2010

Relationship between muscular strength testing to dynamic muscular performance in Division One American football players

Johnathan Fuentes
University of South Florida

Relationship Between Muscular Strength Testing to Dynamic Muscular Performance in Division One American Football Players

by

Johnathan Fuentes

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Arts
Department of Physical Education and Exercise Science
College of Education
University of South Florida

Major Professor: Marcus Kilpatrick, Ph.D.
Bill Campbell, Ph.D.
Yi-Hsin Chen, Ph.D.

Date of Approval:
July 12, 2010

Keywords: squat, sprint, power, college, regression

Table of Contents

List of Tables

Relationship Between Muscular Strength Testing to Dynamic Muscular Performance in Division One American Football Players

Johnathan Fuentes

Abstract

The purpose of this study is to develop a prediction equation for (performance variables) vertical jump, broad jump, 40-yard sprint time, and pro-agility shuttle time using body mass and 1-RM values of strength for bench press and back squat. Participants (n = 76) used in the study were members of the University of South Florida D-1 football team in fall of 2009. Squat/BM demonstrated the strongest relationship in both correlation and multiple regression data for every performance variable. Squat 1-RM and Squat/BP indicated a decreased relationship and negative impact on performance. Results indicate that with increased Squat/BM improvement for all performance variables can be achieved. In addition analysis divided the entire football team into three positions (AT, LN, and SK), and noted differences for 10 of the possible 12 mean comparisons of performance variables.

Chapter One: Introduction and Overview of Study

Most American football athletes strive to lift greater amounts of mass with the intention of improving playing performance. For this reason universities invest increasing amounts of capital into strength and conditioning programs staffed by individuals with the highest level of expertise. The goal of the strength and conditioning staff is the promotion of bigger, stronger, and faster athletes than their competition. With American football being easily the most popular sport in the United States one would assume that research studies looking into relationship analyses between strength tests and performance variables to be significant. Surprisingly not much research has been conducted.

A cornerstone study was conducted by Berg and colleagues in 1987, which included testing performance characteristics of 880 Division-1 (D-1) football players from 40 schools.[1] This groundbreaking study compiled data obtained from elite collegiate football players into a single source. Further contributing to the research in 2000 a similar study by Secora et al., was performed to determine changes in physical characteristics amongst D-1 football players.[2] The Secora study demonstrated that collegiate football

---

[1] Berg, K., and Latin, R. (1990). Physical and performance characteristics of NCAA division 1 football players. *Research Quarterly for Exercise and Sport. 61*(4). 395-401.

[2] Secora, C., Latin, R., Berg, K., and Noble, J. (2004). Comparison of physical and performance characteristics of NCAA division 1 football players: 1987 and 2000. *JSCR. 18*(2). 286-291.

players in 2000 had become bigger, stronger, faster, and more powerful in comparison to the 1987 study. In locating additional studies on individual strength measurements (squat and bench press), and their relationship to various performance tests (vertical jump, broad jump, 40-yard sprint time, and pro-agility shuttle time) a large body of research does exist for most athletic populations. However, little research is available containing a large sample ($n > 50$) size of elite American football players exclusively. With the current gap in research present, the goal of this study was to obtain baseline testing variables for an entire D-1 football team, and identify if a significant relationship exists amongst them. This study obtained data for one repetition maximum (1-RM) in squat and bench press, and compared the results to performance on broad jump, vertical jump, 40-yard sprint time, and pro-agility shuttle time to determine relationship strength. Data obtained was generated for the team as a whole, and later divided into three positions (Athlete, Linemen, and Skill). We hypothesized that too large of an amount of strength would increase body mass, resulting in more work that is required causing a negative response on performance tests that measure time to completion or displacement. In understanding the baseline strength variables tested and their relationship to performance, we have the ability to determine the optimal strength requirements needed to enable athletes to perform at the highest level.

Purpose of Study

The purpose of this study is to develop a prediction equation for (performance variables) vertical jump, broad jump, 40-yard sprint time, and pro-agility shuttle time using body mass and 1-RM values of strength for bench press and back squat.

Performance variables selected for this study are believed to predict American football playing potential.

Predictor and Criterion Variables

The predictor and criterion variables for this study were formulated based upon common maximal strength and performance testing that is currently being administered within collegiate and National Football League (NFL) strength and conditioning settings. Predictor variables utilized include 1-RM bench press and back squat both using a standard 45-pound barbell. The bench press was selected to measure maximal muscular strength of the upper body. The back squat is a measure of maximal muscular strength of the lower body. Criterion variables selected for this study will include broad jump, vertical jump, 40-yard sprint time, and pro-agility shuttle time. The listed criterion variables are used to assess multiplaner and straight line running speed, in addition to maximal power of the lower body musculature in both the frontal and sagittal directional planes.

Muscular Testing

Personnel: Exercise testing protocols were administered by members of the University of South Florida strength and conditioning staff. All members of the strength and conditioning staff are considered experts in their practice, with possession of a degree in Exercise Science or related field. In addition to academic accomplishment all members have obtained certification through the National Strength and Conditioning Association (NSCA) as Certified Strength and Conditioning Specialist (CSCS).

Maximal Strength Testing: Maximal upper body strength was assessed using a barbell bench press. This exercise prescribes for an athlete to load an Olympic barbell with their 1-RM, and complete a full repetition of lowering the weight to the chest cavity proceeded by full extension of the elbows. Maximal lower body strength will be assessed using a barbell back squat. This exercise prescribes for an athlete to load an Olympic barbell with their 1-RM and complete a full repetition of lowering the weight until 80 degree flexion is achieved at the knee joint proceeded by concentrically lifting the load returning back to starting position.

Performance Power Testing: Maximal sprint speed was measured by running 40-yards on a grass surface. Starting position began with the athlete in a three point stance proceeded by sprinting a distance of 40-yards. This test is a measure of dynamic running speed that accounts for stride frequency and stride length. Agility which is measured by lateral speed and coordination was performed on a grass surface using a 5-10-5 pro-agility shuttle. This test is a measure of lateral speed that incorporates acceleration and deceleration while never allowing an athlete to reach maximal speed. To measure maximal vertical leg power a Vertec® was used. This test consists of an athlete standing flat-footed underneath the testing apparatus that measures displacement, and concludes with a vertical jump. This test measures maximal leg power in the frontal plane. Maximal linear leg power was measured using the broad jump. This test consists of an athlete standing flat-footed behind a starting line, and concludes with a jump as far as possible from the initial position sagittaly. This is a test of displacement achieved from start to end position, and measures maximal leg power in the sagittal plane.

Null Hypotheses

Ho_1 There will be no significant relationship with vertical jump to any predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team.

Ho_2 There will be no significant relationship with broad jump to any predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team.

Ho_3 There will be no significant relationship with 40-yard sprint time to any predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team.

Ho_4 There will be no significant relationship with pro-agility shuttle time to any predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team.

H_{O5} There will be no significant differences amongst the means for all criterion variables when divided into the 3 positions (Linemen, Skill and Athlete).

Hypotheses

H_1 There will be a significant relationship with vertical jump to at least one predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team.

H_2 There will be a significant relationship with broad jump to at least one predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team.

H_3 There will be a significant relationship with 40-yard print time to at least one predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team.

H_4 There will be a significant relationship with pro-agility shuttle time to at least one predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team.

H_5 There will be significant differences amongst the means for all criterion variables when divided into the 3 positions (Linemen, Skill and Athlete).

Chapter Two: Literature Review

A significant amount of research exists correlating commonly used strength measurements to performance tests. The majority of the research uses participants from sports other than American football, and as a result very little data is available for the highest level of football competition. The following literature review will provide insight into commonly used performance tests conducted within collegiate strength and conditioning. The review will conclude with presenting significant relationship analyses from previously completed studies using various athletic populations.

Speed, Strength, and Power Among Collegiate Athletes

In the modern era of American football there has been a continued trend towards athletes becoming bigger, faster, and stronger.[3,4] Strength and conditioning has become so technical that prescriptions of exercise aim to develop optimal position specific ranges for: strength, speed and body composition that in theory will translate to success on the playing field.[5] Of all the possible variables that can be tested amongst an athletic

[3] Berg, K., and Latin, R. (1990). 395-401.

[4] Secora, C., Latin, R., Berg, K., and Noble, J. (2004). 286-291.

[5] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) Physical characteristics that predict functional performance in division 1 college football players. *JSCR*. *18*(1). 115-120.

population, power, stamina and body composition (anthropometrics measurements) are of the primary emphasis.[6]

Sprinting speed can be broken up into several different phases such as start, acceleration, and maximal speed, with each requiring a slightly different form of muscular contraction.[7] In a performance test such as the 40-yard sprint, the three phases of a sprint can be divided into the following segments: the initial start consisting of a distance 0-10 yards, acceleration occurring till 10-35 yards, and concluding with maximal speed at 35-40 yards. These phases of speed hold true for many competitive activities. However, in sports where maximal speed is not emphasized, agility or change of direction can become an attribute that enables a participant to distinguish themselves from the competition. A pro-agility shuttle test is a commonly used measurement of an athlete's multidirectional speed. This test requires the participant to start and stop repeatedly while changing direction, using only the first two phases of sprinting, and never obtaining maximal speed.

The ability to propel your body or transfer force generated onto another object could make the difference in nearly all sporting events. Maximal muscular power can be demonstrated by an athlete's ability to make a diving tackle when bringing a running back to the ground or jumping to the highest point to catch a football in an attempt to make a game winning play. Although these specific movements are perceived to be very different, they do share many of the same qualities throughout their range of motion. They require complete body muscular involvement in responding dynamically with

---

[6] Cronin, J. and Hansen, K. (2005). Strength and power predictors of sports speed. *JSCR. 19*(2). 349-357.

[7] Young, W., McLean, B., and Ardagna, J. (1995). Relationship between strength qualities and sprinting performance. *The Journal of Sports Performance Medicine and Physical Fitness. 35.* 13-19.

eccentric and concentric muscular contractions, a result of the stretch shortening cycle and neuromuscular training adaptations acquired. Baseline performance tests that are used to asses movements like the situations previously mentioned are the vertical jump and broad jump. The two jumps attempt to account for lower body muscular power potential and measure displacement in frontal or sagittal planes primarily. [8,9,10,11,12 , 13] Information obtained in the jumping tests are believed to be linked to an athlete's effectiveness or limitations in certain playing situations.

Currently an infinite amount of training techniques and protocols are being prescribed by exercise professionals in an effort to enhance speed, agility, and jump testing performance. It is imperative when prescription is made to not overlook the big picture, which is training that translates to success on the playing field. The importance of strength training on sprinting and jumping performance is often times controversial. [14,15,16,17,18,19,-23] In certain situations it is believed that strength training if overprescribed

---

[8] Berg, K., and Latin, R. (1990). 395-401.

[9] Chelly, M., Fathloun, M., Cherif, N., Ben Amar, M., Tabka, Z., and Van Praagh, E. (2009). Effects of a back squat training program on leg power, jump, and sprint performance in junior soccer players. *JSCR. 23*(8). 2241-2249.

[10] Cronin, J. and Hansen, K. (2005). 349-357

[11] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) 115-120.

[12] Kukolj, M., Ropret, R., Ugarkovic, D., and Jaric., S. (1999). Anthropometric, strength, and power predictors of sprinting performance. *The Journal of Sports Medicine and Physical Fitness. 39.* 120-122.

[13] Nuzzo, J., McBride, J., Cormie, P., and McCaulley, G. (2008). Relationship between countermovement jump performance and multijoint isometric and dynamic tests of strength. *JSCR. 22*(3). 669-707.

[14] Baker, D., and Newton, R. (2008). Comparison of lower body strength. Power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among professional rugby league players. *JSCR. 22*(1) 153-158.

[15] Chelly, M., Fathloun, M., Cherif, N., Ben Amar, M., Tabka, Z., and Van Praagh, E. (2009). 2241-2249.

can potentially lead to an athlete obtaining excessive hypotrophy resulting in a significant increases in body mass. [20,21] This may cause a negative impact on performance if speed or power is compromised. [14, 17, 22, 23] However, other studies indicate a positive relationship with increased absolute strength on athletic performance. [16, 22] With the potential risk associated with performance testing, attention needs to be paid to the proper and most ethical way of evaluating participants. This would enable an increased benefit for both the researcher and the athletic population being studied.

Baseline Testing Variables for D-1 Football Players

In order to have a thorough understanding of the testing data that is to be obtained and interpreted, previous research baseline variables need to be comprehended for the Division-1 (D-1) football population. A landmark study conducted in 1987 by Berg et al. obtained strength and performance testing results using 880 athletes, from 40 D-1

---

[16] Cronin, J. and Hansen, K. (2005). 349-357.

[17] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) 115-120.

[18] Harris, N., Cronin, J., Hopkins, W., and Hansen, K. (2008). Relationship between sprint times and the strength/power outputs of a machine squat jump. *JSCR. 22*(3). 691-698.

[19] Stone, M., Gavin, M., Glaister, M., and Sanders, R. (2002). How much strength is necessary? *Physical Therapy in Sport. 3.* 88-96.

[20] Peterson, M., Alvar, B., and Rhea, M. (2006). The contributions of maximal force production to explosive movement among young collegiate athletes. *JSCR. 20*(4). 867-873.

[21] Young, W., James, R., and Montgomery, I. (2002). Is muscle power related to running speed with changes of direction? *The Journal of Sports Performance and Physical Fitness. 42.* 282-288.

[22] Wisloff, U., Caragna, C., and Helgererud, J. (2004). Strong Correlation of Maximal Squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine. 38*. 285-288.

[23] Nuzzo, J., McBride, J., Cormie, P., and McCaulley, G. (2008). 669-707.

football programs.[24] This study supplied information that provided a snapshot by position of testing variables and anthropometric measurements across a large population. Significant differences were demonstrated when data was divided by position. Data also suggested that defensive players were leaner and had an increased performance on tests such as 40-yard sprint time and vertical jump. Please refer to Appendix One, for further description. Later work by Secura et al. looked to expand on the findings previously presented by Berg, by conducting a similar study design in 2000. [24, 25] The new study retained the same methods and used 797 athletes, from 37 D-1 football programs. Results of the study identify similar results as the Berg et al. findings in displaying significant differences when dividing by position. The current study also identified that college football players in general have become bigger, stronger, faster, and more powerful in comparison to 1987. Appendix Two provides a contrast of these two studies. A study by Carbuhn et al. used 85 first year D-1 football players in tests coinciding to those used in the Berg and Secura studies. [25, 26, 27] This study also noted differences on performance means when dividing by position. Carbuhn went a step further in comparing results obtained to National Football League (NFL) athletes. When analyses were conducted between NCAA D-1 and NFL athletes, collegiate athletes demonstrated increased amounts of strength for 1-RM bench press. However, NFL athletes displayed an increase in height when compared to collegiate athletes. Please refer to Appendix Three for comparison of NCAA D-1 to NFL athletes.

---

[24] Berg, K., and Latin, R. (1990). 395-401.

[25] Secora, C., Latin, R., Berg, K., and Noble, J. (2004). 286-291.

[27] Carbuhn, A., Womack, J., Green, J., Morgan, K., Miller, G., and Crouse, S. (2008). Performance and blood pressure characteristics of first-year national collegiate athletic association division 1 football players. *JSCR. 22*(4). 1347-1354.

The baseline studies mentioned provided a significant amount of descriptive statistical computations for D-1 American football players. This provides strength and conditioning professional with the opportunity to identify trends and basic characteristics that are required for performance at the investigated level of competition. They do however fail to provide further, more complex statistical analyses methods as to identify relationships amongst the baseline variables tested. With only a limited amount of recognizable research contributed to baseline characteristics of D-1 American football players a glaring gap in research can be observed.

Strength to Performance

Muscular strength constitutes to a large component of the amount of success that can be achieved on the football playing field. The previously mentioned studies provided baseline variables for D-1 football players in general and relative to position. This information now allows strength and conditioning personnel to develop training regimens so that similar results could be obtained by their athletes. The goal of any strength and conditioning program is providing the opportunity for athletes to be placed in the best physical position so that they could excel in sport.

Strength training has a positive relationship with muscular performance.[28] The greater the amount of strength is associated with an increase in fat free mass, which is optimal in most competitive sports. Several studies have demonstrated this concept in analyzing the relationship between absolute squat performance to sprinting, jumping, and shuttle ability. [29, 30, 29, 31] These findings demonstrated that a significant relationship does

[28] National Strength and Conditioning Association (2nd Edition). (2000). *Essentials of strength training and conditioning.* Champaign, IL: Human Kinetics.

exist between squat RM (repetition maximum) when compared to sprinting performance (10-40 meters). [29] In addition to the relationship on sprint performance, squat RM is also strongly correlated with vertical jump displacement and shuttle time to completion. [30] However a study conducted by Cronin et al [31] found conflicting results when comparing 3-RM totals from squat to sprinting ability. Results of his study demonstrated no significant relationship between squat strength and sprinting performance (10 and 30 meters).

The previously mentioned studies provide somewhat conflicting results when comparing strength to performance variables. A potential weakness of the studies could be failure in the ability to contribute RM values to be relative to body mass (RM/BM). The populations selected to participate in the studies included athletes from rugby, soccer, and track teams. Being relative to body composition by sport there are significant differences in rugby and track participants when divided by position. However body stature of soccer participants is relatively similar when compared. This potentially is the underlying issue with the previously mentioned studies conflicting results, in not being relative to body mass. Research utilized participants from varied sports backgrounds and attempted to compare results based on absolute strength. In sports with distinct body structures by position such as American football, absolute RM values are not in favor, and have recently begun to be overlooked by strength relative to body mass values.

---

[29] Wisloff, U., Caragna, C., and Helgererud, J. (2004). 285-288.

[30] Baker, D., and Newton, R. (2008). 153-158.

[31] Cronin, J. and Hansen, K. (2005). 349-357.

Strength Relative to Body Mass on Performance

In distinguishing between absolute and relative values of strength body composition can largely impact the outcome of any study. It is agreed that larger athletes are often times stronger than their smaller counterparts when comparison is made in terms of absolute strength. However, this is somewhat misleading in suggesting that smaller athletes are inferior. The reality is that for specific responsibilities within athletics the strongest athlete is not always the best option, but instead the stronger athlete relative to body mass may perform superior. Athletes who have high strength relative to body mass value demonstrate leaner body composition and as a result for certain positions may be more athletically suitable. [32,33,34,35]

An overwhelming amount of research exists suggesting that individuals with an increased squat to body mass ratio (Squat/BM) perform superior in sprinting events when compared to those with a decreased ratio.[36,37,38,39,40] Research conducted by Mcbride et al. concluded with their study that athletes with a Squat/BM greater than 2.10, outperform

---

[32] Berg, K., and Latin, R. (1990). 395-401.

[33] Cronin, J. and Hansen, K. (2005). 349-357.

[34] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004). 115-120.

[35] Kuzmits, F., and Adams, A., (2008). The NFL combine: Does it predict performance in the National Football League? *JSCR. 22*(6). 1721-1727.

[36] Baker, D., and Newton, R. (2008). 153-158.

[37] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) 115-120.

[38] Harris, N., Cronin, J., Hopkins, W., and Hansen, K. (2008). 691-698.

[39] McBride, J., Blow, D., Kirby, T., Haines, T., Dayne, A., and Triplett, N. (2009). Relationship between maximal squat strength and five, ten, and forty yard sprint times. *JSCR. 23*(6). 1633-1636.

[40] Nuzzo, J., McBride, J., Cormie, P., and McCaulley, G. (2008). 669-707.

athletes with a Squat/BM ratio below 1.90 in sprinting events.[40] This data suggested that resistance training to improve strength can be beneficial in improving sprinting speed if body mass is maintained or a reduction in body fat is achieved. In addition to sprint performance, Squat/BM has a strong relationship to jumping ability. This agrees with simple physics indicating that the lighter an object's mass, results in less work required to propel it when working against gravity.[41] A study by Nuzzo et al. is an example of further solidifying this result. This study compared 1-RM Squat /BM to counter-movement jumping performance. Results of the study demonstrated a significant relationship amongst the two variables indicating and increase in 1-RM Squat/BM has a positive effect on jumping performance. . However, when comparing absolute squat to jumping performance, no significant relationships were observed amongst the same participants. [42]

Shuttle tests are also a commonly used performance modality amongst football strength and conditioning personnel. Agility test provide the researcher or coach with information on a participants stop and start, or change of direction speed. The inclusion of Squat/BM has demonstrated a positive effect correlation to performance in agility tests. [43] Additionally, a study conducted by Davis et al., found a positive relationship between bench press relative to body mass (BP/BM) and pro-agility shuttle performance. [44] The Davis et al. study indicates that although agility is perceived to solely be a lower body attribute, the level of performance that is to be achieved is also related to upper

---

[41] Cutnell, J., and Johnson, K. (2005). Physics (6th Edition). Danvers, MA: John Wiley & Sons Inc.

[42] Nuzzo, J., McBride, J., Cormie, P., and McCaulley, G. (2008). 669-707.

[43] Wisloff, U., Caragna, C., and Helgererud, J. (2004). 285-288.

[44] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) 115-120.

body musculature. This can be conceptualized as having a muscular balanced stature of lower and upper body strength with relatively low amount of body fat.

Although the above mentioned research appears to provide training recommendations that would translate to D-1 American football athletes, only two used football players as participants. [43, 45] With one study using four and the other using seventeen D-1-AA participants respectfully. The studies outlined above further convey the lack of relationship analyses research available using D-1 American football athletes as participants.

Summary of Literature Review

The strength and conditioning field is in constant transformations with the latest trends coming and going quicker than sports seasons. With the amount of research currently available justifications can be made for nearly every exercise modality or training protocol aimed at improving performance. The baseline information that was generated in the research by Berg, Secura, and Cabuhn supplied data for comparison with this study for the measurements of strength (1-RM bench press, 1-RM back squat) and performance (vertical jump, broad jump, 40-yard sprint time, pro-agility shuttle time). It also indicated that the fundamental core exercises used in the past (squat, bench press) are still excellent modes of training D-1 American collegiate football athletes. Although the training protocols continue to evolve many of the strength and performance measurements remain constant.

In reflecting upon the literature review, assumptions can be made and performance variables predicted. However, large gaps in research are currently present

[45] McBride, J., Blow, D., Kirby, T., Haines, T., Dayne, A., and Triplett, N. (2009). 1633-1636.

when using a large population (>70) of D-1 American collegiate football players. Substantial research is available for other sports (rugby, soccer, track, field), but research on high level (Division 1) collegiate football athletes is scarce. The proposed study attempts to determine if a relationship exists between strength (1-RM squat, 1-RM bench press) and power (broad jump, vertical jump, 40-yard sprint time, pro-agility shuttle time) testing variables when made relative to body mass. Currently a significant amount of data is available indicating that a relationship does exists in athletes between these variables however, research needs to be conducted using a large D-1 football population.

Chapter Three: Methods

Purpose

The purpose of this study is to assess the relationship between maximal strength measurements, and popular performance tests. The maximal strength measurement data that was obtained are 1-RM values for both bench press and back squat using a standard 45-pound barbell. Performance testing data was obtained for vertical jump, broad jump, 40-yard sprint time, and pro-agility shuttle time. Values gathered in testing were used to determine if a significant relationship exists between strength and performance tests. Results of the strength test were divided into three predictor variables consisting of absolute 1-RM squat strength (Squat), absolute 1-RM squat and bench press ratio (Squat/BP), and absolute 1-RM squat relative to body mass (Squat/BM). Data obtained was compared to performance tests for the team as a whole. Results on performance test were also separated into three positions: athletes (AT), linemen (LN), and skill (Skill). Athletes included: running backs, tightends, defensive ends, and linebackers, linemen included: offensive line, interior defensive linemen, snappers, and skill included: receivers, quarterbacks, defensive backs, kickers and punters, with division into three positions placed participants with similar physical characteristics together.

Data for this study was obtained for the fall portion during the off-season of football training macrocycle. The participants utilized modify resistance training regimens with the use four-week microcycles intervals. Results for this study were conducted on the fourth and fifth weeks of training following three weeks of unsupervised postseason recovery time. Weeks four and five of training concludes with hypertrophy/endurance then transitions to strength training. Muscular strength and performance data collection for this study were administered twice per week for two weeks following a general total body warm-up as a team. Bench press 1-RM, vertical jump, and broad jump were collected on day one of week 4, and following three days rest squat 1-RM was collected, while simultaneously concluding the hypertrophy/ endurance microcycle. On day one of the strength training cycle pro-agility testing was conducted, and following three days of recovery 40-yard sprint results were obtained, completing data collection for all strength and power variables. Descriptive statistics obtained for this study were collected over the course of the first three weeks of training following postseason unsupervised active recovery period. Table 1 further illustrates a timeline for data collection.

Table 1 - Timeline for Data Collection

	Microcycles					
	Off-Season	**Hypertrophy/ Endurance**			**Strength**	
Week (day)	(-)3 - 0	1 - 3	4 (1)	4 (5)	5 (1)	5 (5)
Data Collected	(none)	Descriptive	Vertical Jump Broad Jump Benchpress RM	Squat RM	Pro-Agility	40-Yard

Participants

Seventy-six D-1 male athletes from the 2009 University of South Florida (USF) football team participated in this study. The USF football team is a member of the Big East Conference which is BCS (Bowl Championship Series) eligible. All participants provided consent to maximal testing while maintaining active membership on the football team and general student body.

Constructs

Maximal Strength Testing: Testing variables selected to determine absolute upper and lower body musculature strength included: 1-RM load for the bench press and back squat using a 45-pound barbell.

Performance Power Testing: Testing variables selected to measure dynamic muscular power of the lower body in either displacement or time to completion included: vertical jump, broad jump, 40-yard sprint time, and pro-agility shuttle time.

Constitutive Definitions

Musculature: Single and multiple-joint muscles required to accomplish skeletal movement.

Upper Body: Muscles from the waist-up

In the bench press exercise a force is delivered on a barbell in the sagittal plane away from chest cavity while lying prone. Primary muscles required for movement include the pectoralis major and triceps.

Lower Body: Muscles from the waist-down.

In the back squat exercise a force is delivered on a barbell in the frontal plane away from the ground while standing erect. Primary muscles required for movement include the gluteus maximus, hamstrings and quadriceps.

Load: The amount of mass assigned to an exercise.

Strength: The maximal force that a muscle or muscle group can apply on an object(s).

Muscular Power: The time rate of doing work.

Displacement: A vector that points from an object's initial position to its final or highest position and has a magnitude that equals the shortest distance between the two positions.

Time to Completion: Duration in seconds required to complete a task.

Repetition: The number of times an exercise can be performed with proper technique.

1-RM (repetition maximum): The greatest amount of weight that can be lifted with proper technique for only one repetition.

Mass: The gravitational pull the earth has on an object. Mass can also be substituted for weight.

Directional/Anatomical Planes: Three directional movements of the body.

Sagittal: Movement that occurs in front or behind the body. Divides body anatomically into left and right.

Frontal: Movement that occurs in a lateral direction to the body. Divides body anatomically into front and back

Transverse: Movements that occur in a rotational direction to the body. Divides body anatomically into top and bottom.

Operational Definition

Maximal Strength Testing: Bench Press: Maximal upper body strength was assessed using 1-RM barbell bench press. For this exercise athletes warmed up with 135-pound of barbell mass and progressively increase load until a 1-RM was achieved. The athlete's goal in this exercise is to lift as much mass as possible. The starting position for this test is lying down supine on a bench with arms extended in front of torso gripping a standard 45-pound barbell loaded with athlete's 1-RM value. Recording of amount lifted concluded with a full repetition consisting of lowering the load to the chest eccentrically proceeded with concentrically raising the load returning it back to the starting position. [46,47,48]

Back Squat: Maximal lower body strength was assessed using 1-RM barbell back squat. For this exercise athletes warmed up with 135-pound barbell mass and progressively increased load until a 1-RM was achieved. The athlete's goal in this exercise is to lift as much mass as possible. Starting position is standing while gripping a standard 45-pound barbell on the top of the back posterior to the shoulders loaded with athlete's 1-RM value. Recording of amount lifted concluded with a full repetition consisting of lowering the load eccentrically until 80-degree flexion of the knee is achieved, proceeded with concentrically raising the load returning it back to the starting position. The amortization phase of 80-degree knee flexion was marked by placing an

---

[46] American College of Sports Medicine (8th Ed.). (2010). *Guidelines for exercise testing and prescription.* Philadelphia, PA: Lippincott, Williams & Wilkins.

[47] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) 115-120.

[48] National Strength and Conditioning Association (2nd Edition). (2000). Essential of strength and conditioning.

elastic band at position below the gluteus where 80-degree knee flexion is accomplished. The protocols used for the back squat in this study are unique and were generated partially by each of the articles cited. [47,49,49]

Performance Power Testing: 40-yard sprint: Maximal sprint speed was measured using a distance of 40-yards on a grass surface with a Speed Trap 1™ electric timer. Starting in a three-point stance, the athlete sprints 40-yards as fast as possible. The timer is located at the start and finish line. Data was recorded as the best time to completion following three trials. Rest was compensated by facilitating full recovery for participants, allowing two to five minutes at the conclusion of each trial. [50,51,52,53]

Pro-agility shuttle: Agility which is measured by lateral speed and coordination was performed on a grass surface using a 5-10-5 pro-agility shuttle, with a Speed Trap 1 electric timer. For this test, the athlete started in a three-point stance and sprints 5-yards to the left, 10-yards to the right, and concludes by sprinting 5-yards to the left returning to the initial start position. Data was recorded as the best time to completion following three trials. Rest was compensated by facilitating full recovery for participants, allowing two to five minutes at the conclusion of each trial.[52, 53, 54]

---

[49] Baker, D., and Newton, R. (2008). 153-158.

[50] American College of Sports Medicine (8th Ed.). (2010). *Guidelines for exercise testing and prescription.*

[51] National Strength and Conditioning Association (2nd Edition). (2000). Essential of strength and condition.

[52] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) 115-120.

[53] Baker, D., and Newton, R. (2008). 153-158.

[54] American College of Sports Medicine (8th Ed.). (2010). *Guidelines for exercise testing and prescription.*

Vertical jump: To measure maximal vertical leg power a Vertec® which consists of tiles that measures vertical displacement (in 0.5 inch increments) from the ground was used. For this test the athlete stood flat-footed (on rubber flooring) beside the testing apparatus, with dominant arm extended overhead reaching as high as possible. The athlete then jumped by lowering the hips eccentrically before concentrically jumping extending the hips and swats as many tiles as possible with one hand. Data was recorded as best total displacement achieved vertically from the standing height with one arm extended, to highest tile contacted following three trials. Rest was compensated by facilitating full recovery for participants, allowing two to five minutes at the conclusion of each trial. [55,56,57,58]

Broad jump: To measure horizontal displacement the broad jump was used on a rubber surface. This test begins by having the athlete stand flat footed behind a line, and is completed once they jumped as far away from the line as possible. Lateral displacement from starting point is recorded. Data was recorded as the best total displacement achieved horizontally from start line, to back of the heels at the conclusion of three jump trials. Rest was compensated by facilitating full recovery for participants, allowing two to five minutes at the conclusion of each trial. [56]

---

[55] American College of Sports Medicine (8th Ed.). (2010). *Guidelines for exercise testing and prescription.*

[56] National Strength and Conditioning Association (2nd Edition). (2000). Essential of strength and condition.

[57] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) 115-120.

[58] Baker, D., and Newton, R. (2008). 153-158

Statistical Analyses

Statistical analyses were performed using SPSS's (Statistical Package for the Social Sciences) premier program software PASW (Predictive Analytics SoftWare, 2009-2010) Statistics. Descriptive statistics describing mean, standard deviation, skewness, and kurtosis were used to identify basic characteristics of the population as a whole and further by the three football positions (Linemen, Skill, and Athletes). Means obtained through descriptive statistics were used to test the null and research hypotheses, by determining if significant differences are present between mean values for criterion variables when dividing by position. Skewness determines the asymmetry of the distribution of variables, while kurtosis is a measure of "peakedness" or amount of variance amongst variables. Both of the previously mentioned statistical measures identify characteristics for the data as a whole.

Pearson product moment correlations were conducted to demonstrate the direction, and strength of a correlation between the variables being tested. Correlations will be considered significant with a p-value < 0.05. The correlation "r" will identify whether the two variables have a positive/ negative or strong/ weak association with each other. Correlations were formulated to test null hypotheses and research hypotheses using the entire team. Each predictor variable was correlated to each criterion variable.

Additionally, multiple regression was used to test the null and research hypothesis and identify the relationship that multiple predictor variables have on a single criterion variable. Multiple regression provides a more in depth output than the previously mentioned correlation. Multiple regression determines the best possible weighted combination of the 3 predictor variables tested to a single criterion variable (Vertical

Jump, Broad Jump, 40-Yard Time, Pro-Agility Time). Output will be considered significant with a p-value < 0.05. The βeta's in a regression model identifies the relationship of the predictor variables to the criterion variable in an equation. In addition degrees of freedom will be reported (df) which identifies the number of values that are free to vary once final calculations are completed. Results will be used to test null and research hypotheses and will indicate the relationship effect that each predictor variable has on the criterion variable for the team as a whole.

A one-way ANOVA was used to determine if significant differences were present when comparing means of performance variables by each position. The Tukey-HSD was used to identify where differences reported by ANOVA were located within the analyses. A significant difference will be identified with a p-value < 0.05. In addition degrees of freedom will be reported (df) which identifies the number of values that are free to vary once final calculations are completed. Results will be used to test hypothesis and will indicate if differences are identified amongst means when divided by position

Chapter Four: Results

Descriptive statistics are presented in Table 2. Hypotheses were tested using a variety of statistical tools including ANOVA's, Tukey-HSD, Pearson product moment correlation, and multiple regression. Tukey-HSD was used to determine where significant differences occurred when comparing means of criterion variables when divided by position (Athlete, Linemen, and Skill). Correlation and multiple regression were conducted to identify the significance of the relationship between the predictor variable(s) and a criterion variable.

Table 2 - Descriptive Statistics for Participants

	Team n=76 (43*)	Skew.	Kurt.	Linemen n=21 (11*)	Skill n=29 (15*)	Athlete n=26 (17*)
Variable	Mean ± SD			Mean ± SD	Mean ± SD	Mean ± SD
Age (years)	21.0 ± 1.2	-0.20	-0.92	20.7 ± 1.0	21.0 ± 1.2	21.3 ± 1.3
Height (inches)	72.9 ± 2.5	0.31	0.31	74.3 ± 2.0	71.8 ± 1.7	72.8 ± 3.1
Weight (pounds)	229.1 ± 43	0.65	-0.65	284.4 ± 31	192.1 ± 14	224.3 ± 21
Bench Press (pounds)	315 ± 47	0.21	-0.19	344.7 ± 44	282.1 ± 36	330.4 ± 38
Squat (pounds)	435 ± 66	-0.07	-0.70	475.9 ± 68	393 ± 53	452.9 ± 51
Vertical Jump (inches)	30.2 ± 4.1	-0.40	-0.50	25.9 ± 3.7	32.5 ± 3.2	30.9 ± 2.9
Broad Jump (inches)	106.4 ± 10.3	-0.62	-0.40	94.2 ± 9.2	112.8 ± 5.9	108.1 ± 6.5
Forty Sprint (seconds)	5.07 ± 0.37	0.65	-0.66	5.51 ± 0.26	4.75 ± 0.15	4.97 ± 0.20
Pro-Agility (seconds)	4.6 ± 0.34	0.65	-0.56	4.99 ± 0.26	4.32 ± 0.17	4.51 ± 0.18
Squat/ BodyMass (ratio)	1.95 ± 0.31	0.23	0.55	1.66 ± 0.20	2.07 ± 0.31	2.01 ± 0.29
Squat/BenchPress (ratio)	1.39 ± 0.15	0.86	2.23	1.37 ± 0.15	1.42 ± 0.17	1.39 ± 0.14

***= valid n**

Table 3 - Correlation of Predictor to Criterion Variables

Criterion	Squat 1RM	Squat/ BM	Squat/BP
Vertical Jump x = 66	r= -0.02	r= 0.65**	r= 0.13
Broad Jump x = 66	r= -0.26*	r= 0.57**	r= 0.02
Forty Yard x = 61	r= 0.31**	r= -0.64**	r= -0.14
Pro-Agility x = 60	r= 0.36**	r= -0.66**	r= -0.12

(Sig. p ≤ 0.01, * Sig. p ≤ 0.05)**

Table 4 - Whole Team Multiple Regression Results

Multiple Regression Formula, $y = a + b_1x_1 + b_2x_2 + b_3x_3$

Criterion (y)	Squat(β_1)	Squat/BM(β_2)	Squat/BP(β_3)	Constant	F	df	p - value
Vertical Jump x = 66	-0.18	+0.81**	-0.23*	22.95	18.2	3, 56	p≤ 0.001
Broad Jump x = 66	-042**	+0.82**	-0.27*	107.15	24.9	3, 56	p ≤ 0.001
Forty Yard x = 61	+0.45**	-0.78**	+0.09	5.33	26.2	3, 47	p≤ 0.001
Pro-Agility x = 60	+0.50**	-0.82**	+0.12	4.75	37.0	3, 47	p≤ 0.001

(Sig. p ≤ 0.01, * Sig. p ≤ 0.05)**

Table 5 - Mean Difference Analyses by Position- ANOVA with Tukey

Vertical Jump	**F**		**df**	**p-value**
	21.5		2, 63	≤ 0.0001
	Mean	**vs.**	**Mean**	
Skill vs. Linemen	32.5		25.9	≤ 0.001**
Skill vs. Athlete	32.5		30.9	= 0.24
Athlete vs Linemen	30.9		25.9	≤ 0.000**

Broad Jump	**F**		**df**	**p-value**
	36.1		2, 63	≤ 0.001
	Mean	**vs.**	**Mean**	
Skill vs. Linemen	112.8		94.2	≤ 0.000**
Skill vs. Athlete	112.8		108.1	= 0.060
Athlete vs Linemen	108.1		94.2	≤ 0.000**

40-yard time	**F**		**Df**	**p-value**
	68.2		2, 58	≤ 0.001
	Mean	**vs.**	**Mean**	
Skill vs. Linemen	4.75		5.51	≤ 0.000**
Skill vs. Athlete	4.75		4.97	≤ 0.003**
Athlete vs Linemen	4.97		5.51	≤ 0.000**

Vertical Jump	**F**		**Df**	**p-value**
	51.8		2, 57	≤ 0.001
	Mean	**vs.**	**Mean**	
Skill vs. Linemen	4.32		4.99	≤ 0.000**
Skill vs. Athlete	4.32		4.51	≤ 0.003**
Athlete vs Linemen	4.51		4.99	≤ 0.000**

(Sig. p ≤ 0.01, * Sig. p ≤ 0.05)**

Table 3 provides Pearson product moment correlations noting strength and significance of possible correlations between a single predictor variable to a single performance variable. Multiple regression data found on Table 4 identify βeta weights and direction, significance, and standard error of estimate using multiple predictor variables to a single performance variable. Table 5 presents significant mean differences noted when comparing performance variables, in addition to providing post-hoc analyses subdivided by position.

Performance Test Results

Vertical Jump: Ho_1 stated that there will be no significant relationship with vertical jump to any predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team. Inversely H_1 stated there will be a significant relationship with vertical jump to at least one predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team. Statistically significant Pearson product moment-correlations were noted for vertical jump to Squat/BM ($p \leq 0.01$, $r = 0.65$), but not for Squat 1-RM ($p = 0.85$, $r = -0.02$) and Squat/BP ($p \leq 0.33$, $r = 0.13$). Multiple regression analyses revealed two significant predictors for vertical jump. Results identified relationships to Squat/BM ($p \leq 0.01$, $\beta = 0.81$) and Squat/BP ($p \leq 0.05$, $\beta = -0.23$), but not for Squat 1-RM ($p \leq 0.08$, $\beta = -0.23$) predictor variables with a large effect size (f^2 0.98) ($y = 22.95 - 0.18x_1 + 0.81x_2 - 0.23x_3$). Therefore, the null hypothesis (H_{O1}) is rejected and the research hypothesis (H_1) is accepted.

Broad Jump: Ho_2 stated that there will be no significant relationship with broad jump to any predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team. Inversely H_2 stated that there will be a significant relationship with broad jump to at least one predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team. Statistically significant Pearson product moment-correlations were noted for broad jump to Squat/BM ($p \leq 0.01$, $r = 0.57$) and Squat-RM ($p \leq 0.05$, $r = -0.26$), but not for Squat/BP ($p = 0.87$, $r = 0.02$). In addition, multiple regression analyses revealed significant predictors of broad jump. Results identified relationships to all predictor variables [Squat 1-RM ($p \leq 0.01$, $\beta= -0.42$), Squat/BM ($p \leq 0.01$, $\beta = 0.82$), and Squat/BP ($p \leq 0.05$, $\beta = -0.27$] with a large effect size (f^2 1.33) ($y= 107.1 - 0.42x_1 + 0.82x_2 - 0.27x_3$). The null hypothesis ($H_{O2}$) is rejected and the research the hypothesis (H_2) is accepted.

40-yard sprint time: Ho_3 stated that there will be no significant relationship with 40-yard sprint time to any predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team. Inversely, H_3 stated that there will be a significant relationship with 40-yard sprint time to at least one predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team. Statistically significant Pearson product moment-correlations were noted for 40-yard sprint time to Squat 1-RM ($p \leq 0.01$, $r = 0.31$) and Squat/BM ($p \leq 0.01$, $r = 0.64$), but not for Squat/BP ($p = 0.31$, $r = -0.14$. Multiple regression analyses revealed two significant predictors of 40-yard sprint time. Results identified relationships with Squat 1-RM ($p \leq 0.01$, $\beta = 0.45$), and Squat/BM ($p \leq 0.01$, $\beta = -0.78$), but not for Squat/BP ($p = 0.38$, $\beta = 0.09$) predictor variables with a large effect size ($f^2= 1.67$) ($y= 5.33 + 0.45x_1 - 0.78x_2 + 0.09x_3$). The null hypothesis ($H_{O3}$) is rejected and the research the hypothesis (H_3) is accepted.

Pro-agility shuttle time: Ho_4 stated that there will be no significant relationship with pro-agility shuttle time to any predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team. Inversely, H_4 stated there will be a significant relationship with pro-agility shuttle time to at least one predictor variable including: Squat 1-RM, Squat/BM, and Squat/BP for the entire football team. Statistically significant Pearson product moment-correlations were noted for pro-agility shuttle time to Squat 1-RM ($p \leq 0.01$, $r = 0.36$) and Squat/BM ($p \leq 0.01$, $r = -0.66$), but not for Squat/BP ($p = 0.39$, $r = -0.12$). Multiple regression analyses revealed two significant predictors of pro-agility shuttle time. Results identified relationships with Squat 1-RM ($p \leq 0.01$, $\beta = 0.50$), and Squat/BM ($p \leq 0.01$, $\beta = -0.82$), but not for Squat/BP ($p = 0.22$, $\beta = 0.12$) predictor variables with a large effect size ($f^2 = 2.36$) ($y = 4.75 + 0.50x_1 - 0.82x_2 + 0.12x_3$). The null hypothesis ($H_{O4}$) is rejected and the research the hypothesis (H_4) is accepted.

Mean performance test analyses by position: H_{O5} stated that there will be no significant differences amongst the means for criterion variables when divided amongst the 3 positions (Linemen, Skill and Athlete). Inversely H_5 stated there will be significant differences amongst the means for criterion variables when divided amongst the 3 positions (Linemen, Skill and Athlete). Completion of a one-way ANOVA determined that differences do exists. Tukey-HSD tests were used to identify which groups differed from each other. Results for the broad jump and vertical jump exhibited significant mean differences when comparing the means for Skill vs. Linemen, and Athlete vs. Linemen positions. However no statistical significant differences were noted when comparing means for Athlete vs. Skill positions for the two jump criterion variables. In addition, statistically significant differences were observed using the Tukey-HSD for all of the possible mean comparisons by position with the 40-yard sprint time and pro-agility shuttle time. Therefore, the null hypothesis (H_{O5}) is rejected and the research hypothesis (H_5) is accepted.

Chapter Five: Discussion

Muscular power performance in running and jumping dynamic activities are considered required components in order to achieve success on the American football playing field. Football strength and conditioning settings for collegiate and professional teams often use muscular performance testing to determine athletic potential of participants. Popular strength and conditioning muscular performance test variables include: bench press 1-RM, squat 1-RM, broad jump, vertical jump, 40-yard sprint time, and pro-agility shuttle time. This study collected data for those variables from a population of 76 division one (D-1) American football participants. The purpose of this study was to determine if a significant relationship exists between popular muscular testing variables, enabling strength and conditioning professionals to provide accurate exercise prescription in an effort to improve athletic performance.

The major findings of this study indicate that popular strength and conditioning resistance training exercises such as bench press and squat do have a significant relationship with many performance testing variables (ie. broad jump, vertical jump, 40-yard sprint time, and pro-agility shuttle time). Data also revealed significant differences when dividing the entire football team into three positions (Athlete, Linemen, and Skill). Previously mentioned studies obtaining descriptive statistics for age, height, weight, predictor, and criterion variables for American football athletes are similar to those obtained in this study with the exception of 40-yard sprint time. [59,60,61,62,63] The decrease in 40-yard sprint time for this study could be the result of the macrocycle that athletes were training in and the grass surface the test was performed on.

Vertical Jump: Significant relationships were identified between variables when using correlation and multiple regression. Vertical jump established a significant correlation with squat relative to body mass (r = 0.65), but not the other two predictor variables. The positive correlation between Squat/BM and vertical jump indicates that improvement in the ratio will increase vertical jumping ability. Multiple regression noted significant relationships when predictor variables were placed into the regression model identifying that increase in Squat/BM mass will improve vertical jumping ability, however increased Squat/BP would have a negative effect.

Broad jump correlated with two predictor variables, Squat 1-RM and Squat/BM. A positive correlation with Squat/BM indicated that improvement in broad jump can be attributed to an increase in the ratio. Correlation indicated a negative relationship with broad jump performance with increase Squat 1-RM. Multiple regression noted significant relationships when predictor variables were placed into the regression model. Identifying that improvement in Squat/BM mass will improve broad jumping ability, however increased Squat 1-RM and Squat/BP would have a negative effect.

---

[59] Berg, K., and Latin, R. (1990). 395-401.

[60] Carbuhn, A., Womack, J., Green, J., Morgan, K., Miller, G., and Crouse, S. (2008). 1347-1354.

[61] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) 115-120.

[62] National Strength and Conditioning Association (2nd Edition). (2000). *Essentials of strength training and conditioning.*

[63] Secora, C., Latin, R., Berg, K., and Noble, J. (2004). 286-291.

40-yard sprint time correlated with two predictor variables, Squat 1-RM and Squat/BM. A positive correlation with Squat/BM expressed that improvement in 40-yard sprint time can be attributed to an increase in the ratio. Correlation did indicate a negative relationship with 40-yard sprint time performance with an increase in Squat 1-RM. Multiple regression noted significant relationships when predictor variables were placed into the regression model. Identifying that improvement in Squat/BM mass will improve 40-yard sprint time, however increase Squat 1-RM would have a negative effect.

Pro-agility shuttle time correlated with two predictor variables, Squat 1-RM and Squat/BM. A positive correlation with Squat/BM expressed that improvement in pro-agility shuttle time can be attributed to an increase in the ratio. Correlation did indicate a negative relationship with shuttle time performance with an increase in Squat 1-RM. Multiple regression noted significant relationships when predictor variables were placed into the regression model. Identifying that improvement in Squat/BM mass will improve pro-agility shuttle time, however increased Squat 1-RM would have a negative effect.

Further exploration of the predictor variables relationship to criterion variables draws attention to Squat 1-RM and Squat/BM ratio's. Correlation results consistently identified a positive relationship with increased Squat/BM ratio for all criterion variables, and a negative relationship with increased Squat 1-RM and most of the criterion variables. In addition multiple regression confirmed that an increased Squat/BM will significantly improve athletic performance. Inversely an increased Squat 1-RM will have a negative to most of the performance variable with the only exception being vertical jump which failed to identify a significant relationship. Data identified in this study is similar to much of the research currently published. One study related to Squat/BM conducted by Baker et al. obtained 3-RM squat outputs and identified a significant relationship with sprinting performance (10 – 40 meters) when considered relative to body mass.[2] The results identified in this and other studies suggest improvement in athletic performance with high ratio of lower body strength to overall mass. [64,65,66,67,68] The negative relationship observed in the Squat 1-RM values in this study is similar to research outlined previously that used absolute strength values in particular squat RM and indicated a decrease in performance. [66, 67,69,70,71]

Squat/BP failed to identify a correlation to performance variables for this study, surprisingly however a relationship was noted with multiple regression. Multiple regression noted a negative relationship on jumping performance with an increase Squat/BP. The current study indicates a less frequent relationship to criterion variables when using squat relative to bench press as a predictor. The outcome of this study somewhat conflicts with previous research conducted by Davis et al. which found a positive relationship between Bench Press/BM and pro-agility shuttle time performance

---

[64] Berg, K., and Latin, R. (1990). 395-401.

[65] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) 115-120.

[66] Harris, N., Cronin, J., Hopkins, W., and Hansen, K. (2008). 691-698.

[67] McBride, J., Blow, D., Kirby, T., Haines, T., Dayne, A., and Triplett, N. (2009). 1633-1636.

[68] Peterson, M., Alvar, B., and Rhea, M. (2006). 867-873.

[69] Chelly, M., Fathloun, M., Cherif, N., Ben Amar, M., Tabka, Z., and Van Praagh, E. (2009). 2241-2249.

[70] Hoffman, J., Ratamess, N., Faigenbaum, A., Mangine, G., and Kang, J. (2007). Effects of maximal squat exercise testing on vertical jump performance in American college football players. *Journal of Sports Science and Medicine. 6.* 149-150.

[71] Kukolj, M., Ropret, R., Ugarkovic, D., and Jaric., S. (1999). 120-122.

when using collegiate football athletes as participants. [72] Although the previously mentioned study used bench press as part of its predictor variables, research suggests that the possible explanation for the positive relationship on performance most likely is attributed in being relative to body mass. [72,73,74,75,76] Data for this study identifies that although squat to bench press ratio does not relate to running performance, it does have an impact on jumping ability.

Results related to criterion variables demonstrated significant differences when divided by position (Skill, Linemen, and Athlete). Results noted using the Tukey-HSD found differences in 10 of the possible 12 means comparisons for the four criterion variables. The two mean comparisons that did not identify significant differences were the Athlete vs. Skill analyses for vertical jump and broad jump. Tukey-HSD results provided insight into the possible justification for pairing football players by the three outlined positions (Athlete, Skill, and Linemen) with significant differences presented in nearly all comparisons. Currently no research has addressed attempting to separate a football team into three broad positions.

Predictor variables utilized in this study had a similar relationship to the previously mentioned studies when using American football and team sport participants. Of the variables used within this study Squat/BM agreed more consistently with previous research, opposed to Squat/BP and Squat 1-RM which presented varied results in several

---

[72] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) 115-120.

[73] Harris, N., Cronin, J., Hopkins, W., and Hansen, K. (2008). 691-698.

[74] Cronin, J. and Hansen, K. (2005). 349-357.

[75] Hoffman, J., Ratamess, N., Faigenbaum, A., Mangine, G., and Kang, J. (2007). 149-150.

[76] McBride, J., Blow, D., Kirby, T., Haines, T., Dayne, A., and Triplett, N. (2009). 1633-1636.

studies. Although Squat 1-RM appeared to be negatively related to athletic performance, research conducted by Wisloff et al. demonstrated just the opposite. This study identified a significant positive effect relationship between squat RM and athletic performance. Although the Wisloff's findings appear compelling, the population used soccer players exclusively.[77] It can become increasingly difficult to compare analyses from a study using participants with similar body structures by position, to a study that contains participants with varied body types such as American football. The conflicting reports across athletics populations using repetition maximum values are justification for the inclusion of the Squat/BM ratio amongst predictor variables for this study. The insertion of the Squat/BM variable is an appropriate way of predicting athletic performance amongst football participants. When identifying studies investigating the relationship for squat relative to body mass a larger amount of research exists supporting the results of the current study. [77,78,79,80,81,82] A recent study by Nuzzo et al.(2008) supported that making squat relative to body mass is a more accurate assessment of projected athletic performance.[82] Although some research indicates significance using absolute strength

---

[77] Wisloff, U., Caragna, C., and Helgererud, J. (2004). 285-288.

[78] Berg, K., and Latin, R. (1990). 395-401.

[79] Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) 115-120.

[80] Harris, N., Cronin, J., Hopkins, W., and Hansen, K. (2008). 691-698.

[81] McBride, J., Blow, D., Kirby, T., Haines, T., Dayne, A., and Triplett, N. (2009). 1633-1636.

[82] Nuzzo, J., McBride, J., Cormie, P., and McCaulley, G. (2008). 669-707.

values as a predictor for improving athletic performance, this study and more current research indicates otherwise. [83,84,85]

The current study indicates that the regression analyses provided can be used by strength and conditioning personnel to identify the impact each predictor variable has to increase or decrease athletic performance. In addition to identifying the weighted effect of predictor variables, the regression analyses can be used by personnel as a motivational tool, to encourage participants to improve specific variables in an attempt to reach maximum potential for performance attributes. The model presented will allow D-1 strength coaches the ability to prescribe a strength relative to mass ratio, that allows their athletes to be put in the best physical position to achieve success on the playing field. As a result, American football players will obtain as much lean muscle mass as possible without compensating sprinting, agility, or jumping performance.

Limitations and Strengths

The current study assessing D-1 American football participants has notable limitations that could affect the results presented. First, the population size was 76 however the study only collected complete data from 43 of the participants. Having incomplete data could result in false interpretation of analyses. Second, the study failed to explore the relationship amongst variables when divided into position (Athlete, Linemen, and Skill). With significant mean differences noted for the current it would have been intriguing to identify if they would persist when divided by position. Lastly, the study

---

[83] Wisloff, U., Caragna, C., and Helgererud, J. (2004). 285-288.

[84] Cronin, J. and Hansen, K. (2005). 349-357.

[85] National Strength and Conditioning Association (2nd Edition). (2000). *Essentials of strength training and conditioning.*

should have used more predictor variables outside of the ratios for body mass and bench press. Incorporating body mass a predictor variable for this study could have provided intriguing results. These weaknesses not with standing of the current study also have several noteworthy strengths. First, D-1 football athletes were used as a population. This study contributes to the relative small amount of research using only D-1 athletes as participants. Second, practical strength and conditioning muscular assessment tests were performed. The inclusion of commonly used testing variables allows easy replication of study design. Lastly, the advanced statistical analyses provided in this study provided more in depth analyses. The multiple regression results provided in this study allowed for significant relationships to be identified when using multiple predictors.

Future Direction

Future research should look to replicate protocols on a similar population to allow comparison. The inclusion of body mass as a predictor variable may provide important information and should be considered when doing a similar study especially if conducting a multiple regression analyses. The three research positions (Athlete, Linemen, and Skill) utilized for this study may become the standard when using a small population size, if future studies identify similar results as the current study. In using the three position approach (Athlete, Linemen, and Skill) as opposed to 8-10 found in traditional studies, statistical analyses will become cleaner and lower the effect that possible outliers may have when working with minimal participants for a position. Reflecting upon the weaknesses of the study, although encouragement was made in using D-1 football players as a population, in the future more emphasis needs to be made in obtaining a larger amount of complete data. The lack of complete data could potentially create glaring weaknesses in results.

Conclusion

This study supports previous research that Squat 1-RM, Squat/BM, and Squat/BP have a significant relationship to vertical jump, broad jump, 40-yard sprint time, and pro-agility shuttle time. Results of the study identified relationships using correlation, and multiple regression comparing predictor to criterion variables. In addition to relationships between variables, significant differences were identified for means by position (Athlete, Linemen, and Skill) for performance variable. Data overwhelmingly supported that squat relative to body mass is the best predictor of athletic performance of all the criterion variables utilized. The outcome of this study provides researchers and strength and conditioning personnel with significant regression models that can be used to assess performance in American football players ability to sprint, jump, and change direction.

List of References

American College of Sports Medicine (8th Ed.). (2010). *Guidelines for exercise testing and prescription.* Philadelphia, PA: Lippincott, Williams & Wilkins.

Baker, D., and Newton, R. (2008). Comparison of lower body strength. Power, acceleration, speed, agility, and sprint momentum to describe and compare playing rank among professional rugby league players. *The Journal of Strength and Conditioning Research. 22*(1) 153-158.

Berg, K., and Latin, R. (1990). Physical and performance characteristics of NCAA division 1 football players. *Research Quarterly for Exercise and Sport. 61*(4). 395-401.

Carbuhn, A., Womack, J., Green, J., Morgan, K., Miller, G., and Crouse, S. (2008). Performance and blood pressure characteristics of first-year national collegiate athletic association division 1 football players. *The Journal of Strength and Conditioning Research. 22*(4). 1347-1354.

Chelly, M., Fathloun, M., Cherif, N., Ben Amar, M., Tabka, Z., and Van Praagh, E. (2009). Effects of a back squat training program on leg power, jump, and sprint performance in junior soccer players. *The Journal of Strength and Conditioning Research. 23*(8). 2241-2249.

Cronin, J. and Hansen, K. (2005). Strength and power predictors of sports speed. *The Journal of Strength and Conditioning Research. 19*(2). 349-357.

Cutnell, J., and Johnson, K. (2005). Physics (6th Edition). Danvers, MA: John Wiley & Sons Inc.

Davis, S., Barnette, B., Kiger, J., Mirasola, J., and Young, S. (2004) Physical characteristics that predict functional performance in division 1 college football players. *The Journal of Strength and Conditioning Research. 18*(1). 115-120.

National Strength and Conditioning Association (2nd Edition). (2000). *Essentials of strength training and conditioning.* Champaign, IL: Human Kinetics.

Harris, N., Cronin, J., Hopkins, W., and Hansen, K. (2008). Relationship between sprint times and the strength/power outputs of a machine squat jump. *The Journal of Strength and Conditioning Research. 22*(3). 691-698.

Hoffman, J., Ratamess, N., Faigenbaum, A., Mangine, G., and Kang, J. (2007). Effects of maximal squat exercise testing on vertical jump performance in American college football players. *Journal of Sports Science and Medicine. 6.* 149-150.

Hoffman, J., Cooper, J., Wendell, M., and Kang, J. (2004). Comparison of Olympic vs. Traditional Power Lifting Training Programs in Football Players. *Journal of Strength and Conditioning Research. 18*(1). 129-135.

Kale, M., Asci, A., Bayrak, C., and Acikada, C. (2009). Relationship among jumping performances and sprint parameters during maximum speed phase in sprinters. *The Journal of Strength and Conditioning Research. 23*(8). 2272-2279.

Kukolj, M., Ropret, R., Ugarkovic, D., and Jaric., S. (1999). Anthropometric, strength, and power predictors of sprinting performance. *The Journal of Sports Medicine and Physical Fitness. 39.* 120-122.

Kuzmits, F., and Adams, A., (2008). The NFL combine: Does it predict performance in the National Football League? *The Journal of Strength and Conditioning Research. 22*(6). 1721-1727.

McBride, J., Blow, D., Kirby, T., Haines, T., Dayne, A., and Triplett, N. (2009). Relationship between maximal squat strength and five, ten, and forty yard sprint times. *The Journal of Strength and Conditioning Research. 23*(6). 1633-1636.

Marieb, E. (2004). Human Anatomy & Physiology (6th Edition). San Francisco, CA: Pearson Education, Inc.

Nuzzo, J., McBride, J., Cormie, P., and McCaulley, G. (2008). Relationship between countermovement jump performance and multijoint isometric and dynamic tests of strength. *The Journal of Strength and Conditioning Research. 22*(3). 669-707.

Peterson, M., Alvar, B., and Rhea, M. (2006). The contributions of maximal force production to explosive movement among young collegiate athletes. *The Journal of Strength and Conditioning Research. 20*(4). 867-873.

Secora, C., Latin, R., Berg, K., and Noble, J. (2004). Comparison of physical and performance characteristics of NCAA division 1 football players: 1987 and 2000. *The Journal of Strength and Conditioning Research. 18*(2). 286-291.

Stone, M., Gavin, M., Glaister, M., and Sanders, R. (2002). How much strength is necessary? *Physical Therapy in Sport. 3.* 88-96.

Wisloff, U., Caragna, C., and Helgererud, J. (2004). Strong Correlation of Maximal Squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine. 38*. 285-288.

Young, W., James, R., and Montgomery, I. (2002). Is muscle power related to running speed with changes of direction? *The Journal of Sports Performance and Physical Fitness. 42.* 282-288.

Young, W., McLean, B., and Ardagna, J. (1995). Relationship between strength qualities and sprinting performance. *The Journal of Sports Performance Medicine and Physical Fitness. 35.* 13-19.

Young, W., Benton, D., Duthie, G., and Pryor, J. (2001). Resistance training for short sprint and maximum-speed sprints. *Strength and Conditioning Journal. 23*(2). 7-13.

Appendices

Appendix One: Berg Study

Physical and performance characteristics of NCAA division 1 football players.

Comparison of Positions

Variable	Quarterback			Offensive Back			Tight End			Wide Receiver			Offensive Line			Defensive Line			Linebacker			Defensive Back		
	n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
Height (cm)	40	185.6	4.2	120	181.0	5.7	40	191.5	3.9	40	183.5	7.2	200	191.7	4.5	160	191.0	3.9	120	187.2	3.6	160	182.2	5.1
Weight (kg)	40	89.3	5.7	120	91.9	8.5	40	106.2	6.3	40	85.9	8.5	200	123.4	7.5	160	115.6	7.7	120	103.1	5.2	160	86.2	5.7
Percent body fat (%)	29	9.9	3.0	86	8.8	2.7	28	12.0	2.8	29	8.0	2.6	145	17.1	4.0	114	14.6	4.0	85	11.6	3.4	116	8.6	2.6
Forty-yard dash (s)	39	4.79	0.18	110	4.57	0.14	38	4.76	0.15	38	4.57	0.11	189	5.13	0.21	151	4.92	0.18	112	4.77	0.14	152	4.60	0.13
Vertical jump (cm)	39	72.4	7.3	112	79.9	7.7	38	75.4	7.0	38	78.7	8.6	192	66.2	7.6	151	70.7	8.2	114	73.9	8.3	153	79.9	8.5
Power ($kgm \cdot s^{-1}$)	39	167.5	13.1	112	181.1	18.8	38	203.0	14.0	38	167.7	19.5	192	220.7	17.5	151	213.5	18.0	114	194.7	13.2	153	169.3	14.0
Bench press (kg)	39	126.1	15.8	117	152.1	20.9	38	151.4	18.0	38	127.3	16.4	197	174.8	20.8	156	171.5	22.4	118	162.7	20.5	157	139.4	17.5
Bench press/weight (%)	39	141.5	15.6	117	165.8	20.3	38	142.7	16.8	38	148.4	18.1	197	142.0	17.9	156	148.3	17.4	118	158.0	18.6	157	161.9	20.1
Squat (kg)	25	172.4	23.1	78	214.1	34.8	25	211.1	30.3	25	177.1	19.9	134	241.3	35.9	99	228.0	31.9	75	216.2	36.6	102	188.5	24.9
Squat/weight (%)	25	193.6	24.6	78	233.2	34.3	25	198.1	27.4	25	209.1	28.1	134	196.3	28.0	99	198.5	25.2	75	211.3	30.9	102	217.9	27.9

*$p < .01$

Appendix Two: Secura Study

Comparison of physical and performance characteristics of NCAA division 1 football players: 1987 and 2000.

Table 10. Statistically significant ($p \leq 0.01$) percent differences between present and previous positions for each variable (negati scores indicate a decrease in the variable).

Variable	Positions							
	QB*	RB	TE	WR	OL	DL	LB	DB
Height (cm)	—	—	—	—	—	−1.0	−1.0	1.0
Weight (kg)	6.0	5.0	5.0	—	8.8	5.7	—	—
40-yd dash (s)	—	—	—	−1.7	—	—	−2.0	1.0
Vertical jump (cm)	9.9	7.7	—	12.7	3.6	9.0	12.5	10.0
Body fat (%)	—	—	—	−19.9	15.2	—	−15.5	−20.9
Bench press (kg)	23.0	11.0	10.0	15.0	—	4.8	—	—
Squat (kg)	—	5.7	—	9.8	—	6.9	6.7	7.9
Bench/wt (%)	12.0	—	−7.9	—	—	—	—	—
Squat/wt (%)	—	—	—	—	−6.8	—	—	7.3
Power ($kgm \cdot s^{-1}$)	11.0	9.0	10.5	6.5	6.2	10.8	7.3	5.4
Fat-free mass (kg)	6.0	6.8	6.9	—	5.7	6.8	3.9	—

* QB = quarterback; RB = running back; TE = tight end; WR = wide receiver; OL = offensive tackle, guard, and center; DL = defensive lineman; LB = linebacker; DB = defensive back.

Appendix Three: Carbuhn Study

Performance of first-year national collegiate athletic association division 1 football players correlated to NFL athletes.

TABLE 4. Performance values and *SDs* of first-year National Collegiate Athletic Association Division I football players versus National Football League, Division I, Division II, Division III, and junior college players, by position.

Division	Age (y)	Height (cm)	Weight (kg)	1RM BP (kg)	1RM SQ (kg)	1RM PC (kg)	VJ (cm)	CP (W)
OL								
First-year	18.8 ± 2	196.7 ± 3.7	136.95 ± 9.4	154.9 ± 12.6	229.9 ± 33.6	136.2 ± 11.6	69.2 ± 7.1	249 ± 17.2
NFL	24.1 ± 2.8	193.3 ± 3.9	117.7 ± 8.8	160.9± 20.9				
Division I		191.3 ± 1.9	133.2 ± 8.1	174 ± 27.6	251.3 ± 33.8	143.4 ± 16	68.8 ± 6.2	244.2 ± 16.9
Division II		189 ± 2	128.4 ± 11.9	160 ± 25	221.6 ± 35.8	132 ± 17.4	60.4 ± 8.6	220.6 ± 23.3
Division III				138.7	177.3	118	62.5	
Junior college		189.7 ± 5.2	121.6 ± 12.5	147.6 ± 23.1	201.4 ± 28.8		56.3 ± 8.2	
TE								
First-year	18	194.7 ± 5.3	112 ± 2.5	148.5 ± 13.1	205.3 ± 19.1	126.7 ± 7.6	86.8 ± 6	230.4 ± 7.8
NFL	24.2 ± 2	190.5 ± 4.34	104.5 ± 6.2	154.6 ± 25.3				
Division I		190.3 ± 1.1	113.7 ± 6.4	172.4 ± 16.5	232.4 ± 37.3	140.9 ± 14.3	79.6 ± 7.2	224.4 ± 15.3
Division II		190 ± 1.9	104.5 ± 8.8	144.3 ± 16.2	202.5 ± 29	122.6 ± 18.7	70.1 ± 8.7	194 ± 18.6
Division III				150.3	165.4	116.5	74.2	
Junior college		190 ± 3.7	101.3 ± 5.3	136.6 ± 17	179.7 ± 20.6		68 ± 7.2	
DL								
First-year	18.2 ± 0.6	193 ± 3.6	125.5 ± 12.4	161.2 ± 11.4	216.7 ± 13.2	131.5 ± 15.3	75.4 ± 5.9	240.3 ± 23.3
NFL	24.1 ± 2.8	193.3 ± 3.9	117.7 ± 8.8	160.9± 20.9				
Division I		188 ± 2.7	120.7 ± 8.8	180.1 ± 24	246.5 ± 34.8	146.8 ± 17.4	77.9 ± 8.2	234.8 ± 18.1
Division II		187.3 ± 1.8	116.9 ± 11.6	161.7 ± 20.7	219.3 ± 36.4	132.7 ± 22	66.9 ± 11.3	210.4 ± 23.6
Division III				134.2	163.2	127.4	70.5	
Junior college		187.9 ± 5.2	112.8 ± 10.8	148.5 ± 22	199.4 ± 38.1		62 ± 10.7	
QB								
Division								
First-year	18 ± 0.7	190 ± 3.8	94 ± 5.8	128.6 ± 14	175.5 ± 26.2	110 ± 11.7	75.2 ± 5.8	180 ± 13.4
NFL	24 ± 2.4	184.7 ± 4.01	94.1 ± 8.1	133.2 ± 18.2				
Division I		185.8 ± 2	92.7 ± 6.3	162.9 ± 21.7	200.2 ± 45	124.6 ± 18.7	80.7 ± 6.4	184 ± 15.4
Division II		186.1 ± 1.9	93.4 ± 7.9	128.9 ± 23.3	179 ± 40.3	120 ± 19.2	70.3 ± 9.3	174.9 ± 16.4
Division III				121.6	189.5	103.9	67.1	
Junior college		186.7 ± 6.2	85.8 ± 7	113.4 ± 20.9	155.8 ± 33.7		68.6 ± 10.1	
LB								
First-year	20 ± 2.5	187.4 ± 4.4	105.3 ± 6.5	146.9 ± 22.6	200 ± 24	125 ± 19	79.6 ± 7.31	208.4 ± 17.2
NFL	24.2 ± 2	190.5 ± 4.3	117.7 ± 8.8	154.5 ± 25.3				
Division I		185.1 ± 1.4	103.8 ± 5.2	159.5 ± 23.7	240.5 ± 36.5	144.3 ± 16.4	83.2 ± 7.8	209 ± 13.8
Division II		184.2 ± 1.7	104 ± 29.4	146.2 ± 21.7	209 ± 37.7	131.6 ± 22.8	72.4 ± 10.8	188.5 ± 16.4
Division III				163.3	156.6	121.9	71.5	
Junior college		185.8 ± 3.8	99 ± 5.8	142 ± 23.5	184.7 ± 35.4		68.8 ± 8	
K								
First-year	18 ± 1	188 ± 5.1	86.95 ± 10.1	103 ± 13.1	140.9 ± 19.3	90 ± 7.1	71.1 ± 4.4	162.3 ± 22.9
NFL	24 ± 2.4	184.7 ± 4	94.1 ± 8.1	133.2 ± 18.2				
Divisions I–III and junior college								
WR								
First-year	18.4 ± 0.7	187.5 ± 3.7	87 ± 6.9	123.2 ± 20.4	164.5 ± 18.2	109.5 ± 10.7	81.3 ± 3.3	173.4 ± 15.9
NFL	24.6 ± 2.8	181.9 ± 4.8	85 ± 7.1	124.5 ± 26				
Division I		183 ± 2.3	85.6 ± 7	151.2 ± 26.5	205.6 ± 40.4	127.5 ± 15.2	87.4 ± 7	177 ± 17.9
Division II		184 ± 2.3	83.4 ± 5.5	122.6 ± 20.4	173.8 ± 35.3	123.7 ± 16.9	77.8 ± 12.1	162.4 ± 17.1
Division III				150.3	165.4	116.5	74.2	
Junior college		180.8 ± 5.7	80.3 ± 6.1	110.7 ± 17	160.6 ± 24		72.6 ± 9.9	