog lasting approximately five minutes. Each participant then stretched as needed to be able to perform a maximal running effort. The participant then proceeded to the marked testing area to begin the familiarization phase (Draper & Whyte, 1997).

The testing area of the track was a 35-meter straightaway marked by orange cones at each end. During the familiarization phase, a technician gave a demonstration of the run and turn-around procedures. Each participant was then allowed to perform some sprints to become familiar with the track surface and the turn-around procedures. When the participant indicated he/she was ready, he/she moved on to the testing phase (Draper & Whyte, 1997).

The test consisted of six 35-meter non-continuous sprints. The participant lined up at the starting line, using whatever starting position was comfortable (standing, three-point, or four point). The first technician (timer) said, "set." When the participant was steady, the technician yelled "GO!" and started the stopwatch. The participant sprinted at maximal effort down the 35-meter stretch. The timer stopped the watch as soon as the participant passed by the marker cones. The time was recorded onto the data sheet (Draper & Whyte, 1997).

The runner was given ten seconds (timed by second timer) to turn around and return to the cones he/she just passed. These cones were used as the starting point for the return sprint. The second timer counted down the ten seconds out loud which enabled the participant to prepare for the next run. At the end of the ten seconds, the second timer yelled "GO!" the first timer started the stopwatch and the participant sprinted back down the straightway towards the original starting point. The six sprints and turn-arounds were timed and recorded in the same manner as the first. At the completion of the six sprints the participant began the cool down phase (Draper & Whyte, 1997).

The cool down phase consisted of slow walking for approximately five minutes. The participant then did some light stretching followed by a slow jog lasting five minutes.

Instrumentation

Wingate Anaerobic Test (WAnT)

The Monark cycle ergometer is a commonly used ergometer for the Wingate test. This ergometer is capable of applying force immediately to a flywheel and provides the resistance against which the participants work. The resistance can be increased or decreased by simply turning a knob on the ergometer.

The Wingate test has been shown to be reliable and valid in the twenty years since it's inception. The validity of it's anaerobic capacity measurement, as compared with a 300m run, has been found to range from r= -.64 and -.83 (Adams, 1998) to r= -.92 (Inbar et al., 1996). Reliability has ranged from r= .89 (Adams, 1998) to r= .99 (Inbar et al., 1996).

Cunningham and Faulkner Anaerobic Treadmill test

The anaerobic treadmill test requires a motorized treadmill. The treadmill must be capable of maintaining a speed of 8mph, and an incline of 20%. Handrails must be mounted on the treadmill to provide a measure of safety for the participants.

Anaerobic treadmill testing has been shown to be both reliable and valid. Reliability coefficients range from r= .76 to r= .94 (Adams, 1998). Validity, as compared with a 329m run, has been shown with a coefficient of r= -.82 (Adams, 1998). However, Adams (1998) feels that more reliability and validity studies are needed on this test.

Running-based Anaerobic Test (RAST)

At this time, no current scores on reliability or validity are available for the RAST (Draper & Whyte, 1997). In a recent e-mail correspondence, Whyte stated that reliability and validity testing are part of an ongoing study (Whyte, personal communication, October 17, 2000).

Statistical Design

The relationship of anaerobic capacity results of the three tests was examined by running a correlational analysis. A Pearson-Product correlation was used, and the data were analyzed at the $p \leq .01$ level of significance.

Summary

Track and field athletes at a medium sized midwestern university completed three test of anaerobic capacity. The tests were completed with a minimum of seven days and a maximum of fourteen days between tests. The test were integrated into the track and field workout routine. Scores on the tests were measured using a Pearson-Product correlation to examine the relationship among the three tests. In addition, percentile-based norms for both the men and the women were created for the Cunningham and Faulkner anaerobic treadmill test.

CHAPTER 3

RESULTS

The purpose of this study was to determine the relationship among the scores of three tests of anaerobic capacity for Division II collegiate track and field athletes. Participants completed each of the following tests: the Wingate Anaerobic Cycle Test, the Cunningham and Faulkner anaerobic treadmill test, and the Running-based Anaerobic Sprint Test. A sub-area of this study was to develop a preliminary set of percentile-based norms for the Cunningham and Faulkner anaerobic treadmill test based on the results of Division II collegiate track and field athletes.

This chapter presents an analysis of the data obtained from the results of the three tests. Data were collected from 38 participants (24 men and 14 women) with a range in age from 18 – 23 years, and a mean age of 19.68 years. The age range for the males was 18 – 23 years with a mean age of 19.60 years. The age range for the females was 18 – 22 years with a mean age of 19.71 years. Descriptive statistics, including the range, mean and standard deviation for each of the test results are presented in Table 1. A compilation of results of mean anaerobic power (watts) for all three tests can be found in Table 2

The hypothesis states that there is a relationship among the test scores of the Wingate anaerobic cycle test, the Cunningham and Faulkner anaerobic treadmill test, and the Running-based Anaerobic Sprint Test. A Pearson-Product correlation was used to determine the strength of the relationship among the anaerobic capacity measurements of the tests. The correlation among all tests was significant at the $\underline{p} \leq 0.01$ level. The relationship between the Wingate and the treadmill tests was r=.705, the Wingate and the

RAST was r=.760, and the treadmill and the RAST was r=.891 (Table 3). The hypothesis was not rejected.

TABLE 1 – Descriptive Statistics for Anaerobic Capacity Test Results (watts)

Participants N = 38

	Minimum	Maximum	Mean	Std. Deviation
WAnT	322.91	805.64	547.6316	112.1175
Tread	371.02	676.95	522.2271	73.9072
RAST	255.38	991.52	561.2895	187.7380

WAnT = Wingate Anaerobic Test

Tread = Cunningham and Faulkner Anaerobic Treadmill Test

RAST = Running-based Anaerobic Sprint Test

TABLE 2 – Compilation of Mean Anaerobic Power Results

Mean Anaerobic Power scores (watts)

N = 38

	WAnT	Tread	RAST
M1	746.59	595.58	742.81
M2	573.68	481.67	590.50
M3	670.79	550.02	671.55
M4	638.80	566.29	646.86
M5	693.00	584.19	625.64
M6	610.91	523.98	667.36
M7	644.59	533.75	595.89
M8	538.02	497.95	543.21
M9	613.64	598.84	722.35
M10	538.50	605.35	792.40
M11	514.64	480.05	477.87
M12	623.76	517.47	646.78
M13	679.09	543.51	877.49
M14	597.82	449.13	560.61
M15	572.37	676.95	991.52
M16	657.20	598.84	784.14
M17	592.04	605.35	751.44
M18	492.70	566.29	659.68
M19	447.75	631.38	698.77
M20	613.64	589.07	672.44
M21	512.73	533.75	501.21
M22	589.09	520.73	521.40
M23	696.82	595.58	799.94
M24	805.64	670.44	802.36
F1	385.06	406.82	255.38
F2	559.64	495.50	359.41
F3	420.27	436.11	330.56
F4	472.67	478.42	388.69
F5	448.50	455.64	374.19
F6	351.31	371.02	327.38
F7	510.55	510.96	395.96
F8	448.36	442.62	360.49
F9	450.00	432.85	331.51
F10	322.91	471.91	361.56
F11	435.17	455.64	338.69
F12	448.50	462.15	385.58
F13	468.75	452.38	383.54
F14	424.50	456.45	391.84

TABLE 3 – Pearson-Product Correlation Coefficients for Anaerobic Capacity Tests

	WAnT	Tread	RAST
WAnT	1.0	.705*	.760*
Tread	.	1.0	.891*
RAST			1.0

* Correlation is significant at the $p \leq 0.01$ level

WAnT = Wingate Anaerobic Test

Tread = Cunningham and Faulkner Treadmill Test

RAST = Running-based Anaerobic Sprint Test

A sub-area of this study was to develop a preliminary set of percentile-based norms for the Cunningham and Faulkner anaerobic treadmill test based on the data obtained in this study (Tables 4 and 5). Due to the small and selective sample, these tables are for comparison use only.

TABLE 4 – Women's Percentile-Ranked Norms for Cunningham and Faulkner Anaerobic Treadmill Test

Female collegiate (NCAA Div II) track & field athletes
N = 14

		Watts
Mean		452.03
Median		455.64
Mode		455.64
Std. Deviation		34.99
Percentiles		
	95	510.96
	90	503.23
	85	491.23
	80	478.42
	75	473.53
	70	467.03
	65	460.72
	60	456.45
	55	455.84
	50	455.64
	45	454.83
	40	452.38
	35	445.06
	30	439.37
	25	435.30
	20	432.85
	15	413.33
	10	388.92
	5	371.02

Due to the small and selective sample, this table represents percentile-ranked norms for comparison use only.

TABLE 5 - Men's Percentile-Ranked Norms for
Cunningham and Faulkner Anaerobic Treadmill Test

Male collegiate (NCAA Div II) track & field athletes
N = 24

		Watts
Mean		563.17
Median		566.29
Mode		533.75*
Std. Deviation		57.85
Percentiles		
	95	675.32
	90	650.91
	85	611.86
	80	605.35
	75	598.84
	70	597.21
	65	595.58
	60	589.07
	55	579.72
	50	566.29
	45	554.09
	40	543.51
	35	533.75
	30	528.87
	25	521.55
	20	517.47
	15	493.88
	10	480.86
	5	456.86

*Multiple modes exist. The smallest value is shown

Due to the small and selective sample, this table represents percentile ranked norms for comparison use only.

CHAPTER 4

DISCUSSION AND RECOMMENDATIONS

The purpose of this study was to determine the relationship among the scores of three tests of anaerobic capacity for Division II collegiate track and field athletes. Participants (N=38) completed each of the following tests: the Wingate Anaerobic Cycle Test (WAnT), the Cunningham and Faulkner anaerobic treadmill test, and the Running-based Anaerobic Sprint Test (RAST). The tests were conducted over a three-week period during the indoor track and field season.

The hypothesis stated that there would be a relationship among the three anaerobic tests. Correlational analysis indicated a relationship among the tests results. The hypothesis was not rejected.

The correlation was lowest between the Cunningham and Faulkner treadmill test and the Wingate cycle test (r=.705). Since the research concerning the use of the Cunningham and Faulkner test is very limited, this finding is encouraging in its support of the test as a valid indicator of anaerobic capacity.

The strongest relationship was found between the Cunningham and Faulkner treadmill test and the RAST (r=.891). This strong relationship may be due to the fact that the participants in these tests were track and field athletes and their familiarity with running may have lead to better results on running style tests. This relationship lends credibility to the claim by some researchers that those athletes whose primary mode of movement is a running motion may perform better on a running-based anaerobic capacity test rather than a cycle-based test (Draper & Whyte, 1997; Falk et al., 1996; Haub, M., personal communication, October 3, 2000).

The RAST had a higher correlation with the Wingate (r=.760) than the Cunningham and Faulkner test. This data supports the preliminary research done by Draper & Whyte (1997) who stated that the RAST was comparable to the Wingate cycle test. It appears that using the RAST could be a economical alternative for those coaches and athletes wishing to test anaerobic capacity but do not have the proper laboratory equipment to perform the more traditional tests.

A sub-area of this study was to develop a preliminary set of percentile-based norms for the Cunningham and Faulkner anaerobic treadmill test based on the results of collegiate level athletes. However, due to the small and selective sample, the norms presented are to be used with caution and are for comparison purposes only. Higher numbers of participants are needed to develop a true set of norms.

Limitations of the Study

The research was done in such a way that all participants were simply labeled as track and field athletes despite the fact that they were a diverse group in regards to event area. Each event area probably warrants its own study in anaerobic capacity tests, due to the differences in training methods among the different events. The small numbers used in this study may have affected the statistical analysis.

These tests were conducted during a three-week period during the beginning of the indoor track and field season. The tests were incorporated into the workouts on days that anaerobic training was to take place. However, due to the size of the sample, it was not possible to test each athlete at the same time. While the sprinters and mid-distance athletes were tested at the beginning of practice, when their muscles were relatively fresh, the jumpers often were tested at the end of practice after they had completed the technique portion of their workout. It is important for jumpers to be as fresh as possible during technique work. Due to the fatiguing nature of anaerobic capacity tests, concessions where made for the jumpers to participate in the study after their technique work was done. Although technique work in itself is not particularly muscle fatiguing, the amount of time spent on it can deplete an athlete's energy stores. The participants who did jump technique work prior to the test, may have reached muscular fatigue earlier in the tests than if they been able to perform the test prior to technique work.

In addition, the diversity of track athletes (mid-distance, sprinters, jumpers, multi-eventers) did not lend itself well to controlling the effects of workouts prior to and during the data collection phase. Although tests were scheduled on days typically devoted to anaerobic training, the training that took place the day or days prior to the test day may have been largely different among the participants. This difference in training may have affected the ability of the athlete, mentally or physically, to perform at a maximum level during the test.

These types of physical tests are difficult, even for trained athletes, and require a high level of self-motivation in order to be done correctly. This type of motivation is beyond the control of the researcher. The inability to control the internal motivation of the participants may have caused a distortion of the test results.

Recommendations for Future Research

The following are recommendations for future study:

1. Data should be collected among a wider variety of athletes who participate in sports or activities that require a high use of the anaerobic energy system. A more diverse athletic

population can lead to a better generalization of results. More numbers are also needed for stronger statistical analysis.

2. Data collection should be conducted during the athlete's off-season when control over workouts prior to testing days can be more firmly established, thus providing consistency of overload and recovery periods among a wide variety of athletes.

3. Practice tests should be conducted for each participant prior to data collection. Familiarization with each test may increase the maximal performance for participants.

4. A continuation of data collection for the Cunningham and Faulkner anaerobic treadmill test. More participants are needed, especially among sports other than track and field. Larger numbers are needed to develop a proper set of percentile-based norms.

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Appendix A

Wingate Anaerobic Cycle Test Formula

Wingate Anaerobic Test formula

N x (R x 6) = Work (joules)

then

Work/30sec = **M–AnP (watts; mean anaerobic power)**

W = Work (joules)

N = Newtons (body weight in kg x 10 x .075; force setting on Monarch cycle)

R = total pedal Revolutions completed in 30 seconds

6 = 6m, the distance traveled by the flywheel of the Monarch cycle ergometer

M–AnP = Mean Anaerobic Power (watts)

Example:

60kg participant   50 pedal revolutions in 30 sec

W (joules) = **45 N** (60kg x 10 x .075) x **50** (revs) x **6** (distance traveled by flywheel)

W = 45 x 50 x 6

W = 13500 joules

then

M–AnP = Joules/time

M–AnP = 13500/30

M–AnP = 450 watts (mean anaerobic power)

(Adams, 1998)

Appendix B

Cunningham and Faulkner Anaerobic Treadmill Test Formula

Cunningham & Faulkner Anaerobic Treadmill Test formula

F x D(v) = Work (joules)

then

Work/Time = **M–AnP (watts; mean anaerobic power)**

W = Work (joules)

F = Force (weight of participant) in N (Newtons, N = 10 x kg)

D(v) = Distance (vertical)

D(h) = Distance (horizontal)

M–AnP = Mean Anaerobic Power (watts)

T = Time (total seconds)

D(h) = Distance (horizontal) is determined by multiplying the speed (m/s) by the total time (seconds)

D(v) = divide the % of slope (20%) by 100 then multiply by D(h) horizontal distance

This is constant in this equation: 20/100 x 3.58m/s(8mph) = **.716** D(v) = **.716**

M–AnP (mean anaerobic power) = Work/Time (joules/total seconds)

Example:

68 kg participant 20% grade 8mph 60 seconds

W (joules) = **680 N** (68kg x 10) **x .716** (Dv) **x 60** (total seconds)

W = 680 x .716 x 60

W = 29,212.8 j

then

M–AnP = 29,212.8/60

M–AnP = 486.88 watts (mean anaerobic power) (Adams, 1998)

Appendix C

Running-based Anaerobic Sprint Test Formula

Running-Based Anaerobic Sprint Test formula

Power Value for each 35m sprint is calculated with the following formula:

Power = Weight(kg) x Distance x Distance/Time x Time x Time

then

Sum of all 6 Power Values/6 = M-AnP; **Mean anaerobic power (watts)**

Example

76 kg participant 35m 4.52, 4.75, 4.92, 5.21, 5.46, 5.62 (times)

Power Value #1 = 76 x 35 x 35/4.52 x 4.52 x 4.52

Power Value #1 = 93100/92.35

Power Value #1 = 1008.12 watts

Repeat formula for each of the 6 times taken

then

Mean Anaerobic Power (M-AnP) = sum of all 6 Power Values/6

P1 + P2 + P3 + P4 + P5 + P6 = P total / 6

1000.12 + 868.70 + 781.73 + 658.32 + 571.97 + 524.49 = 4413.33

M–AnP = P(total)/6

M–AnP P(mn) = 4413.33/6

M–AnP = 735.55 watts (mean anaerobic power)

(Whyte, 1997)

Appendix D

Institutional Review Board for Treatment

of Human Subjects Permission Letter

EMPORIA STATE UNIVERSITY

1200 Commercial
Emporia, Kansas
66801-5087

316-341-5351
316-341-5909 fax
www.emporia.edu

GRADUATE STUDIES AND RESEARCH
RESEARCH AND GRANTS CENTER
Campus Box 4003

November 1, 2000

Paul Luebbers
603 E. 11th, Apt. F
Emporia, KS 66801

Dear Mr. Luebbers:

The Institutional Review Board reviewed your application for approval to use human subjects, entitled "A Correlational Study of Two Methods of Anaerobic Testing: The Wingate Cycle Test and the Cunningham and Faulkner Treadmill Test." I am pleased to inform you that your application was approved and you may begin your research with subjects as outlined in your application materials.

On behalf of the Institutional Review Board, I wish you luck with your research project. If I can help you in any way, do not hesitate to contact me.

Sincerely,

Timothy M. Downs

Timothy M. Downs, Ph.D.
Dean, Graduate Studies and Lifelong Learning

pf

cc: Mark Stanbrough

Appendix E

Informed Consent Document

Informed Consent Document

The Department/Division of HPER at Emporia State University supports the practice of protection for human subjects participating in research and related activities. The following information is provided so that you can decide whether you wish to participate in the present study. You should be aware that even if you agree to participate, you are free to withdraw at any time, and that if you do withdraw from the study, you will not be subjected to or reprimanded or any other form of reproach.

Procedures to be followed in the study, identification of any procedures which are experimental and approximate time it will take to participate:

Three types of anaerobic capacity tests will be used throughout this project.

All subjects will be given ample opportunity to practice and familiarize themselves with both the cycle and treadmill before any tests are conducted.

<u>The Wingate Cycle Anaerobic Test.</u>

The subject is instructed to pedal as fast as possible for 30 seconds. The resistance is adjusted (determined by sex and body weight) in the first 2 or 3 seconds and at that time the clock and counter are activated. The number of pedal revolutions is counted every 5 seconds.

Anaerobic capacity is determined by 1) total number of revolutions made in 30 seconds and 2) peak number of revolutions within a 5 second period.

<u>The Cunningham and Faulkner Treadmill Anaerobic Test.</u>

The subject is instructed to run on a motor driven treadmill. The treadmill is set at 8mph and at a 20% incline. The subject runs as long as possible. The general time for this test is approximately 30 – 60 seconds. Anaerobic capacity is determined by the amount of time run.

<u>The Running-based Anaerobic Sprint Test</u>

Subject will complete a series of 6 35-meter nonconsecutive sprints. General time for the test will be approximately 30 – 40 seconds.

Participation time: 3 sessions (1 for each test), each at least 2 days apart, will be conducted. The actual time to take the test is 30 seconds for the Wingate, generally less than a minute (depending on the individual), for the Treadmill test, and approximately 30-40 seconds for the running test. Allowing time for stretching and proper warm-up, the total test time for each test will be approximately 15-20 minutes.

Description of any attendant discomforts or other forms of risk involved for subjects taking part in the study:

The testing sessions will require some physical exertion which may induce temporary discomfort and/or muscle soreness. *Subjects may terminate testing at any time.*

Description of benefits to be expected from this study:

To gain further knowledge of the Cunningham and Faulkner Anaerobic Treadmill Test and the Running-based Anaerobic Sprint Test. These tests may be more pertinent to athletes and coaches since the majority of intercollegiate sports utilize running on a daily basis, whereas cycling, which is employed by the Wingate test, is unique to it's own sport.

If a correlation is found to exist, a set of norms based on the data obtained from this study may begin to be developed, which would enable and encourage a more widespread use of the tests.

"I have read the above statement and have been fully advised of the procedures to be used in this project. I have been given sufficient opportunity to ask any questions I had concerning the procedures and possible risks involved. I understand the potential risks involved and I assume them voluntarily. I likewise understand that I can withdraw from the study at anytime without be subjected to reproach."

____
Participant

____
Date

Signature of Author

5.04.01

Date

An Examination of the Relationship
Among Three Tests
of Anaerobic Capacity

Title of Thesis

Signature of Graduate Office
Staff Member

May 4, 2001

Date Received