PERFORMANCE MEASURES AND STRENGTH EVALUATION

IN THE HIGH SCHOOL FEMALE ATHLETE

by

DEBBIE A. BORN

(Under the Direction of Michael Horvat)

ABSTRACT

The purpose of this study was to investigate relationships between one-repetition maximum (1RM) strength measures and various sport performance measures in evaluating upper and lower body strength. Fifty-seven high school female athletes ages 14-18 participated in this study. All of the participants completed a 1RM bench and leg press test to determine absolute and relative strength. Athletes were also evaluated on eight different performance measures including: sit-ups, 40-yd sprint, vertical jump, sit and reach, medicine ball toss, shuttle run, leg press repetitions-to-fatigue (91 kg), and bench press repetitions-to-fatigue (27 kg) in conjunction with various body composition variables. A Pearson product correlation and Stepwise regression analysis was utilized to determine relationships between 1RM strength and the performance measures for upper and lower body strength. Based on the data analysis, it was concluded that bench press repetitions-to-fatigue (BPRTF27) using a weight load of 27 kg had the highest correlation with 1RM bench press strength (r= 0.802) and leg press repetitions-to-fatigue using a weight load of 91 kg had the highest correlation with 1RM leg press strength (r= 0.793) indicating that these tests were viable alternatives to 1RM testing for strength assessment. The Stepwise Regression analysis further confirmed that BPRTF27 and LBM (lean body mass) were significant variables in developing the model 1RMBP= 48.44 + (1.42) BPRTF27 + (.153) LBM for upper body strength testing. Similar results occurred in the lower body model (1RMLP= 69.92 + (3.65) LPRTF91 + (1.42) LBM + (2.63) with the addition of the SIT/REA (sit/reach) variable. A positive relationship between 1RM strength and repetitions-to-fatigue testing was evident for all models ($p < .001$).

INDEX WORDS: Strength, Performance, Female athletes

PERFORMANCE MEASURES AND STRENGTH EVALUATION
IN THE HIGH SCHOOL FEMALE ATHLETE

by

DEBBIE A. BORN

B.S. Ed., Augusta State University, 1991

M.Ed., Augusta State University, 1995

Ed.S., Augusta State University, 1998

A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF EDUCATION

ATHENS, GEORGIA

2004

© 2004

Debbie A. Born

All Rights Reserved

PERFORMANCE MEASURES AND STRENGTH EVALUATION

IN THE HIGH SCHOOL FEMALE ATHLETE

by

DEBBIE A. BORN

Approved:

Major Professor: Michael Horvat

Committee: Bruce Blasch
Bryan McCullick
Steve Olejnik

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
May 2004

DEDICATION

I would like to dedicate this dissertation to my mother, who passed away before she could see me receive this degree. Even though she is not here physically, her love and support is still felt close within me and my wish is for her to smile and be proud the day I walk across that stage. This one's for you, Monika, my dearest mom.

ACKNOWLEDGEMENTS

I would like to thank my close circle of friends for their encouragement throughout this journey. Without their support, this degree would have not been possible. I would especially like to thank my lifelong friend, Kim, for her unwavering support and confidence in my abilities to attain this degree at times when I needed them the most.

I would also like to thank my father, Emory, who instilled values and work ethics possible for me to pursue my dreams and become what I am today.

Lastly, I would like to thank the faculty and staff at Greenbrier High School for being supportive of my endeavors to become a better teacher and role model for all students.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

In order to measure the effectiveness of strength training programs, accurate assessments of upper and lower body strength are needed that can generalize to various populations. The rationale for developing strength in females has become an issue because of the relationship between strength and performance. Competitive sports for females at the high school and college levels has increased the need for conditioning programs that can assess upper and lower body strength effectively. Teachers and coaches are beginning to use alternative means of strength assessment to maximize training time for athletes in specific sports. For high school athletes and notably female athletes, other considerations may play a role in strength assessment at the high school level. Athletes in high school are at various stages of physiological and maturational development, which may place unnecessary stressors on the body and increase the susceptibility to injury when using traditional strength assessments (Faigenbaum, 2001; Naughton, 1991) and 1RM (one-repetition maximum) testing. Many of the existing protocols and assessments are based on performances for men and associated with explosive sports like football (Sawyer, Ostarello, Suess, & Dempsey, 2002; Ware, Clemons, Mayhew, & Johnston, 1995). In contrast, young females vary physiologically in the development of muscular strength and may require other methods to assess performance. Sub-maximal testing (repetitions-to-fatigue) and sport specific performance measures such as the vertical jump, 40-yard, medicine ball throw and body composition variables have been used to measure strength in a variety of populations (Klavora, 2000; Umberger, 1998: Cummings & Finn, 1998) and may be more appropriate of high school females.

Typically, maximal loads are used to determine absolute strength without taking into consideration differences in body size and fitness abilities but during adolescence, maximal loading can increase the possibility of injuries from physiological immaturity (Brown & Kimball, 1983; Pearson, Faigenbaum, Conley, & Kraemer, 2000), improper lifting techniques and poor supervision. At certain stages in the developmental process changes are occurring throughout the bone structure including: increased rates of cell division, increased length of replicating columns, increased number of cells, and increase in size of the cells (Faigenbaum, 2001; Schafer, 1991). These changes increase the diameter of the growth plate but do not provide sufficient injury protection from compressive and shear forces during this time period providing some rationale for abstaining from maximal lifts when implementing strength assessments in training programs. Research suggests that during these developmental years, adolescents should participate in a periodized program using loads that will allow a 6-12 repetitions range with lower volumes of weight loads so that inappropriate physiological stress does not occur (Faigenbaum, Kraemer, Cahill, Chandler, Dziados, Elfrink, Forman, Gaudiose, Micheli, Nitka & Roberts, 1996; Fleck & Kraemer, 1997; Pearson, Faigenbaum, Conley, Kraemer & William, 2000). Since maximal lifting can be detrimental at this period of growth, relative muscular strength testing has begun to replace maximal testing because it takes into account lean body mass and a proportion of the 1RM. According to the protocols designed by the NSCA (2000), a resistance training program that involves relative muscular strength emphasizes repetitions with light to moderate weight loads employing short rest periods for all populations. Sub-maximal testing, such as repetitions-to-fatigue, has been found reliable as a measure of 1RM strength (Bryzcki, 1993; Heyward, 2000; Rose & Ball, 1992), as well as, when certain body composition and sport performance measures are taken into account in assessments using sub-maximal loads (Mayhew, Prinster, Ware, Zimmer, Arbas & Bembem, 1995).

Upper body strength is generally measured by the bench press (Bryzcki, 1993; Chapman, Whitehead & Prinster, 1998; Cummings & Finn, 1998; Dalton & Wallace, 1996; LeSeur, McCormick, Mayhew, Wasserstein & Arnold, 1997). The bench press is the most common exercise because it represents several major muscle groups used in the upper body including the chest, shoulders, triceps and biceps. The 1RM bench press test is a procedure that requires an individual to successfully lift the maximum amount of weight one time through a full range of motion. This test has been utilized as an indicator of absolute muscular strength without adjustments for total body weight based upon previous research studies involving the bench press test (Arthur, 1982; Cummings & Finn, 1998; Invergo, Ball & Looney 1991; Kuramoto, 1995; LeSeur, McCormick, Mayhew et al., 1997; Morales & Sobonya, 1996).

Lower body strength is also regularly measured by 1RM tests including Olympic free-weight squats techniques and different types of leg press machines. The most commonly performed test for lower body strength assessment is the back squat exercise which consists of placing an Olympic free-weight barbell on the upper back and shoulders and flexing the hips and knees until the thighs are parallel to the floor (Knuttgen & Kraemer, 1987; Sawyer, Ostarello, Suess & Dempsey, 2002). Although mainly used to test male athletes, the 1RM leg press machine measurement has been utilized to determine strength in college-aged females involving the major muscle groups of the lower body (Dalton & Wallace, 1996; Gravelle & Blessing, 2000). According to the National Strength and Conditioning Association (2000), the hip sled leg press machine utilizes the same muscles as the typical squat exercise including the: Gluteus maximus, Semimenbranosus, Semitendinosus, Biceps femoris, Vastus lateralis, Vastus intermedius and Rectus femoris. The hip sled/leg press can be effective and provide a safer alternative to the squat machine by eliminating stress to the neck and back due to maximal loading and poor lifting technique.

Since sub-maximal testing has been found reliable in assessing upper and lower body strength in the realm of older collegiate and professional athletes, teachers and coaches are incorporating these tests in their training programs for younger athletes and females. There are many variations of repetitions testing using different amounts of repetitions, weight loads and adjustments made for different body composition factors. The basic principle of repetitions to fatigue testing is to use a given percentage of an athlete's 1RM and stay within a range of 8-15 repetitions (Bryzcki, 1993). Other studies, using loads as light 45% of the 1RM have accurately achieved 1RM prediction. Furthermore, these same studies have indicated that the use of more repetitions (10 to 20) does not appear to diminish the accuracy of predicting 1RM strength (Abadie & Wentworth, 2000; Braith, Graves, Leggett & Pollock, 1993; Mayhew, Ball, Arnold & Bowen, 1992). Additionally, some studies have used sub-maximal assessments in conjunction with adjustments in body composition to accurately predict 1RM strength (Horvat, Ramsey, Franklin, Gavin, Palumbo & Glass, 2003).

In specific settings related to performance, teachers and coaches are supplementing sub-maximal testing by using sport specific measures to test muscular strength (Gardner, Stimson, Propst, & Berry, 1994; Mayhew, Bemben, Rohrs, & Bemben, 1994). Measures such as the vertical jump, standing long jump, medicine ball throw 40-yard sprint, shuttle runs, and push-ups have been used as a measure of upper and lower body strength. Vossen, Kraemer, Burke, & Vossen (2000) investigated the strength differences between two push-up training programs with a 1RM bench press test and seated medicine ball put test. The researchers employed these tests based on the reliability of the 1RM test and medicine ball for training and evaluating upper extremities (Heiderscheit, McClean & Davies, 1996). For lower body strength, Misner, Boileau, Plowman, Elmore, Gates, Gilbert & Horsewill (1988) yielded a moderate correlation between the vertical jump and isotonic leg press exercises in females over the age of eighteen. No specific evidence was uncovered regarding assessing maximal strength of female athletes at the high school level.

Statement of the Problem

There has been no evidence of the most efficient and developmentally appropriate procedure for assessing strength in high school female athletes. Most assessments of strength require an excessive amount of weight and are based on male athletes. In addition, performance measures, such as the medicine ball throw, vertical jump, shuttle run, sit and reach, sit-ups and 40-yard sprints, has not been studied as useful measures to evaluate strength for high school female athletes between the ages of 14-18.

Purpose of the Study

The purpose of this investigation was to evaluate alternative strength and performance measures for assessing strength for high school female athletes. The study also investigated different body composition measures, such as age, height, weight, body fat percentage and body mass index, to test their relationship with assessing body strength between the ages of 14-18.

Justification for the Study

Strength training is an area that has aided all athletes in improving performance. However, little information is available on how to monitor and evaluate the female athlete’s capabilities. Alternative types of strength measurement would allow high school coaches to test female athletes in their typical training routines without equipment or require the female athlete to lift heavy loads during the developmental years. Strength assessment can also be very time consuming, which detracts from skill related instruction and practice for competition. Testing must occur to determine the levels of strength necessary for competition and improvement in performance indicators of that sport. Therefore, this study was designed to investigate relationships among sport specific performance measures and muscular strength tests.

Significance of the Study

The significance in this study was that it was an initial attempt to determine absolute upper and lower body strength in the female high school athlete by correlating performance measures including: vertical jump, medicine ball throw, sit-ups, sit and reach for flexibility, 40-yard sprint and shuttle run with standard measures of muscular strength. The success of this investigation justified a major change in how strength can be measured in all high school weight-training programs for females. It provided a safe, simple and effective method to guide all coaches in their endeavor of empowering the high school female athlete to excel in their sport.

Hypothesis

Although there has been no documentation of a method of assessing upper and lower body strength in the high school female athlete population, it is hypothesized that there is a relationship between muscle strength and different performance measurements.

The following hypotheses will be tested:

I. There is a relationship between upper body strength as measured by the 1RM with body fat percentage, body mass index, lean body mass, repetitions-to-fatigue bench press test, a 3 kg medicine ball throw, sit-ups and the sit and reach test.

II. There is a relationship between lower body strength as measured by the 1RM with body fat percentage, body mass index, lean body mass, repetitions-to-fatigue seated leg press test, the double leg standing vertical jump, 40-yard sprint, sit-ups, shuttle run, and sit and reach test.

Delimitations of the Study

Participants for this study were recruited from a public high school in the Central Savannah River Area in Georgia. The findings of this study may not be generalized to other participants and other settings and environments. This study was delimited to the high school female athletic population, and to programs that utilize the strength training equipment available in certain high school athletic programs. All participants were post-pubescent, ranging in age from 14-18 years old and participating in at least one of the following sports: volleyball, basketball, softball, cross-country, track and field, soccer, golf and swimming.

Limitations of the Study

The limitations of the study were that the findings of this study are only comparable to other studies targeting the high school female athlete population between the ages of 14 to 18. The participants in this study were selected based on unique criteria for the investigation. However, certain participants may have age, height and weight demographics that may account for some of the variability in test results.

Definition of Terms

Absolute Muscular Strength: The maximal amount of strength that is not adjusted for age, height and weight demographics and is generally measured in units of work, power or energy (Cummings & Finn, 1998).

Bench Press Test: Measured using a free-weight Olympic bar and plates. The subject grasps the bar at a position slightly greater than shoulder width. Spotters assist the subject in lifting the bar off the support rack. The subject slowly lowers the bar touching the chest (without resting on the chest) and returns it to full arms length (Fleck & Kraemer, 1997).

Body Fat Percentage: Also known as percent body fat. The percentage of your body weight that is fat (Rainey & Murray, 1997).

Body Mass Index: An evaluation that gives you a description of your weight relative to your height (Rainey & Murray, 1997).

Leg Press: Also known as the hip sled, is a machine that exercises the major muscles in the lower body while in a sitting position. It can be utilized to test leg strength and endurance performing maximal and sub-maximal loads (Earle & Baechle, 2000).

Load: The amount of weight assigned to an exercise set (Earle & Baechle, 2000).

Medicine Ball Throw Test: A test that measures upper body strength while seated. Using different size medicine balls, the subject is seated against a wall, with the legs straight on the floor. The subject places the ball against the chest and pushes forward with maximal effort without the shoulders leaving the wall and releases the ball (Gardner et al., 1994).

Muscular Endurance: The ability of a certain muscle or muscle group to perform repeated contractions against a sub-maximal resistance. This form of strength training produces lower gains in overall strength and power but allows all muscles employed to adapt to repetitive type movements without becoming overly fatigued (Horvat & Kalakian, 1995)

Muscle Strength: The maximal amount of force a muscle or muscle group can generate in a specific movement at a determined velocity (Knuttgen & Kramer, 1987)

One-Repetition Maximum: The most frequently used procedure to evaluate muscular strength and requires an individual to lift the most weight possible one time through a full range of motion using the proper technique (Baechle & Earle, 2000; Mayhew et al., 1993; Mayhew et al., 1995). There is some risk of injury using this method of evaluation because of the heavy loads utilized in the testing procedure.

Power: The time rate of doing work (Baechle & Earle, 2000).

Relative Muscular Strength: The maximal amount of strength that is adjusted for physiological differences in height, weight, age and certain other characteristics.

Reps-to Fatigue: A testing procedure that requires the lifter to properly lift a certain amount of weight until exhaustion within a certain period of time.

Resistance Training: Also known as strength or weight training; A type of exercise that requires the body's musculature to move (or attempt to move) against an opposing force, usually presented by some type of equipment (Fleck & Kraemer, 1997).

Sport Specific Performance Measures: Performance measures used in assessing strength and power in different sports, such as, 40-yard dash, standing long jump, vertical jump.

Sub-Maximal Testing: Testing protocols that utilize a percentage of the maximal load designed to accurately predict muscular strength.

Vertical Jump Test: This is also known as the double-leg vertical jump and this test is used to determine lower body strength. The subject assumes an upright stance with the feet shoulder width apart. Begin with a double arm counter movement, bending at the knees and jump explosively using both arms to reach a target and land in the starting position. Can be measured using a wall with the subject touching the wall at their highest point and recording the measure or using a commercial apparatus such as the Vertec™ to measure the jump (Baechle &Earle, 2000; Gardner et al., 1994).

CHAPTER 2

REVIEW OF LITERATURE

Introduction

This chapter introduces the bench press and leg press resistance exercises as valid measures of determining upper and lower body strength. It presents two types of strength testing protocols including the one-repetition maximum test (1RM) and sub-maximal test known as repetitions-to-fatigue test (RTF), as well as different applications of these protocols when evaluating strength. Various types of performance measures are also introduced as alternative means of assessing upper and lower body strength in the female population.

Bench Press As A Predictor of Upper Body Strength

Strength tests typically revolve around exercises that are representative of the body's major muscle groups such as the bench press, which combines the major muscles in the upper body (chest, shoulders, triceps). According to the National Strength and Conditioning Association's Testing and Evaluation Manual (2000), the bench press is the test of choice by most strength coaches because it does not require expensive machinery and measures the strength necessary in sport activities. The Guidelines for Exercise Testing and Prescription Manual (1991) indicates when using weight lifting exercises to assess strength, the bench press was a valid measure of general upper body strength. According to several other strength training researchers (Bryzcki, 1993; McCardle, Katch & Risser, 1993; Semenick, 1994), the bench press is the most popular and frequently used exercise for evaluating upper body strength, and it is typically associated with determining how much weight an individual can lift properly for one repetition. Using the bench press test for one repetition maximum (1RM) testing has become a valid measure of assessment and is one of the primary tests used for evaluating muscle strength (Abadie & Wentworth, 2000; Dean, Foster & Thompson, 1987; Jaric, Ugarkovic & Kukolj, 2002).

An example of the utilization of 1RM tests to assess upper body strength can be found in a research study performed by Bates, Clemson, Busby, Mayhew, Glover and Bemben (1995). The investigators employed the 1RM bench press test to measure changes in strength following free weight and machine weight (Nautilus) resistance training in college-aged females (N= 57). Females were pre-tested for 1RM bench press strength for both types of machines and then trained three days a week over an 8-week period. At the end of the session, all females were re-tested on the same equipment. The results indicated higher significant ($p < 0.05$) improvements in strength when using the weight resistance machine compared to free weight equipment. Bench press values on the Nautilus equipment averaged 12.6-30.0% higher than for free weight machines. The differences noted between the two tests could be assigned to the reduced need for balance control and synergistic muscle action necessary during the machine bench press performance, but more importantly, the 1RM was a reliable measure for both types of tests.

The 1RM bench press test was utilized in another study to determine relationships between 1RM free-weight and Universal machine performances. The subjects were 57 female and 67 male college students enrolled in general fitness courses with varying weight-training experience. All subjects performed one upper body and lower body test over a six-day period in a counterbalanced order. The results indicated significant differences ($p<0.005$) between genders for all physical and performance characteristics except age. The relationship between free-weight and Universal 1RM bench press strength in women was significant ($r= 0.95$, $p<0.05$) and similar for males ($r = 0.94$, $p < 0.05$). Regression equations were developed to determine equivalent workloads for the different 1RM tests. Stepwise multiple regression analyses revealed that body mass and 1RM measures were significant predictor variables for all female equations. Double cross-validation comparison analyses determined low measurement errors and no significant differences between actual and predicted criteria, which resulted in prediction equations generalizable to similar populations. Outcomes of this investigation signified tests of 1RM using free-weights and Universal machine exercises appear to be reliable.

Kim, Mayhew & Peterson (2002) studied the influence of cadence while performing the YMCA bench press test to determine 1RM bench press strength. Medical students (N=58) were evaluated on certain body composition variables, as well as the 1RM bench press tests. Two cadence tests were then performed at 30 and 60 repetitions per minute on separate days within a five-day period. Results suggested no significant differences among the repetitions performed at each cadence by the men (n=37), while the women (n=21) performed significantly more repetitions at the slower cadence. Repetitions at the 30-second cadence were good predictors of 1RM upper body strength for both men ($r=0.757$, SE= 8.0 kg) and women ($r=0.884$, SE=8.2 kg). Repetitions at the 60-second cadence were also strong indicators of 1RM upper body strength for men ($r=0.884$, SE= 8.2 kg) and women ($r=0.816$, SE= 2.7 kg). Body composition factors did not improve accuracy when prediction equations were developed using the cadence tests. Based on the 1RM bench press, both cadence tests provided an accurate estimation of upper body strength.

In another research study (Rose and Ball, 1992) employed the 1RM bench press test to determine the relationship between absolute muscular endurance and maximal loading in college women (N=84) from 18 to 25 years old. The 1RM bench press test was performed using free-weights and then compared to results from a modified YMCA bench press test using loads of

15.9 kg and 20.4 kg. A cross-validation (n=19) of prediction equations and 1RM bench press test revealed that modified YMCA bench press tests using these loads accounted for 66% and 67% of the variance between the measured and predicted 1RM bench press ($p < .05$). Even though different testing protocols were used in these investigations, 1RM tests proved to be an integral part of strength assessment.

Validity of Sub-Maximal Bench Press Testing

The repetitions-to-fatigue bench-press test, also known as the repetitions-to-failure test, is a similar technique consistent with the 1RM test requiring the subject to perform in the same manner with one exception. The subject uses a percentage of the 1RM and lifts the weight until exhaustion. When the subject cannot lift the weight to a full arm's length within the time period, the test is terminated and recorded as the reps-to-fatigue measure. A number of studies have investigated on the amount of repetitions to be performed that provide the most accurate correlation with 1RM strength. For example, according to the National Strength and Conditioning Association's Resistance Training Program Design (Baechle, Earle & Wathen, 2000), when 1RM testing is not reasonable or appropriate for the population, testing with a 10RM load is recommended and is appropriate for nearly all subjects who are knowledgeable about proper lifting techniques. The protocol is similar for 1RM testing except that approximately half of 1RM load is lifted successfully for 10 repetitions. A different testing protocol for muscular endurance testing comes from the National Strength and Conditioning Manual (2000). For this type of endurance testing, a training load of less than or equal to 67% of the actual 1RM should be used in conjunction with performing 12 or more repetitions. Pollock, Wilmore, and Fox (1978) recommended a measure of 75% of the 1RM for exercises based on their research findings; additionally, individuals should be able to complete 12 to 15 repetitions using this percentage. Vivian Heyward purported in her Advanced Fitness Assessment and Exercise Prescription Manual (2002) that the average individual should be able to perform 12 to 15 repetitions using a sub-maximal load at similar training percentages. Variations of repetitions and loads have revealed significant correlations ($r = 0.44$ to 0.94) between actual 1RM and sub-maximal testing procedures (Ball et al., 1995; Bates et al., 1995) in many different research investigations.

In one investigation of testing procedures, repetition testing was performed to estimate a 1RM bench press for untrained women (Cummings & Finn, 1998) between the ages of 18 to 50 (N=57). The performance variables included a reps-to-fatigue bench press test (4-8 RM) and a 1RM test to determine reps-to-fatigue and the amount of weight lifted during the sub-maximal test. The reps-to-fatigue bench press test was performed by warming up with a light amount of weight and then attempting to lift a set of 4 to 8 repetitions to fatigue at 85% of their 1RM. If the subject could not perform between 4 to 8 repetitions then weight was taken off of the bar. There was a rest period of two minutes between each reps-to-fatigue attempt. When the testing process was finished, the weight and number of full repetitions performed were recorded. All strength tests were performed according to the National Strength and Conditioning Association (2000) and Kraemer and Fry (1995). The results from using 4 to 8 repetitions for testing evaluated by the Epley regression equation (1985) proved significant ($p < 0.001$) predictability in estimating 1RM strength in adult-aged untrained women.

In another study, Bryzcki (1993) developed a broad reference guide for both adult males and females determining the predicted maximum amount of weight that can be lifted based on reps-to-fatigue testing with 10 or fewer repetitions in relationship to weight (45 to 310 pounds) of a person for all major muscle group strength exercises. His research was based on published and unpublished literature reviews on strength training (Anderson & Haring, 1977; Sale & MacDougall, 1981) which demonstrated a direct relationship between reps-to-fatigue and percentage of maximal loads. As the percentage of the load increased, the number of repetitions performed decreased in a linear regression. It was also theorized that 10 repetitions could consistently be performed at approximately 75% of the maximal load. If the repetitions were to exceed 10, the correlation was less accurate in estimating 1RM strength. Genetic influences were established as a factor in the accuracy of using this reference guide because of individuals differences in muscle fiber types, limb lengths and neurological abilities (Enoka, 1988) that may allow them to either do more or less than the 10 repetitions. Bryzcki proposed from his research findings that a more specific process to determine how maximal strength relates to muscular endurance.

Mayhew et al. (1992) performed a cross-validation study that included the college aged female population (N=251) and emphasized the accuracy of using relative muscular endurance tests for predicting 1RM strength. Basic physical characteristics for each subject were obtained prior to testing, which included height, weight and age. Means and standard deviations for the following performance characteristics were measured throughout the investigation: repetition weight, percent of 1RM, repetitions, and bench press. The actual testing procedure was slightly different than the majority of research; whereas, instead of lifting a percentage of weight until muscle exhaustion, subjects were asked to do as many repetitions as possible in one minute. Each subject was randomly assigned a workload between 55 and 95% of his or her 1RM. The initial study population (the validation group) included 184 men and 251 women who were randomly selected from a fitness course at an area college. At the end of their 14-week resistance-training program, all were tested for 1RM strength; in addition, all performed a reps-to-fatigue test by randomly selecting endurance load percentage from the 1RM results. All of the data collected were combined and developed into an exponential equation that accurately predicted the percentage of the 1RM, which lead to accurately predicting the 1RM. In the initial testing group, the equation could accurately predict the 1-RM for the group (male and female) at a high correlation ($r = 0.98$) and a standard error of ± 5.4 kg.

To test the hypothesis that this equation could be used in a different population, another group was tested using the same procedures. The other group studied included 70 men and 101 women randomly selected from a fitness class the following semester at the same institution as the initial group. Both samples were the same ($p < 0.05$) on all the variables being observed. The statistical analysis performed on the cross-validation study of the second sample consisted of unpaired t-tests to evaluate differences between men and women and between the validation and cross-validation groups. The interrelationship among all of the variables tested was determined by a Pearson product-moment correlation and the accuracy of the exponential prediction equation was evaluated by standard errors of estimate. Results indicated that there were obvious differences in physical and performance characteristics between the men and women throughout the entire investigation. The relationship between percent 1RM and repetitions was exponential for both men and women. However, when compared on a graph that measured slope and intercept, both curves were not significantly different ($p < 0.05$). Therefore, the data was combined to form one predictive equation for percent of 1RM, which eventually lead to the determination of the 1RM based on this equation. There was one limitation to this equation--most of the subjects performed less than 15 repetitions before muscle failure. This study illustrated the relationship of the 1RM percentage to repetitions based on that number. When the cross-validation study was completed, the correlations between the validation group and the subsequent college-aged group for both men and women were high (r = 0.96 and 0.90). The procedure over-predicted the 1RM in men by an average of 1.2% (SD= 9.6) and over-predicted for the women by 0.2% (SD= 13.2). Even so, neither of the predictions was significant ($p > 0.05$). The results of this study indicated even though there were slight changes among the correlations when higher repetitions were used, the correlations were not significantly different from each other.

A study similar to the present investigation utilized two repetitions to fatigue tests to develop regression equations in collegiate female athletes (N=65) capable of predicting absolute upper body strength (Horvat, M., Ramsey, V., Franklin, C., Gavin, C., Palumbo, T., & Glass, L.A., 2003). The testing procedure consisted of two bench press tests using sub-maximal loads of 25 kg and 31.8 kg along with a 1RM bench press test in random order. Body composition variables such as total body weight, lean body mass, height and percent body fat were recorded. The statistical analysis revealed small standard errors indicating homogeneity among all variables. A stepwise regression analyzed which of the variables were useful in predicting 1RM. Pearson product correlations indicated three explanatory variables (lean body mass, 25 kg and 31.8 kg loads) had p-values of < 0.05 revealing significant contributions in predicting 1RM strength. The highest correlations were found between repetitions at 25 and 31.8 kg ($r= 0.938$, $p< 0.001$), repetitions at 31.8 kg and 1RM ($r=0.909$, $p<0.001$) and repetitions at 25 kg and 1RM ($r=0.866$, $p < 0.001$). A colinear multivariate regression revealed that the 31.8 kg load along with lean body mass was the most accurate predictor of 1RM upper body strength in the collegiate population ($r=0.909$, $p= 0.000$; $r=0.445$, $p= 0.000$). Also, a split-case, cross-validation design further validated these results of the regression analysis. As demonstrated in a number of investigations, many variations of repetitions and 1RM loads can accurately predict absolute upper body strength in different populations. Since the high school female athlete population is a new investigation, all of the theories explored by previous researchers will be utilized to develop the sub-maximal testing procedures for high school female athletes.

Leg Press as a Predictor of Lower Body Strength

The leg press is a valid measure of lower body strength according to the American College of Sports Medicine (2000). It has been substituted for the squat exercise in some research studies as a means of lower body strength assessment. One study performed by Dalton and Wallace (1996) attempted to establish new ranges of normative data for college-age women (N=272) using the leg press test for ages 17 to 25. The rationale for this study was to provide new guidelines for this younger age group since the norms set by the ACSM (1995) does not offer the normative distribution one would expect. They chose the leg press because while investigating different types of 1RM tests, they found it was the most commonly used type of exercise machine and a valid measure of assessment. Results using means and standard deviations from the data analysis established five new strength and fitness categories based on the normative curve for the leg press and also indicated considerably higher categories than those established in ACSM norms. This suggests a more normalized distribution of scores among the new categories in comparison; moreover, the new classifications accurately represent the scores of the average college-aged women.

In an earlier investigation, Hoeger and his colleagues (1990) tested a sample (N=129) of resistance trained and untrained females (n= 66) and males (n=63) ranging in age from 21 to 47 to determine the relationship between repetitions and selected percentages of 1RM between the two groups. The leg press test was employed as a performance measure with the knees bent at a 100-degree angle at the start position. Repetition tests were performed at 40%, 60%, and 80% of the 1RM for the leg press and a variety of other weight training lifts. Results indicated no significant differences ($p > 0.05$) were found for any percentage 1RM of the leg press. When comparing untrained and trained females, significant differences ($p < 0.05$) occurred at 60% and 80% of their 1RM. The conclusion of this investigation indicated that a given percent of 1RM does not always elicit the same number of repetitions when performing different percentage loads of 1RM.

Ball, Van Fleet, Lahey and Glass (1995) also used the leg press to determine the relationship between maximal lifting capacity and relative muscular endurance. College female subjects (N=85) and male subjects (N=121) with ages ranging from 18 to 22 were tested to determine their 1RM strength for the leg press and lat pull down. Within one week, they were assigned a load between 55% to 95% of their 1RM measure and asked to perform as many repetitions as possible. Although the men were significantly stronger ($p < 0.05$), there were no differences between them when comparing the number of repetitions performed at different loads ($p > 0.05$). The number of repetitions completed was regressed on the percent of 1RM to produce an equation that could be used to determine the percentage of 1RM from the repetitions completed. The predicted percentage of 1RM and sub-maximal load were then used to determine the subject's actual 1RM. There was a high correlation ($r = 0.94$) between the predicted and actual 1RM for the leg press, which resulted in the validity of using the testing procedure as an assessment of lower body strength.

Performance Measures As Determinants of Assessing Strength

Many different approaches in assessing strength performances have been employed to investigate beyond the typical weight lifting exercises such as the commonly used bench press and leg press exercises. Lack of facilities, equipment and knowledge about typical weight training tests has forced trainers and coaches to find viable alternatives to testing outside the weight room. According to Heyward (2002), callisthenic type strength and muscular endurance tests are becoming common field tests for athletic performance. Using these different varieties of performance measures has become a growing interest of women in the athletic realm.

Gardner, Stimson, Propst & Berry (1994) designed a training program for off-season female and male high school athletes at the SMI/St. Francis Hospital-Sweeney Fitness Center in Memphis to fill the need for quality and productive strength and conditioning that was lacking in the region. All athletes were assessed using a battery of tests not limited to the weight room area. These tests included the following: vertical jump for lower body strength, medicine ball throw for upper body power, bench press for upper body strength, hamstring flexibility to measure flexibility, 50-yard sprint to test speed, 60-yard shuttle run to test agility, and body composition to test the percentage of body fat. In order to keep the testing as standard and accurate at possible, a pre-test and post-test were performed on each of the participating athletes and administered by the same trainer. The results of this study set new norms for the high school population to better assess this age group and not compare it to norms given at a typical category of “18 and younger.” The conclusions provided the groundwork needed to set new goals and truer measurements using performance standards to assess different types of athletic parameters such as power and endurance.

In one study Mayhew, Bemben, Rohrs & Bemben (1994) tested anaerobic power in 64 college female athletes ranging from 17 to 23 in age using seven different performance measures. These measures included the Margaria-Kalamen test, vertical jump, Lewis power jump, standing long jump, 40-yard sprint, seated shot put, and bench press power. An inter-correlation analysis was performed to determine the relationships among the performance measures. One of the results of the correlation and factor analyses was a seated shot put throw and its correlation to bench press power. The seated shot put was closely related to the seated medicine ball-throw and did not demonstrate a significant relationship with bench press power. This was possibly due to the discrepancy between the two tests, both of which could be considered measures of upper body strength (Mayhew, Bemben, Piper, Ware, Rohrs & Bemben, 1993). Yet the procedures used in the bench press power test were linked more to a speed component, according to the authors. This finding could be the reason, although significant ($p < 0.05$), for only 14% of their common variance. When fat free mass was controlled (removed or included), approximately half of the inter-correlations increased or decreased. More specifically, when fat free mass was included in the factor analyses, the vertical jump ($r = 0.92$) offered the best representation of the component that could be labeled mass/power and the seated shot put ($r = 0.67$) had similar results.

Practical applications within the limits of this study suggested that no single power test can identify an individual's various anaerobic abilities, but the specificity rule should be applied. Athletes involved in sports dominated by power should be evaluated with tests such as vertical jump and seated shot put. Athletes that are involved in sports that are dominated by speed should be evaluated using vertical jump and bench press power tests, according to the guidelines set in this study. Assumptions cannot be made about the strength in the upper and lower body; consequently, one should select performance measures that reflect the demand on the sport the female athlete participates. The results indicated that vertical jump, bench press, and seated shot put are some of the practical instruments of assessing strength and power in the female athlete.

Another non-traditional form of assessment employed push-up training and distance achieved from a two-handed medicine ball throw as a criterion measure. Thirty-five healthy women over the age of 18 completed an 18-week training program encompassing two different types of push-ups as the exercise regimen (Vossen et al., 2000). The females were pre-tested and post-tested to establish the amount of improvement that occurred throughout the training program by the distance of the seated medicine ball throws. The researchers chose the medicine ball test based on it being a valid measure of power and strength in the chest and throughout the shoulder girdle. When an analysis of variance was performed to assess the differences between the two types of push-up training programs, both groups demonstrated significant ($p < 0.05$) improvements for both criterion measures. Vossen's research (2000) demonstrated that a simple criterion measure such as the medicine ball throw can be considered a valid means of assessing different types of strength training programs such as the push-up programs used in this study. It provides the researcher with a safe, simple and time-effective method way of evaluating strength and power in the adult female athlete.

In a recent study, Stockbrugger and Haennel (2001) assessed competitive female sand volleyball players (N=10) performed backward overhead medicine ball tosses to evaluate their validity and reliability with explosive power found in the standard countermovement vertical jump. The subjects ranged in age from 16-30 with the average age of 22.8 (SD ± 3.7). The researchers chose the medicine ball in view of the fact that other research studies widely used the seated shot put and the medicine ball throw as reliable and economical field tests to determine upper body strength in a time consuming manner (Gillespie & Keenum, 1987; Roetert, McCormick, Brown & Ellenbecker, 1996). The statistical analyses revealed from an intra-class correlation to examine test-retest reliability that the three measures including medicine ball throw, vertical jump and power index calculated from body weight and jump height that all coefficients were significant ($p< 0.01$). More importantly, the Pearson product analyses revealed there was a strong correlation between the distance of the medicine ball throw and the power index for the countermovement vertical jump($r = 0.906$, $p < 0.01$). These findings suggest not only the medicine ball being a reliable and inexpensive field test for assessing explosive power but the possibility of more research into the use of the medicine ball for more than just upper body and trunk power but total body activities in subjects between these ages.

The vertical jump test has been commonly used to measure lower body strength in a variety of athletes. For example, Ashley and Weiss (1994) evaluated healthy college-aged women (N=50) to measure the association between two common countermovement vertical jumps, in conjunction with a variety of physiological characteristics. The first vertical jump incorporated restricted upper body movement while the second jumping style involved unrestricted upper body movement. Results of this study indicated that all correlations between vertical jumps and force and power measures were significant ($p < 0.01$) in females ranging in age from 18 to 35 except for jumping performance and percent body fat. Also, there was a significant correlation between the two styles of vertical jumps ($r = 0.87$, $p < 0.01$) for this specific population. Reliability coefficients indicated that peak power occurred when knees were bent between 70 and 85 degrees. This investigation suggested that power and force could be tested by vertical jump measures utilizing variations of vertical jump tests.

Jaric, Ugarkovic and Kukoli (2002) studied the normalization of standard muscle strength tests for isometric forces of various leg muscle groups by analyzing the vertical jump. The study involved thirteen groups of male and female athletes who were categorized as elite, pubescent and prepubescent athletes. The female categories included 30 basketball players, ages 20 to 29 and 21 karate specialists, ages of 12 or 13. Maximal isometric force of knee extensors and hip flexors were measured by a strain gauge dynamometer; also, the maximum height of the counter movement vertical jump was measured by an Ergojump™ apparatus. These tests were chosen as standard tests of muscle power, as well as a common performance criterion already typically performed by most of the athletes tested. The results signified that exponential parameters (b-values) from the data obtained on most of the experimental groups are close to the theoretically predicted value (b=0.67) but also different from b=0 and b=1 and should be used for calculation of the normalized strength independent of body mass. The study proved to be significant in normalizing a value to incorporate into different muscle strength tests when using the vertical jump as a performance measure.

Summary

In summary, research has validated the use of the bench press and leg press tests as valid instruments to measure strength in the female athlete typically ranging between the ages of 18 and 50. There is also a substantial amount of evidence for using sub-maximal testing, such as the repetitions-to-fatigue test, as a measure of muscular strength. Alternative means of assessment are becoming just as common as traditional methods with proven effectiveness and possibly more efficiency in their protocols. While many investigations focus on adult female athlete populations, none have targeted the uniqueness at the high school level and the effect of these alternative performance measures as justifiable upper and lower body strength assessments.

CHAPTER 3

METHODS AND PROCEDURES

This chapter provides the framework for the intended study on the topic of strength and the high school female athlete. It outlines the methods and procedures utilized to conduct the study. It will include the following: participants, setting, instrumentation and equipment, data collection, testing procedures, research design and the statistical analysis to be performed using all of the information gathered throughout the investigation.

Participants

A total of 57 female high school athletes between the ages of 14-18 in grades 9-12 were recruited from Greenbrier High School in Columbia County, Georgia. All participants were involved in at least one sports team including: volleyball, softball, basketball, track and field/cross-country, swimming and soccer. All participants were volunteers who understood the nature of the investigation and signed a form of consent from their parent or guardian. The participants and their parents were also aware that the Institutional Review Board (IRB) at the University of Georgia and the Columbia County Board of Education approved the investigation. All results were discussed with the participants and parents/guardians after the analyses was completed. All athletes were post-pubescent, as determined by the Tanner scale characteristics such as secondary sex characteristics and menarche (Tanner, 1962). This element of the study takes into consideration the decrease in likelihood of any growth plate (epiphysis) damage in the long bone that may occur before the onset of puberty according to previous research (Fleck &

Kraemer, 1997; Schafer, 1991). All participants were tested during an after school off-season weight training program for female athletes not currently participating in a sport and were knowledgeable on proper lifting techniques and spotting procedures.

Setting

The investigation took place in a suburban area of Evans, Georgia just beyond the city limits of Augusta, Georgia in an affluent socio-economic community setting. Greenbrier high school has an approximate enrollment of 1650 students that participate in the AAAA state athletic classification. The Southern Association of Colleges and Schools accredits the school district and over 75% of each graduating class at Greenbrier High School attends a 4-year college institution. On average, approximately 10 % of the female athletes receive some form of athletic scholarship. Over 35% of the entire female population participates in at least one extra-curricular sport. This encompasses a female athletic program highly recognized for quality programs typically ranked among one the top ten in their classification for their respective sport. All female athletes have participated in an off-season after school conditioning program that includes weight training, cardiovascular conditioning and plyometric training two to three days a week Data collection occurred in the gymnasium and female strength and conditioning room at Greenbrier High School.

Instrumentation and Equipment

The weight room equipment in this study included the bench press and leg press sled. All equipment utilized free-weights, progressing in increments of 2.25 kg. A standard 20.25 kg (45 lb) Olympic style bar was part of the equipment needed for the bench press procedure. According to Champion Barbell ™ the leg press sled carriage itself, without any weight added, is 31.5 kg. The performance measures that used for assessment were a rubberized medicine ball for upper body strength and a Vertec™ machine for the vertical jump to test lower body strength.

Two different types of strength tests were performed using the bench press and leg press. The one-repetition maximum (1RM) test was chosen based on strength and conditioning research as a valid measure of strength assessment by the National Strength and Conditioning Association (2000). The repetitions-to-fatigue test is a viable alternative to the 1RM test according to this organization, whose members are leading experts in this field of study. Both tests have been found in previous research studies to be valid measures of upper body strength (Ball et al., 1995; Bates et al., 1995). A repetitions-to-fatigue test (27 kg weight load) was used to provide an alternative to measure upper body strength without causing undue stress on the body due to maximal loading. Both tests were investigated to determine if there was a difference in results when relating them to absolute or relative strength. All exercises and equipment were selected to fit the needs of the study, the uniqueness of the participants and were based upon an extensive review of literature that indicated that there are relationships between strength and different performance measures indicated in the results of 1RM and repetitions-to-fatigue testing.

Data Collection Procedures

All data collected for upper and lower body strength were assessed in the female weight room located at Greenbrier High School. The strength apparatus used to evaluate upper body strength was the bench press exercise. The strength apparatus designed to assess lower body strength was the leg press, also known as the hip sled according to the National Strength and Conditioning Association (NSCA) Guidelines (2000) resistance training manual. Each assessment followed the general guidelines set forth in this manual and was applied to both upper and lower body measurements. Upon returning the consent forms and prior to all strength testing, the researchers recorded physiological characteristics including age, height, weight, body mass index and body fat percentage for further analysis within the experimental design. The participants were instructed on proper lifting and spotting techniques, as well as, a proper warm-up, which included calisthenics and stretching exercises to warm-up the muscles of the body prior to testing. The calisthenics included the following exercises: 15 jumping jacks, 15 push-ups and 15 sit-ups. The stretching exercises incorporated all the major muscle groups of the body including: arm, chest, back, quadriceps and hamstring stretches and were directed by the female strength and conditioning coach at the high school. All strength and conditioning coaches at the school supervised all tests and other female athletes assisted in spotting the lifters. Spotting the lifters involved helping the participant in lifting the weight off of the bar, counting the amount of repetitions performed correctly and helping put the weight back on the rack when the participant was at the point of exhaustion or completed the test. All strength tests were performed in a counterbalanced method by testing upper body then lower body the next training session. This allowed for proper muscle recovery and maximal effort for the test performed in that workout session.

<u>Testing Procedures</u>

<u>Body Composition Assessment</u>

Personal data was collected by the investigator including age, height and weight of each participant. Also, body mass index and body fat percentage were measured using an Omron™ Body Fat Analyzer (Model HBF-306BL). The procedure for measuring these components begins by the participant grasping the machine with both hands for seven seconds. By electrical impedance, the analyzer determines body fat percentage and body mass index when the age, height and weight of the participant are entered into the data bank of the analyzer. Three measurements were recorded with the average of both measurements being documented as the body fat percentage and body mass index for each participant. Lean body mass was also calculated according to guidelines developed by Fleck and Kraemer (1997). It was determined by calculating fat weight (BF%) and subtracting it from total body weight. Lean body mass is typically used in strength training programs to mirror increases in muscle tissue weight.

Upper Body Strength Assessment

1RM bench press test

This exercise required each subject to lift the maximal amount of weight with proper technique for only one repetition and is based on procedures standardized by the National Strength and Conditioning Association (2000). Prior to beginning the test, the participant performed a warm-up set of 5-10 repetitions with an unweighted Olympic bar (20.25 kg) and after a one minute rest period completed 3-5 repetitions with 2.25-9.0 kilograms added to the load. After a two-minute rest period, an estimated near maximal load was added allowing the participant to complete 2-3 repetitions with the free-weight Olympic bar. The participant grasped the bar with a comfortable grip at a position slightly greater than shoulder width apart. The spotter assisted in lifting the bar off the rack and the subject lowered the bar slowly to touch the chest, without bouncing it off the chest, and then fully extend the arms to the starting position. A recovery time of 2-4 minutes was allowed between each lift and the load increased 2.25-9.0 kg depending on the amount of difficulty of the prior 1RM attempt. This procedure was repeated in a counterbalanced manner until the participant failed to lift the weight. The highest weight lifted successfully was recorded as the 1RM (Mayhew et al., 1992).

Repetitions-To-Fatigue bench press test

This test was conducted after a 24-hour rest period after the 1RM test was performed. It required each participant to perform as many repetitions as possible using a 27 kg weight load. The average individual typically is able to complete 12-15 repetitions at 60-70% of their maximal load (NSCA, 2000; Bryzcki, 1993). Similar repetition tests have been performed with college-aged females and adult females using similar weight loads.

The YMCA bench press test requires a participant to lift 24.75 kg for a 30 or 60 repetitions per minute cadence (Kim, Mayhew, & Peterson, 2002) and has been found to be an effective method of evaluating upper body strength. Another investigation was performed at the University of Georgia Movement Studies Laboratory (Horvat, Ramsey, Gavin, Palumbo, & Glass, 2003) using a weight load of 31.5 kg with the repetitions-to-fatigue bench press test and found that this weight in conjunction with lean body mass can be used to accurately predict 1RM bench press strength in collegiate women athletes. Testing was terminated if the subject exceeded 35 repetitions as a safety mechanism to prevent any possibility of injury occurring. Research has demonstrated that there is little difference in statistical significance between 15 repetitions performed and higher amount of repetitions performed, such as 30-40 at the same 1RM percentage (Invergo, Ball & Looney, 1991; Mayhew et al., 1992; Ball & Rose, 1991). It is safer, easier, less time consuming and easily incorporated into training sessions when the use of sub-maximal loads and 8-15 repetitions guidelines are followed (Mayhew et al., 1993). The participant performed a warm-up with an un-weighted Olympic bar for 5-10 repetitions, rested for two minutes and repeated the warm-up prior to the beginning of the test. The same guidelines followed as the 1RM bench press test. The spotter assisted the lifter in taking the bar off the rack and the participant lowered the bar to the chest without bouncing and then fully extending the arms on each repetition completing as many repetitions as possible until exhaustion. The spotter then assisted in placing the bar back on the rack and the test was completed. If there was a significant hesitation (more than 2 seconds), a repetition not completed or improper form used, the test was terminated and the amount of repetitions properly executed was recorded (Mayhew et al., 1995).

Seated Medicine Ball Throw

This exercise was utilized as an alternative means of assessing upper body strength. A 3 kg (6.6lb.) rubberized medicine ball was the equipment necessary to perform the test. It is recommended that a 2.25-3.15 kg medicine ball be used for testing (Gardener et al., 1994; Vossen, Kramer, Burke & Vossen, 2000) females as a result the most compatible ball available in the Greenbrier High weight room was employed for the test. The test was performed in the gymnasium with the athlete seated against the wall with the buttocks approximately 5 inches away from the wall with the legs straight. The participant placed the ball against the chest with both hands and then pushed upward (30^{o} above horizontal) and forward with maximal effort without the shoulders leaving the wall and no rocking or movement from the legs or pelvis. The distance from the point of release to the spot where the medicine ball touched the floor was recorded with a one-minute rest between throws. A mark was placed on the wall as a guide for the participant to release the medicine ball at the appropriate angle for maximum distance. The best of 5 attempts was recorded and analyzed.

<u>Lower Body Strength Assessment</u>

1RM Leg Press Test

The leg press test uses similar protocols to the bench press test except for the amount of weight loads used in each test. According to the testing procedures set by the NSCA (2000), the warm-up loads are increased in increments of 13.5-18 kg or 10-20% for lower body exercises. If the subject fails an attempted lift, the load is decreased by 6.75-9 kg or 5-10%. Resting intervals should occur within five testing sets. The unweighted platform is 31.5 kg and the free-weights are placed evenly on both sides. The leg press/hip sled involves the major muscles of the lower body without placing undue pressure on the neck and shoulders as in when performing the squat exercise. The participant begins by sitting in the machine with the lower back, hips and buttocks pressed to the padding. The feet are placed flat, parallel and hip-width apart. Using the feet, the participant pushes the platform and removes the supports, grasping the handles on each side of the machine for support. The downward movement phase allows the hips and knees to slowly flex to lower the platform, keeping the hips and buttocks on the seat and the back flat at all times. The hips and knees flex until the thighs are parallel to the platform and the LaFayette™ Goniometer measures a 90^{o} angle measurement. The upward phase pushes the platform up to a fully extended position (not forcefully locking the knees) by extending the hips and knees (NSCA, 2000). It is important not to allow the knees to shift in or out and keep the heels in contact with the platform and the legs approximately shoulder distance apart.

Repetitions-To-Fatigue Leg Press Test

Since this is a new approach to measure lower body strength, norms and guidelines have not been established in research literature. The researcher followed the same procedures developed in the repetitions-to-fatigue bench press test (NSCA, 2000) and incorporated the 1RM leg press/hip sled test guidelines into this unique test. The athletes involved in this study typically perform 8-15 repetitions using 90-kg with exhaustion occurring between 12-15 repetitions during regular weight room routines. The researcher applied this same weight during testing based on the inquiry.

Vertical Jump

This performance measure was evaluated as an alternative measure of lower body strength. The jumps were performed using the commercial Vertec™ apparatus in a standard countermovement jump. The colored horizontal vanes were 1.27 centimeters apart from one another. To execute the jump, participants stand sideways and the tester adjusts the height of the Vertec™ low enough for the subject to reach with one hand and touch a horizontal colored vane. The highest vane that can be touched while standing flat-footed determines the standing touch height. The athlete gets into the starting position underneath the apparatus. In a downward countermovement, the athlete swings the arms down and back to start the jump. The knees and hips flex, bringing the trunk downward and forward prior to the upward propulsion. The participant jumps without any stutter step, propels forward and upward, reaching for the highest vane with full knee and hip extension. The score is the vertical distance between the highest vane reached during the standing reach and the vane touched at the highest point of the jump. Three attempts were performed and the highest jump from the three attempts was recorded as the vertical jump measure (NSCA, 2000; Stockbrugger & Haennel, 2001).

Additional Performance Measures Used For Assessment

Sit-Up Test

This measure was performed to evaluate possible relationships with upper and lower body strength. The bent knee technique (NSCA, 2000) commonly used in regular weight room training was employed except for a change in hand position for testing purposes. The participant assumes a supine position on a floor mat with the knees flexed and heels close to the buttocks. The fingers must be interlocked behind the neck and the backs of the hands must touch the mat. Another person holds the athlete's ankles with the hands only and helps count the repetitions performed. On the “go” command, the stopwatch will start and the athlete raises the upper body to the up position with the elbows touching the thighs. The athlete lowers the body until the upper portion of the back touches the mat without the head, hands, arms and elbows not touching the ground. The tester records the amount of repetitions performed in one minute. A repetition does not count if the participant fails to reach the up position, unlocks the fingers, raises the buttocks off the ground or the upper portion of the back does not touch the ground.

40-yard sprint

The athlete tests speed during this sprint and analyzed the time with 1RM for correlation purposes. The athlete performs a warm-up and stretch before two sub-maximal practice runs are performed. The athlete should position themselves behind the starting line with one or two hands on the ground. On the “go” command, the participant will sprint at maximal speed for 40-yards (NSCA, 2000). The average of two trials was recorded to the nearest 0.1 second.

Sit and Reach Test

This exercise tests flexibility and the relationship to upper and lower body strength. The athletes stretch prior to testing. The tester tapes a yardstick to the floor with one piece of tape approximately 60.96 centimeters long across the stick and at a right angle to it at the 38.1-cm mark. The participant is shoeless and sits with the yardstick between the legs with the zero inch mark toward the body. The feet are 30.48 cm apart with the toes pointed upward and the heels nearly touching the edge of the taped line at 38.1 cm mark. The athlete slowly reaches forward with both hands as far as possible, holding this position for a moment. The tester should inform the participant in order to get the best stretch to exhale and drop the head between the arms when reaching. The tester monitors the athlete’s hands, making sure they are adjacent to one another and one does not lead more so than the other. The tester may hold the athlete’s knees down, if necessary, to keep them straight. A score of less than 38.1 cm indicates the participant could not reach the bottom of the feet (NSCA, 2000). The best of three trials were recorded to the nearest 0.635 cm.

Line Drill Shuttle Run

This exercise tests aerobic capacity and lower body strength. The drill is performed on a regulation high school basketball court measuring 25.60 meters in distance. The participant performs stretching exercises and is allowed one sub-maximal run of the course to warm the muscles necessary for the test. The participant starts at the baseline of the basketball court and on the “go” command, sprint to the near free-throw line and back. The tester must emphasize to the participant to touch each line with their foot. The participant continues and after touching the baseline, sprints to half-court, touches the line and return to the baseline. Upon touching the baseline, the participant then sprints to the far free-throw line in the same manner previously, touches the baseline and sprints to the far baseline and completes the course by finishing where the course began. The athlete completes four roundtrips without stopping in as straight of line as possible to minimize the time. After the test is completed, the participant rests for exactly two minutes and repeats this process three more times with a two minute rest in between each trial. The average of the four times were recorded as the line shuttle drill time. The participant is disqualified if they fail to touch the line with their foot or does not begin the next time trial after exactly after the two-minute rest period (Semenick, 1990).

Experimental Design

This study incorporated two separate Pearson product correlation coefficient matrixes to determine relationships between absolute strength as measured by the 1RM strength tests for both the upper and lower body with different performance measures. A variable selection procedure was used to assess the relative importance of the performance measures and determine which measures have the highest relationship in determining absolute strength (Pedhazur, 1997).

Data Analysis

Descriptive statistics were calculated on all variables including means, standard deviations and ranges. The data analysis attempted to support a linear relationship between 1RM strength and different performance measures. According to Keppel (1991), there are three basic approaches to establish relationships. These include scatter graphs to visualize an association among data points across a regression line, correlation coefficients to measure the strength of the relationship and a regression analysis to predict and explain the relationship between the dependent and independent variables in the study. The present study followed this outline throughout the investigation.

A Pearson correlation coefficient explained the variance in 1RM strength for both upper and lower body that was explained by the variability in different performance measures. Two matrices (upper and lower body) were developed to easily identify significant relationships between 1RM strength and specific performance measures. A comparison analysis was performed to demonstrate the change in performance between different age groups in strength relationships.

Cook's Distance (Cook's D) and Studentized residual (standardized) examined possible extreme data points, which may have an effect on the regression analysis. The data also examined collinearity, correlations among the independent variables, to detect any increase in the variance of the regression coefficient. Two statistics, VIF and Tolerance, were utilized to detect how much variance of the estimated regression coefficients were inflated compared to when the explanatory variables were not linearly related. The detection of collinearity problems could influence the estimates of the regression equation and not provide the best model for the investigation (Kerr, Hall, & Kozub, 2002).

A stepwise regression procedure was selected to choose the significant performance measures in the development of the regression model. The criteria was set at $P \leq 0.10$ for entry and $P < 0.15$ for removal of variables. This method adds variables to the model, re-evaluating previous variables until the addition of a new variable does not increase the R^2- statistic significantly and the deleting of additional variables does not reduce the R^2- statistic significantly (Pedhazur, 1997). The R^2-squared statistic is an index of the overall strength in the relationship between 1RM strength and performance measures. The closer the value is to the value of one, the stronger the relationship between those variables. The F-stat and significance level detected in the regression model were reported (Kerlinger & Pedhazur, 1973). All statistical analyses procedures were used to validate the results of the investigation. The significance level was set at $\propto = 0.05$ to reduce the chance of a Type I error occurring. SPSS v.12 statistical analysis software was used to perform all analyses.

CHAPTER 4

RESULTS

Overview

A Pearson product correlation and stepwise selection method regression analysis were used to examine relationships between 1RM (repetition maximum) strength as measured by the bench press and leg press tests with physical characteristics, performance measures and repetitions to fatigue performance. Results include: descriptive statistics, a Pearson Correlation matrix, a Stepwise regression analysis and a scatter graph depicting the relationship between 1RM strength and the independent variables (Pedhazur, 1997). All hypotheses were tested at the $\propto = 0.05$ level.

Participants included 57 female athletes and further divided into two age groups of 14-15 (n=37) and 16-18 (n=20) to compare performances of the independent variables included in the study. The independent variables in the analysis with the upper and lower body 1RM weight (dependent variable) were 27 kg repetitions to fatigue bench press (BPRTF27) and 91 kg repetitions to fatigue leg press (LPRTF91), sit-ups (SIT-UP), sit and reach (SIT/REA), medicine ball (MB), 40-yard sprint (40-YD), vertical jump (VJ), and shuttle run (SHUTTLE), body mass index (BMI), percent body fat (BF%) and lean body mass (LBM).

Participants

Demographic and physical characteristics documented for this study were comprised of the following: age, sport, height (cm), weight (kg), percent body fat, body mass index and lean body mass (kg). Percent body fat and body mass index were calculated by an Omron™ Body Fat

Analyzer (Model HBF-306BL). The analyzer calculated these measures by bioelectrical impedance by screening the amount of body fat from a weak electrical current. Body fat percentage was calculated by ({body fat mass (kg)/body weight (kg)} x 100) that included five factors: electrical resistance, height, weight, age and gender. This formula has been widely used as a valid means of assessing percentage of body fat (Baechle & Earle, 2000; Dean, Foster & Thompson, 1987; Faigenbaum, 2001; Knuttgen & Kraemer, 1987; Kuramoto & Payne, 1995; Moffatt & Cucuzzo, 1993).The metric formula for body mass index (weight (kg)/height $(m)^2$) was based on the procedure recommended by the NSCA (2000). Lean body mass was calculated by subtracting fat weight (BF%) from total body weight according to the procedure by Fleck & Kraemer (1997). Means, standard deviations and ranges were calculated for the variables used in the investigation and reported in Table 4.1. The majority of the athletes participated in two sports throughout the school year and the primary participants tested were volleyball, softball and basketball players. The tallest athlete measured at 185 cm (volleyball player) and the shortest at 150 cm (softball player). The heaviest female weighed 94.35 kg (volleyball player) and the lightest female at 44.9 kg (softball player). The highest body fat percentage (35.7) and body mass index (30.8) were recorded from the same individual. The lowest body fat percentage (15.5) and body mass index (18.0) were recorded from a volleyball/soccer and cross-country/track athlete. The average lean body mass was 47.19 kg. The results of descriptive statistics indicated that the largest variation occurred in weight indicated by the biggest standard deviation.

Table 4.1 Physical characteristics (N=57).

Variable	Mean ± SD	Minimum	Maximum
Age (y)	15.17 ± 1.21	14.00	18.00
Height (cm)	166.73 ± 6.27	150.00	185.00
Weight (kg)	63.68 ± 11.30	44.90	94355
BF (%)	25.13 ± 4.96	15.50	35.70
BMI	22.93 ± 3.50	18.00	30.80
LBM (kg)	47.19 ± 5.67	36.78	69.36

BF= body fat
BMI= body mass index
LBM= lean body mass

Table 4.2 Upper body measures.

Variable	Mean ± SD	Minimum	Maximum
1RMBP (kg)	36.25 ± 6.02	27.00	52.16
BF (%)	25.13 ± 4.96	15.50	35.70
BMI	22.93 ± 3.50	18.00	30.80
LBM (kg)	47.19 ± 5.67	36.78	69.36
SIT-UP (reps/min)	27.18 ± 6.89	10.00	39.00
BPRTF27 (reps)	10.98 ± 7.14	2.00	35.00
SIT AND REACH (cm)	50.44 ± 7.77	25.00	66.00
MB THROW (cm)	284.30 ± 32.06	222.89	338.46

(rep/min) = repetitions per minute
reps = repetitions

Upper Body Measures

The upper body measures (Table 4.2) that were tested for their relationship with the dependent variable (1RMBP) included: body fat percentage (BF), body mass index (BMI), lean body mass (LBM), sit-ups (SIT-UP), bench press repetitions-to-fatigue (BPRTF27), sit and reach (SIT/REA) and medicine ball throw (MB). Pearson product correlations for 1RM bench press with upper body strength measures demonstrated that bench press repetitions to fatigue at 27 kg

(BPRTF27) had the highest correlation ($r = 0.802$, $p = 0.000$) with 1RMBP indicating a strong relationship between the variables (Table 4.3). Other measures that were correlated at a statistically significant ($p < 0.05$) level with 1RMBP included: body fat ($r = 0.329$, $p= 0.013$), body mass index ($r= 0.353$, $p= 0.007$), lean body mass ($r= 0.337$, $p= 0.005$) sit and reach ($r = 0.283$, $p = 0.033$), and medicine ball throw ($r = 0.635$, $p= 0.000$) (Table 4.3). BPRTF27 provided the strongest relationship to the 1RM bench press strength and supports the premise that a bench press repetitions to fatigue test is a determinant of muscular strength in high school female athletes. Medicine ball performance had the second highest correlation to 1RM strength ($r = 0.635$, $p= 0.000$) and could also be a factor as a determinant of upper body strength. The maximum amount of weight lifted on the bench press was 52.16 kg (a member of the volleyball and softball teams) and the minimum amount of weight lifted was 27 kg (two members of the softball team). Ten sit-ups were the fewest repetitions documented and 39 repetitions were the highest amount performed during the one-minute time period (both members of the softball team). At 27 kg, the minimum number of repetitions attained from testing 2 (a basketball player) and the maximum was 35 (softball player). A volleyball player performed the longest reach of 66 cm during the sit and reach test and a softball player performed a sit and reach of 25 cm. Softball players at 338.46 cm and 222.89 cm obtained the highest and lowest medicine ball throws.

Table 4.3 Pearson correlations for upper body measures.

Variable	1RM BP	BF	BMI	SIT-UP	SIT/REA	BRTF27	MB
BF	0.329 0.013*						
BMI	0.353 0.007*	0.945 0.000*					
SIT-UP	0.023 0.867	-0.576 0.000*	-0.534 0.000*				
SIT/REA	0.283 0.033*	-0.016 0.907	- 0.018 0.896	0.111 0.413			
BRTF27	0.802 0.000*	0.322 0.014*	0.290 0.028*	0.016 0.906	0.316 0.017*		
MB	0.635 0.000*	0.299 0.024*	0.088 0.513	0.081 0.547	0.186 0.166	0.688 0.000*	
LBM	0.337 0.005*	0.706 0.000*	0.765 0.000*	-0.468 0.000*	0.170 0.103	0.255 0.028*	0.255 0.028*

* $p < 0.05$

BF= body fat percentage
BMI= body mass index
SIT-UP= sit up test
SIT/REA= sit and reach test
BRTF27= bench press repetitions to fatigue (27 kg)
MB= medicine ball throw
LBM= lean body mass

Lower Body Measures

The following measures were tested for their relationship with 1RM leg press strength. They included: body fat percentage (BF), body mass index (BMI), lean body mass (LBM), sit-ups (SIT-UP), sit and reach (SIT/REA), 40- yard sprint (40-YD), vertical jump (VJ), shuttle run (SHUTTLE), and leg press repetitions to fatigue using 91 kg (LPRTF91). The Pearson product correlations for lower body strength (Table 4.4) demonstrated that leg press repetitions to fatigue using 91 kg (200 lbs) had the highest correlation (r= 0.793, p= 0.000) with 1RMLP denoting a significant relationship between the two variables. More specifically, this test appears to be a viable indicator of lower leg strength and correlates with the maximal strength test.

Table 4.4 Pearson correlations for lower body measures.

Variable	1RM LP	BF	BMI	SIT-UP	40-YD	VJ	SIT/REA	LPRTF	SH
BF	0.529								
	0.000*								
BMI	0.540	0.945							
	0.000*	0.000*							
SIT-UP	-0.217	-0.576	-0.534						
	0.106	0.000*	0.000*						
40-YD	0.183	0.349	0.375	-0.459					
	0.172	0.008*	0.004*	0.000*					
VJ	0.112	-0.179	-0.153	0.381	-0.427				
	0.407	0.184	0.255	0.003*	0.001*				
SIT/REA	0.368	-0.016	-0.018	0.111	0.046	-0.004			
	0.005*	0.907	0.896	0.413	0.735	0.976			
LPRTF91	0.793	0.561	0.630	-0.199	0.098	0.126	0.327		
	0.000*	0.000*	0.000*	0.138	0.470	0.351	0.013*		
SH	0.221	0.579	0.55	-0.532	0.462	-0.598	0.014	0.204	
	0.098	0.001*	0.001*	0.001*	0.000*	0.001*	0.919	0.129	
LBM	0.685	0.706	0.765	-0.468	0.332	-0.048	0.170	0.658	0.379
	0.000*	0.000*	0.000*	0.000*	0.006*	0.363	0.103	0.000*	0.002*

* $p < 0.05$

BF= body fat percentage
BMI= body mass index
SIT-UP= sit up
40-YD= 40- yard sprint
VJ= vertical jump
SIT/REA= sit and reach test
LPRTF91= leg press repetitions to fatigue (91 kg)
SH= shuttle run
LBM= lean body mass

Table 4.5 presents means and standard deviations for lower body measures. The maximum amount of weight lifted using the leg press was 226.79 kg by a volleyball player and a softball player at performed the minimum amount of weight of 117.93 kg. The minimum vertical jump was 26.67 cm (a member of the softball team) and the maximum jump was 49.53 cm (a few different athletes from different teams). The most repetitions were 35 performed by nine athletes and this number of repetitions was also the termination point of the test due to safety concerns. The least amount of repetitions performed was 8 by the same young softball player earlier noted in the 1RM leg press test. The fastest time (30.7 sec) for the shuttle run was performed by a softball/basketball player and the slowest shuttle run time recorded was 39.18 seconds by a softball player. Softball players recorded the fastest and slowest 40-yard sprint times at 5.19 and 6.80 seconds.

Table 4.5 Lower body performance measures.

Variable	Mean ± SD	Minimum	Maximum
1RM LEG PRESS (kg)	159.23 ± 26.61	117.93	226.79
40-YARD SPRINT (sec)	6.044 ± 0.365	5.19	6.80
VERTICAL JUMP (cm)	39.37 ± 5.58	26.67	49.53
LPRTF91 (reps)	22.22 ± 8.82	8.00	35.00
SHUTTLE (sec)	33.32 ± 1.67	30.70	39.18

sec. = seconds
reps = repetitions

Table 4.6 presents a comparison analysis of the age group differences in performance for the independent variables tested in the study. Body composition measures, such as, body mass index, body fat percentage and lean body mass increased due to overall increases in age, height and weight of the older participants. Flexibility increased by over 4.56 cm and five more repetitions were performed on upper and lower body strength tests while 1RM, sit-ups and medicine ball averages increased with age. Vertical jump and the shuttle run performance was greater in the older age group while a slightly negative relationship with age occurred in the 40-yard sprint, in which, performance times increased by 0.04 of a second. This was probably due to the increase in height, weight and percent body fat of the older athletes.

A Pearson correlation analysis was investigated for each group to demonstrate any changes in relationship and significance for the variables with the strongest correlation to 1RM strength for the entire group (N=57). Upper body strength results indicated that BRTF27 had the strongest relationship ($r=0.802$, $p=0.000$) with 1RMBP. This was also evident with age group comparisons: $r= 0.794$, $p=0.000$ ($n =37$) and $r= 0.824$, $p=0.000$ ($n=20$). Lower body results yielded a correlation between 1RMLP and RTF91 for the entire group ($r= 0.793$, $p=0.000$) while also indicating a strong relationship for ages 14-15 ($r = 0.804$, $p=0.000$) and for ages 16-18 ($r = 0.720$, $p=0.000$). These results demonstrated that repetitions to fatigue testing are highly indicative of muscular strength in the upper and lower body of post-pubescent teenage female athletes.

Table 4.6 Differences in variables for groups.

	14-15 (N=37)		16-18 (N=20)		
Variables	M	SD	M	SD	Mean Difference
AGE (year)	14.40	0.49	16.60	0.75	+ 2.20
HT (cm)	165.94	5.95	168.18	6.75	+ 2.24
WT (kg)	62.18	10.89	66.45	11.92	+ 4.27
BF (%)	24.54	5.34	26.22	4.07	+ 1.68
BMI	22.62	3.81	23.52	2.85	+ 0.90
LBM	46.50	5.26	48.65	2.85	+ 2.15
SIT-UP (reps/min)	26.92	7.49	27.65	5.76	+ 0.73
40-YD (sec)	6.03	0.36	6.07	0.38	+ 0.04
VJ (cm)	38.65	5.96	40.70	4.63	+ 2.05
SIT/REA (cm)	48.84	6.92	53.40	8.53	+ 4.56
1RM BP (kg)	35.18	6.01	38.22	5.67	+ 3.04
LP RTF91 (reps)	19.86	8.01	26.60	8.76	+ 6.74
1RM LP (kg)	150.36	19.85	175.68	30.07	+ 25.32
BP RTF27	9.08	5.78	14.50	8.20	+ 5.42
MB (cm)	279.04	32.05	294.00	30.45	+ 14.96
SH (sec)	33.50	1.94	32.98	0.97	- 0.52

Cook's Distance (D) and Studentized residuals were utilized to identify possible influential data points when all variables were in the model. The largest value for D was .166 for upper body measures and the largest Studentized residual for upper body measures was 2.30 indicating no outliers or influential data points in the data set. In observing the lower body scatter graph (Figure 4.2) between 1RMLP and LPRTF91, four participants lifted unusually heavy amounts of weight compared to the rest of the group. The average 1RMLP lift was 159.23 kg, while these females averaged 177.27 kg and these females were all in the older age group and veteran weight room participants. Studentized residuals detected one observation, in particular, with an unusually high residual value (3.121) that could possibly affect the results of the explanatory variable LPRTF91 by creating a larger typical (mean square) error (36.10) and smaller R^2-value (.6281). With the use of the Cook's distance value (0.343) for this observation, it was concluded that the observation was not extreme enough to greatly skew the analysis.

In addition, a stepwise regression analysis was performed to analyze which performance measures were valuable in predicting 1RM strength with the criteria set at $P \leq 0.10$ for entry and $P < .15$ for removal of variables from the model which is commonly used when performing exploratory analysis. This type of regression analysis was selected because of it's ability to continuously add and delete variables in the pool at different steps of the analysis to produce the best regression equation (Kerr, Hall & Kozub, 2002; Pedhazur, 1997) Table 4.7 demonstrates the best overall regression models for upper and lower body strength, in which, BPRTF27, LPRTF91, SIT/REA and LBM are used as predictors in this age group. Furthermore, Figures 4.1 and 4.2 illustrate the scatter graphs for the most significant performance measures and examination of tolerance levels and VIF values revealed no evidence of collinearity.

From the regression analysis for upper body (Model 1) two significant variables, bench press repetitions to fatigue (BPRTF27) and lean body mass (LBM) were found statistically noteworthy. The F-value ($F(2, 54) = 52.89$, $p < 0.001$) indicated that one-repetition maximum bench press was positively associated with bench press repetitions-to-fatigue at 27 kg and lean body mass. For this model, the Adjusted R^2-value (0.650), a measure of effect size indicated that the explanatory variables (BPRTF27 and LBM) accounted for more than 65% of the variability in 1RMBP strength and provided the lowest standard error of estimate (3.56), further justifying this as the best model for predicting upper body strength. These outcomes are sufficient to allow comparisons to populations of the same age and strength characteristics in predicting upper body strength using specific performance measures.

The stepwise regression analysis for lower body variables (Model 2) three significant variables (LPRTF91, LBM, SIT AND REACH) when all participants (N=57) were evaluated using this model. The F-value of ($F (3,53)= 39.67$, $p< .001$) indicated that one-repetition maximum leg press was positively associated with leg press repetitions-to-fatigue test at 91 kg, lean body mass (LBM) and the sit and reach test (SIT/REA). The Adjusted R^2 - value of 0.674, indicated that the explanatory variables accounted for more than 67% of the variability in 1RMLP. This model demonstrated the highest R-squared value in conjunction with the lowest standard error estimate (15.16) constructing the best equation to predict lower body strength without actually performing the 1RM leg press test.

Table 4.7 Stepwise regression models.

Model	Equation	N	R^2
1	1RMBP = 22.03 + (.645) BPRTF27 + (.150) LBM	57	0.650
2	1RMLP = 32.21 + (1.66) LPRTF91 + (1.41) LBM + (.470) SIT/REA	57	0.674

Figure 4.1 Scatter graph for upper body variable.

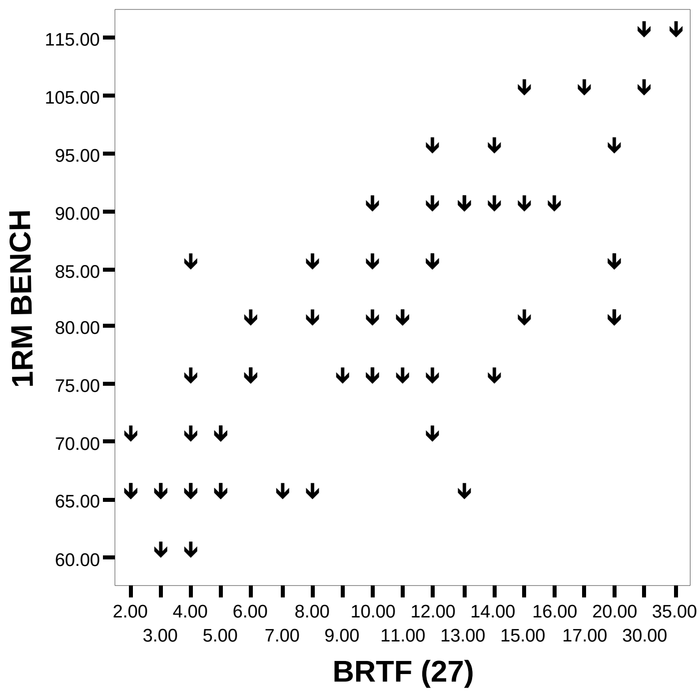
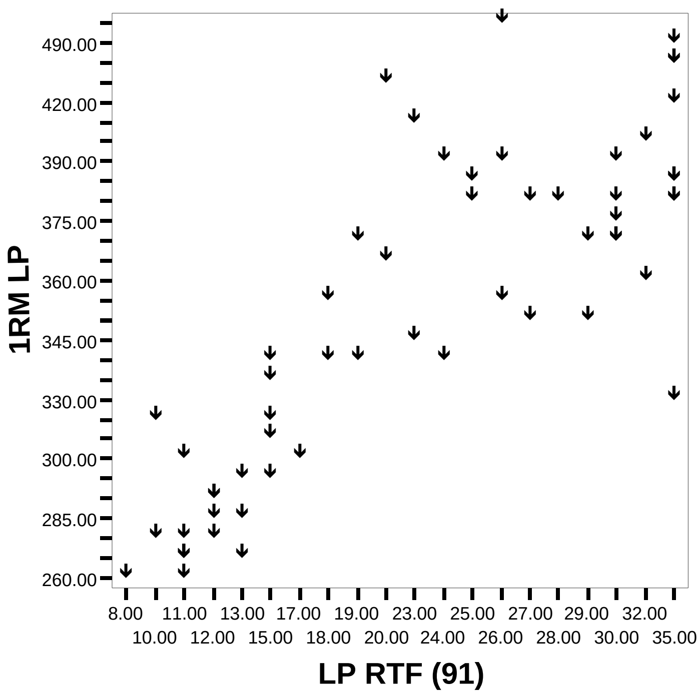


Figure 4.2 Scatter graph for lower body variable.



CHAPTER 5

DISCUSSION

As female athletes continue to improve their level of skill it is essential to improve their physical functioning to meet the demands for performance. Strength training for female athletes has been identified as a key to increasing sport performance at the college level and is an integral part of their success and necessary to improve performance (Horvat et al., 2003). In this context, the majority of available research on strength is based upon male athletes, women in older age groups and youth physical fitness tests intended to evaluate overall fitness for the general population (Knutzen, Brilla, & Caine, 1999; Mayhew, et al., 1993; Mayhew, et al., 1994; Mayhew et al., 1995; Rainey & Murray, 1997). Inherent in this study was to apply previous methods for assessing strength and performance (upper and lower body) to female high school athletes who developmentally are just beginning to mature physiologically from their male counterparts.

The rationale for developing strength assessment data for the high school female athletic population was based on the absence of guidelines for this age group in the NSCA manual and other similar guides for strength assessment (Baechle & Groves, 1994; Corbin & Pangrazzi, 1999; Dalton & Wallace, 1996; Hale & Franks, 2001; Rainey & Murray, 1997).

The practicality in the results of this study allows coaches and instructors to perform the repetitions test and mathematically calculate the athlete’s 1RM using a regression equation. Since the 1RM often provides the basis for designing weight-training programs, this will allow more concentration on training while decreasing the likelihood of potential muscle soreness and injury caused by performing the 1RM test in high school female athletes. Also, sub-maximal tests are performed easily, which may result in more accurate assessments of strength because of the athlete's confidence in their abilities in lifting lighter weight loads. Furthermore, at the high school level, concerns arise from parents about the detrimental effects to the body that can be caused by maximal loading in strength training programs.

Based on the data analyses, the repetitions to fatigue test was a viable alternative approach in testing maximal upper body strength indicated by significant correlations ($p < .05$), which were consistent with previous investigations that incorporated the bench press while varying the percentage of 1RM load lifted (Dalton & Wallace, 1996; Mayhew et al., 1992; Rose & Ball, 1992). It was also similar to earlier efforts with collegiate female athletes at the University of Georgia (Horvat et al., 2003) who demonstrated repetitions to fatigue testing, in combination with lean body mass accurately predicts 1RM bench press strength ($p = 0.000$). This study expands the earlier work to high school female athletes and indicates a strong relationship exists between 1RM bench press strength and repetitions to fatigue testing. For high school athletes this is also evident as results demonstrated significant relationships ($p = 0.000$) between 1RM bench press strength and repetitions to fatigue using a weight load of 27 kg indicating that the repetitions test can be correlated to 1RM strength without actually performing the 1RM test. For coaches and teachers this is helpful for conducting conditioning programs and evaluating strength with a maximal effort or repetitions to fatigue procedure.

For the lower extremity data analyses, the leg press repetitions to fatigue test provided the most important variable in determining lower body muscular strength ($r=0.793$, $p=0.000$). These results were similar to one of the few investigations utilizing the leg press to test maximal lower body strength of college-aged women. Based on their investigation, Dalton & Wallace (1996) reported new normative data for lower body strength for women in the twenties signifying changes to previous strength fitness norms currently used by the American College of Sports Medicine (1991). This is relevant to the present study because the female high school athletes investigated in the present study did not fit in the guidelines developed by the ACSM, as well as the new guidelines developed in the previous study with college-aged women. It demonstrates that the age groups need to be viewed specific to their level of development when assessing strength.

In contrast, other variations of leg machines have been utilized for assessment in evaluating lower body strength. In an earlier study (Hackney, Deutsch & Gillam, 1984), a Universal Gym leg extension machine tested 1RM isometric leg strength and results indicated convincing correlations ($r = 0.81$, $p < .01$) between isometric leg strength and the leg extension apparatus. In another study by Fiatarone (1996), a sample (N=19) of healthy untrained young women performed the double leg press to evaluate leg power and it's correlation to vertical jump performance. Results indicated that double leg press power had a correlation to vertical jump performance ($r = 0.538$, $p < .01$), indicating that vertical jump could be used as a measure of leg muscle power in young women. Furthermore, Jaric, Ugarkovic & Kukolj (2002) utilized a strain gauge Dynamometer to evaluate methods for normalizing muscle strength in young elite athletes. These studies indicate that a wide range of equipment can accurately predict lower body strength.

<u>Sport Performance and Upper Body Strength</u>

Sport performance variables were compared to the 1RM bench press to determine any relationships to muscular strength. These variables included: reps-to-fatigue bench press test, body fat percentage, body mass index, sit-ups, sit and reach, and medicine ball throw. The variables in this study were selected because they are typically utilized in physical fitness assessments at the high school level (Rainey & Murray, 1997) and the athletes were familiar with their testing protocols. The Pearson correlation matrix for upper body strength demonstrated statistical significance (p. < .05) in six out of the seven independent variables with the response variable (1RM Bench Press). The variables were: body fat percentage (p = 0.013), body mass index (p = 0.007), lean body mass (p= 0.000), sit and reach (p = 0.033), bench press repetitions to fatigue (p = 0.000), and medicine ball throw (p = 0.000) indicating a considerable relationship with 1RM upper body assessment. As stated previously, the repetitions to fatigue bench press test (r =0.802) had the highest correlation with 1RM bench press and is consistent with other investigations attempting to correlate 1RM strength. Even though these studies performed different percentages of 1RM loads specific to that population, reliable significant findings were revealed in all settings (Mayhew et al., 1994; Kim, Mayhew & Peterson, 2002).

The second highest correlation with the 1RM bench press was the medicine ball throw (r = 0.635, p=0.000). This sport performance variable has been used to determine upper body strength in all populations because of its simplistic testing procedure of throwing a weighted ball in some variation. For example, ten female volleyball players performed a backward overhead medicine ball toss and vertical jump to assess explosive power resulting in a strong correlation between the two sport performance tests (r= 0.96, p< 0.01). In another study with college female athletes (N=64), a seated shot put was performed to assess anaerobic power and results indicated significant (p < .05) inter-correlations among the different power tests used in the study (Mayhew et al. 1994). Although the positions were different with athletes in a seated or standing position, the technique and weight of the ball varied. However, the mean distances were similar between the throws for both studies (288 cm and 284.30 cm) indicating similar performances for a weighted throw or push. In addition, a recent study utilized the distance of a seated two-hand medicine ball chest throw as a determinant of upper body strength. The intent of the study was to measure the change in strength for different types of push-up programs using medicine ball was because of its ability to significantly ($p < 0.01$) assess strength of the chest and shoulder girdle (Vossen et al., 2000).

Sport Performance and Lower Body Strength

Similar sport performance measures were investigated with 1RM leg press strength to test lower body strength relationships. They included: reps to fatigue leg press, percent body fat, body mass index, lean body mass, sit-ups, 40-yard sprint, vertical jump, sit and reach, and shuttle run (Table 4.4). The Pearson correlation matrix determined that five of the independent variables were significant ($p < .05$) indicating a connection between these variables and 1RM leg press strength. They included: body fat percentage ($p = 0.001$), body mass index ($p = 0. 001$), lean body mass ($p=0.000$), sit and reach ($p = 0.005$), medicine ball throw ($p = 0.004$) and leg press repetitions to fatigue ($p = 0.000$). Once again, the repetitions to fatigue test had the highest relationship with 1RM lower body strength but other variables typically associated with lower body strength were found non-significant which including the vertical jump, 40-yard sprint and shuttle run. This is in contrast to earlier studies that found vertical jump to be a good indicator of lower body strength. In one particular study, vertical jumping ability was found to be a good means of testing leg strength. Results indicated a moderate correlation ($r= 0.40$, $p< .001$) between vertical jump performance and strength measured by isotonic leg press exercises as opposed to low correlation and non-significant findings ($r= 0.112$, $p = 0.172$) in this investigation. The low correlation may be linked to the skill related components of synchronizing the arms and legs to accurately jump. This aspect may counter the pure assessment of the vertical jump test because of the mechanics necessary for maximal performance (Umberger, 1998).

The lower body analyses identified four heavy lifters who averaged 177.3 kg for the 1RM leg press while the rest of the sample averaged 159.2 kg. These same lifters outperformed the testing group in the amount of leg press repetitions performed by an average of 13 repetitions. A few possible explanations exist for the above average performance by these lifters. They were 17-18 years old with at least 3 years experience in the weight-training program. They were above average in height, weight and lean body mass when compared to the group. In regards to lean body mass, research has shown that higher levels of fat free mass are synonymous with increased levels of muscle hypertrophy and athletic success (Petosa & Zupan, 1995). The four lifters were 10 kg higher (57.1 kg) than the average for the group (47.1 kg). They were also considered outstanding athletes in their sport and very dedicated workers in the weight room. Pearson Correlation analysis and Stepwise Regression Analysis was performed without the four heavy lifters and the results were different. Five variables become significant at $p < .10$ (leg press repetitions to fatigue, sit and reach, 40-yard sprint, shuttle run and vertical jump) and three become significant at the $p <. 05$ level (repetitions to fatigue, sit and reach and vertical jump). The leg press repetitions to fatigue variable is still the most important variable in determining a relationship between leg press strength and different types of performance measures. This is evident in the Stepwise Regression models (Table 4.7). However, by including the four heavy lifters other performance measures contribute to the analysis indicating if the sample tested were closer in abilities, more performance measures would be significant in their relationship with 1RM lower body strength.

Based on the data from the National Strength and Conditioning Association (2000) guidelines for strength assessment, including the sport performance measures, comparisons to the present study were investigated for differences in abilities. Testing protocols were followed closely in the procedures in this investigation but college-aged women performed the majority of the results of the descriptive data. The average 1RM bench press was 51 kg by college basketball players, as compared to 36.25 kg for the high school female athletes. Competitive college athletes performed a vertical jump between 41 and 47 cm and ran the 40-yard sprint between 5.5 and 5.96 seconds. The average high school athlete performed a vertical jump of 39.37 cm and performed the 40-yard sprint on average over 6 seconds. The only descriptive data from the National Strength and Conditioning Association (NSCA) manual that was close to the present study was vertical jump performance by 17-year old girls (not necessarily athletes), in which, the female athletes (age 16-18) outperformed them by approximately 10 cm. The protocols and data given by the NSCA provided guidelines for college-age women but not specifically for the high school coach who may have the same need for similar data for the younger female athletic population. Table 5.1 presents a comparison between the results of this investigation and normative data in the NSCA manual for Testing and Evaluation (Harmon et al., 2000), the ACSM’s guide for exercise and testing prescription (1995) and fitness assessment manuals used in the high school setting (Johnson & Nelson, 1986; Rainey & Murray, 1997).

Table 5.1 Mean comparisons of scoring data for females.

Variable	Established Norms		Present Study (N=57)
1RM BP	College Basketball players	51 kg	36.25 kg
VJ	17-year old girls	33 cm	39.37 cm
	18-34 year old women	20 cm	
SIT-UP (reps/min)	Ages 20-29	35 reps	27.18 reps
	Ages 13-18	18-35 reps	
SIT AND REACH	Ages 20-29	51 cm	50.44 cm
	Ages 14-18	25-31 cm	
BF%	Basketball/Volleyball/Softball	21-25%	25.13 %
	Ages 14-17	15-24%	

1RM BP= one repetition maximum bench press
VJ= vertical jump
BF %= body fat percentage

Summary

In conclusion, the intention of this study was to investigate methods of effectively evaluating strength in high school female athletes. Because of the scarcity of research of strength in women, the results of this study are noteworthy. High school girls are a unique population that must have considerations taken when designing a conditioning program that includes strength evaluation. Coaches and teachers who work with females of this age can evaluate strength easily and effectively by the outcomes of this study. The significant correlations demonstrate relationships between 1RM and sport performance measures do exist and can be incorporated into a training program. By using alternative measures of assessment, the coach and teacher can confidently build a program that doesn’t focus on lengthy 1RM testing but increasing performance of the athlete. The regression equations provide a simple method for calculating upper and lower body strength based on repetition testing and are accurate for a wide variety of sports programs. All of the equipment utilized in this study is readily available in most weight rooms and require little technical knowledge to accurately perform. The sport performance measures are common methods of evaluation found in general youth fitness tests, which most athletes are familiar with and comfortable performing.

Future Research

Future research should examine closer age groups with similar performance measures testing their relationships with 1RM upper and lower body strength. Another consideration would be to classify the light, moderate and heavy lifters in some fashion to distinguish subsets of lifting capacities. As demonstrated in the results of lower body strength, there can be unexplained variability in the analyses due to outstanding female athletes. This study took a wide variety of athletes in an off-season conditioning program and tested their weight lifting capabilities. Comparison studies could investigate different female sports programs and the differences in strength performance, both upper and lower body. Also, compare the role of strength evaluation and which sports programs perform better using different performance measures. As demonstrated in this investigation, moderate correlations were indicated between variables other than 1RM and repetitions to fatigue tests. Specifically, it was demonstrated in upper body strength, whereas, the medicine ball was significantly correlated to BPRTF using a 27 kg weight load ($r = 0.688$, $p = 0.000$). In lower body, body mass index was found significant ($r= 0.630$, $p = 0.00$) to LPTRF using a load of 91 kg. This demonstrates the possibility of other investigations utilizing different performance measures to analyze muscular strength.

BIBLIOGRAPHY

1. Abadie, B.R., & Wentworth, M.C. (2000). Prediction of one-repetition maximal strength from a 5-10 repetition submaximal strength test in college-aged women. *Journal of Exercise Physiology, 3 (3),* 211-213.

2. ACSM. (1995). ACM'S guidelines for exercises testing and prescription. 5th ed. Baltimore, MD. Williams & Wilkins, Publishers.

3. Arthur, M. (1982). NSCA tests and measurement survey results. *National Strength and Conditioning Association Journal. 3,* 38A-38-C.

4. Ashley, C.D., & Weiss, L.W. (1994). Vertical jump performance and selected physiological characteristics of women. *Journal of Strength and Conditioning Association, 8 (1),* 5-11.

5. Baechle, T.R., & Earle, R.W. (Eds.). (2000). Essentials of strength training and conditioning. Champaign, IL. Human Kinetics, 393-422.

6. Baechle, T.R., & Groves, B.R. (1994). Weight training instruction: Steps to success. Champaign, IL. Human Kinetics, Publishers.

7. Ball, T.E., C. Van Fleet., R.J LaHey, & Glass. (1995). The relationship of relative muscular endurance to maximal lifting capacity in college men and women (abstract). *Journal of Strength and Conditioning Research, 9,* 277.

8. Basford, J.R. (1985). Weightlifting, weight training and injuries. *Orthopedics, 8 (8),* 1052-1056.

9. Bates, E.L., Clemens, C.T., Busby, J.S., Mayhew, J.L., Glover, J.E., & Bemben, M.G. (1995). Measurement specificity in the determination of 1-RM bench press strength changes following training. *Journal of Strength and Conditioning Research, 9,* 27.

10. Braith. R.W., Graves, J.E., Leggett, S.H. & Pollock, M.L. (1993). Effect of training on the relationship between maximal and submaximal strength. *Medicine, Science and Sports Exercise, 25,* 132-138.

11. Brown, E., & Kimball, R. (1983). Medical history associated with adolescent power lifting. *Pediatrics, 72,* 636-644.

12. Brzycki, M. (1993). Strength testing- predicting a one-rep max from reps-to-fatigue. *JOPERD, 64,* 88-90.

13. Chapman, P.P., Whitehead, J.R., & Brinkert, R.H. (1998). Prediction of 1 RM bench press from the 225 lbs reps to fatigue test in college football players. *Journal of Strength and Conditioning Research, 12 (4),* 258-261.

14. Cohen, J (1998). Statistical power analysis for the behavioral sciences, 2nd ed. Hillsdale, NJ. Lawrence Erlbaum Associates, Publishers.

15. Corbin, C.B., & Pangrazi, R. P. (Eds) (1999). Toward a better understanding of physical fitness and activity. Scottsdale, AZ. Holcomb Hathaway, Publishers.

16. Cummings, B., & Finn, K.J. (1998). Estimation of a one repetition maximum bench press for untrained women. *Journal of Strength and Conditioning Research, 12 (4),* 262-265.

17. Dalton, N.J., & Wallace, J.E. (1996). Strength testing protocols for college-age women. *National Strength and Conditioning Journal, 18 (2),* 7-10.

18. Dean, J.A., Foster, C., & Thompson, J. (1987). A simplified method of assessing muscular strength. *Medicine, Science and Sports Exercise, 19 (2),* 563.

19. Dunn, B., & Halstead, S. (1982). Strength training for women: Issues and answers. *National Strength and Conditioning Journal, 4 (3),* 32-34.

20. Enoka, R.M. (2002). Neuromuscular basis of kinesiology. 3rd ed. Champaign, IL. Human Kinetics, Publishers.

21. Epley, B. (1985). Poundage chart. Boyd Epley workout. Lincoln, NE.

22. Faigenbaum, A.D. (2001). Preseason conditioning for high school athletes. *Strength and Conditioning Journal, 23 (1),* 70-72.

23. Faigenbaum, A.D., Kraemer, W.J., Cahill, B., Chandler, J., Dziados, J., Elfrink, L.D., Forman, D., Gaudiose, M., Mitchell, L., Nitka, M. & Roberts, S. (1996). Youth resistance training: Position statement paper and literature review. *Strength and Conditioning, 18 (6),* 62-75.

24. Fleck, S.J., & Kraemer, W.J. (1997). Designing resistance-training programs. 2nd ed. Champaign, IL. Human Kinetics, Publishers.

25. Fiatarone, T.M. (1996). Leg power in young women: relationship to body composition, strength, and function. *Medicine, Science and Sports Exercise, 28 (10),* 1321-1326.

26. Gadeken, S.B. (1999). Off-season strength, power and plyometric training for kansas state volleyball. *Strength and Conditioning Journal, 21 (5),* 49-55.

27. Gardner, P.J., Stimson, K., Propst, R., & Berry, C.E. (1994). Sports performance evaluation for high school athletes. *National Strength and Conditioning Association, 20 (5),* 20-25.

28. Gillespie, J., & Keenum, S. (1987). A validity and reliability analysis of the seated shot put as a test of power. *Journal of Human Movement Studies, 13*, 97-105.

29. Goranson, G. NSCA convention report: Gail Weldon: Strength training for women's track: Skill improvement and injury prevention. *National Strength Coaches Association Journal, 3 (5),* 22.

30. Gravelle, B.l., & Blessing, D.L. (2000). Physiological adaptation in women concurrently training for strength and endurance. *Journal of Strength and Conditioning Research, 14 (1),* 5-13.

31. Hale, B.S., & Franks, B.D. (2001). Get fit: a handbook for youth ages 6-17: how to get in shape to meet the president's challenge [Electronic Version]. Washington, DC: President's Council on Physical Fitness and Sports.

32. Harmon, E., Garhammer, J., & Pandorf, C. (2000). Testing and evaluation: Essentials of strength and conditioning. 2nd. ed. Champaign, IL. Human Kinetics, Publishers.

33. Healthy People 2000: National Health Promotion and Disease Prevention Objectives. Washington, DC: Dept. Health and Human Services.

34. Heiderscheit, B.C., McClean, K.P., & Davies, G.J. (1996). The effects of isokinetic versus plyometric training on the shoulder internal rotators. *Journal of Orthopedic Sports and Physical Therapy, 23,* 125-133.

35. Heyward, V. (2002). Advanced fitness assessment and exercise prescription. 4th ed. Champaign, IL. Human Kinetics, Publishers.

36. Hoeger, W. K., Hopkins, D.R., Barette, S.E., & Hale, D.F. (1990). Relationship between repetitions and selected percentages of one repetition maximum: A comparison between untrained and trained males and females. *Journal of Applied Sport Science Research, 4,* 47-54.

37. Horvat, M., Ramsey, V., Franklin, C., Gavin, C., Palumbo, T., & Glass, L.A. (2003). A method for predicting maximal strength in collegiate women athletes. *Journal of Strength and Conditioning Research, 17 (2),* 324-328.

38. Horvat, M.A., & Kalakian, L.H. (1995). Assessment in adapted physical education and therapeutic recreation. Dubuque, IW. Wm. C. Brown, Publishers.

39. Invergo, J.J., Ball, T.E., & Looney, M. (1991). Relationship of push-ups and absolute muscular endurance to bench press strength. *Journal of Applied Sports Science Research,* 121-125.

40. Jaric, S., Ugarkovic, D., & Kukolj, M. (2002). Evaluation of methods for normalizing muscle strength in elite and young athletes. *Journal of Sports Medicine and Physical Fitness, 42,* 141-151.

41. Johnson, B.L., & Nelson, J.K. (1986). Practical measurements for evaluation in physical education. 4th ed. Edina, MN. Burgess, Publishers.

42. Keppel, G. (1991). Design and analysis: A researcher's handbook. 3rd ed. Englewood Cliffs, NJ. Prentice Hall, Publishers.

43. Kerlinger, F.N., & Pedhazur, E.J. (1973). Multiple regression in behavioral research. New York, NY. Holt, Rinehart and Winston, Inc.

44. Kerr, A.W., Hall, H.K., & Kozub, S.A. (2002). Doing statistics with spss. Thousand Oaks, CA. Sage, Publishers.

45. Kim, P.S., Mayhew, J.L., & Peterson, D.F. (2002). A modified YMCA bench press test as a predictor of one repetition maximum bench press strength. *Journal of Strength and Conditioning Research, 16 (3),* 440-445.

46. Kraemer, W., & Fleck, S. (1993). Strength training for young athletes. Champaign, IL. Human Kinetics, Publishers.

47. Klavora, P. (2000). Vertical jump tests: A critical review. *National Strength and Conditioning Association, 22 (5)*, 70-75.

48. Knuttgen, H.G., & Kraemer, W.J. (1987). Terminology and assessment in exercise performance. *Journal of Strength and Conditioning Research, 1 (19)*, 1-10.

49. Knutzen, K.M., Brilla, L.R., & Caine, D. (1999). Validity of 1rm prediction equations for older adults. *Journal of Strength and Conditioning Research, 13 (3)*, 242-246.

50. Kraemer, W., & Fry, A. (1995). Strength testing: Development and evaluation methodology. In: Physiological assessment of human fitness. P.J. Maud and C. Foster, eds. Champaign, IL. Human Kinetics, Publishers, 121-122.

51. Kroemer, K.H. (1970). Human strength: Terminology, measurement and interpretation of data. *Human Facilities, 12 (3)*, 297-313.

52. Kuramoto, A.K., & Payne, V.G. (1995). Predicting muscular strength in women: A preliminary study. *Research Quarterly for Exercise and Sport, 66*, 168-172.

53. Lee & Febiger. (1991). Guidelines for exercise testing and prescription. Philadelphia, PA. Lippincott Williams & Wilkins, Publishers.

54. Lesuer, D.A., McCormick, J.H., Mayhew J.L., Wassertein, R.L., & Arnold, M.D. (1997). The accuracy of prediction equations for estimating 1-RM performance in the bench press, squat, and deadlift. *Journal of Strength and Conditioning Research, 11(4)*, 211-213.

55. Mayhew, J.L., Ball, T.E., Arnold, M.D., & Bowen, J.C. (1992). Relative muscular endurance performance as a predictor of bench press strength in college men and women. _Journal of Applied Sports Science Research, 6 (4),_ 200-206.

56. Mayhew, J.L., Ball, T.E., & Bowen, J.C. (1992). Prediction of bench press lifting ability from submaximal repetitions before and after training. _Sports Medicine, Training and Rehabilitation, 3,_ 195-201.

57. Mayhew, J.L., Bemben, M.G., Piper, F.C., Ware, J.S., Rohrs, D.M., & Bemben, D.A. (1993). Assessing bench press power in college football players: The seated shot put. _Journal of Strength and Conditioning Research, 7 (2),_ 95-100.

58. Mayhew, J.L., Bemben, M.G., Rohrs, D.M., & Bemben, D.A. (1994). Specificity among anaerobic power tests in college female athletes. _Journal of Strength and Conditioning Research, 8 (1),_ 43-477.

59. Mayhew, J.L., Prinster, J.S., Ware, D.L., Zimmer, J.R. Arbas., & M.G. Bemben. (1995). Muscular endurance repetitions to predict bench press strength in men of different training levels. _Journal of Sports Medicine and Physical Fitness, 35,_ 108-113.

60. Mayhew. J.L., J.R. Ware., & J.L. Prinster. (1993). Using lift repetitions to predict muscular strength in adolescent males. _National Strength and Conditioning Journal, 15,_ 35-38.

61. McCardle, W.D., Katch, F.J., & Risser, W.L. (1993). Weight training injuries: Common injuries and preventive methods. _Sports Medicine, 16,_ 57-63.

62. Misner, J.E., Boileau, R.A., Plowman, S.A., Elmore, B.G., Gates, M.A.,Gilbert, J.A. & Horswill, C. (1988). Leg power characteristics of female firefighter applicants. _Journal of Occupational Medicine, 30,_ 433-437.

63. Moffatt, R.J., & Cucuzzo, N. (1993). Strength considerations for exercise prescription. American College of Sports Medicine: A resource guide for exercise testing and prescription. 2nd ed. Champaign, IL. Human Kinetics, Publishers.

64. Naughton, D. (1991). Resistance training: The strength wave. *National Strength and Conditioning Journal 13 (5),* 36-37.

65. Nindl, B.C., Mahar, M.T., Harman, E.A., & Patton, J.F. (1995). Lower and upper body anaerobic performance in male and female adolescent athletes. *Medicine and Science in Sports and Exercise, 27(2),* 235-241.

66. Palmer, S., & Mayhew, J.L. (2001). Comparison of absolute and relative muscular endurance techniques for predicting strength in high school athletes (Abstract). *Journal of Strength and Conditioning Research, 15(3),* 397.

67. Pearson, D., Faigenbaum, A.,Conley, M., & Kraemer, W. (2000). The national strength and conditioning association's basic guidelines for the resistance training athletes. *Strength and Conditioning Journal, 22 (4),* 14-27.

68. Pedhazur, E.J. (1997). Multiple regression in behavioral science: Explanation and prediction. 3rd ed. New York. Holt, Rinehart and Winston, Publishers.

69. Petosa, P.S., & Zupan, M.F. (1995). Aerobic training, lean body mass, and athletic performance. *Strength and Conditioning,* 11-17.

70. Pollock, M.L., Wilmore, J.H., & Fox, S.M. (1978). Health and fitness through physical activity. New York, NY. Wiley Associates, Publishers.

71. Rainey, D.L., & Murray, T. D. (1997). Foundations of personal fitness. St. Paul, MN. West Publishing Company.

72. Roetert, E.P., McCormick, S.W., & Ellenbecker, T.S. (1996). Relationship between isokinetic and functional trunk strength in elite junior tennis players. *Isokinetic Exercise and Science, 6,* 196-202.

73. Rose, K., & Ball,T.E. (1992). A field test for predicting maximum bench press lift of college women. *Journal of Applied Sport Science Research, 6*, 103-106.

74. Sale, D.G., & MacDougall, D. (1981). Specificity in strength training: A review for the coach and the athlete. *Canadian Journal of Applied Sport Sciences, 6 (2),* 87-92.

75. Sawyer, D.T., Ostarello, J.Z., Suess, E.A., & Dempsey, M. (2002). Relationship between football playing ability and selected performance measures. *Journal of Strength and Conditioning Research, 16 (4),* 611-616.

76. Schafer, J. (1991). Prepubescent and adolescent weight training: Is it safe? Is it beneficial? *National Strength and Conditioning Association Journal, 13 (1),* 39-46.

77. Semenick, D.M. (1990). Tests and measurements: The t-test. *National Strength and Conditioning Journal, 12 (1),* 68-69.

78. Semenick, D.M. (1994). Testing protocols and procedures: Essentials of strength and conditioning . T.R. Baechle, ed. Champaign, IL. Human Kinetics, Publishers.

79. Simpson, S.R., Rozenek, R., Garhammer, J., Lacourse, M., & Storer, T. (1997). Comparison of one-repetition maximums between free weight and universal machine exercises. *Journal of Strength and Conditioning Research, 11* (2), 103-106.

80. Stockbrugger, B.A., & Haennel, R.G. (2001). Validity and reliability of a medicine ball explosive power test. *Journal of Strength and Conditioning Association, 15 (4),* 431-438.

81. Tanner, J.M. (1962). Growth at adolescence. 2nd ed. Springfield, IL Oxford, Publishers.

82. Thorndyke, M.A. (1995). Evaluating flexibility with the sit and reach test. *Strength and Conditioning,17,* 12-15.

83. Umberger, B.R. (1998). Mechanics of the vertical jump and two- joint muscles: Implications for training. *Strength and Conditioning, 16 (6),* 70-74.

84. Vossen, J.F., Kraemer, J.E., Burke, D.G., & Vossen, D.P. (2000). Comparison of dynamic push-up training and plyometric push-up training on upper body power and strength. *Journal of Strength and Conditioning Research, 14 (3),* 248-253.

85. Ware, J.S., Clemens, C.T., Mayhew, J.L., & Johnston, T.J. (1995). Muscular endurance repetitions to predict bench press and squat strength in college football players. *Journal of Strength and Conditioning Research, 9 (2),* 99-103.

86. Wathan, D. (1994). Load assignment: Essentials of strength training and conditioning. T.R. Baechle, ed. Champaign, IL. Human Kinetics, Publishers. 435-439.

87. Zatsiorsky, V. (1995). Science and practice of strength training. Champaign, IL. Human Kinetics, Publishers.

APPENDIX A

CONSENT FORMS

PERFORMANCE MEASURES AND STRENGTH EVALUATION IN THE HIGH SCHOOL FEMALE ATHLETE

I, ________________________, agree to participate in a research study titled "PERFORMANCE MEASURES AND STRENGTH EVALUATION IN THE HIGH SCHOOL FEMALE ATHLETE" conducted by Debbie Born from Greenbrier High School (706-650-6040) and the Department of Physical Education and Sport Studies at the University of Georgia. I understand that I do not have to partake if I do not want to and I can terminate my involvement at any time. I also understand that participation or non-participation will have no impact on my grades and there will be no instruction time missed during the school day for testing purposes.

The purpose of this study is twofold. The first reason is to determine if there is a significant relationship between upper body strength as measured by the one-repetition maximum and the repetitions to fatigue bench press tests with different performance measures (medicine ball throw, vertical jump, 40-yard sprint, shuttle run, sit and reach flexibility and sit-ups). The second reason for this study is to determine if there is a significant relationship between lower body strength as measured by the one-repetition maximum and repetitions to fatigue seated leg press and the same performance measures used for upper body strength assessment.

The data collected from this study will allow the researcher to determine the correlation for upper and lower body strength using performance measures. This research will allow high school teachers and coaches an easy and effective method of determining upper and lower body strength in female athletes.

If I volunteer to take part in this study, I will be asked to do the following:

1. Have their height and weight measured.
2. Have their total body weight, lean body mass and percent body fat calculated.
3. Participate in warm-up exercises before each bench press and leg press test that includes stretching and calisthenics.
4. Participate in two separate bench press and leg press tests over a course of 3 to 4 weeks.
5. The maximum bench press and leg press tests will be conducted as follows:

    - A warm-up set of several repetitions with a standard 45-lb. free weight bar Olympic bar for the bench press and 160-lbs for leg press machine using the proper weight lifting techniques and assisted by a spotter.
    - Weight will be added to each lift after the warm-up with a standard recovery time of three minutes between each lift until the subject cannot perform the lift successfully.
    - The highest weight lifted will be recorded as the one-repetition maximum.

6. The repetition-to-fatigue tests will be conducted using the same guidelines as the one-repetition test. These tests will determine a sub-maximal bench press weight or percentage of the one-repetition maximum. The participant will use a weight they are comfortable with (typically between 45-95lbs) and perform the bench press until fatigued to the point they cannot lift the weight any longer. The amount of repetitions performed will be recorded.

7. Six performance measures will be utilized to measure upper and lower body strength and endurance

    A. Seated Medicine Ball Throw will measure upper body strength. Participants will sit with the back and shoulders against a wall and perform a two-handed chest pass with a 3-kg medicine ball. Three throws will be performed and marked on the floor and the furthest distance thrown will be recorded.

    B. Double Leg Standing Vertical Jump will measure lower body strength. Participants will stand flat-footed using a countermovement to jump and reach with one hand using a Vertec™ Machine. Three jumps will be performed and the highest jump will be recorded.

    C. Sit and Reach Test will measure flexibility. The participant will sit on the floor with straight legs and reach as far as possible in front of there feet.

    D. Sit-ups will measure core abdominal strength. The participant will perform as many bent knee sit-ups as possible in one minute.

    E. Shuttle Run will measure agility and lower body strength. The participant will sprint from one point to another for a distance no further than 10 yards.

    F. 40-yard sprint will measure lower body strength and power. The participant will run as fast as possible for 40 yards.

8. All tests will require the participant to be tested in the weight room and gymnasium at Greenbrier High School during off-season summer workouts.

9. These tests will then be statistically analyzed to determine relationships for upper and lower body strength using different performance measures for high school female athletes.

Safety procedures will be in place to avoid risk of injury including proper warm-up routines, a spotter for each lift and a terminal number of repetitions. No risk of injury is expected except for soreness in the upper body the following day after each test.

Any information that is obtained in connection with this study and that can be identified with me will remain confidential and will be disclosed only with my permission or as required by law.

Debbie Born will answer any questions about the research, now or during the course of the project, and can be reached by telephone at (706) 650-6043-220. I may also contact the professor supervising the research, Dr. Michael Horvat, Physical Education and Sport Studies, (706)-542-4455.

My signature below indicates that the researchers have answered all of my questions to my satisfaction and that I consent to volunteer for this study. I have been given a copy of this form.

____

Name of Researcher Signature of Researcher Date

____

Name of Participant Signature of Participant Date

Please sign both copies, keep one and return one copy

Questions or problems regarding your rights as a participant should be addressed to Human Subjects Office: Institutional Review Board; Office of V.P. for Research, University of Georgia, 606A Graduate Studies Research Center, Athens, GA 30602-7411. Telephone 706-652-6514.

PARENTAL CONSENT FORM

PERFORMANCE MEASURES AND STRENGTH EVALUATION IN THE HIGH SCHOOL FEMALE ATHLETE

I agree to allow my child ______________________________ to take part in a study titled, "Performance Measures and Strength Evaluation In The High School Female Athlete", which is being conducted by Debbie Born, from Greenbrier High School (706-650-6040) and the Department of Sport Studies at the University of Georgia (706-542-4455). I do not have to allow my child to be in this study if I do not want to. My child can stop taking part at any time without giving any reason, and without penalty. I can ask to have the information related to my child returned to me, removed from the research records, or destroyed.

- The first reason for this study is to determine if there is a significant relationship between upper body strength as measured by the one-repetition maximum and repetitions to fatigue bench press tests with different performance measures (medicine ball throw, vertical jump, 40-yard sprint, shuttle run, sit and reach flexibility and sit-ups).

- The second reason for this study is to determine if there is a significant relationship between lower body strength as measured by the one-repetition maximum and repetitions to fatigue seated leg press with the same performance measures.

- Participation is voluntary and the data that will be collected and that can be identified with the participant will remain confidential and will be disclosed only with the participant's permission or as required by law.

- If I allow my child to take part, my child will be asked to do the following:

    1. Have their height and weight measured.
    2. Have their total body weight, lean body mass and percent body fat calculated.
    3. Participate in warm-up exercises before each bench press and leg press test that includes stretching and calisthenics.
    4. Participate in two separate bench press and leg press tests over a course of 3 to 4 weeks.
    5. The maximum bench press and leg press tests will be conducted as follows:

        - A warm-up set of several repetitions with a standard 45-lb. free weight bar Olympic bar for the bench press and 160-lbs for leg press machine using the proper weight lifting techniques and assisted by a spotter.

- Weight will be added to each lift after the warm-up with a standard recovery time of three minutes between each lift until the subject cannot perform the lift successfully.
- The highest weight lifted will be recorded as the one-repetition maximum.

6. The repetition-to-fatigue tests will be conducted using the same guidelines as the one-repetition test. These tests will determine a sub-maximal bench press weight or percentage of the one-repetition maximum. The participant will use a weight they are comfortable with (typically between 45-95lbs) and perform the bench press until fatigued to the point they cannot lift the weight any longer. The amount of repetitions performed will be recorded.

7. Six performance measures will be utilized to measure upper and lower body strength and endurance

   A. <u>Seated Medicine Ball Throw</u> will measure upper body strength. Participants will sit with the back and shoulders against a wall and perform a two-handed chest pass with a 3-kg medicine ball. Three throws will be performed and marked on the floor and the furthest distance thrown will be recorded.

   B. <u>Double Leg Standing Vertical Jump</u> will measure lower body strength. Participants will stand flat-footed using a countermovement to jump and reach with one hand using a Vertec™ Machine. Three jumps will be performed and the highest jump will be recorded.

   C. <u>Sit and Reach Test</u> will measure flexibility. The participant will sit on the floor with straight legs and reach as far as possible in front of there feet.

   D. <u>Sit-ups</u> will measure core abdominal strength. The participant will perform as many bent knee sit-ups as possible in one minute.

   E. <u>Shuttle Run</u> will measure agility and lower body strength. The participant will sprint from one point to another for a distance no further than 10 yards.

   F. <u>40-yard sprint</u> will measure lower body strength and power. The participant will run as fast as possible for 40 yards.

8. All tests will require the participant to be tested in the weight room and gymnasium at Greenbrier High School during off-season summer workouts.

9. These tests will then be statistically analyzed to determine relationships for upper and lower body strength using different performance measures for high school female athletes.

- Safety procedures will be in place to avoid risk of injury including proper warm-up routines, a spotter for each lift and a terminal number of repetitions. No risk of injury is expected except for soreness in the upper body the following day after each test.

- Debbie Born will answer any questions about the research, now or during the course of the project, and can be reached by telephone at 650-6043-220. I may also contact the professor supervising the research, Dr. Michael Horvat, Physical Education and Sport Studies, 706-542-4455

I understand the study procedures described above. My questions have been answered to my satisfaction, and I agree to allow my child to take part in this study. I have been given a copy of this form to keep.

Name of Researcher___________________ Signature of Researcher_________________________

Telephone ___________________________ Email _________________________

Name of Parent/Guardian___________________________

Signature of Parent/Guardian ____________________________________ Date ________________

Please sign both copies, keep one and return one to the researcher

Questions or problems regarding your child's rights as a participant should be addressed to Human Subjects Office: Institutional Review Board; Office of V.P. for Research, University of Georgia, 606A Graduate Studies Research Center, Athens, GA 30602-7411. Telephone 706-652-6514. E-mail Address- IRB@uga.edu.