# Evaluating the Importance of Strength, Power, and Performance Tests in an NCAA Division I Football Program.

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# Evaluating the Importance of Strength, Power, and Performance Tests between Starters and Non-starters in An NCAA Division I Football Program

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## ABSTRACT

Strength and conditioning professionals spend a great deal of time and effort trying to improve athletic performance. Even as coaches evaluate each athlete by using the results of a vast battery of tests, there has been considerable speculation and discussion about the physical attributes of Division I football players and their playing status. The purpose of this study was to determine what influence strength, power, and performance tests scores have on an individual's playing status.

One hundred and five football players from Virginia Tech, between the 1994 and the 2000 season were used in this study. The subjects had to be in the Virginia Tech strength and conditioning program for at least 4 years and in their last year of competition. The subjects were classified as "starters" or "non-starters" according to their playing status. The subjects were grouped into one of three groups. The three groups were the Skill group, Combo group, and the Line-of-Scrimmage (L.O.S.) group.

Each subject participated in a series of tests conducted by the strength and conditioning staff. Starters and non-starters were compared to each other on 6 different tests and bodyweight. The tests used in this study consisted of the bench press, back squat, power clean, push jerk, vertical jump, 40-Yard dash, and bodyweight. The tests were ranked in order of importance, by using a Proc StepDisc statistical procedure, from highest to lowest for each of the three groups.

The results of the Proc StepDisc statistical procedure showed that there are distinct rankings for each group. The Skill group rank ordering were: 1) vertical jump, 2) power clean, 3) 40-Yard dash, 4) back squat, 5) bodyweight, 6) push jerk, 7) bench press. The Combo group rank ordering were: 1) 40-Yard dash, 2) bodyweight, 3) bench press, 4) back squat, 5) vertical jump, 6) push jerk, 7) power clean. The L.O.S. group rank ordering were: 1) bodyweight, 2) vertical jump, 3) bench press, 4) back squat, 5) power clean, 6) push jerk, 7) vertical jump.

The Skill group results indicate that power is the most important factor differentiating between starters and non-starters. Simultaneously, the Combo group results indicate that speed is the most important factor differentiating between starters and non-starters. Also, the L.O.S. group results indicate that bodyweight is the most important factor differentiating between starters and non-starters.

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# INTRODUCTION

The sport of football is one of the most popular sports in the United States. We, as fans, are amazed at the size and the strength of the athletes who play this physical game. The sport of football, at the Division I level or professionally, is comprised mainly of athletes of uncharacteristic size, speed, and strength. Strength and conditioning programs have helped many athletes become stronger, faster, and, in some cases, larger. These programs have also succeeded in providing athletes with the ability to enhance their performance. "It is a commonly accepted fact that many football skills can be enhanced through proper strength training and conditioning. Although one repetition maximum strength tests and related assessments such as sprint and jump tests are not measures of football ability, they are believed to reflect the physical performance characteristics representative of football playing potential" (Fry & Kramer, 1991, p. 126).

Outside of practice, football players at the Division I level spend a great deal of time and effort in training sessions that are conducted by strength and conditioning coaches. These training sessions are designed to make the football athlete stronger, more powerful, quicker, faster, and in some cases larger. These resistance-training programs are designed to enhance the performance of the athletes. A strength and conditioning program is an important fixture in the career of a football player. The effectiveness of a well-developed strength and conditioning program that is designed to improve the athlete's physical development and his performance on the field has been documented through scientific research. The program design needs to consist of research-based and scientifically proven principals that will yield significant benefits (Pearson Faigenbaum, A., Conley, M. & Kraemer, W.J., 2000).

Athletes spend a lot of time and effort trying to improve their athletic performance. Strength and conditioning coaches have helped these athletes achieve a high level of athletic performance through resistance training. This training is used to help improve the athlete's strength, power, flexibility, and speed. The

improvement of all or one of these factors may help in enhancing the athlete's performance on his or her respective playing field or court (Pearson & Gehlsen, 1998). Resistance training has had a major impact on the physical characteristics and the performance characteristics of football players. This impact is representative of Arthur & Bailey's (1998) explication on the history of the performance of football players: "The improvement of performance in football over the past few years has been phenomenal. Twenty years ago, the average lineman weighed 240 to 250 pounds and ran a 5.2-second 40-yard dash. This was considered to be nearing the genetic potential for a player. Now running backs that weigh 240 pounds are running 4.4-second 40-yard dashes. Strength training has made the single, most positive contribution to this improvement. Today sports conditioning and strength training influence every football program in the country. Players now find it necessary to lift weights and do conditioning drills to better prepare themselves for the competitive rigors of a football season" (Arthur & Bailey, 1998, p. 82 ).

Evaluating an athlete's performance tests is a very common occurrence for many strength and conditioning professionals. For a couple of decades researchers and coaches have taken test scores and used them to predict the potential of an athlete. In the sport of football everything is measured and evaluated. These evaluations may lead to some position changes in some of the athletes. Testing athletes in physical performance tests is extremely important to the evaluation process of NCAA Division I athletes.

Testing athletes may provide the coach with information about the physical attributes of the players. This information may be used as a predictor of the athlete's playing status. This information may also give the coaches information about the physical conditioning of the players. The information can then be processed in a manner to help make accurate evaluations of the athletes.

The physical attributes of Division I football players are measured in a variety of ways by a battery of very different tests designed to assess an athlete's ability to perform a certain skill or function. For example, testing football players provides a way to assess their ability to play the sport of football. "One reason for

testing is to assign positions and ranking. All coaches want to be sure they are putting their best athletes in the game" (Graham, 1994).

In 1994, Arce identified two main objectives for the evaluation of athletes. The first is to determine whether the athlete has the strength, power, and skill to play the game. The second is to evaluate whether the athlete is making gains in his or her training program.

Testing athletes can help a coach determine the potential of a player to play at a certain position. Testing also provides a way to evaluate an athlete's ability or potential to perform specific skills needed to excel in their respective positions. Coaches often use these tests to evaluate not only athletic ability but as a predictor of the potential for injuries that may arise during the season. In addition, testing will also help the strength and conditioning staff to develop individual programs for the athletes who may be injured or need assistance in certain areas of training. Strength and conditioning professionals need some type of testing protocol to help in the evaluation process of their athletes. This testing process needs to include all areas of training, such as strength, power, and speed, that might reflect strengths and weaknesses that the athlete may posses. The testing needs to be administered in a safe and effective manner to ensure an accurate evaluation (Ebben, 1998).

Evaluating performance tests of a football player may not only give a coach in-sight regarding an athlete's playing status and position potential but it also may be used as a way for strength and conditioning professionals to re-evaluate their own program. These findings may give the strength and conditioning staff insight to areas that may need more attention. For example, if an athlete tests poorly in power tests then the strength and conditioning professionals could alter the program to help the athlete improve in this area.

In addition, evaluating strength, power, and performance tests may yield some interesting data. These data may inform the strength and conditioning coach which test or tests may be more accurate in predicting playing status; thus providing the correct information for implementing changes in program design. This knowledge of prediction may be useful in changing the strength and conditioning program to be modified to fit

the information gained from the evaluation of the strength, power, and performance tests. The strength and conditioning coach could then quantify which test more accurately identifies the characteristics of that position or position group. For example, the coach may be able to rank the tests in order of importance pertaining to position groups and this ranking may give the strength and conditioning coach new insight into program implementation.

Strength and conditioning professionals have conducted evaluations of various physical tests for many years. These professionals have obtained much needed information about the performance of their athletes. Now with the same information the strength and conditioning professional can draw conclusions regarding which tests are more accurate in predicting playing status. If these professionals can make these predictions and if they are able to rank these tests in order of importance then we can begin to see what tests or areas of training are more important than others for a specific position or position group. Having information regarding the usefulness of tests and their ranking can give the strength and conditioning professional insight regarding which areas should be addressed more intensely than others for different positions or position groups. This information can help strength and conditioning professionals create sport specific strength and conditioning programs for athletes.

## Statement of the Problem

Strength and conditioning professionals spend a lot of time and effort trying to improve athletic performance. Coaches evaluate each athlete by utilizing the results of a number of tests. These tests help the coach determine position rankings on a depth chart. The evaluation of these tests could help the coaches decide which position is best suited for a particular athlete, while it is not clear as to what extent this assessment may influence the coach's decision regarding the playing status of an athlete, it is possible that these assessments may become a useful tool to a coach in determining the playing status of an athlete. There has been

considerable speculation and discussion about the physical attributes of Division I football players and their playing status (Berg, K., Latin, R.W. & Baechle, T. 1990; Black & Roundy, 1994; Fry & Kraemer, 1991). Many strength and conditioning coaches test their athletes and make evaluations based on their performance on the tests. The problem, therefore, lies in the inability of many coaches to determine which tests are important indicators of playing status. One important area of inquiry is to evaluate strength, power, and performance tests between starters and non-starters at a NCAA Division I football program in order to determine whether starters score higher on the strength, power, and performance tests compared to the non-starters.

## Purpose

The purpose of this study was to determine what the relationship is between strength, power, and performance test score on a playing status. These findings may be used to help the strength and conditioning professional develop programs that may be more sport specific for certain positions or position groups.

## Research Questions

The specific questions addressed by this study are:

1. Is there a relationship between these various tests and playing status?
2. Can the ranking of these tests in order of importance help the strength and conditioning professional create programs that are more training group-specific?

## Research Hypothesis

1. Ho: There is no statistical difference in the strength, power, and performance tests that are ranked in order of importance between the starters and the non-starters in the Skill group.

2. Ho: There is no statistical difference in the strength, power, and performance tests that are ranked in order of importance between the starters and the non-starters in the Combo group.
3. Ho: There is no statistical difference in the strength, power, and performance tests that are ranked in order of importance between the starters and the non-starters in the Line of Scrimmage (L.O.S.) group.

**Limitations**

The following limitations were inherent in the design of this study:

1. The dependent variable in this study encompasses only four parameters [strength, power, performance tests (40-yard dash, Vertical Jump), and body weight] which might influence playing status in this sport. Therefore, generalizations to playing status are limited to the variables this study covers.
2. Only subjects who have participated in at least 4 years in the Virginia Tech strength and conditioning program were considered for this study.
3. The effects of only six tests and body weight were measured and investigated: There are two strength tests (bench press, and back squat), two power tests (push jerk and power clean), two performance tests (40 yard dash, and vertical jump), and a body weight measurement.
4. Subjects were placed into one of three groups that will be consistent with conditioning groups during their training sessions. These three categories are the Skill group, Combo group, and the L.O.S. group.

**Significance of the Study**

Evaluating strength, power, and performance tests have yielded valuable information for the strength and conditioning profession. This study was designed to indicate a rank ordering of tests in order of importance that would separate starters from non-starters. This rank ordering of tests have produced interesting information that may lead to a re-structuring of program design among many strength and conditioning programs.

This study has helped strength and conditioning professionals, at Virginia Tech and hopefully elsewhere to understand the difference between athletes in the three position groups. This study also indicates what area of training needs to be a focus for these different position groups.

Most strength and conditioning programs would like for their programs to be as sport-specific, in their training methods, as possible. The data presented in this study will help the Virginia Tech strength and conditioning program, and hopefully other programs, gravitate towards a more sport-specific training protocol.

**Definitions**

Speed is "the displacement per unit time and is typically quantified as the time taken to cover a fixed distance. Tests of speed are not usually conducted over distances greater than 200m because longer distances reflect anaerobic or aerobic capacity more than absolute ability to propel the body at maximal speed" (Baechle & Earle, 2000, p. 290).

Strength is "the force or tension a muscle or, more correctly, a muscle group can exert against a resistance in one maximal effort" (Foss. & Keteyian, 1998, p. 340). Strength can be measured by a number of different tests, such as the bench press and the back squat. Baechle and Groves define strength as "the ability to exert maximum force during a single effort. It can be measured by determining a 1-repetition maximum effort, referred to as a '1RM', in one or more exercises" (1998, p. 5).

Power is "a measurement of the ability to exert force at higher speeds. More precisely, power is the product of the force exerted on an object and the velocity of the object in the direction in which the force is exerted" (Baechle, 1994, p.29). Power is tested in a variety of ways. "Understanding power capacity and how it can be created is one of the primary keys to optimizing athletic performance. Power should not be confused with strength. Power is the capacity to do a given amount of work as rapidly as possible. By this definition, power includes the elements of strength and speed. It is dynamic strength coupled with movement speed. Speed is the ability to apply force rapidly when snatching, cleaning, throwing, or sprinting" (O'Shea, Patrick, 1999, p. 34). There are a few lifts that qualify as an evaluation for power. These lifts are the Olympic style lifts: the snatch, push jerk, and the power clean.

# Chapter II

## REVIEW OF LITERATURE

Football is one of the most popular games in the U.S. today (Arnold, J.A., Coker,T.P., & Micheli, R.P., 1977). The history of football goes back as early as 500 B.C., and is believed by many historians to have its roots in the Greek and Roman Culture. We know that the English laid the blueprint for this sport around 1600 A.D. In 1866, Henry Chyadwick presented the game of football to the United States. No one expected this game to be as popular as it is today. After World War I football began to show signs of its popularity among the people (Arnold et al., 1977).

The game has changed dramatically since those early days on the gridiron. Many people are attracted to the game by the size and the pure athletic ability of the athletes. One of the most significant changes has been the addition of a strength and conditioning program to help the athletes obtain superior strength and conditioning status unlike the athletes that are not being trained. College football is big business in these modern times. Many athletic departments spend a tremendous amount of money in order to support this sport. The hope and determination of the athletic department is to receive monetary returns in the success of their football program. Athletes and coaches are always looking for ways to gain an edge on their competition. In the last few decades, this edge has been sought through the strength and conditioning programs. The importance and effectiveness of a strength and conditioning program is a considerable advantage for the athlete, coach, and entire athletic department (Pullo, 1992).

Since the game of football is very popular the thought is that there would be a large body of research devoted to this popular sport. However, the reality is that there is very little research available in this area. “Football is the least studied sport in the U.S. today. We have very little direct scientific evidence on the physical demands of the sport, the recovery process, or the effects of long-term participation. The reason for

the lack of direct research on a sport that is one of the leaders in revenue generation remains unclear. Research on the training related aspects of the sport also remains indirect and speculative, due to the fact that the subjects are typically untrained men and not football players" (Kraemer, 1997, p. 131). Although football is one of the least studied sports, the players have been involved in resistance training for decades. This training has given the player the ability to become a more complete athlete. The research that is available indicates that strength and conditioning programs have shown to improve strength, power, speed, and vertical jump measures. The increases in these variables have been proven to improve athletic performances (Stone et al., 2000).

Making a reliable evaluation on a collegiate strength and conditioning program will consist of many variables that are measurable and some that are not measured in this study. Programs are evaluated primarily on measurable variables that can be quantified, but to make an accurate yet reliable evaluation of a program, the coach has to consider the intangible portion of a program. The "intangibles" are non-measurable characteristics that a good strength and conditioning program must have in order to be successful. Examples of the "intangibles" are knowledge of the game, heart, and motivation. The "intangible" characteristics will not be investigated in this study.

**Program Objectives and Goals**

Each strength and conditioning program has set some "formal" and "informal" program objectives to be obtained. These objectives are set as guidelines to be met in order to have a successful strength and conditioning program.

Baechle and Earle stated that "program objectives are specific means of attaining program goals. To state program goals without listing ways in which these goals might be attained can result in athletes never achieving them. Program objectives should encompass all areas of the program to ensure that the goals are attained. Following is a list of goals that strength and conditioning programs should incorporate into their

regime if they are not already present. These goals will help the athlete obtain a high level of competition and these goals are also used in the evaluation process of each athlete.

1. Design and administer strength, flexibility, aerobic, plyometric, and other training programs that reduce the likelihood of injuries and improve athletic performance. More precisely, designing training programs that create the desired results in body composition, hypertrophy, strength, muscular endurance, cardiovascular endurance, speed, agility, coordination, balance, and power.
2. Develop training programs to account for biomechanical and physiological differences among individual athletes, taking into account their ages, sex training status, physical limitations, and injury status.
3. Recognize acute and chronic physiological responses and adaptations to training and their implications for the design of sport-specific training programs.
4. Educate athletes on the importance of good nutrition and its role in health and performance.
5. Educate athletes about the abuse and effects of performance-enhancing substances, relevant school policy, legal legislation, and safe and viable alternatives" (Baechle & Earle, 2000, p. 568).

This description of the "program objectives" outlines what most strength andconditioning programs want to accomplish in their own program. If the strength and conditioning staff can reach these objectives, then they are on the right path for success.

The benefits of a strength and conditioning program can be broken up into two parts. All strength and conditioning programs want to increase athletic performance and prevent injury. These are two common universal goals that every program states in their "mission statement". Baechle and Earle have given an example of a mission statement that is widely used, in one form or another, by most strength and conditioning programs. "To provide to athletes the means by which they can train consistently, sensibly, and systematically over designated periods of time, in a safe, clean, and professional environment to help prevent injury and

improve athletic performance" (Baechle & Earle, 2000, p. 568). This mission statement encompasses the two universal goals of a strength and conditioning program. If the strength and conditioning staff attains this mission then the program should be successful.

Before an evaluation of a strength and conditioning program can proceed, there has to be a set of specific goals to be obtained. The evaluation of tests, programs, and athletes needs to first be stated in obtainable goals that are specific. The most significant goal, of the strength and conditioning program, is to improve athletic performance. This concept is the central ideal for the prosperity of the strength and conditioning program. The improvement of variables, such as, strength, power, speed, and vertical jump ability will contribute to the enhancement of athletic performance. "This alone could serve as the mission statement for the program; however, strength and conditioning professionals in whose programs injuries have occurred realize that injury prevention should also be a goal" (Baechle & Earle, 2000, p. 568).

## Testing and Evaluation

When the first year athletes begin the program they are tested, on strength, power, and speed, so the strength and conditioning coaches can evaluate the athlete's fitness levels. The testing and evaluation process of athletes has two main objectives. The first objective is to identify the possibility of any pre-existing physical conditions that might hinder the athlete's performance. This might range from pre-existing injuries to lower than average scores on strength, power, and speed tests. Low strength, power, and speed test scores may show weaknesses in specific areas. The identification of inadequacies in some of these tests could give the strength and conditioning coach the ability to design a program to help the athlete in these specific areas (Arce, 1994).

The second objective is to measure the athlete's sport-specific skills. This measurement will produce information about the level of preparation the athlete has achieved. This information might also render information about the position or positions that might be most suited for the athlete. Once these two objectives

are met then the strength and conditioning coach can begin the process of tailoring the program for the athletes (Arce, 1994).

The athletes are evaluated at the beginning to determine their fitness level. The strength and conditioning coach has the responsibility of assessing the level of fitness for every athlete. Once this has been attained then the strength and conditioning coach must be able to coach athletes at different fitness levels. A university's strength and conditioning program can be evaluated on its ability to accommodate all levels of athletes at the same time. There could be athletes that have participated in structured strength programs and also some athletes that have never resistance trained a day in their lives. The goal is to be able to have a program that can accommodate both types of athletes. "It is important to understand that in training football players, the 'pretraining' status of the players will affect the amount of development that can be expected with just short-term training. Thus mistakes in exercise prescription can lead to little or no changes. Individualized and periodized training is vital for development" (Kraemer & Gotshalk, 2000, p. 803).

Most strength and conditioning programs test their athletes for the purpose of monitoring the progress of their athletes. This testing enables the strength and conditioning coaches to evaluate their athletes and their program. The testing process needs to be an integral part of the strength and conditioning program. This process should be in direct concurrence with the design of the program. The evaluation of athletes should not be conducted in a manner in which, the process does not follow the design of the program. This should work together within the training program at the appropriate times to produce the most accurate results (Gambetta, 1998).

The testing of athletes needs to be sport-specific. This will enable the coaches or the investigators to evaluate these tests under the assumption that they are valid quantifiers since they are sport-specific. The strength and conditioning coach needs to understand the athlete's sport. The tests that are chosen by the strength and conditioning coach need to fit the parameters of the sport for optimal evaluation. "When selecting

tests, the strength and conditioning professional should analyze the energy system demands of the sport the athlete is being measured for. For example, while a 1.5 mile run is an excellent field test for measuring cardiorespiratory endurance in sports requiring a lot of energy from the oxidative energy system, it is not an appropriate test for football, which primarily on the ATP-PC energy system. A more appropriate running test for football would be a short-distance sprint such as a 40-yard dash" (Graham, 1994, p. 9). Sport-specific training is crucial to the success of every strength and conditioning program. Sport-specific programs create training that is designed to mimic movements that the athletes perform in competition. The idea, therefore, is to make these movements stronger, faster, and more powerful (Foss & Keteyian, 1998). "According to the principle of specificity, conditioning programs must approximate the mechanical and movement speed requirements of the sport. Test items should assess the physical characteristics it takes to succeed in a specific sport and the adaptations that occur in response to the prescribed conditioning program" (Ebben, 1998, p. 42). During testing, the strength and conditioning staff wants to ensure that the tests being used on the athlete reflect the sports physical demands on the athlete. This is a major concept when discussing the testing of athletes. Many coaches will evaluate athletes on tests that do not reflect the sports energy system demands. The tests being administered have to be able to evaluate not only the athlete but also the sport in which the athlete participates in, in this case football. Tests that represent the sports energy system are a must.

**The Age Factor**

Many investigators conclude that strength, speed, power, and size are all good indicators on the ability to start. It seems that a few studies are designed to show predictors on the ability to become a starter over a non-starter. The one variable that many of these studies do not take in consideration is the chronological age factor. Many of these studies are not designed to control for age. The literature that is being reviewed does not focus on this issue but age is a very important factor when discussing playing status. Age could possibly play

an important role in playing status. Usually, the more physically mature athlete will score higher on power, strength, and speed tests, than the less physically mature athlete. These higher test scores may result in a starting position for the physically more mature athlete. The maturation of an athlete is a concept that might be overlooked in many studies. In a study by Barker and colleagues in 1993, they found that the, "starters were stronger than non-starters; consequently, 1-RM and 1-RM x body mass squat strength may be a determining factor as to which players start. It should be noted that starters were also older than non-starters (20.4 +- 1.0 vs. 19.3 =- 0.9 years). Therefore the strength differences between starters and non-starters may be related to strength training experience and maturation" (Barker et al., 1993, p. 231). Barker and colleagues realized that age is a very important factor in determining playing status. Many athletes are starters because they have been in the program longer than other athletes. The starters may have a greater understanding of the program and this understanding places them with the opportunity to start. Evaluating athletes by testing them on strength, power, speed, and endurance might render conclusions about an athlete's physical maturation. This study, as in other studies, reveals that age is also a factor to be recognized and controlled. Age might not be able to be controlled completely but there needs to be a serious attempt in controlling for age. Older athletes have usually been in a sound strength and conditioning program longer than younger athletes therefore, the older athletes have had more time to reap the benefits of the strength and conditioning program.

In this study, players who have participated in four years of the strength and conditioning program have been investigated. Starters and non-starters have to be in the Virginia Tech strength and conditioning program for at least four years. This will allow all of the subjects to be exposed to the strength and conditioning program for the same amount of time. Hopefully, this will counter the problems that Barker et al ran into.

**Bodyweight and Performance**

There are many studies that are concerned with bodyweight and performance. Many studies direct their attention to the bodyweight issue. Bodyweight, in the sport of football is an interesting issue. The sizes of the players have always been discussed as an important issue. There is a lot of emphasis placed on bodyweight by the coaches and by the players themselves. Coaches want the biggest athletes possible. In 1975, Wickkiser and Kelly researched the topic of body composition. They asked coaches and players what they thought was their "ideal" bodyweight. "It was found that the players perceived their 'ideal weight' to be 9.1 pounds heavier than the ideal weight selected by the investigators. The coach also overestimated the weight by 6.2 pounds. This finding in conjunction with a negative correlation of .69 between percentage of fat and 40-yard dash speed for players evaluated in the present study, would appear to indicate the need for increased emphasis in making recent body compositional findings more accessible to football coaches and players. It appears that far too much emphasis is placed upon total body weight by the coach and the athlete" (Wickkiser & Kelly, 1975, p. 201).

In 1993, Mayhew, J.L., Bemben, M.G., Piper, F.C., Ware, J.S., Rohrs, D.M. & Bemben, D.A. conducted a study to determine the relationship between the seated shot put test and the bench press. The investigators found that the seated shot put test and the bench press "may be influenced by size and muscularity" (1993, p. 95). The same investigators concluded that the most determinant factor between the relationship of the seated shot put test and the bench press is bodyweight. They found that being a larger person may produce higher scores on the seated shot put test - bench press relationship (Mayhew et al., 1993). The investigators were not attempting to make a connection between body size and performance on the field. The investigators were making a connection between two different upper body strength-power tests. The investigators found that body size does play an important role in upper body strength but this finding does little to distinguish between upper body strength and performance on the field. Mayhew et al. even states that, "two

important questions are left unanswered by the current research: What is the relationship between bench press power and football performance? And what is the relationship between sports performance and changes in upper body strength and power resulting from periods of heavy training" (Mayhew et al., 1993).

In 1994, Bale, P., Colley, E., Mayhew, J.L., Piper, F.C., & Ware,J.S. conducted a similar study where they wanted to compare strength measures between positions. The investigators reported that the back is relatively stronger than the offensive linemen when bodymass is taken into consideration (Bale et al., 1994). But the linemen have greater strength than the back when comparing absolute strength (Bale et al., 1994). The investigators found that, "the larger player is also stronger when strength is measured by the ability to perform maximum absolute bench press and deadlift exercises" (Bale et al., 1994, p. 388).

In this sense, the studies by Bale et al. and by Mayhew et al. conclude with the same findings. Both of these studies have found that typically larger athletes produce greater absolute strength and power than smaller athletes.

Bodyweight is undoubtedly a very important measure to be evaluated by the coaches. However, how much emphasis should be placed on this measure alone? In a study by McDavid in 1977, the researcher investigated football playing potential tests. Bodyweight as used in a classification index was used to determine the relationship to the test criterion. "The investigator was surprised to note that the classification index item had a negative but non-significant relationship to the test criterion. This may cause a re-evaluation of the importance of size alone in football. It seems obvious that size combined with other attributes contributes to a stellar performer" (McDavid, 1977, p. 101). In these studies that investigate bodyweight, the researchers have distinguished that bodyweight is a predictor for playing status. However, they all also agree that an excess in body fat could be detrimental to the athletes overall performance.

Seiler et al. conducted a study very similar to McDavid and to Wickkiser and Kelly by evaluating forty-one collegiate football players, through an investigation their anaerobic power. This study examined the idea

that larger athletes are always the superior performers. The authors used a battery of anaerobic power tests to answer the question. They found that football players are much more powerful than untrained males. It is interesting to note that while the authors almost had the same conclusions as the previous studies, they also conceived that "for linemen to be able to execute the explosive movements necessary at the higher levels of collegiate football, greater efforts should be made to bring their body composition closer in line with other athletes on a football team. A leaner, more explosive lineman may out-perform a heavier but less powerful counterpart if both display the same technical proficiency on the field" (Seiler et al., 1990, p. 14). This study has the same conclusion as McDavid (1977) and Wickkiser & Kelly (1975).

In this sense, the issue of bodyweight has become a very important issue, with regard to its direct correlation to performance. These studies are in agreement that being a larger athlete may increase performance capabilities in some positions, although, having an excess amount of body fat may be detrimental to the athletes performance (Bale et al., 1994; Mayhew et al., 1993; McDavid, 1977; Seiler et al., 1990;& Wickkiser & Kelly, 1975).

**The Placement of Athletes into Position Groups**

The authors of many studies have placed the various positions into position groups. This is a very common occurrence since many of the positions are very similar in movement and skill performance. "These different biomechanical and physiologic position demands tend to separate into distinct categories according to physical attributes. In general, offensive linemen and defensive linemen can be grouped together because these players today tend to be taller, and larger, and have higher levels of body fat, are relatively slower, and have greater absolute strength and power than do the other positions. In general, offensive backs, wide receivers, and defensive backs tend to have the lowest levels of body fat, fastest sprint times, quickest reaction times, and highest relative VO2 max value. Inside linebackers and tightends tend to form a group next to the linemen in

body size, strength, and power, where as outside linebackers and fullbacks form the group between the small backs and the inside linebackers and tightends" (Kraemer & Gotshalk, 2000, p. 796).

Pinciervero and Bompa classify the positions into three groups. "Based on measurements of size, body composition, strength, speed and endurance, 3 distinct groups of football players may be established: (i) offensive and defensive linemen; (ii) defensive backs, and offensive backs, and wide receivers; and (iii) linebackers and tight-ends. The position of tightend may also represent a transitional group along with linebackers, although they have been grouped with either the offensive backs, the offensive linemen or the linebackers. Since the position of tight-end requires the player to make blocks on defensive linemen as well as to run down field to catch passes as a receiver, it would seem justifiable to place these players in a category with the linebackers as a transitional group between backs and linemen" (Pinciervero & Bompa, 1997, p. 256). These are some examples of how to categorize position into position groups. There may be some different position groups in other studies but the main theme is consistent.

**Comparisons of Football Players by Positions**

The research indicates that Division 1 football players are becoming bigger and stronger. Throughout the years the game of football has seen an increase of size, strength, and speed of the athletes. This increase is caused by the preparation of the athletes, genetics, and the rule changes of the game. For example, the rule changes have allowed for the offensive linemen to use their hands in pass protection. The use of the hands has given the offensive linemen the ability to position block. The offensive linemen have become extremely large and strong athletes since they can now use their hands in pass protection. The linemen do not have to move as much during blocking since they can use their hands. These athletes have to become big and strong to keep the defensive players away from the quarterback. This physical development can also be attributed to the athlete's preparation in a strength and conditioning program. Genetics has also played an important role in the athlete's

physical capabilities. Rule changes and strategy changes of the game have caused a shift in the prototype athlete. Depending upon the position, the athlete has to be able to fulfill the requirements of that position (Kraemer & Gotshalk, 2000). These days it is not unusual to find an offensive lineman who is over 6'6" in height and who weighs more than 300 pounds. This was unheard of 15 – 20 years ago. The linemen in that era were not near as large, on an average, as the linemen now. Athletes are making incredible strides in strength, speed, and size. Strength and conditioning programs are influencing every major Division I football program in the nation. Athletes that were once thought of being near or at their genetic potential are making great increases in their physical capabilities. This was once thought to be impossible. Athletes that were once the size of linemen are now playing various skill positions, like running backs, and they are faster than the backs of previous years. This occurrence is caused by the influence of a strength and conditioning program (Arthur & Bailey, 1998).

In 1985, Olson and Hunter sent out surveys to see if athletes were bigger, stronger, and faster than athletes ten years before. The investigators looked at football players from the 1974 season and compared them to the players of the 1984 season. The investigators found that the athletes in 1984 were faster, bigger, and stronger than those ten years previous in 1974. The improvements that the athletes made over this ten-year period suggest that the strength and conditioning program had a major influence in this occurrence (Olson & Hunter, 1985). Today's athletes spend so much time and effort in the strength and conditioning facility that they are reaping benefits those previous generations did not have the opportunity to participate in.

In 1968, Costill, D.L., Hoffman, W.M., Kehoe, F., Miller, S.J. & Myers, W.C. produced a study that compared the anaerobic power among college football players by position and by players that were grouped by ability levels. The investigators found that there are clear and distinct differences between backs and linemen, in regards to anaerobic power. The investigators found that for all athletes to be successful, the major

characteristic is lower body power production. This power production is a key element for an athlete to have a successful college career (Costill et al., 1968).

In 1976, Smith and Byrd conducted a similar test to that of Costill et al. The investigators concluded, "it appears that participation in football provides no particular advantage in pulmonary function, but does beneficially affect the percentage body fat and aerobic capacity of players. Further, there are clear physiologic differences between backs and linemen" (Smith & Byrd, 1976, p. 302).

These early studies try to identify the various tests that will help coaches evaluate their athletes. These early studies are the beginning research for this topic. They laid the groundwork for other investigators who need to expand the field of research in the sport of football. For example, two decades later Seiler et al. conducted a study to try and quantify power outputs of collegiate football players as a team and by position. This study is very similar to the studies conducted by Smith and Byrd (1976) and Costill et al. (1968). In the study by Seiler et al., the investigators placed athletes into three position groups according to their performance requirements on the field. The data from this study suggests that football players are more powerful than untrained males. This is a very obvious occurrence point, but it is one that needs to be mentioned. The investigators also concluded that linemen were stronger and more powerful than the backs and skill position players (Seiler et al., 1990). This finding is in agreement with the conclusions from Smith and Byrd in 1976 and Costill et al. in 1968.

Kraemer and Lincoln observed how much change occurs in the body of football players over a longitudinal period. "We analyzed the rosters of Pennsylvania State University football players for height and body mass over a 30-year period (i.e., 1967, 1977, 1987, and 1997 teams). For major colleges, the move toward offensive and defensive players averaging 300 pounds each is closer each decade, and many NFL teams have already achieved it. It is interesting to note that the largest athletes in our sample, such as the offensive linemen, made the most significant gains in body mass over the 3 decades, whereas the smallest athletes, such

as the defensive backs and running backs, essentially made no changes at all in body mass. With all of the recent attention to the larger fullbacks who block and are tackled by bigger people, we noted the same trend in our data, as the middle-sized athletes (the fullbacks and linebackers) made significant weight gains only over the last 10 years. The size differences among players have been a classic finding over the years, with only the magnitude being different" (Kraemer & Gotshalk, 2000, p. 799).

In 1990 Berg and colleagues produced a study on the relationship between size, strength, speed, power, and body fat in Division I college football players to team success. "The purpose of this study was to describe 65 Division I NCAA football teams with respect to height, weight, bench press and squat strength, 40-yd dash speed, vertical jump, and body fatness" (Berg et al., 1990, p. 395).

The investigators found that the interior linemen were stronger when absolute strength is taken into consideration. The athletes that are performing in these positions contain a higher level of body fatness but these athletes are still extremely strong. Size and strength seem to be the two main physical attributes of these positions (Berg et al., 1990).

The linebackers and tightends make up the intermediate group and these athletes are representative of the larger linemen group and the smaller, quicker, skill position and backs group. The athletes in this group tend to have a combination of physical attributes from the lineman and from the backs. These athletes are large, leaner than the linemen, and they are strong and fast (Berg et al., 1990). The offensive and defensive backs are typically representative of low body fatness and these athletes are usually the fastest athletes on the team (Berg et al., 1990).

The problem with this study (Berg et al.) is that it is another survey-based study. The study lost its validity when the authors could not control the testing of the athletes. The authors even mentioned, "the validity of these data is limited by the fact that measurements were made by many different people using no

pre-established methodology. For example, 40-yd dash time was measured at most schools by stopwatch; only two used electronic measurement" (Berg et al., 1994, p. 396).

Much of the data in the study by Berg et al. is not as valid and objective, as the authors would like it to be. For instance, when judging a parallel back squat the strength and conditioning coach should judge the lift "good" when the top of the quadriceps is parallel to the floor. Baechle and Earle have described accurately the testing techniques for a strength and conditioning coach. Many strength coaches might judge this lift differently or on how they "see it". Parallel to some is not parallel to others. The investigators would gain consistency and validity if they had control over the testing. Because of the great number of subjects, presented in this study, this concept was impossible to achieve. Therefore, there is a realization and an understanding that this data is not as valid, reliable, and objective, as the investigators would like it to be.

In a study by Fry & Kraemer, the investigators seemed to take a look at the issue of positions groups compared to other position groups. They found that "linemen had greater absolute strength when compared with backs and receivers. On the other hand, backs and receivers exhibited greater vertical jump ability and faster sprint times when compared to linemen, as has also been previously reported. When strength values are corrected for body weight, backs and receivers sometimes exhibit greater relative strength levels than linemen, but not in all instances. Power cleans, 40-yard sprints and back squats have all been reported to significantly discriminate between starters and non-starters" (Fry & Kraemer, 1991, p. 126).

**Comparisons of Starters vs. Non-Starters**

Today's research also spends a lot of energy dealing with comparisons of strength, power, and speed tests between starters and non-starters. Athletes are becoming bigger and stronger; but does this size and strength actually determine who is going to become a starter and who is a non-starter? Performance evaluations of collegiate football players are of continuing interest among the strength and conditioning professional.

In 1999, Schmidt examined the strength and physiological measures in a Division III football program. Although Schmidt is utilizing information from a Division III College, it is still very applicable to this study and to other studies that involve only Division I athletes because the athletes train in the same manner and the athletes are the same age (Schmidt, 1999). Schmidt compared starters to non-starters on various tests. The tests were the seated medicine ball put, sit and reach, vertical jump, timed sit-ups (1 minute), pull-ups, leg press (1 rep max), bench press (1 rep max), dips, and the 300-yard shuttle. The investigator did not distinguish between position groups or positions. The investigator classified the athletes by being a starter or a non-starter and not by positions. By doing this the investigator cannot make comparisons based on positions or position groups. The investigators found that the starters typically scored higher on every test. The one exception was the timed sit-up test (Schmidt, 1999). This finding explains that starters are typically stronger, faster, and more powerful than the non-starters (Schmidt, 1999).

In 1987, McCormick et al. conducted a study earlier than Schmidt (1999). This study by McCormick et al. is very similar to that of Schmidt. The investigators compared the starters to the non-starters as a whole. They did not break the athletes up into positions or position groups. This is the same format that Schmidt did in 1999. McCormick evaluated 70 South Dakota players. The athletes were evaluated on six tests. The tests used were the 1 rep max bench press, power clean, leg press, five-yard shuttle, 10-yard sprint, and the 40-yard dash (McCormick et al., 1987). "Starters had significantly ($p<.05$) greater bench press and power clean strength scores, faster 10 yard dashes that non-starters. Discriminent analysis selected the power clean, 10 yard dash, 40 yard dash, body weight, and height as major factors differentiating starter form non-starters (Wilk's lambda=0.73). The fundamental performance characteristics of speed, power, size, and cardiovascular condition can be used to successfully select football players" (McCormick, 1987, p. 60).

A study by Black and Roundy found that there are differences between positions and between playing status, starters vs. non-starters. They found that players who scored high on tests of strength, power, and speed

were more likely to be starters on a given team. Black and Roundy sent surveys to 44 head strength and conditioning coaches. Comparisons were made between starters and non-starters for 16 positions. The tests used in this study were the bench press, back squat, vertical jump, bodyweight, and the 40-yard dash. The starters at the positions of offensive line, tight-end, quarterback, fullback, defensive tackle, inside linebacker, cornerback, and free safety scored higher on the bench press than the non-starters. The starters at the positions of defensive tackle, outside linebackers, cornerbacks, offensive center, offensive guard, wide receiver, and quarterback scored higher on the 40-yard dash than the non-starters. The starters at the positions of outside linebacker, cornerback, offensive guard, tight-end, wide receiver, and running back scored higher on the squat than the non-starters. The starters scored higher on the vertical jump test in the positions of outside linebacker, cornerback, and wide receiver. The starters at the positions of defensive tackle, outside linebacker, inside linebacker, strong safety, and tightend had significantly higher bodyweights than the non-starters (Black & Roundy, 1994). This data concludes that the evaluation of tests may be used as a tool to distinguish starters from non-starters.

Fry and Kraemer conducted a study in 1991 that is very comparable to Black and Roundy's study that was conducted in 1994. Fry and Kraemer found that "the bench press, power clean, 40 yard dash, and vertical jump effectively differentiated between division of play as well as playing abilities, but the back squat was a relatively poor differentiator" (Fry & Kraemer, 1991, p. 136).

Fry and Kraemer produced 6 position groups (offensive backs, Offensive linemen, Receivers, Defensive linemen, linebackers, and Defensive backs). Comparisons of playing ability were made between the starters and the non-starters for each position group. "Significant differences were found between starters and non-starters for five position groups reported significant differences for the 40-yard dash. On the other hand, only offensive backs demonstrated significant differences between starters and non-starters for five position groups for the bench press, power clean and vertical jump, while four position groups reported significant differences

for the 40-yard dash. On the other hand only offensive backs demonstrated significant differences between starters and non-starters for the back squat" (Fry & Kraemer, 1991, p. 137).

There are many tests that can be used to compare starters to non-starters. The investigators in all of the previous studies that have been mentioned found that starters typically scored higher on some or all of the tests (Berg et al., 1994; Black & Roundy, 1994; Fry & Kraemer, 1991; McCormick, 1987; Schmidt, 1999). Coaches want their strongest, largest, and fastest athletes on the field. The review of the studies in this section indicates that stronger, larger, more powerful, and the faster athletes are typically starters. "The effectiveness of test items for evaluating football playing ability is controversial. There are numerous examples of players with outstanding test scores who seldom play. However, there are also numerous examples of players with outstanding test performances who are outstanding on the field. This study shows that, in general, those players who score high on tests of strength, power, and speed were also selected as starters by their coaches" (Black & Roundy, 1994, p. 83).

**Speed**

The test for speed is an important component of an athlete's physical capabilities to be measured. The 40-yard dash is a universal test for speed in the sport of football. Speed is a very important criterion for a football player's ability. "One important criterion measure, which could be used to test the concurrent validity of predictors of football ability, is speed. Football is clearly a sport where short all-out explosive bursts of power play an important part in performance" (Burke, E.J., Winslow, M.S. & Strube, W.V., 1980, p. 178).

The 40-yard dash is an extremely controversial test for speed. "Speed is often tested with the 40-yard dash. It is doubtful this practice will ever be discontinued. Speed is an important physical ability in football. Many conditioning programs seek to develop and test the athlete's speed" (Ebben, 1998, p. 44). The 40-yard dash is a test that most professionals and non-professionals identify football players with speed. "The 40-yard sprint has been the traditional 'gold standard' of assessing speed in football players, although few players ever

run this distance in a game. This is especially true for linemen. This distance is probably most important for many special team players, who routinely cover 40 to 60 yards on punts and kickoffs. As with many traditional beliefs in football, almost all professional scouts and most professional, collegiate, and high-school teams have used this test as a marker of football speed" (Kraemer & Gotshalk, 2000, p. 800 ). Many people believe that the 40-yard dash is a poor test of speed. There has been some question as to the specificity of this test since there is rarely a time when football players run 40 yards (Crews & Meadors, 1978). Many people believe that the 40-yard dash is not representative of speed for football players since they rarely run that distance. These opposers of the 40-yard dash may consider a 5-yard dash or a 15-yard dash as a more comparable test for speed among football players (Crews & Meadors, 1978).

Crews and Meadors investigated this problem with the testing of speed in 1978. They concluded that, "It has been questioned by some persons as to whether the 40-yard dash, the traditional method of measuring speed in football players, is an appropriate test of football speed. This doubt is a reflection of the fact that there is few times a player actually runs 40 yards during a game. This is especially true of a lineman. A finding of this investigation was a high positive relationship between 5 and 40-yard run times (.80) and between 15 and 40-yard run times (.94). It is apparent that performance in a 40-yard run is representative of how fast a player moves at 5 and 15-yards, and thus is an appropriate test of football speed" (Crews & Meadors, 1978, p. 169).

**The Vertical Jump as a Test of Power**

The vertical jump is a test for lower body power. This is a non-resistant exercise used to measure jumping ability. This test is very important because the ability to jump is a measure of power. In many sports, such as football and basketball, power is a very important component for athletes. The athletes in these sports rely on power to succeed (Hedrick & Anderson, 1996).

Power cleans and jerks are exercises that can be used to measure total body power. These indicators of power are a different measure than the vertical jump since a resistance is being used by the two Olympic-style lifts. "The snatch and the clean and jerk have been widely accepted as a viable means for increasing lower body power" (Hedrick & Anderson, 1996, p. 8).

The clean and jerk are two Olympic-style lifts that can be used to increase vertical jump ability. The Olympic-style lifts involve speed. This speed is transferred from the body to the bar. In performing these lifts power is produced in much the same way as an athlete jumping in the air as high as they can. Coaches would often give cues to their athletes when performing Olympic-style lifts. One of the most common cues is to perform vertical jump with the bar in your hands (Garhammer & Gregor, 1992).

The vertical jump test, the power clean, and the push jerk are all tests of power. The difference is that the power clean and the push jerk are exercises that can increase vertical jumping ability. But performing the vertical jump cannot increase the power clean and the push jerk (Hedrick & Anderson, 1996).

The vertical jump is a non-resistance test of lower body power while the power clean and the push jerk are weight-bearing tests of total body power.

**Summary**

All of the studies agreed on one level or another that in Division 1 football, the athletes are becoming bigger, stronger, and faster than the athletes of previous years. The research has also indicated that starters seem to score significantly higher in the performance tests than non-starters. "The game of football in the United States continues to grow in popularity as a spectator sport. In addition, players are becoming bigger, stronger, faster, and more powerful. The physiologic demands of the game have been highly influenced by official rule changes and football strategies to gain competitive advantages on the field" (Kraemer & Gotshalk, 2000, p. 812).

The actual benefits that an athlete will gain from a collegiate strength and conditioning program are fairly obvious. The athlete, in most cases, will leave the program stronger, faster, and in better condition, in most cases, than when they came into the program. In the sport of football, the athletes are usually bigger in lean body weight than when they first came into the program. Pearson and Gehlsen found that performance enhancement was significantly increased through a strength and conditioning program at Ball State University. This study used football players who were on the roster to complete the investigation. "Two players were unable to complete the study because of injury. The remaining 20 players had an average body mass increase of 1.1 kg. From 84.2+/- 8.8 kg to 85.3 +/- 8.4 kg. There were significant decreases in the 40-yard dash and flying 40, respectively, a 2% and 3% decrease in time. All other performance test values showed a significant increase (Pearson, D., R., & Gehlsen, G., M., 1998)". This explains the basic concept presented in this research. Athletes are going to become stronger, faster, and more powerful when participating in a strength and conditioning program. The starters are usually going to score higher in the strength, power, and performance tests than the non-starters. In completing the review of existing research on this topic, it is logical that the athletes in today's venue are stronger, faster, and more powerful than those of venues past. This concept also coincides with the notion that starters are more likely to score higher on strength and conditioning tests than non-starters.

These findings produce more evidence in the importance of a strength and conditioning program. The evaluation process of the strength and conditioning program is also noted to be of the utmost importance to the strength and conditioning professional. The evaluations made in the testing of athletes have given the strength and conditioning professional reliable information about the athletes, the program, and about the significance of the tests themselves.

# Chapter III

# METHODS

In this chapter the methods, procedures, and the subjects are described. The design and the analysis of this study are also explained. Furthermore, a description of the subjects is presented and is followed by a general methodology. Following this, the test section is explained. The procedure section has been explained thereafter. This section includes information concerning the step-by-step procedures used in this study. Finally, the design of this study is explained and then the statistical analysis is discussed in this chapter.

## Subjects

The total subject pool consisted of 452 Virginia Tech football players between the 1994 season and the 2000 season. These subjects were all male. The subjects participated in the Virginia Tech strength and conditioning program for at least 4 years. The subjects were academic seniors, red-shirt seniors or juniors, or graduate students. These subjects had to be in their final year of competition to be included in this study. Transfers, however, were not included in this study.

A total of 105 football players who were a mean age of 22 were used in this study. The subjects were classified as "starters" or "non-starters" according to their playing status. Subjects had to start at least 7 games in their final season of competition to be classified as a "starter". If a player was considered a starter in an earlier year of competition but not in his final year of competition, he was considered a "non-starter".

The subjects were placed into one of three groups according to their training group during the summer strength and conditioning program in their final year of competition at Virginia Tech. The 3 groups were the Skill group, the Combo group, and the Line of Scrimmage (L.O.S.) group. The Skill group consisted of the receivers, cornerbacks, rover linebackers, whip linebackers, and safeties. The Combo group consisted of inside linebackers, tight-ends, quarterbacks, tailbacks, fullbacks, and defensive ends. The L.O.S. consisted of

defensive tackles and offensive linemen. The offensive linemen consist of the guards, tackles, and the centers. The specialists group, which contains the place-kickers, kick-off specialists, holders, and punters, were omitted from this study. The specialists group was omitted from this study because they did not identify with the norms of any of the 3 position groups. Table 1 clarifies the break up of positions into position groups in which the subjects were categorized according to their training groups:

**Table 1**

| | |
|---|---|
| **Skill Group** | receivers, cornerbacks, rover linebackers, whip linebackers, safety's |
| **Combo Group** | inside linebackers, tight-ends, quarterbacks, tailbacks, fullbacks,defensive ends |
| **L.O.S. Group** | offensive linemen, defensive tackles |

The number of athletes in each group is illustrated in Table 2.

**Table 2**

| **Group** | **Starters** | **Non-Starters** | **Total** |
|---|---|---|---|
| **Skill** | 18 | 10 | 28 |
| **Combo** | 24 | 19 | 43 |
| **L.O.S.** | 21 | 13 | 34 |
| | **Total 63** | **Total 42** | **Grand Total 105** |

**General Method**

Each subject participated in a series of tests conducted by the strength and conditioning staff. Starters and non-starters were compared to each other on 6 different tests and body weight. The tests were ranked in order of importance, by using a Proc StepDisc statistical procedure, from highest to lowest for each of the three groups. There were two strength tests, which were the bench press and the back squat, two power tests, which were the power clean, and the push jerk, and there were two performance tests, which were the 40-yard dash and the vertical jump. The athlete's body weight was also measured.

The groups were formed in a way that they train and condition together during the summer. There are 3 groups during summer conditioning and the groups in this study are consistent with the summer conditioning groups.

**Tests**

Each test represents a parameter in evaluating athletic performance. Strength is measured using the bench press and the back squat.

The bench press is a good indicator of strength in the upper body since it requires involvement of many of the major muscles in the upper body. This exercise targets the pectoralis major, tricep, and the anterior deltoid muscle groups. Moreover, this exercise can be used as a test for upper body strength. The procedure for the bench press exercise is located in Appendix A. "Many coaches and athletes incorporate the bench press as a major exercise to develop the upper body. The bench press is a good lift for developing muscular size and strength and should be included in your program" (Arthur& Bailey, 1998, p. 76).

The back squat is the most common test used to measure lower body strength in a strength and conditioning program that follows the principle of functional lifting. This exercise targets the gluteus maximus,

semimembranosus, semitendinosus, biceps femoris, vastus lateralis, vastus medialis, and the rectus femoris. This exercise can be used as a test for lower body strength. The procedure for the back squat exercise is located in Appendix A. "Many strength coaches and professionals consider the squat exercise essential for the full development of athletic potential. O'Shea and Wegner stated that "the full squat must be considered the cornerstone exercise, because it quickly stimulates overall strength increases in both men and women. Neglecting this exercise retards overall physical development and prevents the athlete from achieving optimal performance" (Chandler & Stone, 1991, p. 52). When discussing lower body strength, the squat is the most common comparison test that strength and conditioning coaches use to compare scores. The back squat is a lift that incorporates all of the major muscle groups of the lower body. The back squat is looked upon as the best test or indicator of lower body strength.

To measure power we use the push jerk and the clean. The power clean is an exercise for power. This exercise is targets maximum muscular power (high-speed strength) (Baechle & Earle, 2000). This test targets the gluteus maximus, semimembranosus, semitendinosus, biceps femoris, vastus lateralis, vastus intermdius, vastus medialis, rectus femoris, soleus, gastrincnemius, deltoids, and the trapezius muscles groups (Baechle & Earle, 2000). The procedure for the power clean exercise is located in the Appendix A.

The push jerk is an exercise for training power. This exercise targets maximum muscular power (high-speed strength) (Baechle & Earle, 2000). This exercise can also be used as a test of power. This test targets the gluteus maximus, semimembranosus, semitendinosus, biceps femoris, vastus lateralis, vastus intermedius, rectus femoris, soleus, gastrocnemius, and the deltoid muscle groups (Baechle & Earle, 2000). The procedure for the push jerk exercise is located in the Appendix A.

Performance tests are measured by the 40-yard dash and the vertical jump. The vertical jump test is a test of lower body, non-resistance maximum power (Baechle & Earle, 2000). In simplistic terms, the vertical jump tests jumping ability. This is an important test for any athlete. "Many strength and conditioning programs

use the vertical jump test to measure the physiological adaptations from training. Vertical jump testing is commonly used (a) to measure improvements in the vertical jump for sports (e.g., basketball) in which jumping ability helps performance, and (b) as a general measure of lower body power in sports such as football that require high levels of lower body power“ (Hedrick & Anderson, 1996, p. 9 ). The vertical jump is an excellent measure of lower body power and it is easy for the athlete to perform with a low-risk of injury. The procedure for the vertical jump exercise is located in Appendix A.

It is a common notion that in football, speed is measured by the 40-yd dash. Speed is an important component of any athletic venue. The 40-yard dash is a test for speed. The athlete runs as fast as he can for forty yards. Investigators with watches take the athlete’s 40-Yard dash times with watches.

This is a test that everyone can identify with. People can tell what a fast 40-yd dash time is but they might not know what a fast 10-yd dash time would be. So, the 40-yd dash is the gold standard test. “Speed is often tested with the 40-yd dash. It is doubtful this practice will ever be discontinued. Speed is an important physical ability in football. Many conditioning programs seek to develop and test the athlete’s speed” (Ebben, 1998, p. 44). The procedure for the 40-yard dash exercise is located in Appendix A.

**Instruments and Apparatus**

The equipment used in performing the bench press is discussed in this quote. “Olympic-style weightlifting set with enough total weight to accommodate the maximum lift of the strongest athlete. A sturdy bench-press bench with integral bar rack of adjustable height” (Baechle & Earle, 2000, p. 292).

In performing the back squat, the equipment used is discussed in this quote. “Olympic-style weightlifting set with enough total weight to accommodate the maximum lift of the strongest athlete. A sturdy

squat rack with adjustable spotting bars to support the weight bar should the athlete be unable to rise" (Baechle & Earle, 2000, p. 292).

For the power clean and the push jerk, the equipment used in performing is discussed in this quote. "Olympic-style set weightlifting with enough total weight to accommodate the maximum lift of the strongest athlete. A lifting platform or designated area set apart from the rest of the facility for safety" (Baechle & Earle, 2000, p. 292).

The equipment used in performing the vertical jump is discussed in this quote. The use of a commercial Vertec device. The Vertec consists of a met al base, with a long met al shaft. At the top are colored vanes that are spaced ½" apart that rotate when touched for easy measurement.

The equipment used in performing the 40-yard dash is discussed in this quote. "Flat running surface with start and finish lines marked 40 yards apart, with at least 20 yards after the finish line for deceleration" (Baechle & Earle, 2000, p. 300). Furthermore, stopwatches should be used.

Bodyweight was taken on a scale that is calibrated for maximum accuracy.

**Procedures**

There are two major testing periods throughout the year. The first testing period is in the spring semester around mid-March. Athletes are tested immediately before spring break. It is during this testing period that the athlete's 40-yard dash times are obtained. An athlete's scores in the bench, squat, clean, jerk, and the vertical jump are also recorded during this testing period.

The second testing session begins right before the football season starts. This session is usually in late July or early August. Test scores are gathered in the bench, squat, clean, jerk, and vertical jump during this testing period. This is a very important testing session because it is the last testing session of the year. The

investigator of this study want to look at the athlete's last testing session so all of the athletes test scores over their four-year to five-year period can be taken into account. After all of the test scores have been gathered in the respective athletes playing tenure, here at Virginia Tech, the investigator then picked their personnel best in each lift. Even though the last testing period scores are gathered, a test score from one of the previous maxing sessions might be recorded if it is a higher score than the last test score. The athlete's personnel best test scores over their four to five years of participation are recorded and used in this study.

The reason the 40-yard dash times are taken from the first testing session is because the 40-yard dash is administered during this testing period. The 40-yard dash is not performed during the second testing period because there is a chance of injury when running the 40-Yard dash. It is to close to the season to test this test because of the risk of injury.

The bench press was measured by using a one-repetition max. The athlete performs the lift with as much weight as he can for one repetition. Both the push jerk and the power clean are measured in this same manner. The squat was measured by using a three-repetition max because it lowers the risk of injury. The athlete performs the lift with as much weight as he can execute for three repetitions. The weight that the athlete used for the three-repetition max is then divided by 91% to get an estimated max. Example: 500 pounds (weight used for 3 repetitions) is divided by 91% or .91 = approximately 550 pounds. So 550 pounds would be the athlete's max on back squat.

The vertical jump was measured by using a Vertec. To measure vertical jump the coach wants to take the standing height of the subject with both arms fully extended overhead. Then the athlete will jump-up and touch the highest possible vane. The athlete will continue to jump until he has three misses. To get the vertical jump score the coach will measure the difference between the standing height and the jumping height.

Three coaches with watches timed the 40-yard dash. Each athlete received three attempts. The times of the three watches were averaged together for each attempt. The best averaged time was the athletes 40-yard dash score.

Body weight was taken by a scale that is calibrated correctly so that there will be an accurate reading.

**Testing**

The basic design of the study consisted of the testing of the athletes and ranking the tests in order of importance or significance. The athletes have been tested in their relative years of participation. Their test scores from all six tests and their bodyweight have been recorded. While the athletes have been placed into groups according to their positions, they have also been given a playing status of either starter or non-starter. The details of these groupings have been explained in the previous section.

The athlete's test scores were then compared to each other by playing status. Starters were compared to non-starters by group. A Proc StepDisc statistical analysis was used to place the tests in order of importance, starting with the test which most signifies a difference between starters and non-starters, and then working down to the test that least signifies a difference between starters and non-starters.

This procedure was carried out for each of the three position groups (Skill group, Combo group, L.O.S. group). A Proc StepDisc statistical analysis has been performed on each position group. This analysis produces the order of importance for each test, for each group. This information can and will be used by the strength and conditioning professional. This information is a way to evaluate the tests being administered to the athletes and this information is a way to evaluate the strength and conditioning program.

All of the testing during this study was conducted under the direction of Dr. Mike Gentry. The collection of data has been performed in the same process between the 1994 and the 2000 season. Because the collection of data has been under the direction of Dr. Gentry the data has been collected in a reliable and consistent manner.

**Data Analysis and Statistical Treatment**

The statistical analysis used to test the hypotheses in this study was a Proc StepDisc Procedure. This analysis was used to rank the tests in order of importance from the most significant to the least significant test. This procedure was carried out for all three position groups, comparing starters to non-starters. (Skill group, Combo group, L.O.S. group)

Essentially, this procedure is appropriate when you have "a classification variable and several quantitative variables, the STEPDISC procedure performs a stepwise discriminate analysis to select a subset of the quantitative variables for use in discrimination among the classes. The set of variables that make up each class is assumed to be multivariate normal with a common covariance matrix. The STEPDISC procedure can use forward selection, backward elimination, or stepwise selection. The STEPDISC procedure is a useful prelude to further analyses using the CANDISC procedure or the DISCRIM procedure. With PROC STEPDISC, variables are chosen to enter or leave the model according to one of two criteria:

1. the significance level of an F-test from an analysis of covariance, where the variables already chosen act as covariates and the variable under consideration is the dependent variable.
2. The squared partial correlation for predicting the variable under consideration from the CLASS variable, controlling for the effects of the variables already selected for the model. (Proc Stepdisc, 2001).

# Chapter IV

# RESULTS

The results suggest that for each position group, there are tests that are ranked in order of importance. Or more specifically, the tests are ranked in order of most differentiating significance between starters and non-starters. Therefore, each test is ranked in order from most difference to least difference. The results were recorded for each position group: Skill group, Combo group, L.O.S. group.

The bench press, back squat, push jerk, bodyweight, and the clean were recorded in pounds while the vertical jump was recorded in inches, and the 40-yard dash was recorded in seconds. The descriptive statistics are located in Appendix B. The step tables for the Proc StepDisc procedure are located in Appendix C. The Skill group, Combo group, and the L.O.S. group step procedures are in Appendix C.

## Skill Group Results

The tests for the Skill group are ranked in order of importance, beginning with the most important to the least important:

1. Vertical Jump
2. Power Clean
3. 40-yard Dash
4. Back Squat
5. Bodyweight
6. Push Jerk
7. Bench Press

Table 3 shows the tests that are significant at the $p<.05$ level for the skill group are the: bench press, power clean, push jerk, 40-Yard dash, vertical jump, and bodyweight.

The F-values and the p-values for each test are listed in Table 4. This table shows the results of the Proc Stepdisc Procedure analysis performing a stepwise discriminate Analysis on the Skill position group. The level

of significance is p<0.7. The level of significance is set this high in order to encompass all of the tests in a rank ordering of importance from highest to lowest.

**Table 3**
**Proc StepDisc Procedure for the Skill Group**

**Step 1**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.1965 | 6.36 | 0.0181 | 1.000 |
| Back Squat | 0.1176 | 3.47 | 0.0740 | 1.000 |
| Power Clean | 0.2923 | 10.74 | 0.0030 | 1.000 |
| Push Jerk | 0.2040 | 6.66 | 0.0158 | 1.000 |
| 40-yard Dash | 0.3280 | 12.69 | 0.0014 | 1.000 |
| **Vertical Jump** | 0.3353 | 13.12 | **0.0012** | 1.000 |
| Bodyweight | 0.1866 | 5.96 | 0.0217 | 1.000 |

**Table 4**
**Tests in ranking order from most significant to least significant within the Skill position group.**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| 1. Vertical Jump | 0.3353 | 13.12 | **0.0012** | 1.000 |
| 2. Power Clean | 0.1264 | 3.62 | **0.0687** | 0.7498 |
| 3. 40-yard Dash | 0.0549 | 1.39 | **0.2494** | 0.3382 |
| 4. Back Squat | 0.0341 | 0.81 | **0.3766** | 0.3299 |
| 5. Bodyweight | 0.0679 | 1.60 | **0.2189** | 0.3228 |
| 6. Push Jerk | 0.0086 | 0.18 | **0.6739** | 0.1813 |
| 7. Bench Press | 0.0234 | 0.48 | **0.4972** | 0.1407 |

**Combo Group Results**

The tests for the Combo group are ranked in order of importance between the starters and the non-starters.

1. 40-yard Dash
2. Bodyweight
3. Bench Press
4. Back Squat
5. Vertical Jump
6. Push Jerk
7. Power Clean

Table 5 shows that there are no tests that are significant at the p>.05 level for the Combo group, however, the top 4 ranked tests will be discussed in Chapter V.

The F-values and the p-values for each test are listed in Table 6. This table shows the results of the Proc Stepdisc Procedure analysis on the Combo group performing a stepwise discriminate analysis on the Combo position group. The level of significance is p<0.97. The level of significance is set this high in order to encompass all of the tests in a rank ordering of importance from highest to lowest.

**Table 5**
**Proc StepDisc Procedure for the Combo Group**

**Step 1**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.0004 | 0.02 | 0.8981 | 1.000 |
| Back Squat | 0.0588 | 2.31 | 0.1370 | 1.000 |
| Power Clean | 0.0161 | 0.61 | 0.4411 | 1.000 |
| Push Jerk | 0.0315 | 1.20 | 0.2798 | 1.000 |
| **40-yard Dash** | 0.0718 | 2.86 | **0.0992** | 1.000 |
| Vertical Jump | 0.0194 | 0.73 | 0.3978 | 1.000 |
| Bodyweight | 0.0188 | 0.71 | 0.4053 | 1.000 |

**Table 6**
**Tests in ranking order from most significant to least significant within the Combo position group.**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| 1. 40-Yard Dash | 0.0718 | 2.86 | **0.0992** | 1.000 |
| 2. Bodyweight | 0.1206 | 4.94 | **0.0327** | 0.7087 |
| 3. Bench Press | 0.0365 | 1.33 | **0.2574** | 0.4929 |
| 4. Back Squat | 0.0306 | 1.07 | **0.3072** | 0.4660 |
| 5. Vertical Jump | 0.0210 | 0.71 | **0.4060** | 0.3573 |
| 6. Push Jerk | 0.0070 | 0.23 | **0.6374** | 0.3545 |
| 7. Power Clean | 0.0001 | 0.00 | **0.9637** | 0.3385 |

**L.O.S. Group Results**

The tests for the L.O.S. group are ranked in order of importance between the starters and the non-starters.

1. Bodyweight
2. Vertical Jump
3. Bench Press
4. Back Squat
5. Power Clean
6. Push Jerk
7. 40-yard Dash

Table 7 shows that the tests that are significant at the p>.05 level for the L.O.S. group are the: bench press, push jerk, vertical jump, and bodyweight.

The F-values and the p-values for each test are listed in Table 8. This table shows the results of the Proc Stepdisc Procedure analysis performing a stepwise discriminate analysis on the L.O.S. position group. The level of significance is p<0.99. The level of significance is set this high in order to encompass all of the tests in a rank ordering of importance from highest to lowest.

**Table 7**
**Proc StepDisc Procedure for the L.O.S. group.**

**Step 1**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.2240 | 8.66 | 0.0062 | 1.000 |
| Back Squat | 0.0531 | 1.68 | 0.2046 | 1.000 |
| Power Clean | 0.0733 | 2.37 | 0.1339 | 1.000 |
| Push Jerk | 0.1677 | 6.05 | 0.0199 | 1.000 |
| 40-yard Dash | 0.0491 | 1.55 | 0.2229 | 1.000 |
| Vertical Jump | 0.1276 | 4.39 | 0.0448 | 1.000 |
| **Bodyweight** | 0.2709 | 11.15 | **0.0023** | 1.000 |

**Table 8**
**Tests in ranking order from most significant to least significant within the L.O.S. position group.**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| 1. Bodyweight | 0.2709 | 11.15 | **0.0023** | 1.000 |
| 2. Vertical Jump | 0.2237 | 8.36 | **0.0072** | 0.9925 |
| 3. Bench Press | 0.0599 | 1.78 | **0.1926** | 0.7771 |
| 4. Back Squat | 0.0634 | 1.83 | **0.1876** | 0.6635 |
| 5. Power Clean | 0.0798 | 2.25 | **0.1453** | 0.6074 |
| 6. Push Jerk | 0.0009 | 0.02 | **0.8794** | 0.4821 |
| 7. 40-yard Dash | 0.0000 | 0.00 | **0.9801** | 0.3451 |

The Proc Stepdisc analysis procedure found that between all three groups there are very different rankings of tests being observed. Each group has separate rankings of tests, which are observed in Table 4 for the Skill group, Table 6 for the Combo group, and Table 8 for the L.O.S. group.

# Chapter V

# DISCUSSION, CONCLUSIONS, RECOMMENDATIONS, AND IMPLICATIONS

## Introduction

Today's athletes are becoming bigger, stronger, and faster (Costill et al., 1968; Kraemer & Gotshalk 2000; Olson & Hunter, 1985; Smith & Byrd, 1976; Stone et al., 2000). This is a function of most strength and conditioning programs that evaluate their athletes on various tests used to measure their performance in categories, such as strength, power, and speed. In this sense, the strength and conditioning professional uses these tests to evaluate the athlete by comparing scores to another population's scores.

The tests that are being evaluated, the bench press, back squat, power clean, push jerk, 40-yard dash, vertical jump, and bodyweight, are all core exercises that are a mainstay for many strength and conditioning programs (Black & Roundy, 1994; Fry & Kraemer, 1991). These tests are used to make comparisons between types of athletes. In connection to this, the comparison made in this study, focused primarily on the starters and the non-starters of Virginia Tech's football team between the 1994 to the 2000 season. Playing status is the issue of utmost importance. Also, with the review of literature that has established the importance of evaluating tests (Arthur & Bailey, 1998; Gambetta, 1998; Graham, 1994; Kraemer& Gotshalk, 2000;), many previous investigators showed evaluations between starters and non-starters on the same tests that are instituted in this current study. The collecting of data that represents test scores between starters and non-starters in three position groups, may help the strength and conditioning professional in proper and sport-specific program design.

The purpose of this study was to determine what influence the strength, power, and performance tests scores have on an individual's playing status. These findings may be used to help the strength and conditioning professional develop programs that may be more sport-specific for certain positions or position groups.

Areas of key inquiry to be considered are the ability to rank the tests in order of importance. Can an accurate assumption be made in ranking strength, power, and performance tests in order of importance? Is there a relationship between these various tests and playing status? Can we make an accurate premise concerning sport-specific training when looking at the ranking order of these tests?

**Skill Group Discussion**

Seven tests, which are the bench press, back squat, power clean, push jerk, vertical jump, 40-yard dash, and bodyweight, were ranked in order of importance for each position group by the investigator of this study. A Proc Stepdisc procedure was used to rank the tests in order of importance. In the skill group the tests were ranked accordingly:

1. Vertical Jump
2. Power Clean
3. 40-Yard Dash
4. Back Squat
5. Bodyweight
6. Push Jerk
7. Bench Press

The rank ordering of the tests is the issue of importance. Although some of the mentioned tests may not be significant at the $p>.05$ level the tests will still be discussed in this section.

The rank ordering of these tests suggests that power and speed can be used to distinguish a starter from a non-starter in the skill position group. These data suggest that power and speed, in that order, are the most important factors that separate starters from non-starters.

The tests of vertical jump and power clean are representative of power production. The vertical jump is a test of lower body power. It measures jumping ability, which is a non-resistance test of power. This is the first ranked test. The power clean is also a test of power and this is the second ranked test. These two tests determine that power is the most important factor for the skill position group.

Power is important for this group because of the explosive hip and leg power these athletes need to posses in order to excel (Kraemer & Gotshalk, 2000). Power, being the number one factor in the skill position group is not a surprising finding because of the position requirements. The athletes need to have great lower body power in order to jump, and change directions in a hurry. This jumping ability is a measure of power, which is an important requirement for these positions.

The 40-yard dash is the third ranked test to distinguish between starters and non-starters. Speed is a factor that is easily predicted to rank high, because of the nature of the skill group positions. The skill group positions, such as receivers and defensive backs, rely on speed and power to excel in the game of football (Fry & Kraemer, 1991; Kraemer & Gotshalk, 2000). Athletes in the Skill group depend upon quickness, speed, and power to cover receivers, run routes, and make tackles and blocks (Kraemer & Gotshalk, 2000; Pincervo & Bompa, 1997). According to Kraemer and Gotshalk ,"Wide receivers became taller, big enough to fend off an initial 'bump', and faster runners (for example the San Francisco 49'ers Jerry Rice). In response, defensive backs generally became smaller and less bulky, but also quicker and faster (for example, the Washington Redskins Darrell Green and the Dallas Cowboys, Deion Sanders), relying now on shadowing, quickness, and speed to recover rather than route disruption and more contact downfield to defend against the passing game" (2000, p. 797 )

This study also suggests that bodyweight and strength are the least important factors that distinguish between starters and non-starters. This finding is also consistent with the previous studies conclusions on this topic (Black & Roundy, 1994; Kraemer & Gotshalk, 2000; Pincievero & Bompa, 1997;). Bodyweight was ranked fifth, while push jerk was ranked sixth, and the bench press was ranked seventh. Although the strength and bodyweight factors are not as highly ranked as the speed and power factors, this is not to say that strength and bodyweight do not contribute to the athlete's success.

It is interesting to note that the starters and non-starters are closer together on scores on the bench press, back squat, push jerk, and the bodyweight than initially thought. This finding may suggest that the emphasis of the training program that the athletes take part in may cater to strength movements. This emphasis on strength movements, such as the bench press and the back squat, may create an environment where there is little difference between starters and non-starters. The bench press and the back squat are two core strength lifts that the athletes perform at Virginia Tech.

These two lifts are core strength exercises that the athlete may identify with more than other lifts. The identification of these common lifts may cause the athletes, to place more emphasis on these two exercises than others, which would lead to a closer gap between the starters and the non-starters.

The back squat and the bench press are also two lifts that are less complex to perform than other lifts, such as, the Olympic-style lifts. The less complexity level might also lead to a closer gap between starters and non-starters. These exercises are easier to perform than other exercises. Since the athletes are not pushing and pulling against each other like the linemen and the linebackers do during competition, the skill position players are more related to the types of movements that incorporate speed and power.

These data may also suggest that bodyweight may not contribute much on factors that differentiate between starters and non-starters within the skill position group. This finding is consistent with studies conducted by Berg et al., Black & Roundy, Kraemer & Gotshalk, and Pincivero & Bompa. Typically, the athletes in this position group rely on speed and power to succeed in this sport. Bodyweight, therefore, would not be considered a key factor that would separate a starter from a non-starter. These athletes need to be quick enough to elude bigger linemen, fast enough to cover quick wide receivers, and fast enough to run passing routes. Being bigger and possibly carrying a higher percentage of body fat may be detrimental to the athlete (Kraemer & Gotshalk, 2000; Pinciervero & Bompa, 1997). This higher percentage of body fat will usually translate into a higher bodyweight measurement.

The athletes in the skill group are smaller than athletes in the other two groups. They are also faster than the athletes in the other two groups. These findings seem to conclude that the athletes in the Skill position group are very powerful and fast. This finding is reflective of the difference between the starters and the non-starters in the Skill group.

The main premise that has been established from the findings in the Skill group is that the starters seem to be able to move better than the non-starters. The concept of movement as a major distinguisher between the starters and the non-starters is derived from the vertical jump test, the Olympic-style lifts, such as, the power clean, and the 40-yard dash. These are all tests of movement. For an athlete to be able to excel at one of these positions in the Skill group, he must be able to move. Although this study does not take into consideration lateral movement or shorter sprints, the findings still indicate that the ability to move the body is a key factor in the success of an athlete in the Skill group. Future studies should utilize the short sprint tests and lateral movement tests if the data are attainable. These tests may indicate further evidence that the ability to move the body fast in different planes could be an important role for these athletes.

Another factor that may contribute to the ranking order is genetic potential. The starters could be genetically more gifted in the areas of speed and power. This may be the one factor that could determine playing status without evaluating any tests. In simple terms, the starter may be faster and more powerful than the non-starters and there may be nothing that the non-starters can do about it.

**Combo Group Discussion**

Seven tests, (bench press, back squat, power clean, push jerk, vertical jump, 40-yard dash, and bodyweight), were ranked in order of importance for each position group by the investigator of this study. A Proc Stepdisc procedure was used to rank the tests in order of importance. In the combo position group the tests were ranked accordingly:

1. 40-Yard Dash
2. Bodyweight
3. Bench Press
4. Back Squat
5. Vertical Jump
6. Push Jerk
7. Power Clean

The rank ordering of the tests is the issue of importance. Although some of the mentioned tests may not be significant at the p>.05 level the tests will still be discussed in this section.

The rank ordering of these tests suggests that the findings that distinguish a starter from a non-starter are a combination of speed, size, and strength. This finding is consistent with other investigators conclusions about these positions and/or position group (Berg et al.; Fry & Kraemer; Kraemer & Gotshalk; Pincevero & Bompa). This finding is best represented in a quote by Pincivero and Bompa : "As a result, an equal development of power, strength, speed, endurance, and agility is optimal for linebackers since their duties range from contacting offensive linemen and tackling running backs to running downfield to cover receivers and tight ends" (1997, p. 257). Although this quote only discusses the linebacker position it is still representative of the combo position group. The positions in the Combo group are very similar in position requirements, size, strength, power production, and speed (Kraemer & Gotshalk, 2000; Pinciévero & Bompa, 1997). The athletes, regardless of whether they are linebackers, tightends, or fullbacks, are very similar in their physical capabilities.

The rankings show that speed is the most important factor for this position group. This factor has been an emphasis for Virginia Tech football. Speed has been emphasized on defense and in the skill positions on offense for years. This emphasis might lead to a faster player becoming a starter rather than a player who is not as fast. Virginia Tech plays an attacking defense that penetrates the offensive gaps. This penetration has to be brought about with speed. The faster the athlete, the quicker he can fill the hole or close the gap on a running

back. Speed being ranked number one, reflects the type of athletes that are being recruited for these positions at Virginia Tech. Defensive ends, which are in the combo position group, are smaller and faster than defensive ends of traditional defenses. These ends have to be able to move fast in order to succeed.

Bodyweight, which ranks second, reflects the importance of size on the field. This coupled with speed reflects the importance of athletes in this position group having size and speed (Pincivero & Bompa,1997). Size and speed are important to the athletes in the Combo group. These athletes have to be able to take on larger linemen. This size will help these athletes complete their assignment. Fullbacks have to block larger linemen and linebackers, while the linebackers have to shed blocks from the massive offensive linemen. Size is an important attribute to obtain if the athlete is in the combo position group.

The bench press is ranked third, while the back squat is ranked fourth. This finding suggests that strength is a very important factor that separates a starter from a non-starter. The athletes who belong in this position group have to be strong to take on larger individuals.

For the bench press which is a test of upper body strength, Combo group players must have strong upper bodies in order to shed blocks and make blocks. At the same time, the back squat is a test of lower body strength. These athletes need to have great lower body strength in order to have good leg drive. This leg drive will help the athlete make blocks and tackles.

Power is the last factor that distinguishes between starters and non-starters in this group. The vertical jump is ranked fifth, the push jerk is ranked sixth, and the power clean is ranked seventh. This is a very surprising finding. Before this study, the factor of power was thought to possibly be the most important factor for this group. The reason behind why this result is not so clear may be attributed to the athletes in this group who are quite powerful; also, and there is not much difference between the starters and the non-starters. For whatever reason, power does not differentiate well between starters and non-starters.

In this position group, there is an interesting event that occurs that is more visible than in the other groups. When looking at the p-values for the tests, the changing of the bench press p-value from step 1 to step 3 is of interest. In step 1 the 40-yard dash had the lowest p-value of 0.0992. The bench press had the highest p-value of 0.8981. In step 2 bodyweight had the highest p-value of 0.0327. The bench press had the highest p-value of 0.8011. But during step 3, the bench press was raised to the highest rank with a p-value of 0.2574. This may show a correlation between bench press and bodyweight within the Combo group at Virginia Tech.

These findings can provide strength and conditioning professionals with insight regarding the programming needs of a Combo group athlete. The program needs to reflect an interest in developing faster and larger athletes for these positions. It seems that strength also plays an important role in developing these athletes. The key finding is the speed factor. It seems to play an important role for differentiating between starters and non-starters. Therefore, speed may be an emphasis for the training of these athletes. More specifically, speed coupled with the production of large, strong athletes would be optimal for this position group (Berg et al., 1990; Fry & Kraemer, 1991; Kraemer & Gotsholk, 2000; Pincevero & Bompa, 1997).

The main conclusion that is drawn about the Combo group is that the athletes have to have size and speed in order to succeed. The ability to be able to run fast while having good size can help in many ways. The Combo group is wedged between the L.O.S. group, which contains much larger and stronger athletes, and the Skill group which contains athletes that are smaller and faster. The biggest difference between the starters and non-starters in the Combo group is bodyweight and the 40-yard dash times. This indicates that in order to start an athlete must be able to compete with both types of athletes from the Skill group and the L.O.S group.

Another factor that may contribute to the ranking order is genetic potential. The starters could be genetically more gifted in the areas of speed, size, and strength. The genetic potential may be the one factor that could determine playing status without evaluating any tests. In simple terms, the starter may be faster and larger, and stronger than the non-starters and there may be nothing that the non-starters can do about it.

**L.O.S. Group Discussion**

Seven tests, which are the bench press, back squat, power clean, push jerk, vertical jump, 40-yard dash, and bodyweight, were ranked in order of importance for each position group by the investigator of this study. A Proc Stepdisc procedure was used to rank the tests in order of importance. In the L.O.S. position group the tests were ranked accordingly:

1. Bodyweight
2. Vertical Jump
3. Bench Press
4. Back Squat
5. Power Clean
6. Push Jerk
7. 40-yard Dash

The rank ordering of the tests is the issue of importance. Although some of the mentioned tests may not be significant at the $p>.05$ level the tests will still be discussed in this section.

The rank ordering of these tests suggest that the findings that distinguish a starter from a non-starter in this group are a combination of size, lower body non-resistance power, and strength. Bodyweight was ranked as the number one differentiator between starters and non-starters. This means that the starters were more likely to be heavier than the non-starters. This finding is consistent with findings of other investigators regarding bodyweight and the importance of size in these positions (Berg et al., 1990; Fry & Kraemer, 1991; Kraemer & Gotshalk, 2000; Pincevero & Bompa, 1997). In order to be competitive, the athlete needs to be large. The athlete has to have size to move other large bodies out of the way (Kraemer & Gotshalk, 2000). This finding was not a surprise; as expected, the larger athletes in these positions tend to get more playing time than their small counterparts (offensive linemen and defensive linemen).

The vertical jump was the test that ranked second for the combo position group. Contrary to the bodyweight finding, the vertical jump finding, was a surprise. This finding suggests that not only does the

athlete need size but also lower body power. This lower body power is an indicator of explosion, and therefore can be indicative of offensive and defensive linemen exploding off the line of scrimmage. Explosion is important because these athletes need to move large, strong men off of the line of scrimmage. The offensive linemen are relying on power and size to move the defensive linemen and linebackers out of the way of the play. The defensive linemen are relying on size and power to get rid of the offensive linemen's block so they can make a tackle.

Strength was the next factor to be ranked. The bench press ranked third, while the back squat ranked forth. As discussed earlier, the bench press is a test of upper body strength, while the back squat is a test of lower body strength. Strength has been cited to be an important attribute for these positions since these positions require the athletes to push and pull each other for positional ground (Berg et al., 1990; Fry & Kraemer, 1991; Kraemer & Gotshalk, 2000; Pincevero & Bompa, 1997).

The power clean was ranked fifth, while the push jerk was ranked sixth. These two tests are resistance-bearing exercises that assess total body power. One possible reason that these exercises are not ranked higher may be that most of the athletes in this L.O.S. group are quite powerful and there is not much difference between the starters and the non-starters. For whatever conclusion there may be, total body weight-bearing resistance power is not a highly ranked factor differentiating between starters and non-starters.

Speed was the last factor that differentiated between starters and non-starters. This was not a surprise. Offensive and defensive interior linemen are not required to run long distances at fast speed. These athletes are required to be productive in a 5 to 10-yard distance. These athletes are more suited to place an emphasis on size rather than speed. Size is a more productive attribute than speed is for this position group (Pincivero & Bompa,, 1997).

These findings can give strength and conditioning professional's insight regarding the design of strength and conditioning programs for the L.O.S. group athlete. The program needs to emphasis the

development of larger athletes with lower body power, and strong athletes. The program may incorporate core strength movements to create stronger athletes. Diets may also become available for athletes to follow, in order to become larger. The key is to gain lean body mass and not excess fat. Excess fat has been shown to be detrimental to the athlete's performance (Bale et al., 1994; Mayhew et al., 1993; Wickkiser & Kelly, 1975;).

The most important finding in the L.O.S. group is the idea of lower body power being ranked so high. In order for the athletes in the L.O.S. group to succeed they must possess great size and lower body power. During the game the athletes in this group are making contact and collisions with other athletes that are the same size and strength or in some cases larger and stronger. In order to be a starter the athlete needs to have good size and power in order to succeed.

Another factor that may contribute to the ranking order is genetic potential. The starters could be genetically more gifted in the areas of size, lower body power, and strength. The genetic potential may be the one factor that could determine playing status without evaluating any tests. In simple terms, the starter may be genetically larger, stronger, and more powerful in the lower body than the non-starters and there may be nothing that the non-starters can do about it.

## Conclusions

On the basis of the results of this study, the null hypotheses were rejected for the Skill Group and the L.O.S. group, but the null hypothesis was retained for the Combo Group since there were no tests that significantly distinguished starters from non-starters at the $p>.05$ level. Although there was significant difference in the Combo Group there still appears to be a distinct rank ordering of tests between starters and non-starters in all three-position groups. The tests are ranked in order of most important to least important for each position group. All three-position groups found results that are training group-specific for their position requirements.

For the skill position group, results indicate that power is the most important factor differentiating between starters and non-starters followed by speed, strength, and bodyweight.

In the combo position group, results indicate that speed is the most important factor differentiating between starters and non-starters followed by bodyweight, strength, and power.

And finally, the L.O.S. position group results indicate that bodyweight is the most important factor differentiating between starters and non-starters followed by lower body power, strength, total body power, and speed.

It is interesting to note the different and complex requirements of each position group. It seems that the skill group relies on power, speed, and less on strength and size. The combo group is indicative the fact that they are a combination of the skill position group and the L.O.S. group. These athletes rely on speed, size, and strength. The L.O.S. group relies on size, lower body power, and strength to excel in the game of football.

It should be noted that these results are only indicative of the Virginia Tech football program. However, this study may hold true for teams that run a similar strength and conditioning program, and run a similar offense and defense. Furthermore, this study may also hold true for other Division I universities that concentrate on running the football and who emphasize speed on the field.

## Possible Future Studies and Recommendations

Further inquiry is needed on tests that evaluate shorter sprints and lateral movement. Studies should involve more speed and agility tests, such as, the 10-yard sprint, NFL shuttle, and the 5-yard sprint. This may add more credibility to the study. The addition of these tests may make it more sport-specific for the positions.

Another possible study would be to find if there are any correlations between tests. This finding may bring in a change about the way we train certain athletes and how we train these athletes.

The data in this study recommends that strength and conditioning coaches train their athletes in a more sport-specific method. Skill group positions players need more focus on power and speed development while the Combo and L.O.S. groups need to focus on the size of the athletes. The Combo group athlete is also recommended to train speed development since the 40-yard speed test ranked so high among these athletes. Surprisingly the L.O.S. group athlete also may need to focus on lower body power production in their training regime.

These recommendations are given in direct accordance through the data that has been collected and discussed in this study.

**Implications for the Strength and Conditioning Coach**

This study may help strength and conditioning coaches design their programs in a more training group-specific manner. It may give some professionals the information about what factors to implement more than others in their own program.

Furthermore, this study may be used by some strength and conditioning professionals with the separation of positions into different positions groups used for training purposes. The similarities of the positions, in each group, create an environment in which the athletes will train in a more training group-specific program. This concept will aid the strength and conditioning program to be more specific to the positions and this will adequately fulfill the biomechanical needs and the positional requirements of the athletes.

Based on this study, the strength and conditioning professional, in designing his/her training program, might best understand the different position requirements and the factors that are most important to that position group in order to produce a training group-specific program that fits the needs of the athlete.

The strength and conditioning professional can use this information to provide information about the various training groups to their athletes and coaches. This information can be used to help the strength and

conditioning professional bridge gaps between their field and other fields within the athletic department. The knowledge that is gained through this study may provide information that will help the training aspects of various football programs. In turn, this will benefit the athletic department.

The factors that are discussed in this chapter may help the strength and conditioning coach and they may benefit other strength and conditioning programs that are similar to Virginia Tech.

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# APPENDIX A

## Description of Exercises


This is a standard Olympic bar and plates. The brand name is Eleiko.

This is a bench press rack. The bar and weights are standard Olympic style. The brand name is York.

This is a power rack where the back squat, power clean, and the push jerk are performed.


This is a Vertec used to measure Vertical Jump

Bench Press Description

Figure 1

Use a shoulder width grip. Lie down on a flat bench. Lower the weight slowly until the bar touches the middle of the chest and drive the bar upward towards the rack. Keep feet flat on the floor and buttocks on the bench at all times. Always use a spotter.

Figure 2

Figure 3

Back Squat Description

Figure 1

Figure 4

Figure 2

Rest the bar on the back right below the trapezious, keep the back arched and the weight over the hips at all times. The feet should be slightly wider than shoulder width with the toes slightly pointed out. Go down slowly until the bottom of the thigh is parallel to the floor. Drive up quickly. Do not bounce at the bottom of the lift.

Figure 3

Power Clean Description

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

"The lifter approaches the barbell while it is on the platform with their back straight. Elbows rotated out to sides. Arms straight and shoulders set in advance of bar. From this position by first extending the legs, then the body upward in a violent movement, finally shrugging the shoulders and rising up on to the balls of the feet before dipping and receiving the bar at the shoulders as before (Jones, L., 1994)."

Description of the Push Jerk

Figure 1

Figure 2

Figure 3

Figure 4

Do this exercise standing, take the weight out of the rack. The bar is racked on the shoulders as in the completion of a power clean. Rock up on toes to get your momentum started, then squat 4” to 5” and quickly drive the legs up and throw the weight overhead. The bar should lock-out directly over the lifters head or slightly behind. Bend your knees when you lock-out the weight, then stand up. This is a jerk not a military press. The concept is of throwing and catching the weight.

Description of the Vertical Jump


Figure 1

Figure 3

Figure 2

The athlete's reach is taken by walking the athlete through the vertec and then recording the reach, as seen in Figure 1. The athlete jumps as high as he can with the feet first being stationary on the ground. The athlete cannot take a step. This is presented in Figure 2. The athlete's jump height is subtracted by the reach height in order to get the vertical jump measurement.

Description of the 40-Yard Dash

The 40-Yard dash is taken by a strength and conditioning coach with a watch. The athlete runs as fast as he can for 40-yards.

# APPENDIX B

## Descriptive Statistics

In this section the descriptive data for the subjects are illustrated in Table 9 through Table 20. These tables portray the Number, Mean, Median, Mode, Standard Deviation, and Range for each of the tests. The tables represent the subjects in separate categories.

**Table 9**
**Descriptive Data for All Subjects**

| Variable | n | Mean | Median | Mode | SD | Range |
|---|---|---|---|---|---|---|
| Bench Press | 105 | 350.66 | 355 | 400 | 56.12 | 230-500 |
| Back Squat | 105 | 518.66 | 530 | 550 | 74.95 | 320-700 |
| Clean | 102 | 314.14 | 316 | 300 | 47.36 | 180-445 |
| Jerk | 103 | 312.91 | 320 | 300 | 41.80 | 211-401 |
| 40-Yard | 102 | 4.74 | 4.70 | 4.48 | 0.29 | 4.3-5.5 |
| Vertical Jump | 105 | 32.79 | 33 | 36 | 4.19 | 22.5-43.5 |
| Age | 105 | 22.32 | 22 | 22 | 0.93 | 21-26 |
| Bodyweight | 105 | 234.87 | 235 | 202 | 44.42 | 164-322 |

**Table 10**
**Descriptive Data for All Non-Starters**

| Variable | n | Mean | Median | Mode | SD | Range |
|---|---|---|---|---|---|---|
| Bench Press | 42 | 335.71 | 340 | 370 | 53.27 | 230-420 |
| Back Squat | 42 | 504.64 | 530 | 550 | 76.51 | 320-630 |
| Clean | 41 | 301.09 | 300 | 300 | 48.45 | 180-410 |
| Push Jerk | 42 | 300.76 | 300 | 300 | 40.90 | 211-386 |
| 40-Yard | 40 | 4.81 | 4.8 | 4.67 | 0.29 | 4.32-5.5 |
| Vertical Jump | 42 | 31.52 | 31.75 | 27.5 | 4.07 | 22.5-42 |
| Age | 42 | 22.5 | 22 | 22 | 1.08 | 21-26 |
| Bodyweight | 42 | 227.38 | 234.5 | 235 | 42.43 | 163-322 |

**Table 11**
**Descriptive Data for All Starters**

| Variable | n | Mean | Median | Mode | SD | Range |
|---|---|---|---|---|---|---|
| Bench Press | 63 | 360.63 | 360.63 | 400 | 56.16 | 230-500 |
| Back Squat | 63 | 528.01 | 530 | 500 | 73.00 | 350-700 |
| Clean | 61 | 322.91 | 316 | 300 | 44.90 | 226-445 |
| Push Jerk | 61 | 321.27 | 326 | 331 | 40.65 | 225-401 |
| 40-Yard | 62 | 4.70 | 4.6 | 4.48 | 0.29 | 4.22-5.41 |
| Vertical Jump | 63 | 33.64 | 34 | 30 | 4.07 | 25-43.5 |
| Age | 63 | 22.20 | 22 | 22 | 0.80 | 21-24 |
| Bodyweight | 63 | 239.87 | 235 | 202 | 45.33 | 163- |

**Table 12**
**Descriptive Data for Skill Group**

| Variable | n | Mean | Median | Mode | SD | Range |
|---|---|---|---|---|---|---|
| Bench Press | 28 | 300.89 | 300 | 310 | 46.90 | 230-400 |
| Back Squat | 28 | 448.75 | 455 | 500 | 60.30 | 320-575 |
| Clean | 28 | 282.78 | 277.5 | 226 | 43.35 | 180-365 |
| Push Jerk | 28 | 278.35 | 270 | 250 | 41.26 | 211-390 |
| 40-Yard | 28 | 4.49 | 4.46 | 4.38 | 3.51 | 4.22-4.89 |
| Vertical Jump | 28 | 35.73 | 36 | 36 | 3.51 | 27.5-43.5 |
| Age | 28 | 22.32 | 22 | 22 | 1.12 | 21-26 |
| Bodyweight | 28 | 186.35 | 185.5 | 172 | 14.15 | 163-219 |

**Table 13**
**Descriptive Data for Combo Group**

| **Variable** | **n** | **Mean** | **Median** | **Mode** | **SD** | **Range** |
|---|---|---|---|---|---|---|
| Bench Press | 43 | 356.62 | 355 | 340 | 41.8 | 270-440 |
| Back Squat | 43 | 526.44 | 530 | 550 | 53.06 | 360-650 |
| Clean | 42 | 318.54 | 316 | 300 | 45.42 | 220-410 |
| Push Jerk | 42 | 312.26 | 307.5 | 300 | 33.4 | 255-401 |
| 40-Yard | 41 | 4.64 | 4.62 | 4.7 | 0.16 | 4.3-4.95 |
| Vertical Jump | 43 | 33.8 | 34 | 34 | 3.38 | 28-42 |
| Age | 43 | 22.44 | 22 | 22 | 0.76 | 21-24 |
| Bodyweight | 43 | 224.34 | 227 | 235 | 21.64 | 180-275 |

**Table 14**
**Descriptive Data for L.O.S. Group**

| Variable | n | Mean | Median | Mode | SD | Range |
|---|---|---|---|---|---|---|
| Bench Press | 34 | 384.11 | 385 | 400 | 51.01 | 290-500 |
| Back Squat | 34 | 571.47 | 575 | 530 | 64.08 | 430-700 |
| Clean | 32 | 335.81 | 328.5 | 300 | 39.29 | 275-445 |
| Push Jerk | 33 | 343.06 | 336 | 326 | 26.84 | 270-387 |
| 40-Yard | 34 | 5.08 | 5.1 | 5.1 | 0.19 | 4.64-5.5 |
| Vertical Jump | 34 | 29.02 | 29.25 | 27.5 | 2.68 | 22.5-35.5 |
| Age | 34 | 22.17 | 22 | 22 | 0.96 | 21-25 |
| Bodyweight | 34 | 288.14 | 290.5 | 290 | 19.82 | 243-322 |

**Table 15**
**Descriptive Data for Non-Starters in Skill Group**

| Variable | n | Mean | Median | Mode | SD | Range |
|---|---|---|---|---|---|---|
| Bench Press | 10 | 273.5 | 270 | 270 | 26.03 | 230-310 |
| Back Squat | 10 | 421.5 | 427.5 | 400 | 51.58 | 320-500 |
| Clean | 10 | 251.9 | 250.5 | 246 | 34.96 | 180-316 |
| Push Jerk | 10 | 253.8 | 252.5 | 250 | 26.9 | 211-295 |
| 40-Yard | 10 | 4.61 | 4.57 | 4.57 | 0.17 | 4.38-4.89 |
| Vertical Jump | 10 | 33.05 | 34 | 4.57 | 3.26 | 27.5-38 |
| Age | 10 | 22.7 | 22 | 22 | 1.41 | 21-26 |
| Bodyweight | 10 | 178.3 | 180.5 | 172 | 9.38 | 163-190 |

**Table 16**
**Descriptive Data for Starters in Skill Group**

| Variable | n | Mean | Median | Mode | SD | Range |
|---|---|---|---|---|---|---|
| Bench Press | 18 | 316.11 | 312.5 | 300 | 49.48 | 230-400 |
| Back Squat | 18 | 463.88 | 480 | 500 | 60.72 | 350-575 |
| Clean | 18 | 299.94 | 300 | 280 | 38.28 | 226-365 |
| Push Jerk | 18 | 292 | 300 | 250 | 42.06 | 226-390 |
| 40-Yard | 18 | 4.43 | 4.42 | 4.4 | 0.09 | 4.22-4.59 |
| Vertical Jump | 18 | 37.22 | 37 | 36 | 2.71 | 33-43.5 |
| Age | 18 | 22.11 | 22 | 22 | 0.90 | 21-24 |
| Bodyweight | 18 | 190.83 | 190.5 | 186 | 14.57 | 164-219 |

**Table 17**
**Descriptive Data for Non-Starters in Combo Group**

| Variable | n | Mean | Median | Mode | SD | Range |
|---|---|---|---|---|---|---|
| Bench Press | 19 | 355.26 | 355 | 400 | 43.69 | 270-420 |
| Back Squat | 19 | 511.84 | 530 | 550 | 64.27 | 360-600 |
| Clean | 18 | 312.50 | 300 | 300 | 47.38 | 220-410 |
| Push Jerk | 19 | 305.78 | 300 | 300 | 32.28 | 260-360 |
| 40-Yard | 17 | 4.69 | 4.7 | 4.67 | 0.18 | 4.5-4.95 |
| Vertical Jump | 19 | 33.18 | 33 | 28 | 3.54 | 28-42 |
| Age | 19 | 22.68 | 23 | 23 | 0.74 | 21-24 |
| Bodyweight | 19 | 219.84 | 215 | 235 | 23.54 | 180-270 |

**Table 18**
**Descriptive Data for Starters in Combo Group**

| Variable | n | Mean | Median | Mode | SD | Range |
|---|---|---|---|---|---|---|
| Bench Press | 24 | 357.7 | 357.5 | 340 | 41.15 | 270-440 |
| Back Squat | 24 | 530.83 | 532.5 | 500 | 41.74 | 460-650 |
| Clean | 24 | 323.08 | 320.5 | 316 | 44.36 | 250-450 |
| Push Jerk | 23 | 317.60 | 321 | 280 | 34.06 | 255-401 |
| 40-Yard | 24 | 4.60 | 4.58 | 4.48 | 0.15 | 4.3-4.91 |
| Vertical Jump | 24 | 34.39 | 34.75 | 34 | 3.23 | 28-40.5 |
| Age | 24 | 22.25 | 22.25 | 22 | 0.73 | 21-24 |
| Bodyweight | 24 | 227.91 | 227.91 | 197 | 19.78 | 197-275 |

**Table 19**
**Descriptive Data for Non-Starters in L.O.S. Group**

| Variable | n | Mean | Median | Mode | SD | Range |
|---|---|---|---|---|---|---|
| Bench Press | 13 | 355 | 370 | 410 | 45.73 | 290-410 |
| Back Squat | 13 | 558.02 | 575 | 575 | 53.6 | 430-630 |
| Clean | 13 | 323.13 | 316 | 316 | 31.46 | 275-386 |
| Push Jerk | 13 | 329.53 | 326 | 326 | 29.92 | 270-386 |
| 40-Yard | 13 | 5.13 | 5.12 | 5.12 | 0.19 | 4.78-5.5 |
| Vertical Jump | 13 | 27.92 | 27.5 | 27.5 | 3.08 | 22.5-34.5 |
| Age | 13 | 22.07 | 22 | 22 | 1.18 | 21-25 |
| Bodyweight | 13 | 276.11 | 270 | 303 | 24.11 | 243-322 |

**Table 20**
**Descriptive Data for Starters in L.O.S. Group**

| Variable | n | Mean | Median | Mode | SD | Range |
|---|---|---|---|---|---|---|
| Bench Press | 21 | 402.14 | 400 | 400 | 46.32 | 320-500 |
| Back Squat | 21 | 579.76 | 575 | 530 | 69.74 | 450-700 |
| Clean | 19 | 344.47 | 340 | 300 | 42.46 | 290-445 |
| Push Jerk | 20 | 344.47 | 351 | 331 | 21.88 | 320-387 |
| 40-Yard | 20 | 5.05 | 5.09 | 5.10 | 0.19 | 4.64-5.41 |
| Vertical Jump | 21 | 29.21 | 30 | 30 | 2.21 | 25-35.5 |
| Age | 21 | 22.23 | 22 | 22 | 0.83 | 21-24 |
| Bodyweight | 21 | 295.57 | 296 | 290 | 12.18 | 270-317 |

APPENDIX C

Step Procedures for each position group using the Proc StepDisc statistical procedure

**Table 21**
**Proc StepDisc Procedure for the Skill Group**

**Step 1**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.1965 | 6.36 | 0.0181 | 1.000 |
| Back Squat | 0.1176 | 3.47 | 0.0740 | 1.000 |
| Power Clean | 0.2923 | 10.74 | 0.0030 | 1.000 |
| Push Jerk | 0.2040 | 6.66 | 0.0158 | 1.000 |
| 40-yard Dash | 0.3280 | 12.69 | 0.0014 | 1.000 |
| **Vertical Jump** | 0.3353 | 13.12 | **0.0012** | 1.000 |
| Bodyweight | 0.1866 | 5.96 | 0.0217 | 1.000 |

**Step 2**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.0347 | 0.90 | 0.3519 | 0.7023 |
| Back Squat | 0.0002 | 0.01 | 0.9401 | 0.6695 |
| **Power Clean** | 0.1264 | 3.62 | **0.0687** | 0.7498 |
| Push Jerk | 0.0279 | 0.72 | 0.4054 | 0.6515 |
| 40-yard Dash | 0.0530 | 1.40 | 0.2482 | 0.3747 |
| Bodyweight | 0.0626 | 1.67 | 0.2083 | 0.8172 |

**Step 3**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.0000 | 0.00 | 0.9850 | 0.5029 |
| Back Squat | 0.0162 | 0.39 | 0.5361 | 0.5852 |
| Push Jerk | 0.0240 | 0.59 | 0.4494 | 0.2924 |
| **40-yard Dash** | 0.0549 | 1.39 | **0.2494** | 0.3382 |
| Bodyweight | 0.0049 | 0.12 | 0.7340 | 0.5232 |

**Step 4**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.0006 | 0.01 | 0.9105 | 0.3280 |
| **Back Squat** | 0.0341 | 0.81 | **0.3766** | 0.3299 |
| Push Jerk | 0.0229 | 0.54 | 0.4703 | 0.2920 |
| Bodyweight | 0.0114 | 0.26 | 0.6118 | 0.3235 |

**Step 5**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.0205 | 0.46 | 0.5044 | 0.2659 |
| Push Jerk | 0.0026 | 0.06 | 0.8145 | 0.1852 |
| **Bodyweight** | 0.0679 | 1.60 | **0.2189** | 0.3228 |

**Step 6**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.0081 | 0.17 | 0.6825 | 0.2526 |
| **Push Jerk** | 0.0086 | 0.18 | **0.6739** | 0.1813 |

**Step 7**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| **Bench Press** | 0.0234 | 0.48 | **0.4972** | 0.1407 |

**Table 22**
**Proc StepDisc Procedure for the Combo Group**

**Step 1**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.0004 | 0.02 | 0.8981 | 1.000 |
| Back Squat | 0.0588 | 2.31 | 0.1370 | 1.000 |
| Power Clean | 0.0161 | 0.61 | 0.4411 | 1.000 |
| Push Jerk | 0.0315 | 1.20 | 0.2798 | 1.000 |
| **40-yard Dash** | 0.0718 | 2.86 | **0.0992** | 1.000 |
| Vertical Jump | 0.0194 | 0.73 | 0.3978 | 1.000 |
| Bodyweight | 0.0188 | 0.71 | 0.4053 | 1.000 |

**Step 2**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.0018 | 0.06 | 0.8011 | 0.9948 |
| Back Squat | 0.0441 | 1.66 | 0.2055 | 0.9747 |
| Power Clean | 0.0269 | 0.99 | 0.3252 | 0.9874 |
| Push Jerk | 0.0418 | 1.57 | 0.2180 | 0.9949 |
| Vertical Jump | 0.0045 | 0.16 | 0.6892 | 0.5189 |
| **Bodyweight** | 0.1206 | 4.94 | **0.0327** | 0.7087 |

**Step 3**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| **Bench Press** | 0.0365 | 1.33 | **0.2574** | 0.4929 |
| Back Squat | 0.0014 | 0.05 | 0.8253 | 0.5184 |
| Power Clean | 0.0012 | 0.04 | 0.8387 | 0.6032 |
| Push Jerk | 0.0015 | 0.05 | 0.8198 | 0.3934 |
| Vertical Jump | 0.0124 | 0.44 | 0.5115 | 0.4023 |

**Step 4**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| **Back Squat** | 0.0306 | 1.07 | **0.3072** | 0.4660 |
| Power Clean | 0.0060 | 0.21 | 0.6525 | 0.4663 |
| Push Jerk | 0.0032 | 0.11 | 0.7423 | 0.3770 |
| Vertical Jump | 0.0162 | 0.56 | 0.4588 | 0.3767 |

**Step 5**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Power Clean | 0.0016 | 0.05 | 0.8179 | 0.4506 |
| Push Jerk | 0.0027 | 0.09 | 0.7654 | 0.3631 |
| **Vertical Jump** | 0.0210 | 0.71 | **0.4060** | 0.3573 |

**Step 6**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Power Clean | 0.0019 | 0.06 | 0.8061 | 0.3570 |
| **Push Jerk** | 0.0070 | 0.23 | **0.6374** | 0.3545 |

**Step 7**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| **Power Clean** | 0.0001 | 0.00 | **0.9637** | 0.3385 |

**Table 23**
**Proc StepDisc Procedure for the L.O.S. group.**

**Step 1**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.2240 | 8.66 | 0.0062 | 1.000 |
| Back Squat | 0.0531 | 1.68 | 0.2046 | 1.000 |
| Power Clean | 0.0733 | 2.37 | 0.1339 | 1.000 |
| Push Jerk | 0.1677 | 6.05 | 0.0199 | 1.000 |
| 40-yard Dash | 0.0491 | 1.55 | 0.2229 | 1.000 |
| Vertical Jump | 0.1276 | 4.39 | 0.0448 | 1.000 |
| **Bodyweight** | 0.2709 | 11.15 | **0.0023** | 1.000 |

**Step 2.**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| Bench Press | 0.1236 | 4.09 | 0.0525 | 0.8597 |
| Back Squat | 0.0060 | 0.18 | 0.6775 | 0.8964 |
| Power Clean | 0.0295 | 0.88 | 0.3557 | 0.9388 |
| Push Jerk | 0.1240 | 4.10 | 0.0521 | 0.9498 |
| 40-yard Dash | 0.1728 | 6.06 | 0.0200 | 0.9439 |
| **Vertical Jump** | 0.2237 | 8.36 | **0.0072** | 0.9925 |

**Step 3**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| **Bench Press** | 0.0599 | 1.78 | **0.1926** | 0.7771 |
| Back Squat | 0.0257 | 0.74 | 0.3975 | 0.7279 |
| Power Clean | 0.0288 | 0.83 | 0.3700 | 0.9302 |
| Push Jerk | 0.0387 | 1.13 | 0.2976 | 0.7899 |
| 40-yard Dash | 0.0115 | 0.33 | 0.5726 | 0.4187 |

**Step 4**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| **Back Squat** | 0.0634 | 1.83 | **0.1876** | 0.6635 |
| Power Clean | 0.0355 | 0.99 | 0.3280 | 0.7732 |
| Push Jerk | 0.0057 | 0.16 | 0.6968 | 0.5382 |
| 40-yard Dash | 0.0036 | 0.10 | 0.7587 | 0.4007 |

**Step 5**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| **Power Clean** | 0.0798 | 2.25 | **0.1453** | 0.6074 |
| Push Jerk | 0.0083 | 0.22 | 0.6453 | 0.5106 |
| 40-yard Dash | 0.0004 | 0.01 | 0.9178 | 0.3815 |

**Step 6**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| **Push Jerk** | 0.0009 | 0.02 | **0.8794** | 0.4821 |
| 40-yard Dash | 0.0001 | 0.00 | 0.9629 | 0.3770 |

**Step 7**

| Variable | R-Square | F-Value | Pr > F | Tolerance |
|---|---|---|---|---|
| **40-yard Dash** | 0.0000 | 0.00 | **0.9801** | 0.3451 |

# APPENDIX D

ANOVA p-Values and F-Values for each group

| | Skill | | Combo | | L.O.S. | |
|---|---|---|---|---|---|---|
| | F-Value | p-Value | F-Value | p-Value | F-Value | p-Value |
| Bench | 6.11 | 0.0151* | 0.03 | 0.8558 | 9.34 | 0.0029* |
| Squat | 3.44 | 0.0668 | 1.14 | 0.2887 | 1.12 | 0.2918 |
| Clean | 8.70 | 0.0040* | 0.68 | 0.4131 | 2.06 | 0.1547 |
| Jerk | 9.10 | 0.0033* | 1.41 | 0.2381 | 3.80 | 0.540 |
| 40-Yard | 7.45 | 0.0075* | 2.50 | 0.1175 | 2.12 | 0.14186 |
| V.J. | 12.31 | 0.0007* | 1.71 | 0.1937 | 2.83 | 0.0955 |
| Weight | 3.00 | 0.0864 | 2.05 | 0.1550 | 8.99 | 0.0034* |

* Tests that are significant at the $p<.05$ level.

# Curriculum Vitae

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