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Selected correlates of successful performance in female track and field athletes

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SELECTED CORRELATES OF SUCCESSFUL PERFORMANCE IN FEMALE TRACK AND FIELD ATHLETES

By

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An Abstract

of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health, Physical Education, and Recreation at Ithaca College

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ABSTRACT

The purpose of this study was to investigate the relationships of selected anthropometric and physiological variables to successful performance of female track and field athletes. These variables were also used to develop an equation to predict successful performance. The 12 women were members of the 1984 Ithaca College women's track and field team. A timed run to exhaustion was used to determine anaerobic capacity. The Cybex II isokinetic dynamometer was used to assess peak torques and power outputs of the quadriceps and hamstring muscle groups at two angular velocities. A performance ratio was computed by expressing the subject's best time or distance as a percentage of the current (1984) NCAA Division III record. This ratio was correlated with the independent variables. Five regression equations were developed from the independent variables. The results revealed power output assessment of hamstring balance and right leg balance at the high speed to be the best simple significant correlates of successful performance. Power output of each hamstring at high speed (240 deg/sec) and the modified anaerobic power test provided the best formula for prediction of successful performance. This investigator concluded that power output at high speed was a better correlate and predictor of successful performance than power output at low speed or assessment of peak torque at either high or low speed. Anaerobic capacity, as measured by the

modified treadmill test, was a good correlate as well as a consistent predictor of successful performance. Percentage of body fat and year in college did not reach significance ($p < .05$) as a simple correlate or enter into any of the multiple regression equations.

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A Thesis Presented to the Faculty of
the School of Health, Physical
Education, and Recreation
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Requirements for the Degree
Master of Science

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by

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Ithaca College

School of Health, Physical Education, and Recreation

Ithaca, New York

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

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submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health, Physical Education, and Recreation at Ithaca College has been approved.

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DEDICATION

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Chapter 1

INTRODUCTION

Successful performances in competitive athletics are achieved through hard work and dedication to the particular sport or event. Most of the time this involves months, if not years, of intense physical training and conditioning. Depending on the sport or event, an athlete will need to develop specific anaerobic or aerobic systems. This can be accomplished through a combination of resistive and aerobic training. Fox and Mathews (1981) stated that training is specific to a sport because increase in strength and muscular endurance will improve skill performance to the greatest extent when the training program consists of exercises that include the muscle groups and simulate the movement patterns associated with the specific skill or athletic event to be performed.

Anaerobic capacity and maximal aerobic power can be achieved through training programs that are geared specifically toward each of those systems. Anaerobic capacity is an important factor in the performance of skills or exercises of short duration in which the required rate of work can be maintained for less than 2 or 3 minutes. Conversely, aerobic power is an important factor in the performance of prolonged activities (5 minutes or longer).

Knowledge of the physiological characteristics of successful athletes in a given sport might be useful and advantageous to the coach. The information could be used in predicting performance of the athletes as well as future selection of performers based on previously tested athletes. Parcells (1977) indicates,

> Many coaches involved in football, gymnastics, wrestling, and shotputting feel there is a very high positive relationship between performance and strength. In sports like basketball, golf, tennis, and volleyball, however, the ultimate factor is a combination of strength and speed, commonly called power. Therefore, athletes in these sports require less strength-dominated power and need more speed-dominated power. (p. 1)

Several researchers have examined successful performance of athletes of various sports. Recently, Thomas, Zebas, Bahrke, Araujo, and Etheridge (1983) examined numerous physiological and psychological variables that may be important to performance in male track and field athletes. However, baseline data on sprinters and jumpers and explanations of why some are more successful than others are particularly scarce. Moreover, there seems to be a lack of any data on female track and field athletes. Thus, the purpose of this investigation was to determine success in female sprinters and jumpers, middle distance runners, and heptathletes through several selected parameters.

Scope of Problem

A total of 12 volunteer female undergraduate students, all members of the Ithaca College women's track team, served as subjects. The subjects were classified into three groups, which consisted of seven power athletes (sprinters and jumpers), three middle distance runners, and two heptathletes. The subjects were tested on the following parameters: anaerobic power, muscular strength, and body fat percentage. A performance ratio for each subject was also computed and used as the dependent variable in this study. The physiological parameters were used as independent variables in a multiple regression analysis.

Anaerobic power was measured through the use of a modification of an anaerobic power test created by Schnabel and Kindermann (1983). The Cybex II isokinetic dynamometer, manufactured by Lumex, Inc., was used to assess peak torque and power. Each leg was tested at 60 deg/sec and 240 deg/sec as recommended by the manufacturer. Body fat percentage was determined through the use of an underwater weighing technique that is similar to the one used by Brozek and Henschel (1961). These parameters were correlated with a performance score for each subject. The performance score was computed by expressing the athlete's best time or distance as a percentage of the then current NCAA Division III record.

Statement of Problem

The intent of this investigation was to study the relationship of selected physiological parameters to successful performance of female track and field athletes. These parameters included anaerobic power, leg strength, leg power, body fat percentage, and year in school.

Null Hypotheses

The hypotheses of this study were as follows:

1. There is no relationship between anaerobic power as measured by the modified anaerobic power test (Schnabel & Kindermann, 1983) and successful performance in female Division III college track and field athletes.

2. There is no relationship between leg strength and successful performance in female Division III college track and field athletes.

3. There is no relationship between leg power and successful performance in female Division III college track and field athletes.

4. There is no relationship between body fat percentage and successful performance in female Division III college track and field athletes.

5. There is no relationship between a college-age female athlete's year in school and successful performance in Division III track and field.

Assumptions of Study

The following assumptions have been made for the purpose of this study:

1. The subjects responded to the directions of the investigator and put out their maximum effort during the testing sessions.

2. The calibration of the Cybex II isokinetic dynamometer specified by the manufacturer was maintained throughout the study.

3. Any outside activities, such as weight training, were considered to have no significant influence.

4. Sickness and injury had no effect on the testing results.

5. The subjects did not eat any food for at least 2 hours before being hydrostatically weighed.

Definition of Terms

The following terms are defined below for the purposes of this study:

1. Anaerobic Capacity: The ability to perform work or exercise without the presence of oxygen. This usually involves exercises that can be performed for short periods of time but require maximal effort (Fox & Mathews, 1981).

2. Maximal Aerobic Power ($\dot{V}O2max$): The maximal rate at which oxygen can be consumed. The higher the athlete's $\dot{V}O2max$, the more successfully he or she will perform in endurance events, provided all other factors that contribute to a championship performance are present (Fox & Mathews, 1981).

3. Muscular Strength: The force or tension a muscle or muscle group can exert against a resistance in one maximal

effort (Fox & Mathews, 1981).

4. Work: The application of a force through a distance.

5. Power: The dynamic release of maximum muscle force in a short duration of time (Annarino, 1976).

6. Isokinetic Contraction: A contraction in which the tension developed by the muscle while shortening at a constant speed is maximal over the full range of motion (Fox & Mathews, 1981).

7. Specificity of Training: The principle underlying construction of a training program for a specific activity or skill and the primary energy system(s) involved during performance (Fox & Mathews, 1981).

8. STPD: The volume of a gas expressed under standard conditions of temperature (273° Kelvin or 0° Centigrade), pressure (760 mmHg), and dry (no water vapor) (McArdle, Katch, & Katch, 1981).

9. Torque: The product of the force applied (its magnitude) and the perpendicular distance from the line of force application to the axis (Broer & Zernicke, 1979).

Delimitations of Study

The delimitations of the study were as follows:

1. Only 12 female track and field athletes between the ages of 18 and 22 from Ithaca College were used in this study.

2. Anaerobic capacity was determined through a modification of Schnabel and Kindermann's (1983) anaerobic

power test.

3. Leg strength and leg power were determined through the use of the Cybex II isokinetic dynamometer.

4. Body fat percentage was determined through a hydrostatic weighing method.

Limitations of Study

The limitations of the study were as follows:

1. The investigator was unable to control for the amount of competitive experience of the subjects, and this may have affected performance.

2. The investigator was unable to control environmental factors, such as sleep, outside activities, and motivation of the subjects.

3. Other types of power tests might have produced different results from those of the current study.

4. Speed settings on the Cybex II isokinetic dynamometer other than the ones employed by this study might have produced different results from those of the current study.

5. A different method to determine body fat percentage might have produced different results.

Chapter 2

REVIEW OF RELATED LITERATURE

Many sports are being studied from a scientific perspective to identify factors that may help athletes to reach their full potential, as well as why some athletes consistently perform more successfully than others. Coaches, athletes, and researchers interested in human performance have turned their attention to areas of preparation that may provide the advantage that separates winning from losing when individual competitors or teams are nearly equal in most facets of the sport. One aspect that has sparked considerable interest is an athlete's physical performance capability. For example, are there noticeable differences in strength, power, aerobic capacity, flexibility, reaction and response time, and body composition among athletes who demonstrate different levels of success in their respective sports? If differences exist, the implications of these differences are much more important to the coaches, athletes, and researchers than the differences themselves.

Stine, Ratliff, Shierman, and Grana (1979) identified four suggestions that could benefit the athlete, coach, athletic trainer, and team physician. Information on the physical performance capability of an athlete could be used to identify physical and physiological profiles related to sport performance capability, thus helping an athlete to achieve maximum potential by manipulation of training programs. The development of predictive criteria based on the performance capabilities of other successful performers may guide young athletes toward a sport for which they are best suited. Also, a performance profile that tests and evaluates each athlete for specific strengths and weaknesses could motivate an athlete to set performance goals that have been effective for other successful competitors. Lastly, if certain characteristics were found to be associated causally with a specific type of injury, appropriate training could reduce this risk of injury. This chapter contains a review of literature in the following areas: (a) profiles of various types of athletes, (b) factors that affect performance of the female athlete, (c) relationship between leg strength and leg power, (d) anaerobic power, (e) muscular power, (f) body composition, and (g) summary.

Profiles of Various Types of Athletes

The ultimate performance of mature athletes is the result of a large number of factors. These include genetic, nutritional, climatic, sociological, and psychological factors, as well as the state of health and type of activity and training the athletes have been exposed to through the years. It is not a simple matter for the researcher to isolate a single factor while keeping all others constant in order to learn more about each of these parameters (Bar-Or, 1975). The major obstacle to expanding our knowledge of predicting success in athletes is the inability to conduct longitudinal studies. Ideally, these should start in childhood and continue through adolescence to adulthood. Such studies are very costly and difficult to perform, since they require repeated measures of large populations under different training regimens.

Physiological profiles of elite rowers were compiled by Hagerman, Hagerman, and Mickelson (1979) with the original objective to delineate physiological profiles for international caliber oarsmen and oarswomen. Through the study of highly trained oarsmen and oarswomen the researchers were able to collect enough exercise and recovery data to develop an accurate physiological profile of a successful elite rower. The researchers were able to estimate the relative contributions of aerobic and anaerobic energy sources to competitive rowing and to calculate maximum power and mechanical efficiency for each competitor. Oarsmen and oarswomen were able to function at a high percentage of their $\dot{V}O2max$ (96% to 98%) throughout a competitive effort, and in doing so they incurred an immediate and sizeable oxygen deficit (6.4 to 7.7 liters). Abnormally high energy expenditures during the early stages of competitive rowing caused a significant anaerobic response that produced maximal lactate levels (170 mg%) that had to be tolerated for the remainder of the exercise. Thus, physiological and psychological tolerance for extreme levels of lactate production (anaerobiosis) are important qualities of an elite oarsman or oarswoman.

Stine et al. (1979) compiled a performance profile of wrestlers who qualified for the 1977 NCAA championships and attempted to determine if significant differences existed among three groups of wrestlers who had qualified. (All Americans were those wrestlers who finished in the top six places in their weight division, moderately successful were those wrestlers who won at least one match or more but did not finish in the top six places in their weight division, and relatively unsuccessful were those wrestlers who failed to win any matches.) The results demonstrated that the wrestlers at the NCAA championships represented a rather homogeneous population from the standpoint of physical performance capabilities. However, small differences that favored those who ultimately proved to be the most successful were consistently observed. An athlete with superior strength and endurance would possess the proper characteristics needed to be a championship wrestler.

A study of physiological profiles and selected physiological characteristics of national class American cyclists was conducted by Hagberg, Mullin, Bahrke, and Limburg (1979). The primary purpose of this investigation was to derive data on the physiological profiles of top American road cyclists. In addition, the comparison of such data with those from European cyclists (Saltin & Astrand, 1967; Strome, Ingjer, & Meen, 1977) may have revealed reasons for the lack of success of American cyclists in international competition. The results revealed that the cyclists were more introverted than normal adults, and less tense, confused, depressed, and angry than college age normals. The cyclists were able to average 52.8 ± 4.9 seconds at a load in excess of 3780 kpm x min^{-1} on the bicycle ergometer. This indicates that in addition to highly developed aerobic systems (the $\dot{V}O2max$ for the group averaged 70.3 ± 2.0 ml/kg/min), these cyclists also possessed the capacity for extremely high power outputs for short periods of time (Hagberg et al., 1979). Physiologically, the American cyclists were similar in their characteristics to the European cyclists. Therefore, it was concluded that other factors, including tactics and technique, must have contributed to performance differences seen between American and European cyclists.

Kovaleski, Parr, Hornak, and Roitman (1980) described selected physical and physiological characteristics of women collegiate volleyball players and compared the varsity and junior varsity groups. The results showed that a significant difference ($p < .05$) existed in the average weight of the athletes, with the varsity lighter (61.0 kg) than the junior varsity (67.5 kg). The mean percentage of body fat for the varsity was 19.5 and for the junior varsity, 23.3. On the average the junior varsity had more fat weight (15.8 kg) than the varsity (12.0 kg). The maximal oxygen consumption

(1/min) was noticeably different, with the junior varsity's oxygen uptake (3.8 l/min) higher than the varsity's (3.3 l/min). However, when the weight of the subjects was taken into account, the average maximal oxygen consumptions were similar (56.7 ml/kg/min for the junior varsity and 55.5 ml/kg/min for the varsity). The junior varsity had a greater maximal minute ventilation (121.7 l/min) than the varsity (110.9 l/min). Based on the findings of this study, one should consider the differences in anthropometric and physiological fitness factors among sports teams. This supports the hypothesis that anthropometric and physiological fitness factors are unique for various athletes and athletic teams (Kovaleski et al., 1980).

The last profile to be described here was carried out by Song (1982). He examined the relationship of anthropometric, flexibility, strength, and cardiorespiratory variables to performance in downhill and giant slalom skiing events. Even though performance is influenced by many physiological, biomechanical, and environmental components, lower leg strength, anaerobic power, $\dot{V}O_2max$, and grip strength were moderately correlated with better downhill skiing performance. Grip strength and hip, elbow, and trunk flexion strengths were correlated with successful giant slalom performance. It is very clear that a competitor's skill is a complex blend of many anthropometric, physiological, biomechanical, and environmental components and cannot simply be predicted using only a few factors.

Factors that Affect the Performance of the Female Athlete

This subject area emphasizes some of the physiological responses of girls and women to exercise, physical training, and performance. Fox and Mathews (1981, p. 349) reported differences of track and field and swimming performances between men and women. Their data were expressed as a performance ratio, which was the men's performance score divided by the women's. All ratios reported were greater than one, meaning that the men's performances were better than the women's. The results revealed that (a) the overall performance by women was closer to the men's in swimming than in either running or jumping; (b) in the running events, the women's performance was closer to the men's in the 100-m and 200-m sprints than in the other events; (c) in the swimming events, the women's performance was closer to the men's in the distance events; and (d) the worst relative performances for the women were the 100-m in swimming, the 800-m in running, the high jump, and the long jump (Fox & Mathews, 1981, p. 350).

Some of the observed performance differences can be explained, at least partly, by body weight and height differences. The comparisons between the average adult male and female were examined by Medved (1966). The results of his investigation showed that the average adult female (a) was 3 to 4 in. shorter, (b) was 25 to 35 lb. lighter in total body weight, (c) had 10 to 15 lb. more adipose tissue (fat), and (d) had 40 to 45 lb. less fat-free weight. In a comparison between males and females, the female tends to have the advantage in swimming events because of her body composition. In water, the greater amount of body fat makes the female more bouyant than her male counterparts, thus the female uses less energy per unit of distance swum.

Structurally, the average female has a wider pelvis than the average male. In running, particularly sprinting, the female must shift her pelvis more in order to keep the center of gravity over the weight-bearing foot (James & Brubaker, 1973). As a result, there is greater hip muscle involvement and thus, a decreased mechanical efficiency during running. Theoretically, this should limit the running ability of the female with respect to the male. Nevertheless, research findings indicate that the relationship between width of hips and running speed is very low and should not be a limiting factor from a practical standpoint (Oyster & Wooten, 1971).

Relationship Between Strength and Power

Since strength is one of the components of power, there has been a considerable amount of research done on their relationship. In 1961, Smith measured leg strength with a leg dynamometer and power with the vertical jump and reach test. Although the reliability of each measure was high, individual differences in the ratio of tested strength to body mass showed a low, non-significant correlation with jumping performance. The results were interpreted as support for the hypothesis that strength exerted against a dynamometer involves a different neuromotor pattern than strength exerted by the muscles during a movement.

Some researchers have found a moderate relationship between strength and power. McClements (1966) conducted a study to compare the power of the body, as measured by the product of jumping height and body weight, with strength of leg and thigh flexor muscles. He also compared the effects of strength development of agonistic and antagonistic muscle groups on power. He observed significant correlations of .52 between flexor strength and power scores and .62 between extension strength and power scores before the training period, but the gains in strength were not related to increased gains in power.

Berger (1963) examined whether dynamic or static leg strength was more related to power. The investigator used the maximal squat lift to measure dynamic leg strength, the leg dynamometer to measure static leg strength, and the modified vertical power jump to measure leg power. The results revealed a correlation of .71 between leg power and dynamic strength and a correlation of .64 between leg power and static strength. This investigator concluded that the relationship between dynamic strength and leg power was not significantly different from the relationship between static strength and leg power.

To summarize, strength and power have been shown by researchers to have a moderate correlation. Consequently, strength and power are difficult parameters to separate and measure independently.

Anaerobic Power

A few examples of athletes converting energy to power are the ability to jump, sprint, put the shot, and throw the javelin. Power is the performance of work expressed per unit of time (Fox & Mathews, 1981, p. 619). The ability to develop a considerable amount of power is a prime factor in athletic success. The development of power is related to muscular strength, but particularly to the amount and rate of utilization of the adenosinetriphosphate-phosphocreatine (ATP-PC) system. Hence, anaerobic power tests reflect primarily one's depth and ability to employ the ATP-PC system. In other words, anaerobic power is the exertion of force through a given distance in the shortest possible time (Beckenholdt & Mayhew, 1983). Unlike measuring maximal oxygen uptake to determine one's aerobic capacity, only the concept of generating a maximum amount of energy in a short period of time appears to be valid. However, there is no single, widely accepted test to measure anaerobic power.

Perhaps the most extensively used test of anaerobic power was developed by Margaria, Aghemo, and Rovelli (1966) and was modified by Kalamen (1968). The modification resulted in a more valid power output score than Margaria's original test. This test requires the subject to sprint up an ordinary flight of stairs, three at a time. A timing device records the time required to traverse the distance from the third to the ninth step. Power is estimated as the product of body weight acting through the vertical distance in the recorded time (Beckenholdt & Mayhew, 1983). However, to perform this test properly an elaborate timing device, which includes a clock and two electronic switchmats, is needed.

Other popular tests to assess anaerobic power include the vertical jump, standing broad jump, and 40-yd. dash. Of these, only the vertical jump is easily converted to units of power using the Lewis nomogram (Fox & Mathews, 1981, p. 620). Knowledge of the angle of take-off as well as the distance covered is required to calculate power in the standing broad jump. It is even more difficult to calculate power in the 40-yd. dash because it requires the summation of the vertical and horizontal components of power that were applied during each stride (Fukunaga, Matsuo, Yuasa, Fujimatsu, & Asahina, 1980). Consequently, the absolute scores are usually taken to reflect the generation of power.

For anaerobic power tests to be used interchangeably, they must be highly intercorrelated. Beckenholdt and Mayhew (1983) examined the specificity among anaerobic power tests in male athletes. The tests included the Margaria-Kalamen test (MK), vertical jump test (VJ), standing broad jump

(SBJ), and 40-yd. dash. A factor analysis isolated two power components, one dealing with speed and one associated with mass. The VJ, SBJ, and 40-yd. dash dealt with the speed factor, while the MK and VJ power tests were associated with the mass factor. The authors concluded that anaerobic power tests cannot be used interchangeably when evaluating subjects. While all the aforementioned tests are fundamental movements, the degree or level of motor skill development appears to play a role in successful performance.

A new method for assessment of anaerobic capacity in runners was presented by Schnabel and Kindermann (1983). A modification of that test was employed by the investigator in the present study. In designing the original test, special attention was placed upon simplicity and broad applicability. The rationale was that, in an exhaustive treadmill run of appropriate duration, time to exhaustion is primarily a function of anaerobic capacity. Since the run is performed at the same speed by all subjects, time to exhaustion is a measure for inter-subject comparisons of anaerobic capacity (Schnabel & Kindermann, 1983). The validity of the results was verified with runners of a high competitive level from a variety of events ranging from the 400-m run to the marathon. In conclusion, the apparent differences among the groups examined demonstrated that this procedure was a sensitive method for assessment of anaerobic capacity.

Muscular Power

Muscular power is the rate of work performed or the equivalent to energy output per unit of time (Laird & Rozier, 1979). All valid tests of muscular power must employ a quantitative formulation or measurement that is consistent with the definition of power (Sapega & Drillings, 1983). Therefore, any test that does not meet this criterion does not measure power. Power measurements must be expressed in units that are equivalent to work per unit time. Watts (joules/sec), horsepower, and ft. lb./sec are all common units used to express power. There is no single "correct" muscular performance test for evaluating muscular power output. As long as a valid method of calculating muscular power output is applicable, the actual muscular performance task can be selected in accordance with the functional and/or experimental requirements of the testing situation (Sapega & Drillings, 1983).

An accurate method of measuring muscular power is with a Cybex II isokinetic dynamometer (Moffroid & Kusiak, 1975). Prior to the manufacturing of such an apparatus, the common practice was to measure the work of a single isotonic contraction and to time the movement. However, this procedure does not take into account the acceleration or deceleration of the movement throughout its full range of motion. The concept of isokinetic exercise was developed at the Institute of Physical Medicine and Rehabilitation, New

York University Medical Center (Adeyanju, Crews, & Meadors, 1983). Isokinetic training or evaluation allows a muscle group to develop maximum dynamic tension throughout the range of motion at a constant angular velocity. Isokinetic training modalities provide a range of selectable speeds with the assumption that each speed provides for a maximum resistance throughout the range of movement. The Cybex II isokinetic dynamometer has gained increasing acceptance in the field and is one of the only available isokinetic strength measuring devices (Gleim, Nicholas, & Webb, 1978). The device allows for accurate and objective measurements of contractile muscle strength and endurance under known, reproducible velocities. Johnson and Siegel (1978) have reported reliability coefficients of .93 and .94 for such isokinetic testing of knee flexion and extension.

Campbell (1979) tested the hypothesis that no significant difference in horsepower would be manifested between two rates of dynamic movement (60 and 210 deg/sec) by the use of the Cybex II isokinetic dynamometer. The results showed that a significant difference in horsepower existed between the two rates for knee flexion in sprinters. Distance runners developed greater horsepower at the slow speed, while the sprinters generated more horsepower at the fast speed. Generation of knee extension horsepower by distance runners was more dependent on muscle strength, while in sprinters it was more dependent on speed of the movement.

Lastly, he found that sprinters used a greater maximum percentage of knee flexion strength for the generation of horsepower than did distance runners.

In a recent study by Adeyanju et al. (1983), the effects of two speeds of isokinetic training on muscular strength, power, and endurance were studied. The subjects were 30 female college students, and the training program lasted 7 weeks. The subjects were assigned to one of the following groups: slow speed training group, fast speed training group, or the control group (who did no training). Strength was defined as the maximum torque capability at the slow speed (30 deg/sec). Power was defined as the maximum torque achieved at the fast speed (180 deg/sec). Muscular endurance was defined as the number of repetitions performed before maximum torque decreased by 50% of the initial value. From the results, the researchers were able to conclude that isokinetic training was effective in the development of muscular strength, power, and endurance and that fast speed training was superior to slow speed training in the development of muscular power and muscular endurance (Adeyanju et al., 1983).

Muscular strength was measured on a Cybex II dynamometer in a study performed by Thomas et al. (1983). Quadriceps and hamstrings were assessed for strength at an instrument velocity of 60 deg/sec. The results revealed that hamstring strength was the single best correlate of success in distance runners. Quadriceps strength and leg muscle balance were among several variables that were single correlates of successful sprinting and jumping performance. However, the authors did not test the athletes at a high speed isokinetic muscle contraction. High speed assessment may be a good indicator of successful performance in track and field athletes.

Male varsity track and cross country athletes were examined by Morris, Lussier, Bell, & Dooley (1983). The results displayed a variation in hamstring to quadriceps ratio. At slow isokinetic speeds (30 deg/sec) a ratio of .62 was reported; a .87 ratio was revealed at the fast speed (300 deg/sec). The authors concluded that hamstring/quadriceps ratio does not appear to be a fixed value. It is probably best evaluated in conditions where the velocity of contraction approximates the speed of contraction used in the athlete's specific event.

Body Composition

The measurement of the athlete's body composition in order to establish an optimal playing weight (OPW) is gaining importance in the total training program (Mayhew, Piper, Koss, & Montaldi, 1983). Negative effects of excess body fat on performance, without sacrificing nutritional integrity, can be minimized by the athletes achieving their OPW. Excess weight in the form of fat may impose more severe penalties on females' performance than on that of males (Cureton &

Sparling, 1980). The most widely accepted procedure for determining the components of body composition is by a hydrostatic weighing technique. The procedure is time consuming, requires elaborate laboratory equipment, and demands extensive subject cooperation. However, if administratively feasible, it is one of the most accurate method for determining body composition. Many prediction equations have been developed to estimate body composition, but most have been used on non-athletic populations. Recent evidence indicates that considerable error may be introduced by applying such equations to athletes (Mayhew, Piper, & Holmes, 1981).

Many investigators have studied male and female track and field athletes (Behnke & Wilmore, 1974; Hirata, 1966; Medved, 1966) and have found that the male exhibited higher values in total body mass and overall size than the female in the same event. In 1977, Pipes conducted a study to determine differences between male and female track and field athletes on the basis of their body composition, relative to the event in which they participated. All subjects (27 women and 31 men) were tested and retested using a hydrostatic weighing technique to assure accuracy of the measurement. Pipes found that relative percentage of body fat was similar for both the male and female in the same event, in terms of deviations from the average. Lean body mass, body density, and total body weight were higher for the male in all events.

Lastly, males had a lower relative percentage of body fat than females in the same event. The most consistent relative body fat values of normal individuals were cited as 15% for men and 23% for women (Behnke & Wilmore, 1974). Thomas et al. (1983) found body weight to be a single correlate of successful distance running, while percentage of body fat was a single correlate of both successful sprinting and jumping performance.

Summary

The last decade has seen the accelerated emergence of women in sports. Female athletes now invest great amounts of time and energy in strenuous training programs, because they are no longer content with mediocre performances. There is no longer a haphazard approach to the allied areas of sports training, since the female athlete is more motivated to reach a level of excellence than female athletes of 10 years ago. Through the use of human performance laboratories, sports scientists can test athletes to obtain important practical knowledge of the physiological nature of athletes in a given sport. Nevertheless, the majority of previous research has focused on only a few of the numerous variables that may contribute to performance. Ideally, a physiological and physical profile for baseline evaluation of prospective athletes should include (a) anthropometry, (b) biological age, (c) aerobic capacity, (d) anaerobic capacity and power, (e) genetic markers, (f) hormones, (g) neurological status, and (h) motor performance (Bar-Or, 1975).

Chapter 3

METHODS AND PROCEDURES

This chapter contains a review of the methods and procedures employed in this study. The review has been divided into six areas: (a) selection of subjects, (b) testing instruments, (c) methods of data collection, (d) scoring of data, (e) treatment of data, and (f) summary.

Selection of Subjects

This study was conducted in the spring semester of 1984. The subjects consisted of 12 female track and field athletes ranging in age from 18 to 22 years. The mean age of the subjects was 19.9 years. All 12 subjects were undergraduate students, all members of the 1984 Ithaca College women's track and field team. The subjects consisted of three groups. The groups consisted of seven power athletes (sprinters and jumpers), three middle distance runners, and two heptathletes. All 12 subjects participated voluntarily in this study. Following the explanation of all methods and procedures, informed consent was obtained from each subject (Appendix A).

Testing Instruments

Several testing instruments were used in this study. The Cardio Fitness Testing Treadmill (MacLevy Products, Elmhurst, N.Y.) was used to assess anaerobic power. An Accusplit 705XP digital stop watch was utilized to record the subjects' time to exhaustion. The Cybex II isokinetic dynamometer (Division of Lumex Inc., Ronkonkoma, N.Y.) was used to measure leg strength and leg power.

Underwater Weighing Equipment

A detailed diagram of the underwater weighing tank and other related equipment can be found in Appendix B. In this section and the two subsequent ones, the numbers in parentheses refer to numbers found on the figure in Appendix B. The weighing equipment consists of an underground cement tank (130 x 130 x 220 cm) filled with water at a temperature of approximately 36° Centigrade and open at the top (see #1, Appendix B). Suspended from an electric hoist (see #2, Appendix B) is a legless chair made of stainless steel tubing and rubber webbing. The chair (see #3, Appendix B) hangs from a Detecto (Brooklyn, N.Y.) springless scale (see #4, Appendix B), with a 20-kg capacity and graduated in 20-gm intervals.

Equipment for Measuring Residual Lung Volume

1. Attached to the upper edge of the right side of the tank are three (see #s 5, 6, and 11, Appendix B) plastic hoses 1 3/8 inches in diameter (A. M. Systems, Inc., Everett, Wa.). A three-way respiratory valve (see #7, Appendix B) (W. A. Collins, Braintree, Ma.) is fixed to these hoses for controlling the source of inspired gas. One opening of the valve is connected to a standard respiratory mouthpiece, the second to a tube which carries room air (see #5, Appendix B), and a third to a tube which supplies oxygen (see #6, Appendix B). (The oxygen mixture is approximately 99.7% oxygen and

0.3% nitrogen gas.) The three-way valve can be adjusted in such a way that the subject is connected to only one of the gas sources at any time.

2. A 9-liter Collins Vitalometer (W. A. Collins, Braintree, Ma.) (see #8, Appendix B) is attached in line between the oxygen tank (see #9, Appendix B), and the three-way valve. A check valve (see #10, Appendix B) functions to allow air flow from the vitalometer during the inspiration and prevent backflow during the expiration.

3. A 120-liter Tissot spirometer (see #20, Appendix B) (W. A. Collins, Braintree, Ma.) is attached to the exhaust hose through a three-way valve (see #12, Appendix B), and the valve allows all the expired air from the lungs to either collect in the spirometer or bypass the spirometer and vent into the room. A small pump (see #13, Appendix B) placed between the intake (see #12, Appendix B) and exit (see #14, Appendix B) ports of the Tissot spirometer serves to circulate and mix the gases in the spirometer.

4. A Med-Science 505-Nitrogen Analyzer (see #15 and #16, Appendix B) (Med-Science, St. Louis, Mo.) is attached to the Tissot spirometer by two small three-way valves (see #18, Appendix B) located on the recirculation line (see #19, Appendix B). When the first valve (see #17, Appendix B) to the spirometer is opened and the second one (see #18, Appendix B) closed, gas from the Tissot spirometer is brought into the nitrogen analyzer. When the first valve is closed and the second valve open, room air is brought into the analyzer.

5. A small air pump (see #21, Appendix B) (8 l/min flow) provides room air to the subject via a 5-mm intravenous tube running through the exhaust tube (see #5, Appendix B) to the mouthpiece.

6. A standard thermometer is used to determine the temperature of the collected gas in degrees centigrade.

7. A standard mercury barometer is used to determine barometric pressure.

Methods of Data Collection

Anaerobic Capacity

Anaerobic capacity was assessed through the use of a timed run to exhaustion on the treadmill. The test was a modification of the method used by Schnabel and Kindermann (1983). All subjects were familiarized with treadmill running prior to the actual testing session. This test was a constant load test that was performed at 12 miles per hour (mph) and 7.5% slope. The treadmill was accelerated from 0 to 12 mph within 10 seconds. This was a modification from the original speed and grade of 15 mph and 7.5% slope employed by Schnabel and Kindermann (1983), who tested male international caliber runners. The speed of 12 mph was chosen after a pilot study revealed that this speed allowed a random sample of the subjects to stay on the treadmill for a time period similar to that observed in the original study. The subjects were asked to perform the test twice with a rest period of approximately 15 minutes between the two bouts. The higher value was recorded as that subject's score.

Because this was a maximum test, the subjects ran until they were no longer able to maintain the treadmill speed. They were urged to go to the extremes of performance; they received strong vocal support from the investigator as well as their teammates.

Isokinetic Testing

The second testing session involved the use of the Cybex II isokinetic dynamometer (Division of Lumex, Ronkonkoma, N.Y.). Isokinetic testing was performed on both legs of each subject. Each leg was tested for knee extension and knee flexion at 60 deg/sec and 240 deg/sec. The investigator carefully positioned each subject on the testing table and stabilized all body parts. The subject was asked to grasp the sides of the testing table for support, and velcro straps were secured around the chest and pelvis to stabilize the upper body (Morris, 1977). The subjects were allowed several warmup trials after they were positioned on the apparatus.

For isokinetic testing all subjects were told to move through the entire range of motion of knee flexion and extension as hard and fast as possible. The average of three contractions at each speed was used to compute power output (watts) and peak torques (ft. lbs.). A rest interval of 60 to 90 seconds was allowed between each set of contractions. After testing one extremity, the subject was allowed to move about the laboratory for a few minutes and then repositioned for testing the opposite extremity in the same manner (Morris et al., 1983). The right leg was always tested first.

Underwater Weighing Techniques

1. Before starting, each subject was oriented to the entire procedure.

2. The subject's weight in a light swimsuit was taken to the nearest 30 gm on a calibrated accurate springless balance.

3. Height of the subject was taken to the nearest mm.

4. The subject then sat in the weighing seat (see #3, Appendix B) and was secured with a safety belt.

5. About 10-20 liters of oxygen was flushed through the system to clear out the dead space in the Tissot spirometer. For this, the regulatory valve of the oxygen tank (see #9, Appendix B) was opened and with some weight on the vitalometer bell (see #8, Appendix B) the oxygen was forced into the Tissot spirometer (see #20, Appendix B) by opening its three-way valve (see #12, Appendix B) and setting the mouthpiece valve (see #7, Appendix B) to sample room air from tube 5. When the spirometer was about one-third full, the mixing pump (see #13, Appendix B) was turned on. This allowed the gases to mix for a few minutes. Then the Tissot exhaust valves (see #14, Appendix B) were opened, and by manual pressure all the gas was expelled from the Tissot spirometer. At this point the exhaust valves (see #14, Appendix B) were closed when the Tissot bell reached the bottom. The system was flushed, and the nitrogen content was between .3 to .4 percent. This procedure might need to be

repeated three to four times to reach the proper nitrogen content. The system was now ready for sample collection.

8. The subject was lowered into the tank up to about shoulder height.

9. The mouthpiece was given to the subject, inserted into her mouth with the three-way valve (see #7, Appendix B) connecting her to room air.

10. Noseclips were placed on the subject's nose to prevent air leakage.

11. While breathing comfortably through the mouthpiece, the subject was asked to bend forward slowly until completely submerged.

12. Once the subject felt comfortable underwater and breathing through the mouth piece, she was instructed, with a prearranged signal from the investigator, to make a maximum exhalation while remaining fully submerged. When this was achieved the subject signaled the investigator, who recorded the weight underwater to the nearest 10 gm. The subject only had to hold her breath for 5 seconds. This procedure was repeated three to four times in order to get the maximum underwater weight.

13. The final underwater weight was taken in exactly the same way as described above, except that when a stable weight was achieved the investigator reached down into the tank and turn the respiratory valve (see #7, Appendix B) towards the oxygen delivery line (see #6, Appendix B), thus switching the subject from breathing room air to pure oxygen.

At that time the subject was told to hold her breath. Upon completion of the previous procedure, the subject was told to "breathe and come up." The subject sat with her head out of the water and breathed through the mouthpiece for 4 to 5 minutes to totally flush all nitrogen from her residual airspace into the Tissot spirometer. At the end of this period the subject was asked to hold her breath for a few seconds while the investigator closed the respiratory valve (see #7, Appendix B) as well as the intake valve on the Tissot. The final volume reading on the Tissot spirometer was taken to the nearest mm. The temperatures of the expired gas in the spirometer and the water were taken at this time. The barometric pressure was also recorded.

14. The valves which connect the Tissot to the nitrogen analyzer (see #23 and #17, Appendix B) were opened to sample the subject's expired gas. The mixing pump (see #13, Appendix B) was also turned on for 5 minutes. The percentage of nitrogen was read on the analyzer's digital scale after the mixing pump had been turned off.

15. The underwater weight of the chair and breathing apparatus was taken by placing the hoses and mouthpiece on the chair and lowering it to exactly the same depth reached when weighing the subject.

16. All data were recorded on the densitometry data sheet (Appendix C).

17. The tank was pumped out by submerging the sand pump into the water and plugging it into the electric outlet.

Scoring of Data

Prior to each subject's testing for body fat percentage, her height, weight, and age were recorded on the densitometry data sheet (see Appendix C). Other parameters that were recorded at this time included the barometric pressure and the percentage of nitrogen in the oxygen tank. Upon completion of the test the following additional information was recorded on the densitometry data sheet: Tissot temperature, vapor pressure at Tissot temperature (mmHg), water temperature, Tissot final reading, weight in water (subject and equipment), weight of equipment in water, and final nitrogen analysis in expired air. The Tissot initial reading and the Tissot dead space are constant values. All this information was used to calculate body fat percentage.

Scoring of the Cybex data included several steps. Peak torques were recorded using the Cybex II Chart Data Card by matching the proper grid to the correct ft.-lb. scale on the data strip. Average power was also found at both 60 deg/sec and 240 deg/sec by tracing the area under the curve with the aid of the Apple II Plus computer with the Apple graphics tablet menu. The times of contractions were found by measuring the distance of the curve in mm and dividing that by the constant value of 25 mm/sec (paper speed). The three power outputs of the quadriceps and hamstring for each speed and leg were added and divided by their sum to produce an average work area and an average time. Next, the area was multiplied by a work constant and divided by the time to produce a power output in watts.

Scoring of the anaerobic power test consisted of taking the subject's best time as measured by the Accusplit 705XP digital stopwatch.

Treatment of Data

In an exploratory study, a correlational analysis was computed to determine if there were any single significant relationships between the selected variables and the performance ratio (see Table 2, Chapter 4). A multiple regression analysis was also computed to determine what variables were the best predictors of successful performance. However, due to the small number of subjects relative to the number of variables, four regression equations had to be performed (see Table 3, Chapter 4). Due to this situation, one last regression was performed with six variables that correlated significantly well with successful performance. It was thought that Cybex ratios in the exploratory regression equations were too related to one another and were falsely predicting successful performance.

Summary

The subjects in this study were 12 female track and field athletes ranging in age from 18 to 22 years. The study was conducted at Ithaca College and Cornell University during the months of March and April.

Several testing instruments were used in the present study. The Cardio Fitness Testing Treadmill (MacLevy

Products, Elmhurst, N.Y.) was used to assess anaerobic power. An Accusplit 705XP digital stop watch was used to record the subject's time to exhaustion. The Cybex II isokinetic dynamometer (Division of Lumex Inc., Ronkonkoma, N.Y.) was used to assess peak torques and power output. Lastly, hydrostatic weighing equipment (nitrogen washout technique), located at the Department of Nutritional Sciences at Cornell University, was used to test the subject's percentage of body fat.

All scores were calculated and correlated to the mean performance ratio. Also, four regression equations were computed with successful performance. But, due to the small number of subjects compared to the number of parameters, these results were interpreted cautiously. A final regression analysis was computed with the six variables that were thought to correlate the best with the mean performance ratio.

Chapter 4

ANALYSIS OF DATA

This study was conducted to investigate if any of the selected variables were related significantly to successful track and field performance. Also, if significant relationships existed, how well did those variables predict successful performance? The simple correlations were computed in a preliminary study in conjunction with four multiple regression equations. Four separate equations were used due to the small number of subjects relative to the number of variables. From the information provided above, a final regression analysis was computed with six variables that correlated well with the performance ratio, a ratio computed by expressing the athlete's best time or distance as a percentage of the then current NCAA Division III record. Sections in this chapter include the following: (a) means and standard deviations, (b) simple correlations to successful performance, (c) preliminary regression equations, and (d) final regression equation.

Means and Standard Deviations for all Variables

Table 1 contains the means and standard deviations of all the variables measured in the present study. The means and standard deviations for year in school, anaerobic power, percentage of body fat, Cybex scores and ratios, and performance ratio were computed.

Table 1

Descriptive Statistics for Selected Variables in Female Track and Field Athletes

Variable	M	SD
Year in School (yr.)	2.42	1.51
Anaerobic Power Test (sec)	33.96	13.64
Percentage of Body Fat	18.68	4.44
R. Quad (T 60 deg/sec)[a]	120.42	19.96
(P 60 deg/sec)[b]	93.93	18.63
R. Ham (T 60 deg/sec)[c]	70.50	13.56
(P 60 deg/sec)	65.74	13.30
L. Quad (T 60 deg/sec)[d]	114.75	22.19
(P 60 deg/sec)	94.12	20.89
L. Ham (T 60 deg/sec)	73.17	15.06
(P 60 deg/sec)	68.41	14.61
R. Ham/R. Quad (T 60 deg/sec)	.59	.07
(P 60 deg/sec)	.71	.12
L. Ham/L. Quad (T 60 deg/sec)	.64	.10
(P 60 deg/sec)	.74	.15
Weak Quad/Strong Quad (T 60 deg/sec)	.92	.06
(P 60 deg/sec)	.92	.05
Weak Ham/Strong Ham (T 60 deg/sec)	.91	.04
(P 60 deg/sec)	.90	.06

Table 1 (Continued)

Variable	M	SD
R. Quad (T 240 deg/sec)	63.50	11.71
(P 240 deg/sec)	179.43	34.18
R. Ham (T 240 deg/sec)	44.42	17.20
(P 240 deg/sec)	134.46	60.75
L. Quad (T 240 deg/sec)	65.42	11.36
(P 240 deg/sec)	188.14	35.21
L. Ham (T 240 deg/sec)	49.92	11.63
(P 240 deg/sec)	150.29	45.69
R. Ham/R. Quad (T 240 deg/sec)	.69	.22
(P 240 deg/sec)	.72	.25
L. Ham/L. Quad (T 240 deg/sec)	.77	.16
(P 240 deg/sec)	.80	.18
Weak Quad/Strong Quad (T 240 deg/sec)	.91	.07
(P 240 deg/sec)	.90	.04
Weak Ham/Strong Ham (T 240 deg/sec)	.80	.16
(P 240 deg/sec)	.80	.21
Performance Ratio (% Division III Record)	.91	.05

Note. N = 12 subjects for each variable.

[a]R = right, Quad = quadriceps, T = peak torque.

[b]P = power.

[c]Ham = hamstrings.

[d]L = left.

Simple Correlates of Successful Performance

The level of success for each athlete was defined as the athlete's best time or distance expressed as a percentage of the then current NCAA Division III record. To determine which variables were individually related to successful performance, a Pearson product moment correlation was used. A one-tailed test ($p < .05$) was chosen because if any of the variables studied here were significantly related to successful performance, they were assumed to be related to good, rather than poor, performance.

The simple correlates of success are presented in Table 2. Nine of the 35 variables correlated significantly with the performance ratio. Of the eight Cybex scores or ratios that were significantly related to successful performance, seven of them were assessed at the high speed (240 deg/sec) on the isokinetic dynamometer. The two best simple correlates with the performance ratio were the power output ratio of the weaker hamstring to the stronger hamstring at 240 deg/sec ($r = .79$) and the power output ratio of the right hamstring to the right quadriceps at the high speed ($r = .77$). Other simple correlates of success were peak torque ratio of the right hamstring to the right quadriceps at 240 deg/sec ($r = .69$), peak torque ratio between weak hamstring and the strong hamstring at 60 deg/sec ($r = .64$), power output of the right hamstring at 240 deg/sec ($r = .61$), power output ratio between the weak quadriceps and the strong quadriceps at 240 deg/sec ($r = .58$), peak torque of the right

Table 2

Simple Correlates of Selected Variables with the Performance Ratio in Female Track and Field Athletes

Variable	*r*	r^2
Year in School (yr.)	.28	.08
Anaerobic Power Test (sec)	.63*	.39
Percentage of Body Fat	-.44	.19
R. Quad (T 60 deg/sec)[a]	.29	.08
(P 60 deg/sec)[b]	.09	.01
R. Ham (T 60 deg/sec)[c]	.33	.11
(P 60 deg/sec)	.23	.05
L. Quad (T 60 deg/sec)[d]	.08	.01
(P 60 deg/sec)	.16	.03
L. Ham (T 60 deg/sec)	-.01	.00
(P 60 deg/sec)	-.11	.01
R. Ham/R. Quad (T 60 deg/sec)	.12	.01
(P 60 deg/sec)	.21	.05
L. Ham/L. Quad (T 60 deg/sec)	-.12	.01
(P 60 deg/sec)	-.35	.13
Weak Quad/Strong Quad (T 60 deg/sec)	-.44	.19
(P 60 deg/sec)	.15	.02
Weak Ham/Strong Ham (T 60 deg/sec)	.64*	.40
(P 60 deg/sec)	.41	.17

Table 2 (Continued)

Variable		*r*	r^2
R. Quad	(T 240 deg/sec)	-.03	.00
	(P 240 deg/sec)	.27	.07
R. Ham	(T 240 deg/sec)	.52*	.27
	(P 240 deg/sec)	.61*	.37
L. Quad	(T 240 deg/sec)	.12	.02
	(P 240 deg/sec)	.09	.01
L. Ham	(T 240 deg/sec)	.38	.15
	(P 240 deg/sec)	.21	.04
R. Ham/R. Quad	(T 240 deg/sec)	.69*	.48
	(P 240 deg/sec)	.77*	.59
L. Ham/L. Quad	(T 240 deg/sec)	.38	.14
	(P 240 deg/sec)	.25	.06
Weak Quad/Strong Quad	(T 240 deg/sec)	-.24	.06
	(P 240 deg/sec)	.58*	.34
Weak Ham/Strong Ham	(T 240 deg/sec)	.50*	.25
	(P 240 deg/sec)	.79*	.62

Note. *N* = 12 subjects for each variable.

[a]R = right, Quad = quadriceps, T = peak torque.

[b]P = power.

[c]Ham = hamstrings.

[d]L = left.

*p < .05.

hamstring at 240 deg/sec (r = .52), and peak torque ratio between the weak and strong hamstring at 240 deg/sec (r = .50). The only other statistically significant simple correlate of the performance ratio was the modified anaerobic power test (Schnabel & Kindermann, 1983). Alone it accounted for almost 40% of the variance of successful performance (r = .63).

Preliminary Regression Equations

Four step-wise regression analyses were computed. There were 10 variables in each equation. The variables were divided into four equations due to the large number of variables relative to the number of subjects. The anaerobic power test and year in school were in every equation, while percentage of body fat was in three of the four equations. This was performed because it was the only way to have the above mentioned variables included with all of the Cybex scores and ratios. Table 3 contains the four regression equations used in the present study, however, only the variables that accounted for most of the variability are included in this presentation. Equation 1 was developed by including the anaerobic power test (Anpower) and the peak torques of the right (TRH240) and left hamstring (TLH240) at 240 deg/sec. These three variables accounted for almost 70% of the variability. Three variables were also used in the second equation. Equation 2 was developed by including Anpower and power output of the right (PRH240) and left hamstrings (PLH240) at 240 deg/sec. These variables were

Table 3

Preliminary Multiple Regression Models for Successful Performance in Female Track and Field Athletes

Equation	Variables	beta	Constant	R	R^2
1.	Anpower	.67	.81	.63	.39
	TRH240	.83	.81	.81	.65
	TLH240	- .40	.81	.84	.70
2.	Anpower	.61	.83	.63	.39
	PRH240	1.20	.83	.85	.73
	PLH240	- .76	.83	.97	.95
3.	TRHRQ240	.20	.91	.69	.48
	Anpower	.45	.91	.82	.67
	TLHLQ60	- .86	.91	.84	.71
	TLHLQ240	.79	.91	.90	.82

Table 3 (Continued)

Equation	Variables	beta	Constant	R	R^2
4.	PHH240	.41	.58	.79	.62
	Anpower	.50	.58	.90	.81
	PLHLQ60	- .36	.58	.93	.87
	PQQ240	.27	.58	.96	.92

able to account for about 94.5% of the variability. The third equation was able to account for almost 82% of the variability with four variables. Equation 3 was developed by including peak torque ratio of the right hamstring to the right quadriceps (TRHRQ240) at 240 deg/sec, Anpower, and peak torque ratios of the left hamstring and left quadriceps (TLHLQ60, TLHLQ240) at both speeds. Equation 4 was able to account for about 92% of the variability with four variables. This equation was developed by including power output ratio of the weak hamstring to the strong hamstring (PHH240) at 240 deg/sec, Anpower, power output ratio between the left hamstring and left quadriceps (PLHLQ60) at 60 deg/sec, and power output ratio between the weak quadriceps and the strong quadriceps (PQQ240) at 240 deg/sec.

Final Regression Equation

A final regression equation was computed (see Table 4) with all single significant simple correlates of successful performance. These variables were only moderately, or not at all, related to each other. The four remaining significant simple correlates of successful performance were not included in the final analysis due to the relatively high interrelationship between these variables and the ones employed in this analysis. These variables included peak torque of the right hamstring (TRH240) at 240 deg/sec, peak torque ratio of the weak to strong hamstring (THH240) at 240 deg/sec, peak torque ratio of the right hamstring to the right quadriceps (TRHRQ240) at 240 deg/sec, and power output

Table 4

Final Multiple Regression Model for Successful Performance in Female Track and Field Athletes

Equation	Variables	beta	Constant	R	R^2
Final	PHH240	.77	.74	.79	.62
	Anpower	.46	.74	.90	.81
	PQQ240	.18	.74	.91	.83
	THH60	-.23	.74	.92	.85

of the right hamstring (PRH240) at 240 deg/sec. Although percentage of body fat was not a statistically significant simple correlate of success, it was included in the final analysis because some of the literature (Thomas et al., 1983) stated that percentage of body fat was the best predictor of success in power athletes.

Of the five significant contributors in the final regression equation, four were able to account for over 85% of the variance in successful performance. Excluding percentage of body fat, the four variables that accounted for the large amount of the variance were PHH240 at 240 deg/sec, Anpower, PQQ240 at 240 deg/sec, and peak torque ratio of the weak to strong hamstring (THH60) at 60 deg/sec.

Chapter 5

DISCUSSION OF RESULTS

The purpose of this study was to investigate the relationship among selected variables and successful performance of female track and field athletes and also to develop an equation to predict success based on these selected variables. A treadmill was used to assess anaerobic power, while a Cybex II isokinetic dynamometer was used to assess scores and ratios of peak torque and power output of the quadriceps and hamstrings. Body fat percentage was determined by a hydrostatic weighing technique. Pearson product-moment correlations were computed to determine simple correlates of successful performance when success was defined as the subject's best time or distance expressed in a ratio of the 1984 Division III record. Four preliminary multiple regression equations and one final equation were identified to determine which variables best predicted successful track and field performance. Included in this chapter is a discussion and interpretation of the results reported in chapter 4. The discussion has been divided into the following sections: (a) simple correlates of successful performance, (b) preliminary regression equations, and (c) final regression equation.

Simple Correlates of Successful Performance

This analysis revealed that several of the variables were correlated with the performance ratio. Nine of the 35 variables correlated significantly with successful performance

($p < .05$). Eight of the nine significant variables were either Cybex scores or ratios. Seven of these eight Cybex variables were assessed at the high speed (240 deg/sec). These results were consistent with the findings from previous studies (Adeyanju et al., 1983; Campbell, 1979). However, in these two previous studies peak torque was assessed at 60 and 210 and at 30 and 180 deg/sec, respectively. The present study assessed power output and peak torque at 60 and 240 deg/sec as recommended by Cybex (1983). The results revealed that athletes in the present study were able to produce higher power outputs than peak torques at both speeds of contraction. Therefore, the athletes were more dependent on the speed of the movement than on muscle strength. One might expect track and field athletes to perform better at higher speeds because their angular velocity is closer to the speed at which they perform their given events.

The two highest correlations with the performance ratio (see Table 2) were hamstring balance and right leg balance (power output and peak torque) at 240 deg/sec. These findings were in disagreement with the results of Thomas et al. (1983). They found quadriceps balance and left leg balance (peak torque) at 60 deg/sec to be the most important single correlates of success. In the present study quadriceps balance did correlate significantly with the performance ratio but only at the high speed (power output). Hamstring balance was also a significant correlate at the low speed (peak torque).

While year in school, percentage of body fat, and mean quadriceps strength were also significant simple correlates in earlier studies, the present author could find no significant correlations between these variables and success. Moreover, a significant correlation existed between the mean right hamstring (power output and peak torque) at 240 deg/sec and the performance ratio. The only other simple correlate was not a Cybex score or ratio. It was the modified anaerobic power test (Schnabel & Kindermann, 1983). Almost 40% of the variance was explained by this variable. This is probably because the anaerobic power test is very sport-specific toward power athletes, especially sprinters. From the results of the present study, this test would be very advantageous for coaches to administer to their athletes.

The importance of hamstring balance and right leg balance is apparent from the present results. This is due to the fact that there was a greater variation in power output of hamstring balance (240 deg/sec) when compared to quadriceps balance (240 deg/sec). There was also a greater variation in balance in power output of right leg when compared to left leg balance.

Preliminary Regression Equations

The only previous attempt to correlate multiple variables with sprinting and jumping (power event) success was performed by Thomas et al. (1983). The multiple regression analysis indicated that a combination of physiological and psychological variables could explain a large percentage

(> 85%) of the variation in sprinting and jumping performances. Percentage of body fat, left leg balance, body weight, and two psychological variables were the strongest predictors of power event performance in their study.

In the present study four regression equations were computed due to the small number of subjects relative to the number of variables (see Table 3). The best equation could explain a very large percentage (> 94%) of the variation in power event performance. Equation 2 consisted of Anpower, PRH240, and PLH240. This equation was the strongest predictor of power event performance. Power output of the right and left hamstrings at high speed were also among the variables in this equation. This is probably due to the fact that the standard deviation of the right and left hamstrings showed a larger variation than the standard deviation of the right and left quadriceps (see Table 1). The data also indicate the subjects tested possessed stronger quadriceps muscles as compared with their hamstring muscles. This was true for both angular velocities (60 and 240 deg/sec) as well as for both methods of expressing the Cybex data (peak torques and power outputs).

Equation 4 was the second best predictor of power event performance. This equation could explain approximately 92% of the variation. The variables included PHH240, Anpower, PLHQ60, and PQQ240. Here again the hamstring and the left leg balance at slow speed is probably a fair indicator of power event performance because its variability is slightly larger than that of the right leg. Since the variable was assessed at the slow angular velocity it is far from a replication of the type of activity (events) that the subjects participated in. Quadriceps balance at high speed is probably a good indicator of power event performance because its prime movement is to extend the lower leg while flexing at the hip joint.

Equation 3 could explain about 82% of the variance with the following four variables: TRHRQ240, Anpower, TLHLQ60, and TLHLQ240. From these results it seems that balance of both legs is a good indicator of power event performance. Equation 1 could explain about 70% of the variance. Anpower, TRH240, and TLH240 are the three variables in this equation.

To summarize this section the data seem to indicate the anaerobic power test is a good predictor of power event performance. Power output measurements seem to be better predictors than peak torque measurements. Higher speeds on the Cybex isokinetic dynamometer seem to be better indicators of power event performance than lower speeds. Lastly, the hamstrings seem to be better predictors than the quadriceps in the present study.

Final Regression Equation

A final regression was computed with variables that were statistically significant simple correlates of successful performance. The investigator performed this regression with variables that were only moderately related or were unrelated to each other. Ten variables were not included in this equation because they had correlation coefficients of greater than .92 with the performance ratio. The final regression equation was developed to see if resulting significant relationships might differ from the four already reported in the previous section. The results revealed that PHH240, Anpower, PQQ240, and THH60 could explain over 85% of the variation in successful power event performance. Quadriceps and hamstring balance at high speed (power output), anaerobic power, and hamstring balance at low speed (peak torque) were the best predictors of successful power event performance.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

Summary

The purpose of this study was to investigate the relationship among selected variables and successful performance of track and field athletes and to develop an equation to predict successful performance based on these variables. The subjects were 12 female track and field athletes ranging in age from 18 to 22 years. All subjects were undergraduate students and members of the 1984 Ithaca College women's track and field team.

The entire study consisted of three testing sessions with each subject. The first session consisted of a timed run to exhaustion on a treadmill to determine anaerobic capacity. The test was a modification of the one employed by Schnabel and Kindermann (1983). In the second testing session power output and peak torque of the quadriceps and hamstrings were assessed. Testing was performed with the use of the Cybex II isokinetic dynamometer (Division of Lumex, Ronkonkoma, N.Y.). Each leg was tested for knee extension and flexion at 60 deg/sec and 240 deg/sec. The final testing session was performed at the Department of Nutritional Sciences at Cornell University. Hydrostatic weighing (nitrogen washout technique) was used to assess the subject's percentage of body fat.

At the termination of the season, a performance ratio for each subject was computed by expressing the subject's best time or distance over the then current NCAA Division III record. The performance ratio was used as the dependent variable in the study. Raw scores from the modified anaerobic power test, percentage of body fat, and scores and ratios from the Cybex assessment were used as the independent variables in the study. At the outset of the study, a one-tailed Pearson product-moment correlation and four preliminary and one final multiple regression were computed. The results indicated nine significant ($p < .05$) simple relationships between variables and the performance ratio. All four regression equations could each explain a significant amount of the variation ($p < .05$), ranging from 70% to 95% of the variance explained. A final regression was performed with only those variables that were simple correlates of successful performance and only moderately related to one another. Four such variables were able to account for over 85% of the variance.

Conclusions

The findings of this study support the following conclusions in the present study:

1. Power output scores or ratios seem to predict successful performance better than the peak torque scores or ratios.

2. Assessment of knee flexion and extension at high speed (240 deg/sec) seem to be more related and predicted

performance better than assessment of the same movement at low speed (60 deg/sec).

3. Hamstring balance at 240 deg/sec (power output) and right leg balance at 240 deg/sec (power output) seem to be the two best simple correlates with successful performance in track and field (power events).

4. Anaerobic power, as measured by the modified treadmill test, seems to be a good correlate and a consistent predictor of successful performance in track and field (power events).

5. Anaerobic power and power output of the right and left hamstrings (240 deg/sec) seem to be the best prediction equation of successful performance in track and field (power events).

6. Percentage of body fat and year in school did not significantly relate to or predict successful performance in track and field (power events).

Recommendations for Further Study

The findings of this investigation suggest the following recommendations for further study on the relationships among selected variables of successful performance in track and field power athletes:

1. Involve a larger number of subjects to control for any incorrect conclusion that may have been drawn from a unique response from a single subject.

2. Allow the subjects to have more practice sessions on the treadmill so they are more accustomed to running on it

for the test.

3. Perform the same investigation with NCAA Division I athletes or high school athletes.

4. Use different speed settings on the Cybex II isokinetic dynamometer to assess peak torque and power output of the quadriceps and hamstrings.

5. In addition to the present study, employ a muscle biopsy technique to distinguish between the percentage of fast twitch and slow twitch muscle fibers.

6. Compare the Cybex II isokinetic dynamometer with the similar knee extension and flexion apparatus that is manufactured by Hydra-Fitness (Division of Hydra-Gym, Belton, Tx.).

7. Compare the anaerobic power test employed in the present study with the original one, created by Schnabel and Kindermann (1983), as well as with other simple methods of assessing anaerobic capacity.

Appendix A

INFORMED CONSENT FORM

1. (a) Purpose of the study: To examine selected parameters in order to determine their relationship to track and field performance. Anaerobic power, leg strength (peak torque), leg power (power output), and percentage of body fat will be related to a performance ratio based on a percentage of the current 1984 Division III record.

(b) Benefits: To gain quantitative information about the selected variables and their relationship to successful performance in selected track and field events.

2. Method: Subjects will be assessed in leg strength and leg power through the use of a Cybex II isokinetic dynamometer and a timed run to exhaustion on a treadmill. A total of three contractions at two speeds (60 and 240 deg/sec) will be recorded on each leg. The timed run to exhaustion will be conducted at a treadmill speed of 12 miles per hour and a grade of 7.5%. The subjects will be assessed for percentage of body fat through the use of a hydrostatic weighing techniques.

3. Will this hurt? No physical or psychological risks are evident in the present study.

4. Need more information? Additional information can be obtained from either Chris LaColla (272-2922) or Dr. Paul Thomas (274-3139).

5. Withdrawal from the study: Participation in this study

is voluntary. You are free to withdraw your consent and discontinue at any time.

6. Will the data be maintained in confidence? All data will be kept confidential. Once data are collected, names of subjects will be discarded and replaced by subject numbers. Data will be available only to the subject, investigator, thesis advisor, and track coach. Any scientific report of the data will be in the form of means, standard deviations, correlations, or multiple regressions.

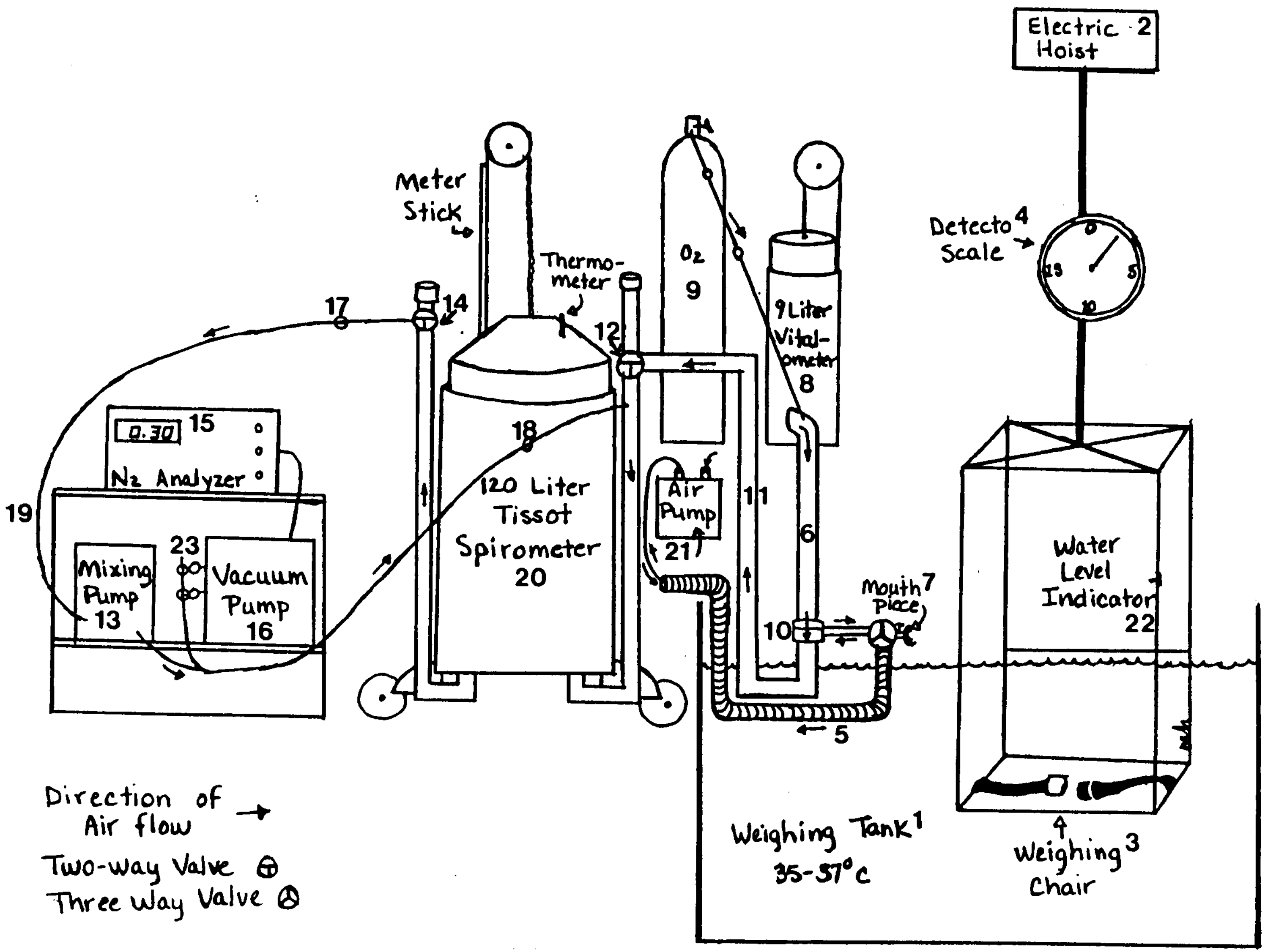
7. I have read the above, I understand its contents, and I agree to participate in the study. I acknowledge that I am 18 years of age or older, and that I have been identified as an individual who does not fall into a risk category for stress testing as classified by the American College of Sports Medicine.

______________________________ ______________________________

Signature Date

Appendix B

SCHEMATIC ILLUSTRATION OF HYDROSTATIC WEIGHING APPARATUS



Appendix C

DENSITOMETRY (UNDERWATER WEIGHING) DATA SHEET

Name______________________________

1.	ID Number	--
2.	Study Day	--
3.	Study Period	--
4.	Date	--/--/--
5.	Time of Day	--/--
6.	Age (years)	--
7.	Barometric Pressure (mm Hg)	---.--
8.	Height (cm)	---.--
9.	Weight in Air (kg)	--.--
10.	Tissot Temperature (C)	--.-
11.	Vapor Pressure at Tissot Temp. (mm Hg)	--.---
12.	Water Temperture (C)	--.-
13.	Tissot Initial Reading (cm)	--.-
14.	Tissot Final Reading (cm)	--.-
15.	Weight in Water (kg) Subject & Equipment	-.--
16.	Weight of Equipment in Water (kg)	-.--
17.	Initial Nitrogen in Oxygen Tank (%)	.-
18.	Final Nitrogen Analysis in Expired Air (%)	-.-
19.	Tissot Dead Space	-.--

Appendix D

SUBJECTS' RAW DATA:

ANAEROBIC POWER TEST AND BODY FAT PERCENTAGE

Subject	Power Test (sec)	Body Fat (%)
1	50.49	13.57
2	32.21	14.42
3	27.66	21.93
4	61.84	12.61
5	30.37	21.23
6	41.21	19.68
7	39.07	16.71
8	21.70	24.04
9	9.24	20.76
10	38.09	16.35
11	25.88	26.89
12	29.77	15.93

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